

Appendix A *Environment Protection Act* – activity assessment against environmental factors and objectives

Table 50 EP referral assessment

Environmental Factors	Project Specific Environmental Factors	Environmental Objectives at Risk	Receiving Environment	Impact Description	Applicable Code of Practice	Mitigation Measures	Potential significant effect on an environmental factor?	Assumptions
Land	Terrestrial Flora and Fauna	Protect NT's flora and fauna so that biological diversity and ecological integrity are maintained.	Corymbia spp open woodland with mixed Terminalia spp. shrubland over low tussock grassland (Triodia bitextura). Area has been subject to low intensity pastoral activities.	•Potential increased risk from bushfire and weed introduction, typical of any construction project. •Regional industries are low intensity and mainly grazing. •Terrestrial systems are intact and generally have limited current or future planned disturbance. •Low risk of vertebrate (bird, mammals, reptiles etc.) to wastewater •No cumulative impacts anticipated from exploration activities.	Part A- Surface Activities A.3.1 Site Selection A.3.2 Well pad site selection requirements A.3.5 Biodiversity protection A.3.6 Weed management A.3.7 Fire management A.3.9 Rehabilitation	•No clearing of vegetation proposed. •Field ecological surveys completed. •Location selected to avoid impacts to high conservation areas. •Site is bunded during wastewater storage to prevent off-site releases (capacity 9.6ML). •Covered tanks to be utilised to store wastewater during the wet season. •Literature confirms wastewater salinity and absence of food sources is likely to reduce vertebrate (including birds) exposure to wastewater •Site fencing, vertical tank walls, wastewater depth and lack of perching places also reduces vertebrate (including bird) access •All equipment to be washed-down and to have valid weed hygiene certificates. •Weed Management Plan implemented to prevent, detect and respond to weed outbreaks •Bushfire Management Plan implemented to prevent and respond to bushfires. •Cameras to monitor fauna interaction with wastewater storages	No	Assessment based upon field surveys. Threatened fauna may be present in the area which were not identified during the surveys.
	Terrestrial Environmental Quality	Maintain the quality of land and soils so the environmental values are protected.	Corymbia spp open woodland with mixed Terminalia spp. shrubland over low tussock grassland (Triodia bitextura). Area has been subject to low intensity pastoral activities.	•No significant erosion impacts or risks are anticipated. •No offsite releases of wastewater or chemical anticipated •Areas are cleared and compacted to accommodate exploration activities which will reduce soil productivity if not rehabilitated •No cumulative impacts anticipated from limited exploration activities.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements A.3.4 Erosion and sediment control and hydrology A.3.9 Rehabilitation Part C- Well site water management C.4.2 Management of produced water and flowback fluid	•Regional industries are low intensity and mainly grazing. •Vegetation is largely intact and soils in good condition. •No releases of drilling and stimulation wastewater to the surrounding environment. •Site is bunded during wastewater storage to prevent off-site releases (capacity 9.6ML). •Site to be rehabilitated. •Erosion and sediment control plan implemented.	No	Assumes internationally accepted erosion and sediment controls are sufficient to manage risk of erosion within the NT.

Environmental Factors	Project Specific Environmental Factors	Environmental Objectives at Risk	Receiving Environment	Impact Description	Applicable Code of Practice	Mitigation Measures	Potential significant effect on an environmental factor?	Assumptions
						•Wastewater Management Plan implemented including enclosed tanks and freeboard for all wastewater storage. •Spill Management Plan implemented to prevent, detect and respond to spills. •Secondary containment will be implemented for all chemical storage and handling areas. •All disturbed areas to be rehabilitated. •All sewage and sullage to be disposed of in accordance with the Department of Health code of practice. •Dedicated sewage treatment area has been sized appropriately to manage the occupancy, with the irrigation area located within fenced-off lease site to prevent stock access.		
	Landforms	Conserve the variety and integrity of distinctive physical landforms so that environmental values are protected.	Low relief area, <1% slope on tertiary lateritic red sands.	•No impacts to landforms anticipated. •Regional industries are low intensity and mainly grazing. •No cumulative impacts anticipated from limited exploration activities.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements A.3.4 Erosion and sediment control and hydrology A.3.9 Rehabilitation	•All disturbed areas to be rehabilitated back to pre-existing condition: a safe stable state consistent with the surrounding landform.	No No major modification to the surrounding landform is predicted.	Assessment is based upon field ecology scouting.
Water	Aquatic Ecosystems	Protect aquatic ecosystems to maintain the biological diversity of flora and fauna and the ecological functions they perform.	•Located ~200km from any Groundwater Dependent Ecosystems (GDEs). • Activity not located within close proximity to any major flow paths, wetlands or permanent watercourses.	•No significant impacts or risks anticipated. •Regional industries are low intensity and mainly grazing. •Limited pressure on existing systems. •Cumulative impacts associated with water extraction assessed by DEPWS as a part of Water Extraction Licence. •No cumulative impacts anticipated from limited exploration activities.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements A.3.4 Erosion and sediment control and hydrology Part C- Well site water management C.4.2 Management of produced water and flowback fluid	•Groundwater extraction modelled by DEPWS and within sustainable yields. •No surface water extraction. •No surface water discharge. •Location of lease pad away from GDEs, wetlands, permanent streams or major watercourses and flow paths. •Site is bunded during wastewater storage to prevent off-site releases (capacity 9.6ML). •Secondary containment used on all chemical and waste storages. •Erosion and sediment control plan implemented to prevent, detect and respond to erosion and sediment releases.	No Activities are not anticipated to impact on the environmental factor.	Modelling based on known and assumed properties of aquifer. Assumes internationally accepted erosion and sediment controls are sufficient to manage risk of erosion within the NT.

Environmental Factors	Project Specific Environmental Factors	Environmental Objectives at Risk	Receiving Environment	Impact Description	Applicable Code of Practice	Mitigation Measures	Potential significant effect on an environmental factor?	Assumptions
						•Spill Management Plan implemented to prevent, detect and respond to spills •All sewage and sullage to be disposed of in accordance with the Department of Health Code of Practice. •Dedicated sewage treatment area has been sized appropriately to manage the occupancy, with the irrigation area located within fenced-off lease site to prevent stock access.		
	Inland Water Environmental Quality	Maintain the quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected.	Cambrian Limestone Aquifer- Gum Ridge Formation.	•67ML extraction of groundwater from the Gum Ridge formation. •No significant impacts or risks on pastoralist bores from groundwater extraction anticipated. •Regional industries are low intensity and mainly grazing. •Limited pressure on existing systems. •Cumulative impacts associated with water extraction assessed by DEPWS as a part of Water Extraction Licence. •No cumulative impacts anticipated from limited exploration activities.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements A.3.8 Containment of contaminants Part B Well operations B.4.1 Well integrity management B4.2 Aquifer protection B.4.3 Well design and barriers B.4.10 Drilling fluids B.4.12 Hydraulic stimulation and flowback operations B.4.17 Groundwater Monitoring B.5 BTEX Limits Part C- Well site water management C.4.2 Management of produced water and flowback fluid C.5 Monitoring mandatory requirements C.7 Mandatory requirements for management plans for wastewater and spills	•Groundwater take is licenced. •Groundwater take is monitored using an approved water flow meter. •Control and impact monitoring bores located on the exploration lease. •All chemical and wastewater storages to have secondary containment. •Spill Management Plan implemented to prevent, detect and respond to spills. •Wastewater Management Plan implemented to prevent wastewater tank overtopping, spills and releases. •Site is bunded during wastewater storage to prevent off-site releases (capacity 9.6ML). •All camp (main and mini-camp) sewage and grey water disposal is undertaken in demarcated irrigation areas in compliance with Department of Health guidelines.	No Assessment indicates activity unlikely to result in significant impacts to groundwater.	Assessment based on hydrological information collected during water bore drilling and assumed transmissivity and storage values.

Environmental Factors	Project Specific Environmental Factors	Environmental Objectives at Risk	Receiving Environment	Impact Description	Applicable Code of Practice	Mitigation Measures	Potential significant effect on an environmental factor?	Assumptions
	Hydrological processes	Maintain the hydrologic regimes of groundwater and surface water so that environmental values are protected.	•Cambrian Limestone Aquifer- Gum Ridge Formation • Activity not located within close proximity to any major flow paths, wetlands or permanent watercourses.	•67ML extraction of groundwater from the Gum Ridge Formation. •No significant impacts or risks anticipated. •Regional industries are low intensity and mainly grazing. •Cumulative impacts associated with water extraction assessed by DEPWS as a part of Water Extraction Licence. •No cumulative impacts anticipated from limited exploration activities.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements A.3.4 Erosion and sediment control and hydrology A.3.8 Containment of contaminants B.4.17 Groundwater Monitoring C.4.2 Management of produced water and flowback fluid C.5 Monitoring mandatory requirements C.7 Mandatory requirements for management plans for wastewater and spills	•Groundwater extraction modelled within sustainable yields. •Groundwater take is licenced. •Groundwater take will is monitored using an approved water flow meter. •No surface water extraction. •Location of lease pad away from GDE's, wetlands, permanent streams or major watercourses and flow paths. •The lease pad has been designed to avoid impacts to overland flow. •Site is bunded during wastewater storage to prevent off-site releases (capacity 9.6ML).	No Assessment indicates activity unlikely to result in significant impacts to groundwater or surface water.	Modelling based on known and assumed properties of aquifer.
Air	Air Quality and Greenhouse Gases	Maintain air quality and minimise emissions and their impact so that environmental values are protected.	Rural environment with minimal industrial or urban inputs.	•No significant impacts or risks anticipated with activity specific and cumulative emissions unlikely to materially increase the GHG emissions of the Northern Territory.	Part A- Surface Activities A.3.1 Site selection Part D- Methane emissions monitoring, leak management, detection and reporting D.4 Regional methane monitoring D.5 Emissions detection and management D.6 Reporting	•Activity intensity low, with no local sensitive receptors within 20km. •Dust suppression to be utilised to minimise dust generation. •Equipment to be compliant with relevant pollution control device requirements and maintained to minimise emissions. •A Methane Emissions Management Plan implemented to minimise GHG emissions through the use of reduced emission completions and leak detection. •A reduced emission completion to be implemented as per NT Code of Practice. •All flaring and venting to be reported as per the National Greenhouse and Energy Reporting Scheme and Petroleum Code of Practice. •Condensate to be sold where permissible •Limited regional sources likely to cause cumulative impacts.	No Assessment indicates activity unlikely to result in significant impacts to air quality of greenhouse gas generation.	Estimates of greenhouse gas generation using estimates from Transport Authorities Greenhouse Group.

Environmental Factors	Project Specific Environmental Factors	Environmental Objectives at Risk	Receiving Environment	Impact Description	Applicable Code of Practice	Mitigation Measures	Potential significant effect on an environmental factor?	Assumptions
People and communities	Social, economic and cultural surroundings	Protect the social, economic, cultural and heritage values of the Northern Territory.	Rural communities, pastoralists and Traditional Owners.	- Limited impact on regional communities due to limited nature of exploration activities. - Minimal competition with existing industries - Engagement with local accommodation providers to inform them of future work programs and potential accommodation demand.	Part A- Surface Activities A.3.1 Site selection A.3.2 Well pad site selection requirements	- The use of NT businesses and Indigenous employment has been prioritised. - Stakeholder Engagement Plan implemented. - Activities located away from communities, with workers based at camps on-site; limited competition with tourism operators. - Short (days) increased traffic during equipment mobilisation consistent with existing regional transport (freight) and mining industries. - Prioritisation of use of local employment and services. - Labour competition with local pastoralists minimal due to limited activities proposed and specialised nature of drilling and stimulation activities. - Land access approvals. - NLC clearances and AAPA certificates for activities. - Activity is limited in scope and nature with no booms or busts anticipated. - Engagement with DIPL regarding ongoing traffic volumes management	No Low intensity activity not anticipated to have significant impacts to the local community or tourism.	All relevant Traditional Owners are engaged by NLC.
	Human health	Ensure the risks to human health are identified, understood and adequately avoided and /or mitigated.	Remote rural environment.	- No impact to human health anticipated from activities from drilling, stimulation and well testing activities - Limited regional sources unlikely to cause cumulative impacts.	Part D- Methane emissions monitoring, leak management, detection and reporting D.4 Regional methane monitoring D.5 Emissions detection and management D.6 Reporting	- Short duration, remote activity with nuisance (dust) likely to be the main issue associated with vehicle and equipment movement. - Closest receptor 20km from activity. - Flaring used to reduce pollutants associated with venting. - A reduced emission completion to be used to minimise GHG and pollutant generation. - Chemical risk assessment - All chemicals considered low concern providing PPE and standard OHS protocols are followed.	No Short (months) duration, remote activity with limited receptors.	None

Appendix B Engineering drawing, layouts and specifications

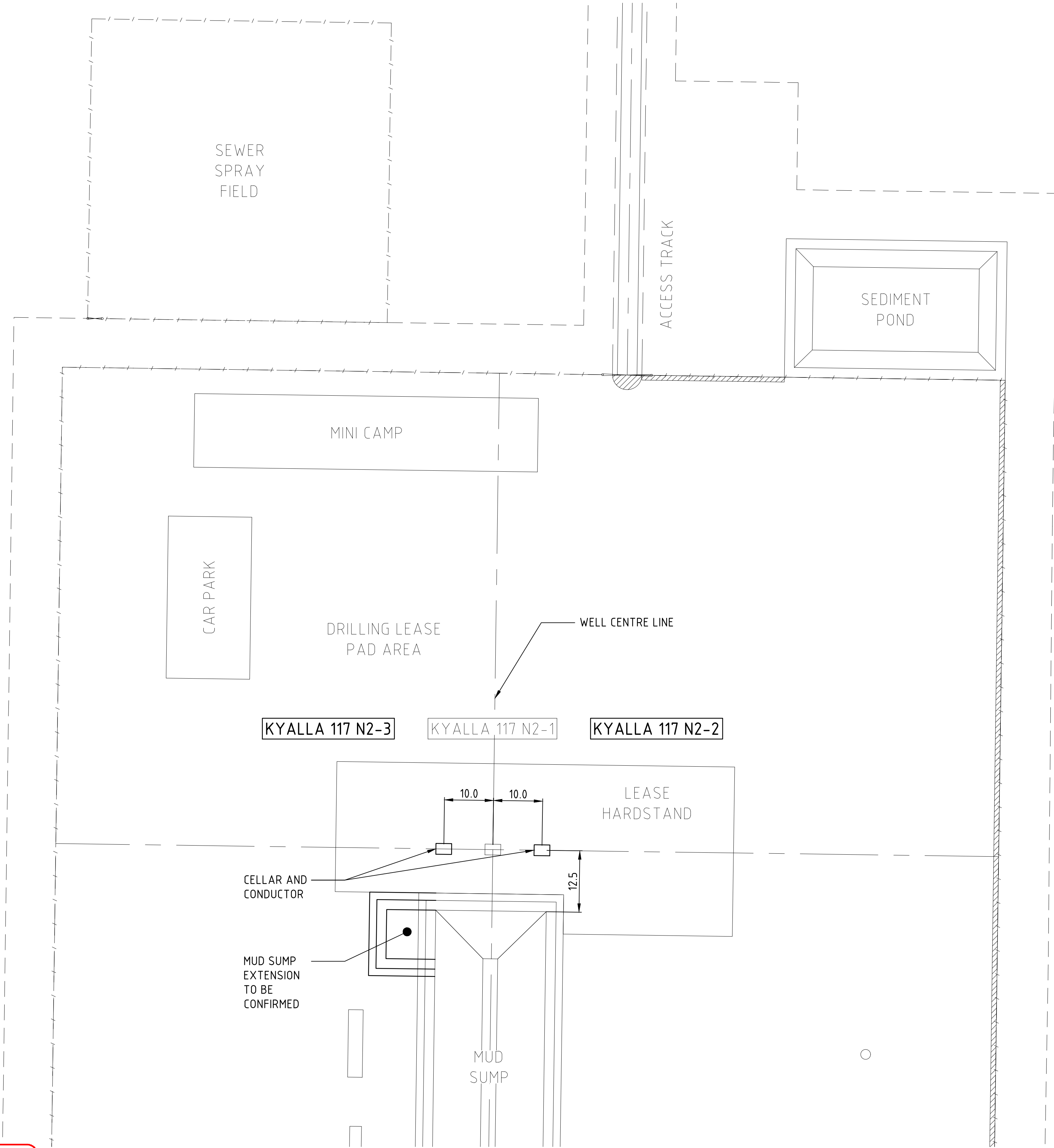
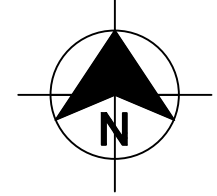
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LEGEND

- EXISTING CONTOUR
- ACCESS ROAD CENTRELINE
- EDGE OF ROAD
- ROAD SHOULDER
- ROAD CLEARANCE
- GRAVEL PAD
- FENCE

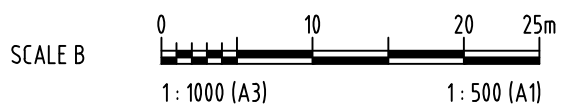
NOTE

- DRILLING CELLAR AND CONDUCTOR DETAILS - REFER STANDARD DRAWING NT-2050-20-DA-1003.



FOR INFORMATION ONLY

NOT FOR CONSTRUCTION



Liner and wastewater tank storage specifications for existing and new wastewater tanks

13 Oct 2016	Enviro Liner® 1000 Properties				
Style	ASTM	EL 1020	EL 1030	EL 1040N	EL 1040
Thickness	D5199	20 mil 0.5 mm	30 mil 0.75 mm	36 mil 0.91 mm	40 mil 1.0 mm
Density (Typical)	D792	0.93	0.93	0.93	0.93
Tensile Strength at Break	D6693	76 ppi 13 N/mm	114 ppi 20 N/mm	136 ppi 24 N/mm	152 ppi 27 N/mm
Elongation	D6693	800%	800%	700%	800%
Tear Resistance	D1004	11 lbs 49 N	16 lbs 70 N	19 lbs 84 N	22 lbs 100 N
Puncture Resistance	D4833	28 lbs 120 N	42 lbs 190 N	54 lbs 240 N	56 lbs 250 N
Carbon Black Content	D6370	≥ 2.0%	≥ 2.0%	2.0%	≥ 2.0%
High Pressure OIT	D5885	400 min	400 min	N/A	400 min
Low Temperature Impact Resistance	D746	-69°F -56°C	-69°F -56°C	-40°F -40°C	-69°F -56°C
Service Temperatures	Max Continuous Use	140°F 60°C	140°F 60°C	140°F 60°C	140°F 60°C

18 Oct 2016	Enviro Liner® 1000 Shop Seam Strengths				
Style	ASTM D6392	Enviro Liner® 1020	Enviro Liner® 1030	Enviro Liner® 1040N	Enviro Liner® 1040
Heat Bonded Seam Strength	25.4 mm (1") Strip	30 ppi 5.2 N/mm	45 ppi 7.7 N/mm	50 ppi 8.7 N/mm	60 ppi 10.3 N/mm
Peel Adhesion Strength (Wedge Weld)	25.4 mm (1") Strip	25 ppi 4.3 N/mm	38 ppi 6.5 N/mm	45 ppi 7.9 N/mm	50 ppi 8.7 N/mm



FlexiPond Wind Loading

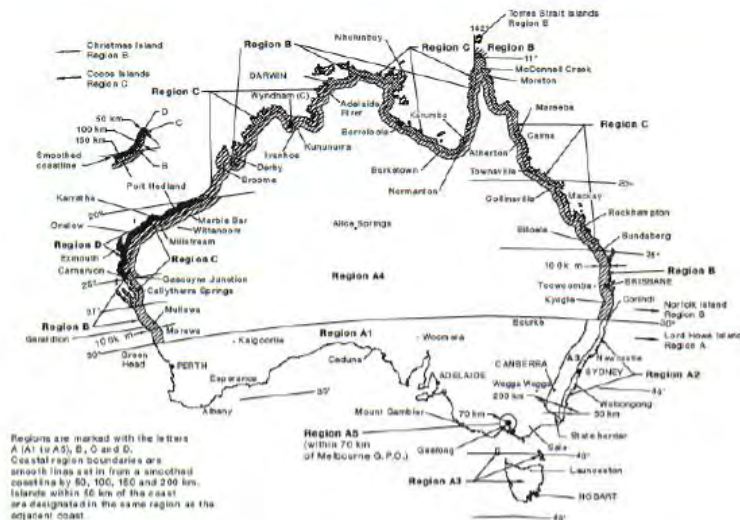
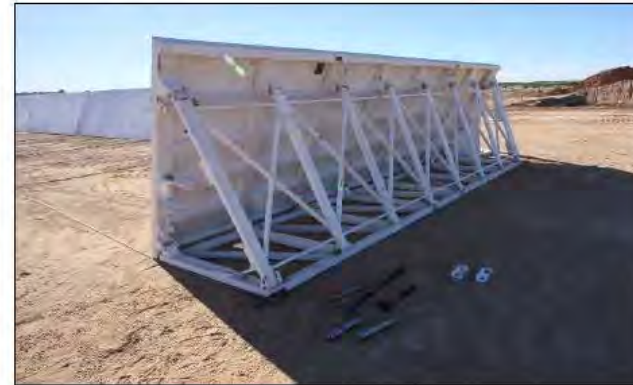


FIGURE 3.1(A) WIND REGIONS



(g) 2 effective surfaces Lateral pressure on windward and leeward walls.		0.9	1.0 (not an effective surface)
(h) 2 effective surfaces Lateral pressure on external and internal surfaces.		0.9	0.9

Wind Rating as per AS1170.2:2011(R2016)

- Individual panel (or a straight line section of assembled panels)
- Overturning/Sliding rating (e.g. in storage or prior to installation) **rated to a maximum of 100km/hr**
- Fully Assembled (with corner pieces, locking pins and cables)
- **Stable to all wind conditions in all wind regions (includes cyclonic)**

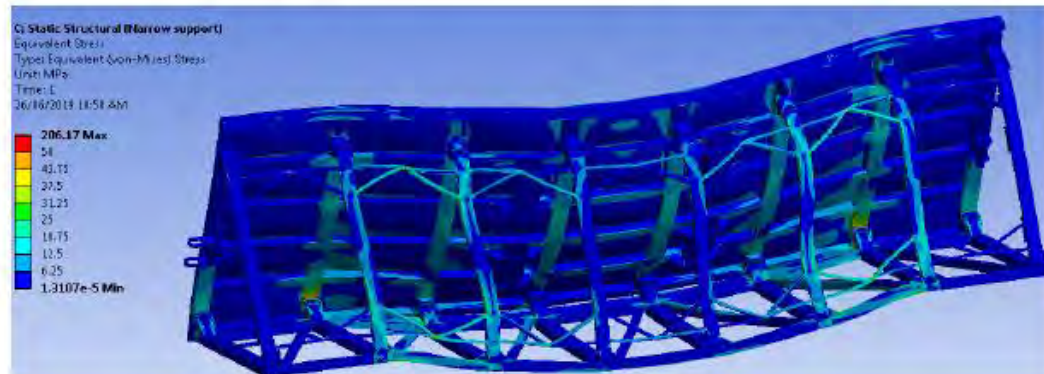
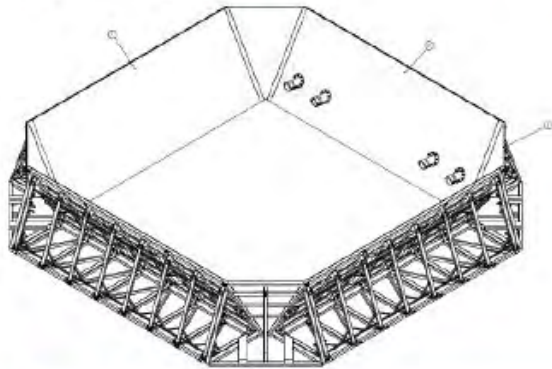
Support Slide: Certified Working Parameters

- Wind Rating as per AS1170.2:2011(R2016), Structural Design Actions Part2 : Wind Actions
 - Individual panel (or a straight line section of assembled panels)
 - Overturning/Sliding rating (e.g. in storage or prior to installation) rated to a maximum of 100km/hr
 - Fully Assembled (with corner pieces, locking pins and cables)
 - Stable to all wind conditions in all wind regions (includes cyclonic)
 - However, recommend minimum 100mm of fluid in tank at shallow end to stop liner from blowing away/tearing
 - Hydrostatic Loading as per AS NZS 1170.1-2011(R2016) and AS3990-1993(R2016)
 - Assembled with cables and pins
 - Fluid maximum specific gravity of 1.2 in conjunction with wind loading
 - Structurally able to handle erosion under 70% of the frame (although not recommended as the liner would be removed under the panel by the hydrostatic fluid)
 - Cables to be capable of being safely loaded to 160kN
 - Installation conditions
 - Site Slope
 - See chart for numbers of panels versus slope
 - Ground Bearing Pressures
 - Uniformly supported panels exert a pressure of 35 kPa beneath the frame members when filled with 1.2 SG fluid
 - The liner exerts a pressure on the ground of 25 kPa when filled with 1.2 SG fluid
 - As a reference – A typical passenger vehicle tyres exert approx. 200kPa on ground
 - Ground/Site Preparation
 - Assessment would be on a site-specific basis
 - Recommended final site preparation of a bedding material of loose sand or fine aggregate to ensure uniform loading under frame members
 - A depth of not less than 100mm would ensure final levelling could be performed during assembly of the panels
 - Alternatively, a ground level tolerance of +/- 16mm should be used to ensure uniform loading under frame members
 - To reduce the likelihood of erosion, it is recommended that a spoon drain or similar be provided around the structure, particularly on the high side or where there is the potential for significant runoff to impact the structure. This would also be site specific.
-

FlexiPond Structural Integrity

FlexiPond is designed and Engineered to AS3990 Mechanical Equipment – Steelwork

Finite Element Analysis (FEA) software used to simulate various load conditions and confirm engineering calculations



Deformed Scale = 340 times

D) Static Structural

Equivalent Stress

Type: Equivalent (von-Mises) Stress

Unit: MPa

Time: 1

26/10/2019 3:12 PM

143 Max

120

105

90.006

75.01

60.013

45.016

30.019

15.012

0.025503 Min



Deformed Scale = 300 times

Structural FEA of Frame Connecting Pin

- Supported in the middle of the pin
- Loaded on either end of the pin

Structural FEA simulating erosion under 70% of Structure

- Supported on either side by the ground and horizontal cables
- Fluid hydrostatic pressure acting on the panel surface

PRODUCT DATA SHEET

COLETANCHE ES 2



DESCRIPTION

COLETANCHE ES 2 is an SBS elastomeric modified bituminous geomembrane.

USE

Moderate level of mechanical resistance, for use an environmental protection and groundworks waterproofing, in particular :

- To cover landfill,
- Hydraulic ponds,
- Containment of Industrial liquid wastes,
- Canals ,
- Contaminated land.

Product use must be validated by Axter

APPLICATION METHOD

By torch welding or other similar technique

STORAGE

Rolls must not be stored directly on the ground. Provide suitable supports (blocks, slides, wooden planks) with a minimum height of 35 cm to be placed under the ends of the mandrel.

COMPOSITION

(indicative)

Reinforcement (g/m ²) :	Glass mat	50
Reinforcement (g/m ²) :	Non-woven geotextile	250
Binder (g/m ²) :	Elastomeric SBS	4300
Surface finish (g/m ²) :	Sand	250
Under surface finish (g/m ²) :	Polyester antiroot film	15

CHARACTERISTICS

		STANDARD	UNITS	AVERAGE	Minimum
Dimensions	Length	-	m	80	79
	Width		m	5.10	5.01
Thickness (on finished product)		ASTM D 5199	mm	4.00	3.60
Surface mass		ASTM D 3776	kg/m ²	4.85	4.30
Resistance to tearing	Longitudinal	ASTM D 4073	N	825	619
	Cross direction			700	525
Tensile properties : maximum tensile strength	Longitudinal	ASTM D 7275	kN/m	27	20.3
	Cross direction			24	15
Tensile properties : elongation	Longitudinal		%	50	35
	Cross direction			50	35
Static Puncture		ASTM D 4833	N	530	477
Flexibility at low temperature	Longitudinal	ASTM D 5147	°C	-20	-15
	Cross direction			-20	-15
Water permeability (liquid tightness)		ASTM E 96	m/s	6.10 ⁻¹⁴	<
Gas permeability (gas tightness)		ASTM D 1434-82	m ³ /(m ² .j.atm)	2.10 ⁻⁴	<

NOTE: AXTER COLETANCHE INC. may modify the composition and/or utilisation of its products without prior notice. Consequently orders will be filled according to the latest specification.



GENERAL

- ALL WORK EXCLUDING WORK ASSOCIATED WITH LINER SUPPLY AND INSTALLATION SHALL BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0001 POND EARTHWORKS AND WITH PROJECT SPECIFIC DRAWINGS, PROJECT STANDARD DRAWINGS AND OTHER CONTRACT DOCUMENTATION AS APPLICABLE.
- ALL WORK ASSOCIATED WITH LINER SUPPLY AND INSTALLATION SHALL BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0002 AND Q-4522-20-TS-0003.
- THE CONTRACTOR SHALL TAKE OUT ALL APPROPRIATE LOCAL GOVERNMENT AND OTHER AUTHORITY PERMITS PRIOR TO COMMENCING WORK.
- THE CONTRACTOR SHALL ASCERTAIN THE EXACT LOCATION OF ALL EXISTING SERVICES ON AND ADJACENT TO THE SITE OF THE WORK PRIOR TO COMMENCING THE WORK AND SHALL BE RESPONSIBLE FOR THE COST OF RECTIFICATION OF ANY DAMAGES TO THE EXISTING SERVICES OCCASIONED DURING THE WORK. LOCATIONS OF EXISTING SERVICES IF AND WHERE SHOWN ON THE DRAWINGS ARE APPROXIMATE ONLY. DRAWINGS MAY NOT INDICATE ALL EXISTING SERVICES.
- THE CONTRACTOR SHALL PROGRAMME WORK AND INCORPORATE APPROPRIATE MEASURES TO MINIMISE DISTURBANCE TO OTHERS BY DUST, NOISE, FLOODING, SERVICES DISCONNECTIONS AND THE LIKE.
- NOTWITHSTANDING THE EXTENT OF FILLING AND EXCAVATION WORK SHOWN ON THE DRAWINGS, NOTED IN THE SPECIFICATION OR NOTED IN OTHER CONTRACT DOCUMENTS, THE EXTENT OF THE WORK SHALL BE CONFIRMED WITH THE SUPERINTENDENT PRIOR TO COMMENCEMENT OF THE WORK.
- THE CONTRACTOR SHALL MAINTAIN THE SITE FREE OF RUBBISH AND EXCESS MATERIALS AND SHALL STACK AND/OR STOCKPILE CONSTRUCTION MATERIALS IN A SUITABLE MANNER AS APPLICABLE FOR EACH OF THE INDIVIDUAL MATERIALS.

ENVIRONMENTAL AND SEDIMENT CONTROL NOTES

- THE CONTRACTOR SHALL AVOID DISTURBANCE OF ENVIRONMENTALLY SENSITIVE AREAS. UNLESS NOTED OTHERWISE IN THE CONTRACT DOCUMENTS, THE CONTRACTOR SHALL INSTALL TEMPORARY FENCING (STAR PICKETS WITH 2 STRANDS OF PLAIN WIRE AND FLAGGING TO SUIT) ALONG THE BOUNDS OF ENVIRONMENTAL BUFFERS. THERE SHALL BE NO ENTRY INTO ENVIRONMENTAL BUFFER AREAS (BEYOND THE FENCED BOUNDS) UNLESS OTHERWISE APPROVED FOR BY THE SUPERINTENDENT.
- THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN, INSTALLATION AND MAINTENANCE OF ALL TEMPORARY EROSION AND SEDIMENT CONTROL DEVICES/MEASURES INCLUDING CUT OFF DRAINS AND BUNDS, REQUIRED DURING THE COURSE OF THE WORK AND UP UNTIL THE WORK IS TAKEN OFF MAINTENANCE.
- A COPY OF THE PROPOSED EROSION AND SEDIMENT CONTROL PLAN, PREPARED IN ACCORDANCE WITH OTHER CONTRACT DOCUMENTATION, SHALL BE SUBMITTED TO THE SUPERINTENDENT PRIOR TO THE COMMENCEMENT OF WORK ON THE SITE.
- THE CONTRACTOR SHALL INSTALL ALL SEDIMENT CONTROL DEVICES/MEASURES PRIOR TO COMMENCEMENT OF THE WORK PROPER. DURING THE COURSE OF THE WORK, THE CONTRACTOR SHALL INSTALL FURTHER SEDIMENT CONTROL DEVICES/MEASURES INCLUDING CUT OFF DRAINS AND BUNDS, DEEMED NECESSARY TO CONTROL SEDIMENT RUNOFF.
- THE CONTRACTOR SHALL INSPECT ALL EROSION AND SEDIMENT CONTROL DEVICES/MEASURES FOR DAMAGE FOLLOWING EACH RAINFALL EVENT. DAMAGED DEVICES/MEASURES SHALL BE REMOVED AND REPLACED. SEDIMENT SHALL BE REMOVED AND ALL ERODED AREAS MADE GOOD.
- ALL EROSION AND SEDIMENT CONTROL DEVICES/MEASURES SHALL BE CLEANED OUT PRIOR TO SEDIMENT VOLUME REACHING 50% OF THE CONTROL DEVICE/MEASURE CAPACITY.

POND EARTHWORKS

- EARTHWORKS SHALL GENERALLY BE COMPLETED IN ACCORDANCE WITH 'ORIGIN' TECHNICAL SPECIFICATION Q-4522-20-TS-0001 POND EARTHWORKS AND WITH PROJECT SPECIFIC DRAWINGS, PROJECT STANDARD DRAWINGS AND OTHER CONTRACT DOCUMENTATION AS APPLICABLE.
- TOPSOIL SHALL BE STRIPPED TO A DEPTH OF 150mm ACROSS THE EXTENTS OF THE WORK AND STOCKPILED FOR REUSE WHERE DIRECTED BY THE SUPERINTENDENT.
- COMPACTION TESTING SHALL BE COMPLETED IN ACCORDANCE WITH THE SPECIFICATION.
- THE PREPARED SURFACE/SURFACES TO BE LINED SHALL BE MAINTAINED (MOISTURE CONTENT AND LEVEL OF COMPACTION) UNTIL IMMEDIATELY PRIOR TO LINER INSTALLATION. WHERE INSTALLATION OF THE LINER IS DELAYED DUE TO ANY CAUSE WHATSOEVER AND/OR THE PREPARED SURFACE/SURFACES ARE SUBJECT TO ELEMENTS OF THE WEATHER WHICH RESULTS IN CHANGES IN THE MOISTURE CONTENT, COMPACTION AND INTEGRITY OF THE SURFACE/SURFACES, THE SURFACE/SURFACES SHALL BE REWORKED IMMEDIATELY PRIOR TO THE INSTALLATION OF THE LINER TO ACHIEVE THE SPECIFIED REQUIREMENTS FOR MOISTURE CONTENT, LEVEL OF COMPACTION AND SURFACE INTEGRITY.

TOPSOIL REINSTATEMENT AND AMENDMENT

- TOPSOIL SHALL BE PLACED TO ALL DISTURBED AREAS EXCLUDING AREAS OCCUPIED BY PAVEMENTS, SPILLWAYS AND CAPPING MATERIAL OR AS DIRECTED BY THE SUPERINTENDENT.
- FINISHED EARTHWORKS SURFACES TO RECEIVE TOPSOIL SHALL BE PREPARED IN ACCORDANCE WITH REQUIREMENTS STATED HEREIN.
 - FINISHED EARTHWORKS SURFACES (SUBGRADE) TO BE TOPSOILED SHALL BE RIPPED/TYED TO DEPTHS OF 150mm.
 - GYPSON SHALL BE SPREAD AT THE RATE OF 50 t/ha (5 kg/m²) AND SHALL BE THOROUGHLY WORKED AND MIXED INTO THE LOOSENEED MATERIAL/MATERIALS VIA TWO (2) PASSES OF A TWO (2) WAY DISC PLOW MINIMUM OR VIA ROTARY HOE.
 - FOLLOWING MIXING, THE MATERIAL SHALL BE RESHAPED TO THE PROFILES REQUIRED OF THE FINISHED EARTHWORKS AND SHALL BE COMPACTED TO 95% MINIMUM OF THE MAXIMUM DRY DENSITY FOR THE MATERIAL - STANDARD COMPACTIVE EFFORT.
- TOPSOIL WORK AND ASSOCIATED SUBGRADE AMENDMENT SHALL BE COMPLETED IMMEDIATELY FOLLOWING THE TRIMMING OF EARTHWORKS.
- TOPSOIL SHALL BE PLACED TO A DEPTH OF 150mm.
- TOPSOIL SHALL BE AMENDED BY THE INCLUSION OF 10 t/ha FEEDLOT MANURE, 100 kg/ha UREA AND 2 t/ha GYPSON OR AS DIRECTED BY THE SUPERINTENDENT BASED ON SOIL ASSESSMENT.
- GRASS SEED OF THE SPECIES AND MIX COMPOSITION AS DETERMINED BY ORIGIN ENERGY SHALL BE SOWN INTO THE TOPSOIL.

BITUMINOUS GEOMEMBRANE LINER PRODUCT DATA

- DESCRIPTION - BGM IS AN SBS ELASTOMERIC MODIFIED BITUMINOUS GEOMEMBRANE.
- USE - EXTREME LEVEL OF MECHANICAL RESISTANCE, FOR USE AS ENVIRONMENTAL PROTECTION AND GROUNDWORKS WATERPROOFING (AGGRESSIVE MATERIALS, REINFORCED PRECAUTIONS)
 - RAILWAYS, DIRECTLY UNDER BALLAST
 - DAMS
- PRODUCT USE MUST BE VALIDATED BY THE MANUFACTURER.
- APPLICATION METHOD - TORCHED.
- STORAGE - ROLLS MUST NOT BE STORED DIRECTLY ON THE GROUND. THEY MUST BE LAID SUPPORTED ON CONCRETE BLOCKS, TRESTLES OR TIMBER BEAMS, MIN 35cm HEIGHT, PLACED UNDER MANDREL ENDS.

COMPOSITION	
GLASS MAT	50 g/m ²
NON-WOVEN GEOTEXTILE	400 g/m ²
ELASTOMERIC SBS	5400 g/m ²
SAND	200 g/m ²
POLYESTER ANTIRIOT FILM	15 g/m ²

CHARACTERISTICS

		STANDARD		UNITS	VALUES	TOLERANCE	
						MIN	MAX
DIMENSIONS	LENGTH			m	54	±	
	WIDTH			m	5.01	±	
THICKNESS (ON FINISHED PRODUCT)		ASTM D 5199		mm	5.40	5.32	6.16
SURFACE MASS		ASTM D 3776		kg/m ²	6.40	6.30	7
RESISTANCE TO TEARING	CROSS DIRECTION	ASTM D 4973		N	1025	769	
	LONGITUDINAL				39	29	
TENSILE PROPERTIES - MAXIMUM TENSILE STRENGTH	CROSS DIRECTION			kN/m	31	23	
	LONGITUDINAL	ASTM D 7275			60	48	
TENSILE PROPERTIES - ELONGATION	CROSS DIRECTION			%	60	48	
	LONGITUDINAL				32	24	
TENSILE PROPERTIES - MAXIMUM TENSILE STRENGTH	CROSS DIRECTION			kN/m	28	21	
	LONGITUDINAL	ASTM D 4595			90	60	
TENSILE PROPERTIES - ELONGATION	CROSS DIRECTION			%	90	60	
	LONGITUDINAL	ASTM D 4839		N	650	585	
STATIC PUNCTURE	SURFACE				-20		
	UNDER SURFACE	ASTM D 5147		°C	-20		
FLEXIBILITY AT LOW TEMPERATURE		ASTM E 96		m/s	6.10 ⁻¹⁶		
WATER PERMEABILITY (LIQUID TIGHTNESS)		ASTM E 96		m/s	6.10 ⁻¹⁶		
GAS PERMEABILITY (GAS TIGHTNESS)		ASTM D 1434-82		m ³ /(m ² ·s·atm)	< 2.3·10 ⁻¹⁴		

BITUMINOUS GEOMEMBRANE LINER INSTALLATION

- BITUMINOUS GEOMEMBRANE INSTALLATION SHALL BE PERFORMED IN ACCORDANCE TO THE MANUFACTURER'S RECOMMENDATION. IF RECOMMENDATIONS ARE IN CONFLICT WITH DESIGN, THE CONTRACTOR TO NOTIFY THE PRINCIPAL IN WRITING FOR CLARIFICATION.
- THE CONTRACTOR SHALL MONITOR AND ACCEPT RESPONSIBILITY FOR THE QUALITY OF MATERIALS PLACED INTO THE WORK. THE PRINCIPAL WILL REJECT MATERIALS INCORPORATED INTO WORK THAT FAIL TO COMPLY WITH SPECIFIED REQUIREMENTS. THE CONTRACTOR SHALL REMOVE REJECTED MATERIALS FROM THE WORK AND REPLACE WITH MATERIALS OF THE SPECIFIED QUALITY.
- MEASUREMENT SHALL BE MADE OF THE TOTAL SURFACE AREA IN SQUARE METRES COVERED BY BITUMINOUS GEOMEMBRANE. FINAL QUANTITIES WILL BE BASED ON AS-BUILT CONDITIONS. CONTRACTOR SHOULD MAKE ALLOWANCE FOR BITUMINOUS GEOMEMBRANE IN ANCHOR TRENCHES, DRAINAGE TRENCHES, AND OVERLAPS; HOWEVER, NO ALLOWANCE WILL BE MADE FOR WASTE OR MATERIALS USED FOR THE CONVENIENCE OF THE CONTRACTOR.
- ROLLS SHALL NOT BE DRAGGED, LIFTED BY ONE END, OR DROPPED. A MANDREL OF SUFFICIENT STRENGTH TO SUPPORT THE FULL WEIGHT OF A ROLL WITHOUT SIGNIFICANT BENDING, SHALL BE USED FOR ALL HANDLING ACTIVITIES. THE DIAMETER OF THE MANDREL SHALL BE SMALL ENOUGH TO BE EASILY INSERTED THROUGH THE CORE OF THE ROLL. CHAINS SHALL BE USED TO LINK THE ENDS OF THE MANDREL TO THE ENDS OF A SPREADER BAR. THE SPREADER BAR SHALL BE WIDE ENOUGH TO PREVENT THE CHAINS FROM RUBBING AGAINST THE ENDS OF THE ROLL. ALTERNATIVELY, A STINGER BAR PROTRUDING FROM THE END OF A FORKLIFT OR OTHER EQUIPMENT MAY BE USED. THE STINGER BAR SHALL BE AT LEAST THREE-FOURTHS THE LENGTH OF THE CORE AND ALSO MUST BE CAPABLE OF SUPPORTING THE FULL WEIGHT OF THE ROLL WITHOUT SIGNIFICANT BENDING.
- THE LINER SHALL BE PLACED IN A RELAXED STATE SUCH THAT THE MATERIAL CAN RESPOND TO THERMAL CHANGES WITHOUT EXCESSIVE BUCKLING, WRINKLING OR TENSIONING.
- ONLY THE QUANTITY OF BITUMINOUS GEOMEMBRANE THAT WILL BE ANCHORED AND SEALED TOGETHER IN ONE DAY SHALL BE DEPLOYED.

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BGM INSTALLATION (CONTINUED)

- THE PROCEDURES AND EQUIPMENT USED SHALL NOT ELONGATE, WRINKLE, SCRATCH, OR OTHERWISE DAMAGE THE BITUMINOUS GEOMEMBRANE, OTHER GEOSYNTHETIC LAYERS, OR THE UNDERLYING SUBGRADE. BITUMINOUS GEOMEMBRANE DAMAGED DURING INSTALLATION SHALL BE REPLACED OR REPAIRED, AT THE CONTRACTOR'S EXPENSE AND AT THE PRINCIPAL'S DISCRETION. ADEQUATE BALLAST (IE. SAND BAGS OR OTHER) SHALL BE PLACED ON THE BITUMINOUS GEOMEMBRANE, WITHOUT DAMAGING THE BITUMINOUS GEOMEMBRANE, TO PREVENT UPLIFT BY WIND. NO EQUIPMENT SHALL BE OPERATED ON THE TOP SURFACE OF THE BITUMINOUS GEOMEMBRANE WITHOUT PERMISSION FROM THE PRINCIPAL. THE METHODS USED TO DEPLOY, BACKFILL, AND BALLAST (TEMPORARY OR PERMANENT) OVER THE BITUMINOUS GEOMEMBRANE SHALL MINIMIZE WRINKLES AND TENSILE STRESSES IN THE BITUMINOUS GEOMEMBRANE. THE BITUMINOUS GEOMEMBRANE SHALL HAVE ADEQUATE SLACK TO PREVENT THE CREATION OF TENSILE STRESS.
- IN GENERAL, SEAMS SHALL BE ORIENTATED PARALLEL TO THE LINE OF MAXIMUM SLOPE. NO HORIZONTAL WELDS ALONG SLOPES OR WITHIN 1 METRE OF SLOPE TRANSITIONS UNLESS APPROVED BY THE PRINCIPAL. IN CORNERS AND ODD SHAPED GEOMETRIC LOCATIONS, THE TOTAL LENGTH OF THE FIELD SEAM SHALL BE MINIMIZED. SEAMS SHALL NOT BE LOCATED AT LOW POINTS IN THE SUBGRADE UNLESS GEOMETRY REQUIRES SEAMING AT SUCH LOCATIONS AS APPROVED BY THE PRINCIPAL.
- QUADRUPLE POINT LOCATIONS DUE TO ALIGNED STRIP ENDS ARE NOT ALLOWED. TRIPLE POINT LOCATIONS WILL BE COVERED WITH AN ADDITIONAL BITUMINOUS GEOMEMBRANE.
- THE BITUMINOUS GEOMEMBRANE SHALL NOT BE ALLOWED TO "BRIDGE OVER" VOIDS OR LOW AREAS IN THE SUBGRADE. THE BITUMINOUS GEOMEMBRANE SHALL REST IN INTIMATE CONTACT WITH THE SUBGRADE.
- THE SUBGRADE UNDER THE BITUMINOUS GEOMEMBRANE SHALL CONFORM TO THE TECHNICAL SPECIFICATIONS.
- TEMPORARY BALLASTING SUCH AS SAND BAGS OR TYRES SHALL BE PLACED ON THE LINER TO PREVENT WIND DAMAGE OR BRIDGING DURING AND AFTER INSTALLATION. IT SHOULD BE NOTED THAT THIS TEMPORARY BALLASTING SHALL BE OF A SUITABLE CONSTRUCTION TO PREVENT AGAINST DAMAGE OF THE LINER. THE CONTRACTOR SHALL BE REQUIRED TO ENSURE THAT THE SPACING OF THESE SAND BAGS/TYRES ARE APPROPRIATELY DESIGNED (THIS COULD INCLUDE TYING THE SAND BAGS/TYRES TOGETHER IN A HORIZONTAL AND VERTICAL DIRECTION) TO PREVENT AGAINST UPLIFT AND ANY POTENTIAL DAMAGE OF THE LINER. ANY LINER MATERIAL THAT HAS BEEN DAMAGED AS THE RESULT OF WIND OR BRIDGING, IN THE OPINION OF THE PRINCIPAL, SHALL BE REMOVED AND REPLACED AT THE CONTRACTOR'S EXPENSE.
- ALL PERSONNEL WORKING ON THE LINER SURFACE SHALL WEAR SOFT-SOLED SHOES, AND SHALL NOT ENGAGE IN ANY ACTIVITY WHICH MAY DAMAGE THE LINER.
- BITUMINOUS GEOMEMBRANE SHALL NOT BE DEPLOYED OR FIELD-SEALED IN THE PRESENCE OF SIGNIFICANT RAIN, IN AREAS OF PONDED WATER, OR IN THE PRESENCE OF WIND IN EXCESS OF 55 KM/HOUR. UNLESS AUTHORIZED BY THE PRINCIPAL, NO PLACEMENT OR SEAMING SHALL BE ATTEMPTED AT AMBIENT TEMPERATURES BELOW -25 DEGREES C (-13 DEGREES F) OR ABOVE 40 DEGREES C (104 DEGREES F). AMBIENT TEMPERATURE SHALL BE MEASURED AT A HEIGHT NO GREATER THAN 150 MM 6 INCHES ABOVE THE GROUND OR BITUMINOUS GEOMEMBRANE SURFACE. IN MARGINAL CONDITIONS, SEAMING SHALL CEASE UNLESS DESTRUCTIVE FIELD SEAM TESTS, CONDUCTED BY THE QC LABORATORY, CONFIRM THAT SEAM PROPERTIES MEET THE DESIGN REQUIREMENTS.
- THE CONTRACTOR SHALL NOMINATE A MASTER WELDING SUPERVISOR BEFORE COMMENCING WORK AND SHALL DEMONSTRATE THAT THE MASTER WELDING SUPERVISOR HAS A PROVEN BACKGROUND IN INSTALLATION OF SIMILAR SYSTEMS AND MATERIALS SIMILAR TO THOSE SPECIFIED. ALL PERSONNEL EMPLOYED IN WELDING SHALL BE COMPETENT AND EXPERIENCED IN THE USE OF THE EQUIPMENT. THE CONTRACTOR SHALL ULTIMATELY BE RESPONSIBLE FOR ENSURING THE QUALITY ASSURANCE PROGRAMME IS FOLLOWED.
- THE CONTRACTOR SHALL BE RESPONSIBLE AND SHALL PROVIDE SUFFICIENT RESOURCES FOR FIELD HANDLING, DEPLOYING, SEAMING, TEMPORARILY RESTRAINING (AGAINST WIND), AND OTHER ASPECTS OF THE DEPLOYMENT AND INSTALLATION OF THE BITUMINOUS GEOMEMBRANE. NO SEAMING SHALL BE PERFORMED UNLESS A MASTER WELDING SUPERVISOR IS PRESENT ON-SITE.
- EVERY WORKER PERFORMING WELDING OF THE BITUMINOUS GEOMEMBRANE WILL NEED TO DEMONSTRATE A CONDAIRI VERIFICATION OF COMPETENCE (VOC) PRIOR TO UNDERTAKING WORKS ON THE FIELD. THE CONDAIRI VOC CERTIFICATION AND TESTING WILL BE ADMINISTERED BY THE LEVEL 1 QC. TRIAL WELD TEST SAMPLES SHALL SUBMITTED TO A THIRD PARTY INDEPENDENT LABORATORY FOR DESTRUCTIVE TESTING.
- DESTRUCTIVE TESTING SHALL BE COMPLETED IN ACCORDANCE TO ASTM D 7056 AND ASTM D 3019. NON-DESTRUCTIVE AIR LANCE TESTING SHALL BE COMPLETED IN ACCORDANCE TO ASTM D 4437.
- CONNECTIONS TO ADJOINING STRUCTURES SHALL BE MADE IN ACCORDANCE WITH THE DETAILS SHOWN ON THE CONSTRUCTION DRAWINGS. CONNECTIONS SHALL BE AT LEAST EQUIVALENT IN STRENGTH TO THE NORMAL LAP JOINTS AND THE SECURITY OF CONTAINMENT SHALL NOT BE DIMINISHED. LOCAL STRESSES IN THE LINER AT CONNECTIONS SHALL BE MINIMISED.
- ANCHOR TRENCHES SHALL BE EXCAVATED IN ACCORDANCE WITH THE DETAILS ON THE CONSTRUCTION DRAWINGS. THE ANCHOR TRENCHES SHALL BE KEPT WELL DRAINED TO AVOID SOFTENING DURING RAIN PERIODS AND MAINTAINED SO AS TO NOT DRY, DESICCATE AND CRACK.
- IN ACCORDANCE WITH Q-4522-20-TS-0001, THE CONTRACTOR SHALL SEEK APPROVAL FROM THE PRINCIPAL PRIOR TO THE COMMENCEMENT OF ANCHOR TRENCH BACKFILLING. ONCE THE ANCHOR TRENCH IS READY TO BE BACKFILLED, IT SHALL BE BACKFILLED IN EARLY MORNING WHEN THE LINER IS AT MAXIMUM CONTRACTION. BACKFILLING SHALL BE CARRIED OUT IN A PLANNED, LOGICAL SEQUENCE TO AVOID OVERSTRESSING OF THE LINER AND MINIMIZE EXPOSURE WET WEATHER DAMAGE.
- ANCHOR TRENCH SHALL BE BACKFILLED WITH FLOWABLE CONCRETE STABILIZED SAND (5% CEMENTIOUS) AND MIX DESIGN SHALL BE SUBMITTED FOR APPROVAL.
- A LEVEL 1 QC IS REQUIRED DURING ALL LINER INSTALLATION, LINER REPAIRS, AND QUALITY/COMPLIANCE TESTING. MATERIAL TESTING SHALL BE CARRIED OUT AT RANDOMLY CHOSEN LOCATIONS, IN ACCORDANCE WITH SPECIFIED TESTING REQUIREMENTS AND FREQUENCIES, AND/OR AT LOCATIONS SELECTED BY THE PRINCIPAL.
- ALL AREAS FOUND TO BE DEFECTIVE SHALL BE REPAIRED AT THE EXPENSE OF THE CONTRACTOR. THE PRINCIPAL SHALL BE NOTIFIED OF DEFECTIVE AREAS PRIOR TO THE REPAIR TAKING PLACE.
- THE CONTRACTOR SHALL ENSURE A PLAN IS MARKED UP SHOWING THE LOCATIONS OF REPAIRS MADE AND THE TYPE OF REPAIR MADE. THE CONTRACTOR SHALL SUBMIT A MARKED UP DRAWING SHOWING THE LOCATIONS OF THE REPAIRS TO THE PRINCIPAL FOR REVIEW AND APPROVAL.
- THE ENTIRE SURFACE OF EVERY SHEET OF LINER MATERIAL SHALL BE INSPECTED BY THE CONTRACTOR DURING PLACING TO IDENTIFY ANY TEARS, ABRASIONS, INDENTATIONS, CRACKS, THIN AREAS, OR OTHER DEFECTS.
- ANY DEFECTS SUCH AS HOLES, TEARS, BLISTERS, LAMINATION, UNDISPERSED RAW MATERIALS OR VISIBLE NON-UNIFORMITY OR CONTAMINATION BY FOREIGN MATTER WHICH IN THE OPINION OF THE PRINCIPAL IS DETRIMENTAL TO THE LONG SERVICE LIFE REQUIRED OF THE LINER, SHALL BE GROUNDS FOR REJECTION OF THE LINER MATERIAL.
- WHERE ADDITIONAL FAULTS ARE FOUND, THE PRINCIPAL RESERVES THE RIGHT TO REJECT THE ROLL. THE CONTRACTOR SHALL REPLACE ANY REJECTED ROLLS AND REPAIR ANY DEFECTS TO THE PRINCIPAL'S SATISFACTION AT THE CONTRACTOR'S EXPENSE.

BGM INSTALLATION (CONTINUED)

- FOLLOWING INSTALLATION OF THE LINER, A DETAILED VISUAL INSPECTION OF THE PRIMARY LINER SURFACE SHALL BE PERFORMED BY THE PRINCIPAL (ACCOMPANIED BY THE CONTRACTOR), TO IDENTIFY ANY DEFECTS IN THE LINER SURFACE CAUSED DURING INSTALLATION. PRIOR TO PERFORMING THE SURVEY, A SURVEY GRID SHALL BE DETERMINED TO ENSURE THAT THE VISUAL SURVEY IS PERFORMED ACROSS 100% PERCENT OF THE LINER SURFACE.
- ALL LINER WELD SEAMS SHALL BE SUBJECT TO BOTH NON-DESTRUCTIVE AND DESTRUCTIVE TESTING. DESTRUCTIVE FIELD TESTING WILL BE AT THE INTERVALS AND ANY LOCATION CHOSEN BY THE PRINCIPAL. THE REPRESENTATIVE SAMPLES OF FIELD SEAMS SHALL BE TAKEN FOR LABORATORY TESTING BY AN INDEPENDENT, APPROPRIATELY QUALIFIED TESTING LABORATORY. WELD AND MATERIAL STRENGTH REQUIREMENTS TO COMPLY WITH MANUFACTURERS RECOMMENDATIONS.
- NON-DESTRUCTIVE AND DESTRUCTIVE TESTING SHALL BE OBSERVED BY THE LEVEL 1 QC/LIS.
- TRIAL WELDS TESTING SHALL BE CARRIED OUT THE SAME AS DESTRUCTIVE TESTING TRIAL WELDS.
- TRIAL WELDS TO BE COMPLETED AT BEGINNING OF PROJECT. WELD TO BE CONDUCTED BY MASTER WELDING SUPERVISOR AND SHALL BE SENT TO LABORATORY FOR TESTING.
- JOINT MUST BE CENTERED IN THE SAMPLE. THE SAMPLE MUST BE AT LEAST 350mm FOR 5 TESTS TO BE CARRIED OUT ON THE SAME SAMPLE. EACH SAMPLE MUST BE CLEARLY IDENTIFIED.
- NON-DESTRUCTIVE FIELD WELD TESTS SHALL BE CARRIED OUT ON ALL WELDED SEAMS. A FAILED TEST IS ANY LOCATION OF WELDED SEAM THAT HAS LESS THAN 150mm OF CROSS SECTIONAL WIDTH.
- DESTRUCTIVE TESTS SHALL BE CARRIED OUT AT AN INTERVAL OF EVERY 1000 METRES OF WELDED SEAMS. A PASSING TEST IS EQUAL OR GREATER THAN 90% OF MATERIAL STRENGTH AND FAILURE OF SAMPLE OUTSIDE OF WELD.
- THE CONTRACTOR SHALL DEPLOY THE BITUMINOUS GEOMEMBRANE PANELS IN GENERAL ACCORDANCE WITH THE LAYOUT DRAWING SPECIFIED. THE LAYOUT DRAWINGS MUST BE APPROVED BY THE PRINCIPAL OR LEVEL 1 QA PRIOR TO INSTALLATION OF ANY LINER.
- A BITUMINOUS GEOMEMBRANE FIELD PANEL IS A ROLL OR A PORTION OF ROLL CUT IN THE FIELD. EACH FIELD PANEL SHALL BE GIVEN A UNIQUE IDENTIFICATION CODE (NUMBER OR LETTER-NUMBER). THIS IDENTIFICATION CODE SHALL BE AGREED UPON BY THE LEVEL 1 QA AND CONTRACTOR.
- FIELD PANELS SHALL BE INSTALLED IN ACCORDANCE TO THE PRINCIPAL APPROVED WORK METHOD STATEMENT.
- PANELS SHALL BE SEALED IN ACCORDANCE WITH THE BITUMINOUS GEOMEMBRANE MANUFACTURER'S RECOMMENDATIONS. IN CORNERS AND ODD-SHAPED GEOMETRIC LOCATIONS, THE NUMBER OF FIELD SEAMS SHALL BE MINIMIZED. SEAMING SHALL EXTEND TO THE OUTSIDE EDGE OF PANELS. THE SEAM AREA SHALL BE FREE OF MOISTURE, DUST, DIRT, AND FOREIGN MATERIAL AT THE TIME OF SEAMING. THE PANELS SHALL OVERLAP A MINIMUM 200mm FOR SEAMING. ENDS AND OVERLAPS MUST BE WELDED ON A HOMOGENEOUS AND CONTINUOUS BASIS, LEAVING A 6mm BITUMEN BEAD ALONG THE SEAM.
- SEAMS SHALL BE WELDED USING PROPANE TORCHES. THE TORCH-WELDS MUST BE APPROVED ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS AND PRINCIPAL.
- BITUMINOUS GEOMEMBRANE TO BE WELDED TO CONCRETE AT INSTALLATION AREAS BY HEATING THE CONCRETE SURFACE AND THE BGM, THEN ROLLING WITH A SMALL ROLLER AND APPLYING HIGH PRESSURE. CONCRETE SURFACE SHALL BE PREPARED BY APPLYING 300 g/m² OF COLD PRIMER (SAMPRIME KS-P OR APPROVED EQUAL) 24 HOURS PRIOR TO WELDING.
- ONE QC SAMPLE, 500 MM IN LENGTH, FOR THE ENTIRE WIDTH OF A ROLL, SHALL BE OBTAINED FOR EVERY 900 SQUARE METERS (100 SQUARE FEET) OF MATERIAL DELIVERED TO THE SITE. SAMPLES SHALL NOT BE OBTAINED FROM THE FIRST METRE OF THE ROLL. THE SAMPLES SHALL BE IDENTIFIED BY MANUFACTURER'S NAME, PRODUCT IDENTIFICATION, LOT AND ROLL/PANEL NUMBER. THE DATE, A UNIQUE SAMPLE NUMBER, AND THE MACHINE DIRECTION SHALL ALSO BE NOTED.
- ANY PORTION OF THE LINER WITH A FLAW OR THAT FAILS A NON-DESTRUCTIVE OR DESTRUCTIVE TEST SHALL BE REPAIRED BY ONE OF THE FOLLOWING METHODS:
 - PATCHING OR CAPPING FOR HOLES, DEFECTS OR TEARS USED TO REPAIR LARGE HOLES, TEARS, LARGE PANEL DEFECTS, AND DESTRUCTIVE SAMPLE LOCATIONS THAT ARE LESS THAN 2M² (TOTAL AREA). PATCHES AND REPAIRS ARE TO BE OVERLAIN WITH A STRIP OF NEW MATERIAL AND SEALED (CAP STRIPPED). STRIP SHALL HAVE ROUNDED CORNERS AND EXTEND A MINIMUM OF 200 MM BEYOND THE EDGE OF THE REPAIR OR DEFECT AREA. AFTER REPAIRS ARE COMPLETED, THE REPAIRED SEAM SHALL BE NON-DESTRUCTIVELY TESTED.
 - REMOVAL AND REPLACE - USED TO REPLACE AREAS WITH LARGE DEFECTS WHERE THE PRECEDING METHODS ARE NOT APPROPRIATE. ALSO USED TO REMOVE EXCESS MATERIAL (WRINKLES) FROM THE INSTALLED LINER.
 - ONCE THE REPAIR HAS BEEN COMPLETED, FURTHER NON-DESTRUCTIVE OR DESTRUCTIVE TESTING SHALL BE CARRIED OUT.
- FULL RECORDS OF LINER TESTING AND INSPECTION SHALL BE SUBMITTED PROGRESSIVELY TO THE PRINCIPAL, AS THE WORK PROCEEDS. FINAL COMPLETION WILL NOT BE CERTIFIED UNTIL ALL RECORDS HAVE BEEN SUBMITTED AND APPROVED BY THE PRINCIPAL.
 - RECORDS SHALL INCLUDE, BUT NOT LIMITED TO, THE FOLLOWING:
 - CONTRACTOR'S AS-BUILT PANEL LAYOUT DRAWING SHOWING PANEL NUMBERS AND JOINT NUMBERS, TO BE MARKED UP PROGRESSIVELY WITH THE ROLL NUMBER USED FOR EACH PANEL, AND WITH THE LOCATIONS OF SAMPLES TAKEN FOR DESTRUCTIVE TESTING;
 - MANUFACTURER'S ROLL PRODUCTION TEST REPORTS FOR ALL ROLLS USED IN THE WORK;
 - SUBGRADE CERTIFICATION REPORTS;
 - DAILY TEST REPORTS REFERENCED TO JOINT NUMBERS;
 - DAILY TEST WELD FIELD TEST REPORTS REFERENCED TO JOINT NUMBERS, EQUIPMENT IDENTIFICATION, AND OPERATOR, AND INCLUDING WEATHER AND TEMPERATURE CONDITIONS AND ANY ADJUSTMENTS TO EQUIPMENT CONTROLS;
 - NON-DESTRUCTIVE AND DESTRUCTIVE TEST FIELD REPORT AND RECORD OF SUBMISSION FOR LABORATORY TESTING REFERENCED TO JOINT NUMBER;
 - LABORATORY TEST REPORTS TO BE AVAILABLE WITHIN TWO WEEKS OF TESTING; AND
 - RECORD DRAWING INDICATING LINER SEAM LOCATIONS, DESTRUCTIVE TEST LOCATIONS, CAP STRIP LOCATIONS, PATCHES AND ALL REPAIRS FOR THE LINER SYSTEM.

BITUMINOUS GEOMEMBRANE LINER BALLAST ANCHORS

- BALLAST ANCHORS SHALL BE SOIL ANCHOR PENETRATOR PE18SQ (OR ENGINEER APPROVED EQUIVALENT).
- BALLAST ANCHOR SPACING INTERVALS ALONG BATTER (AS PER DETAIL 1, Q-4522-20-DH-0003).
 - POINT A - EVERY 5 METRES (NEAREST SEAM OVERLAP).
 - POINT B AND C - EVERY 5 METRES (NEAREST SEAM OVERLAP).
- BITUMISEAL SHALL BE USED BETWEEN THE BALLAST PLATE AND BITUMINOUS GEOMEMBRANE LINER.
- BALLAST ANCHOR LOCATE AT ANCHOR POINT A (CREST OF DAM) SHALL BE PAINTED WITH HIGH VISIBILITY SAFETY PAINT.

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Appendix C Chemical Risk Assessment

Beetaloo Campaign - Hydraulic Fracturing Chemical Risk Assessment

Beetaloo Campaign - Hydraulic Fracturing Chemical Risk Assessment

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1.0 Background

Chemical risk assessments for the hydraulic fracturing fluid systems were undertaken to assess the potential human health effects of the chemicals proposed to be used in the Beetaloo 2019 campaign.

The following fluid systems were assessed:

- Hydraulic fracture stimulation fluids;
- Hydraulic fracture chemical tracers; and
- Drilling fluids.

The risk assessment aligns with the *Northern Territory Government, Department of Environmental and Natural Resources, Draft Guideline for the Preparation of an Environmental Management Plan under the Petroleum (Environment) Regulations, 2019* (herein referred to as NT 2019).

The methods used for this updated chemical risk assessment also follow the guidance provided by the Commonwealth (DOE 2017) and the methodology adopted for the chemical risk assessment is in general accordance with the following:

- National Industrial Chemicals Notification and Assessment Scheme (NICNAS), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017 (herein referred to as NICNAS 2017)
- enHealth. Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, 2012
- National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM); Schedule B4, Site-specific health risk assessment methodology, 2013

The chemical risk assessment comprised the following tasks:

- Hazard assessment. An evaluation of the environmental hazard of the chemical additives in the hydraulic fracturing fluid systems, based on their environmental persistence, bioaccumulation and aquatic toxicity properties. Also included was an evaluation of human health effects (i.e. genotoxicity, carcinogenicity, reproductive toxicity, oral toxicity, inhalation toxicity, dermal toxicity, chronic repeated dose toxicity).
- Exposure assessment. The exposure assessment comprised 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 fracturing fluid system.
- Screening and validation processes via Tier 1 and Tier 2 assessments. Determination of chemicals known to be of low concern, and identification of chemicals for further risk assessment.
 - o Tier 1: using published information about each chemical proposed to be used in the hydraulic fracturing fluid systems.
 - o Tier 2: A quantitative evaluation of the risks using toxicity values and quantitative estimates of chemical intake to provide an estimate of potential human health risk associated with the hydraulic fracturing activities, based on the identification of complete exposure pathways and hazard identification.

2.0 Hydraulic Fracture Chemical Risk Assessment Tier 1 Screen

2.1.1 Outcome of Tier 1 Screen – Stimulation Fluid Recipes

Three stimulation fluid recipes (SW, Hybrid and HVFR) will be used for the Beetaloo campaign.

Comparison of the chemicals with the assessment criteria as presented in DOE (2017) indicated that 10 chemicals were not considered to require a Tier 2 assessment. The chemicals have 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 were identified to be of low concern because of low hazard. **Table 1** presents a summary of the chemicals identified to be of low concern to human health for the hydraulic fracture stimulation fluid recipes.

Table 1 Chemicals identified to be of low human health concern (Tier 1) – Stimulation Fluid Recipes

CAS	Chemical	Reasoning
9003-04-7	Sodium polyacrylate	NICNAS (2017) low concern chemical
25987-30-8	Acrylamide acrylate copolymer	NICNAS (2017) low concern chemical
25987-30-8	Acrylamide, sodium acrylate polymer	NICNAS (2017) low concern chemical
107-21-1	Ethylene glycol	NICNAS (2017) low concern chemical
67-48-1	Choline chloride	NICNAS (2017) low concern chemical
77-92-9	Citric acid	NICNAS (2017) low concern chemical
7681-82-5	Sodium iodide	NICNAS (2017) low concern chemical
9000-30-0	Guar gum	NICNAS (2017) low concern chemical
7757-82-6	Sodium sulfate	NICNAS (2017) low concern chemical
126-96-5	Sodium diacetate	NICNAS (2017) low concern chemical

Based on the Tier 1 screening, most chemicals (24 from SW, 30 from Hybrid and 25 from HVFR) were identified to require a Tier 2 assessment. It is to be noted that none of these chemicals were identified to be persistent and bioaccumulative.

The Tier 1 screening is provided in **Appendix A** to **Appendix C**, and the chemical toxicological profiles are provided in **Appendix D** to **Appendix H**.

2.1.2 Outcome of Tier 1 Screen – Drilling Fluids

Comparison of the chemicals with the assessment criteria indicated that 15 chemicals were not considered to require a Tier 2 assessment. Nine chemicals have been assessed by NICNAS (2017) and were identified to be of low concern. In following the IMAP screening process, a further six chemicals (which were not assessed by NICNAS 2017) were identified to be of low concern to human health.

Table 2 presents a summary of the chemicals identified to be of low concern to human health for the drilling fluid recipe.

Table 2 Chemicals identified to be of low human health concern (Tier 1) – Drilling Fluids

CAS	Chemical	Reasoning
Not Applicable	Proprietary Chemical	NICNAS (2017) low concern chemical
77-92-9	Citric acid	NICNAS (2017) low concern chemical
9004-32-4	Poly Anionic Cellulose	NICNAS (2017) low concern chemical
7447-40-7	Potassium Chloride	NICNAS (2017) low concern chemical

CAS	Chemical	Reasoning
144-55-8	Sodium Bicarbonate	NICNAS (2017) low concern chemical
7647-14-5	Sodium Chloride	NICNAS (2017) low concern chemical
6381-77-7	Sodium erythorbate	NICNAS (2017) low concern chemical
11138-66-2	Xanthan Gum	NICNAS (2017) low concern chemical
1317-65-3	Calcium Carbonate	NICNAS (2017) low concern chemical
1310-73-2	Sodium hydroxide	Acute toxicity only. No evidence of systemic toxicity. Due to the unavailability of a NOAEL, quantification of risks from repeated exposure is not possible. However, due to dissociation into ions which are subject to homeostatic controls in the human body, systemic effects from repeated exposures to sodium hydroxide are not expected (NICNAS 2017).
1310-58-3	Potassium Hydroxide	Acute toxicity only. No evidence of systemic toxicity. Similar results were reported for sodium hydroxide (NICNAS 2017).
9005-25-8	Starch	NICNAS polymer of low concern (PLC)
12199-37-0	Smectite	No chronic data available. Read across to bentonite which is listed as a NICNAS (2017) low concern chemical.
38193-60-1	Polyacrylamide	NICNAS PLC
1332-58-7	Plagioclase Feldspar/Kaolinite	Listed in US Food and Drug Administration (FDA) Generally Recognized as Safe (GRAS) list and Inert Ingredients Eligible for US Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 25(b) pesticide products.

Based on the Tier 1 screening eleven drilling fluid chemicals were identified to require a Tier 2 assessment. It is to be noted that none of these chemicals were identified to be persistent and bioaccumulative.

One of the chemicals is proprietary, the CAS number and name has been redacted from the public submission to protect the intellectual property of chemical manufacturer. Although the proprietary details of the chemical have been redacted in this report, AECOM had access to the chemical name and CAS number and the assessment of risk from the redacted chemical is presented in this report.

The Tier 1 screening is provided in **Appendix D**, and the chemical toxicological profiles are provided in **Appendix G**.

2.1.3 Outcome of Tier 1 Screen – Chemical Tracers

The following chemical tracers may be used for the 2019 Beetaloo campaign – CFT, GFT and WFT. The proprietary chemical CAS numbers and names have been redacted from the public submission to protect the intellectual property of chemical manufacturers. Although the proprietary details of the chemicals have been redacted in this report, AECOM had access to the chemical names and CAS numbers and the assessment of risk from the redacted chemicals is presented in this report. Comparison of the chemicals with the assessment criteria indicated that all chemicals were considered to require a Tier 2 assessment. However, none of these chemicals were identified to be persistent and bioaccumulative.

The Tier 1 screening is provided in **Appendix E**, and the chemical toxicological profiles are provided in **Appendix H**.

3.0 Hydraulic Fracture Chemical Risk Assessment Tier 2 Screen

3.1.1 Tier 2 Screen Methodology

The Tier 2 assessment evaluated the toxicity of the individual chemicals and characterised the cumulative risks of the total fluid mixtures to Workers. The methodology incorporated an assessment of potential exposures to the Workers, with the following identified as the only potentially complete exposure pathways:

- Incidental ingestion and dermal contact of flowback fluid by Workers during the hydraulic stimulation period for a maximum duration of 1 month; and
- Inhalation of mist from the evaporation units at the flowback tank by Workers for a maximum duration of 1 year.

These scenarios are also deemed protective of the following due to the less frequent and short duration of these exposures occurring:

- Worker exposure during a spill (i.e. a coupling breaks on a tank and releases product onto the worker) or leak scenarios

Based on the risk mitigation measures identified in the NT government's Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, the Codes of Practice for Onshore Petroleum activities in the Northern Territory and mitigation measures outlined by Origin in its EMP¹, no potentially complete exposure pathways were identified for hydraulic fracturing chemicals to impact groundwater that is used for beneficial use in the project area. The specific controls implemented by Origin focussed on the protection of aquifers follow industry standard practice and include:

- the physical vertical separation distances of 1400m between the aquifer and target formation to prevent any migration of stimulation fluid to aquifer units (refer to **Appendix I**);
- the 11.4 km horizontal separation distance between the exploration well and the closest groundwater extraction bores (refer to **Appendix I**);
- use of double lined wastewater tanks with leak detection;
- implementation of spill management plan;
- use of enclosed tanks and freeboard requirements; and
- mandatory secondary containment requirements.

Potential exposures to hydraulic fracturing chemicals at the project area were therefore assessed to be limited to the above ground storage and handling of flowback water. Management of flowback water involves temporary storage in above ground fluid holding tanks for evaporation.

3.1.2 Chemicals of Potential Concern

Exposure point concentrations (EPC) were developed for each of the hydraulic fracturing fluid systems using theoretical calculations, where it was conservatively assumed that 100% of the mass of the chemicals injected into the well will be present in the flowback water.

A summary of the chemicals that require further assessment are presented in **Table 3** to **Table 7**.

Table 3 Chemicals requiring further assessment (Tier 2) – Stimulation Fluid SW Recipe (24 chemicals)

CAS	Chemical Name
7647-01-0	Hydrochloric acid
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated
7647-14-5	Sodium Chloride
64-19-7	Acetic acid
81741-28-8	Tributyl tetradecyl phosphonium chloride

¹ Origin 2019. Beetaloo Basin Drilling Stimulation and Well Testing Program, Environmental Management Plan

CAS	Chemical Name
25322-68-3	Polyethylene glycol
7631-90-5	Sodium bisulfite
104-55-2	Cinnamaldehyde
111-46-6	Diethylene glycol
67-56-1	Methanol
61788-90-7	Amine oxides, cocoalkyldimethyl
1310-73-2	Sodium hydroxide
100-52-7	Benzaldehyde
64-17-5	Ethanol
64742-47-8	Hydrotreated light petroleum distillate
61791-00-2	Fatty acids, tall-oil, ethoxylated
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)
71-36-3	Butyl alcohol
68131-39-5	Alcohols, C12-15, ethoxylated
68551-12-2	Alcohols, C12-16, ethoxylated
107-13-1	Acrylonitrile
111-42-2	Diethanolamine
111-30-8	Glutaraldehyde

Table 4 Chemicals requiring further assessment (Tier 2) – Stimulation Fluid Hybrid Recipe (30 chemicals)

CAS	Chemical Name
7647-01-0	Hydrochloric acid
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated
1319-33-1	Ulexite
102-71-6	Triethanol amine
7647-14-5	Sodium Chloride
1310-73-2	Sodium hydroxide
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated
64-19-7	Acetic acid
111-42-2	Diethanolamine
81741-28-8	Tributyl tetradecyl phosphonium chloride
7681-38-1	Sodium bisulfite
7758-19-2	Chlorous acid, sodium salt
12008-41-2	Disodium octaborate tetrahydrate
104-55-2	Cinnamaldehyde
25322-68-3	Polyethylene glycol
111-46-6	Diethylene glycol

CAS	Chemical Name
14808-60-7	Crystalline silica, quartz
67-56-1	Methanol
7775-27-1	Sodium persulfate
61788-90-7	Amine oxides, cocoalkyldimethyl
100-52-7	Benzaldehyde
64-17-5	Ethanol
64742-47-8	Hydrotreated light petroleum distillate
61791-00-2	Fatty acids, tall-oil, ethoxylated
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)
71-36-3	Butyl alcohol
68131-39-5	Alcohols, C12-15, ethoxylated
68551-12-2	Alcohols, C12-16, ethoxylated
107-13-1	Acrylonitrile
111-30-8	Glutaraldehyde

Table 5 Chemicals requiring further assessment (Tier 2) – Stimulation Fluid HVFR Recipe (25 chemicals)

CAS	Chemical Name
64-19-7	Acetic acid
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated
68131-39-5	Alcohols, C12-15, ethoxylated
68551-12-2	Alcohols, C12-16, ethoxylated
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)
61788-90-7	Amine oxides, cocoalkyldimethyl
100-52-7	Benzaldehyde
71-36-3	Butyl alcohol
104-55-2	Cinnamaldehyde
111-42-2	Diethanolamine
111-46-6	Diethylene glycol
64-17-5	Ethanol
68439-54-3	Ethoxylated branched C13 alcohol
61791-00-2	Fatty acids, tall-oil, ethoxylated
7647-01-0	Hydrochloric acid
64742-47-8	Hydrotreated light petroleum distillate
67-56-1	Methanol
25322-68-3	Polyethylene glycol
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)

CAS	Chemical Name
7631-90-5	Sodium bisulfite
1310-73-2	Sodium hydroxide
9005-65-6	Sorbitan monooleate polyoxyethylene derivative
81741-28-8	Tributyl tetradecyl phosphonium chloride
10486-00-7	Sodium perborate tetrahydrate

Table 6 Chemicals requiring further assessment (Tier 2) – Drilling Fluids (11 chemicals)

CAS	Chemical Name
78330-21-9	Alcohol, C11-14, ethoxylated
64742-47-8	Distillates, hydrotreated light
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues
111-30-8	Glutaraldehyde
107-22-2	Glyoxal <1%
67-56-1	Methanol
5064-31-3	Nitrilotriacetic acid, trisodium salt monohydrate
14808-60-7	Quartz/Cristobite
497-19-8	Sodium Carbonate
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione
50-01-1	Guanidine, hydrochloride (1:1)

Table 7 Chemicals requiring further assessment (Tier 2) – Chemical Tracers (4 chemicals)

CAS	Chemical Name
Proprietary	CFT (one chemical selected to represent a group of 20 similar chemicals)
Proprietary	GFT (one chemical selected to represent a group of 15 similar chemicals)
Proprietary	WFT
Proprietary	WFT

3.1.3 Outcome of Tier 2 Screen

For the assessment of the overall potential for adverse human health effects posed by simultaneous exposure to multiple chemicals, the estimated daily intake of the chemicals by inhalation and direct (ingestion and dermal) contact were compared to acceptable risk-based intakes to calculate an individual hazard quotient (HQ) and then summed for all constituents into a hazard index (HI).

Consistent with Australian risk assessment methodologies, if the HI is less than or equal to 1, then no adverse health effects are likely associated with exposures. However, if the total HI is greater than 1, adverse health effects may be possible and therefore the assumptions inherent in the risk characterisation process warrant further evaluation

3.1.3.1 Stimulation Fluids

A summary of the calculated risks for the workers that are relevant to the assessment of potential exposure to COPCs in stimulation fluids on-site, based on the available data is presented in **Table 8**.

Table 8 Risk associated with potential exposure to Workers – Stimulation Fluids

Receptor and Pathway	Threshold Hazard Index
	100% Mass Return
Worker - Exposure to Stimulation Fluid SW Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.01
Dermal exposure to chemicals via incidental contact with flowback water	0.20
Inhalation of mist from the evaporation units containing flowback water	0.05
Total Risk	0.3
Worker - Exposure to Stimulation Fluid Hybrid Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.03
Dermal exposure to chemicals via incidental contact with flowback water	0.08
Inhalation of mist from the evaporation units containing flowback water	0.74
Total Risk	0.9
Worker - Exposure to Stimulation Fluid HVFR Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.01
Dermal exposure to chemicals via incidental contact with flowback water	0.22
Inhalation of mist from the evaporation units containing flowback water	0.05
Total Risk	0.3

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback water, where either SW, Hybrid or HVFR stimulation fluid recipes are used and assuming 100% mass recovery, are below the target 1, hence, risks are considered to be low and acceptable.

3.1.3.2 Drilling Fluid

A summary of the calculated risks for the workers that are relevant to the assessment of potential exposure to COPCs in the drilling fluid on-site, based on the available data is presented in **Table 9**.

Table 9 Risk associated with potential exposure to Workers – Drilling Fluid

Receptor and Pathway	Threshold Hazard Index
	100% Mass Return
Worker	
Ingestion of chemicals via incidental contact with flowback water	0.004
Dermal exposure to chemicals via incidental contact with flowback water	0.01
Inhalation of mist from the evaporation units containing flowback water	0.25
Total Risk	0.3

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback water, where drilling fluid recipe is used and assuming 100% mass recovery are below the target 1, hence, risks are considered to be low and acceptable.

3.1.3.3 Chemical Tracers

A summary of the calculated risks for the workers that are relevant to the assessment of potential exposure to COPCs in the Chemical Tracers on-site, based on the available data is presented in **Table 10**.

Table 10 Risk associated with potential exposure to Workers – Chemical Tracers

Receptor and Pathway	Threshold Hazard Index
	100% Mass Return
Worker – Exposure to Chemical Tracer CFT Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.0000032
Dermal exposure to chemicals via incidental contact with flowback water	0.000010
Inhalation of mist from the evaporation units containing flowback water	0.000018
Total Risk	0.00003
Worker – Exposure to Chemical Tracer GFT Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.0000047
Dermal exposure to chemicals via incidental contact with flowback water	0.0010
Inhalation of mist from the evaporation units containing flowback water	0.000026
Total Risk	0.001
Worker – Exposure to Chemical Tracer WFT Recipe	
Ingestion of chemicals via incidental contact with flowback water	0.30
Dermal exposure to chemicals via incidental contact with flowback water	0.012
Inhalation of mist from the evaporation units containing flowback water	-
Total Risk	0.3

The following can be noted from the table above:

- The calculated risks associated with potential exposure to COPC identified in flowback water, where either CFT, GFT or WFT chemical tracer recipes are used and assuming 100% mass recovery, are below the target 1, hence, risks are considered to be low and acceptable.

3.1.3.4 Combination of Hydraulic Fracturing Fluid Systems

A summary of the calculated risks for the workers that are relevant to the assessment of potential exposure to COPCs from combinations of hydraulic fracturing fluid systems on-site, based on the available data is presented in **Table 11**.

Table 11 Risk associated with potential exposure to Workers – Combination of Hydraulic Fracturing Fluid Systems

Receptor	Threshold Hazard Index
	100% Mass Return
Worker	
Exposure to SW + Drilling Fluid + Chemical Tracer CFT Recipes	0.5
Exposure to Hybrid + Drilling Fluid + Chemical Tracer CFT Recipes	1
Exposure to HVFR+ Drilling Fluid + Chemical Tracer CFT Recipes	0.5
Exposure to SW + Drilling Fluid + Chemical Tracer GFT Recipes	0.5
Exposure to Hybrid + Drilling Fluid + Chemical Tracer GFT Recipes	1
Exposure to HVFR+ Drilling Fluid + Chemical Tracer GFT Recipes	0.5
Exposure to SW + Drilling Fluid + Chemical Tracer WFT Recipes	0.8
Exposure to Hybrid + Drilling Fluid + Chemical Tracer WFT Recipes	1
Exposure to HVFR+ Drilling Fluid + Chemical Tracer WFT Recipes	0.8

The following can be noted from the table above:

- On the basis of the risk evaluation, no unacceptable risk to Workers was identified in all of the possible recipe combinations of stimulation fluids, drilling fluids and chemical tracers. It is noted that conservative risk scenarios assessed included regular exposure to the flowback water during the hydraulic stimulation and evaporation phases, with exposures to high theoretical concentrations of COPC in the flowback water. This may result in overestimation of the risk.

It is to be noted that this assessment does not replace the requirement for appropriate occupational health and safety procedures and management plans. Crystalline silica is scheduled by Safe Work Australia as a chemical for which health monitoring may be required.

The Tier 2 assessment is provided in **Appendix A to Appendix E**, the chemical toxicological profiles are provided in **Appendix F to Appendix H**.

4.0 References

AECOM (2019). Beetaloo 2019 Campaign – Chemical Risk Assessments, April 2019.

Department of the Environment and Energy (DOE 2017), Exposure Draft - Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction, 2017

enHealth (2012). Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, 2012

National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM 2013); Schedule B4, Site-specific health risk assessment methodology, 2013

National Industrial Chemicals Notification and Assessment Scheme (NICNAS 2017), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017

Northern Territory Government, Department of Environmental and Natural Resources, Draft Guideline for the Preparation of an Environmental Management Plan under the Petroleum (Environment) Regulations, 2019

Origin (2019). Beetaloo Basin Drilling Stimulation and Well Testing Program, Environmental Management Plan, 2019

Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, Draft Final Report, December 2017.

Appendix A

Chemical Risk
Assessment Hydraulic
Fracture Stimulation
Fluid – Hybrid

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)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
Hydrochloric acid	7647-01-0	1.152	10,206	0.0392%	11,757	0.0421%	474	Acid	Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	5,253	0.0202%	4,938	0.0177%	199	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	1.40E-03	7.78E-05	7.79E-03	9.26E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ulexite	1319-33-1	1.49	3,476	0.0134%	5,175	0.0185%	209	Crosslinker	Chronic endpoints for Boric acid were available for Daphnia (6 mg/L) and Fish (2.1 mg/L).	Based on Chronic: Moderate	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	7.63E-03	3.21E-03	4.25E-02	5.33E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Triethanol amine	102-71-6	1.1245	3,309	0.0127%	3,721	0.0133%	150	Crosslinker	Fish: 96h-LC50 of 11,800 mg/ Daphnia: 24h-EC50 of 1,390 mg/l Daphnia: 21 d NOEC of 16 mg/l Algae:96 h EC50 of 910 mg/l	Based on Chronic: Low	Inherently biodegradable	Not Bio accumulative (Based on an estimated log Kow value of -1.0, and BCF value of <3.9)	Tier 2	4.21E-04	9.55E-06	2.35E-03	2.78E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium Chloride	7647-14-5	2.165	2,859	0.0110%	6,189	0.0221%	249	Stabiliser	EC50 = 400 to 30000 mg/L EC50 Fish = 1290 mg/L NOEC = 314 mg/L (Daphnia)	Based on Chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value
Sodium hydroxide	1310-73-2	1.515	2,059	0.0079%	3,119	0.0112%	126	pH buffer	Measured acute endpoints were available for fish (196 mg/L). Measured chronic endpoint were available for Daphnia (240 mg/L)	Based on Chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	1,876	0.0072%	1,763	0.0063%	71	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletomema costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	4.99E-04	6.59E-02	2.78E-03	6.92E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Acetic acid	64-19-7	1.05	1,558	0.0060%	1,636	0.0059%	66	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 2	1.93E-05	4.93E-06	1.07E-04	1.32E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Diethanolamine	111-42-2	1.1	1,459	0.0056%	1,605	0.0057%	65	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	Not Bioaccumulative. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 2	1.62E-02	3.37E-04	9.04E-02	1.07E-01	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	736	0.0028%	700	0.0025%	28	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna) Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 2	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only
Sodium bisulfite	7681-38-1	2.44	483	0.0019%	1,179	0.0042%	47	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	1.59E-05	6.79E-11	8.85E-05	1.04E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Chlorous acid, sodium salt	7758-19-2	2.47	458	0.0018%	1,131	0.0040%	46	Breaker	LC50 values above 100 mg/l (fish) LC50 48-hour = 0.063 mg/l (daphnia) EC:50 value at 72 h as 1.2 mg/l (algae)	Based on Acute: Very High	No. Not expected to be persistent due to its instability.	No. Based on an estimated log Kow value of 3	Tier 2	4.10E-03	1.56E-08	2.29E-02	2.70E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Disodium octaborate tetrahydrate	12008-41-2	1.874	336	0.0013%	630	0.0023%	25	Crosslinker	Algae: EC10 (3 d) 96.5 mg/L (Pseudokirchneriella subcapitata) Fish: LC50 (96 h) 314.6 mg/L (Pimephales promelas), NOEC (34 d) 25.2 mg/L (Danio rerio) Invertebrates: NOEC (21 d) 42.5 mg/L (Daphnia magna) Microorganism: EC50 (3 h									

Chemical Risk Assessment
Hydraulic Fracture Stimulation Fluid HYBRID 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)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
Methanol	67-56-1	0.791	125	0.0005%	99	0.0004%	4	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 2	3.76E-04	5.52E-05	2.10E-03	2.53E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium persulfate	7775-27-1	1.68	116	0.0004%	194	0.0007%	8	Breaker	LC50 fish = 163 to 771 mg/L EC50 invertebrates = 133 and 519 mg/L EC50 algae = 116 mg/L	Based on Acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	4.10E-05	1.33E-08	2.29E-04	2.70E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	103	0.0004%	74	0.0003%	3	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-16.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 2	1.30E-04	6.18E-03	7.27E-04	7.04E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Benzaldehyde	100-52-7	1.0415	47	0.0002%	48	0.0002%	2	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L, and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 2	2.29E-05	4.03E-05	1.27E-04	1.91E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethanol	64-17-5	0.7864	45	0.0002%	35	0.0001%	1	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 2	2.07E-07	5.11E-08	1.15E-06	1.41E-06	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Hydrotreated light petroleum distillate	64742-47-8	0.8	43	0.0002%	35	0.0001%	1	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes 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	Tier 2	4.90E-07	4.41E-04	2.73E-06	4.45E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	23	0.0001%	24	0.0001%	1	Surfactant	96h-LL50 > 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 2	3.37E-07	3.27E-06	1.88E-06	5.48E-06	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	22	0.0001%	20	0.0001%	1	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scenedesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No Log Kow 3	Tier 2	5.67E-06	1.86E-04	3.16E-05	2.23E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Butyl alcohol	71-36-3	0.81	22	0.0001%	18	0.0001%	1	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 2	1.98E-06	2.11E-06	1.10E-05	1.51E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	20	0.0001%	18	0.0001%	1	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 - 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 - 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 - 5.36, and BCF value of 1.1 - 1.8, it is not expected to be bioaccumulative.	Tier 2	4.97E-06	3.39E-06	2.77E-05	3.61E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	20	0.00008%	19	0.00007%	1	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 - 0.33 mg/L. Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 - 1.75 mg/L. Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 - 5.36, and BCF value of 1.1 - 1.8, it is not expected to be bioaccumulative.	Tier 2	5.42E-06	2.24E-03	3.02E-05	2.27E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Acrylonitrile	107-13-1	0.806	2	0.00001%	2	0.00001%	0.1	Surfactant	96h LC50 for freshwater fish = 10 - 20 mg/l 96h LC50 for saltwater fish 8.6 mg/l 48h EC50 for Daphnia = 7.6 mg/l 30d NOEC for fish of 0.17 mg/l	Based on Chronic: High	Biodegradable	No based on the low log Pow (0.00-0.30)	Tier 2	1.11E-04	5.95E-05	6.21E-04	7.92E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Glutaraldehyde	111-30-8	1.05	0	0.0000001%	0	0.00000%	0.001	Biocide	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 reproduct'n 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	Based on Chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 2	7.47E-05	1.12E-05	4.16E-04	5.02E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	Oral/Dermal Exposures				Inhalation Exposures				Threshold Chronic TC or RfC (mg/m³)	NOAEC or LOAEC (mg/m³)	NOAEL or LOAEL (mg/kg bw/d)	Reference	UF	Reference
		Threshold Chronic TDI or RfD (mg/kg/day)		Dermal Permeability (cm/hr)	Reference	Inhalation Unit Risk (ug/m³)⁻¹	Non-Threshold Slope Factor (mg/kg/day)⁻¹								
COPC in Hydraulic Fracturing Fluid Injected into Well															
1319-33-1	Boronatrocalcite/Ulexite ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RfD		9.6	NICNAS (2017)	100	NICNAS (2017)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated ^B	0.5	D	1.21E-04	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated ^B	0.5	D	2.87E-01	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
64-19-7	Acetic acid	12	D	5.56E-04	EPI				42	converted from RfD		1200	NICNAS (2017)	100	NICNAS (2017)
25322-68-3	Polyethylene glycol	8	D	2.14E-06	EPI				28	converted from RfD		8000	REACH	1000	D
7631-90-5	Sodium bisulfite ^C	10.5	D	4.16E-09	EPI				36.75	converted from RfD		1050	NICNAS (2017)	100	NICNAS (2017)
104-55-2	Cinnamaldehyde	2	D	5.20E-03	EPI				7	converted from RfD		200	NTP (2004); REACH	100	D
67-56-1	Methanol	0.037	D	3.19E-04	EPI				0.13	converted from RfD		3.7	NICNAS (2017)	100	NICNAS (2017)
61788-90-7	Amine oxides, cocoalkyldimethyl	0.08	D	1.03E-01	EPI				0.28	converted from RfD		80	OECD (2001)	1000	D
100-52-7	Benzaldehyde	0.3	D	3.83E-03	EPI				1.05	converted from RfD		300	OECD (2002); REACH; NICNAS	1000	D
64-17-5	Ethanol	24	D	5.38E-04	EPI				84	converted from RfD		2400	NICNAS (2017)	100	NICNAS (2017)
64742-47-8	Hydrotreated light petroleum distillate	10	D	1.96E+00	EPI				35	converted from RfD		1000	NICNAS (2017)	100	NICNAS (2017)
61791-00-2	Fatty acids, tall-oil, ethoxylated	10	D	2.11E-02	EPI				35	converted from RfD		1000	REACH	100	D
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	0.5	D	7.14E-02	EPI				1.75	converted from RfD		50	USEPA (2010)	100	D
71-36-3	Butyl alcohol	1.25	D	2.31E-03	EPI				4.375	converted from RfD		125	OECD (2001)/NICNAS	100	D
68131-39-5	Alcohols, C12-15, ethoxylated ^B	0.5	D	1.48E-03	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
68551-12-2	Alcohols, C12-16, ethoxylated ^B	0.5	D	8.97E-01	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
107-13-1	Acrylonitrile	0.0025	D	1.16E-03	EPI				0.00875	converted from RfD		0.25	OECD (2005); NICNAS	100	D
111-42-2	Diethanolamine	0.014	D	4.51E-05	EPI				0.049	converted from RfD		14	REACH; OECD (2002); NICNAS	1000	D
111-30-8	Glutaraldehyde	0.04	D	3.25E-04	EPI				0.14	converted from RfD		4	NICNAS (2017)	100	NICNAS (2017)
102-71-6	Triethanol amine	1.25	D	4.93E-05	EPI				4.375	converted from RfD		125	NICNAS (2017)	100	NICNAS (2017)
7758-19-2	Chlorous acid, sodium salt	0.039	D	8.27E-09	EPI				0.1365	converted from RfD		3.9	NICNAS (2017)	100	NICNAS (2017)
12008-41-2	Disodium octaborate tetrahydrate ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RfD		9.6	NICNAS (2017)	100	NICNAS (2017)
7775-27-1	Sodium persulfate	0.67	D	7.05E-07	EPI				2.345	converted from RfD		67	NICNAS (2017)	100	NICNAS (2017)
68439-54-3	Ethoxylated branched C13 alcohol	0.5	D	1.06E-03	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)	25	JECFA	5.02E-02	EPI				87.5	converted from RfD		-	JECFA(1973); US FDA; FSANZ (2018)	-	-
9005-65-6	Sorbitan monooleate polyoxyethylene derivative	10	EFSA	3.54E-09	EPI				35	converted from RfD		-	EFSA (2017)	-	-
111-46-6	2,2"-oxydiethanol (diethylene glycol)	0.3	D	4.17E-05	EPI				1.05	converted from RfD		300	Health Council of the Netherlands (2007); NICNAS	1000	D
7681-38-1	Sodium bisulfate ^C	10.5	D	9.29E-09	EPI				36.75	converted from RfD		1050	NICNAS (2017)	100	NICNAS (2017)
14808-60-7	Crystalline silica, quartz	Not toxic via oral/dermal exposure							0.003	USEPA (2019)		-	-	-	-
10486-00-7	Sodium perborate tetrahydrate	0.05	D	1.81E-06	EPI				0.175	converted from RfD		50	REACH	1000	D

Notes:

A - Read across data from Boric Acid

B - Read across data from Alcohol ethoxylates C6-C12

C - Read across data from Sodium Sulfite

References:

D - Derived (refer to individual Toxicity Profiles)

EFSA - European Food Safety Authority

EPI - USEPA Estimation Programs Interface (EPI) Suite

FSANZ - Food Standards Australia New Zealand

J- JECFA - Joint FAO/WHO Expert Committee on Food Additives

NICNAS - National Industrial Chemicals Notification and Assessment Scheme. Assessed at <https://www.nicnas.gov.au/>

NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associatedwith coal seam gas extraction in Australia, prepared by the National Industrial ChemicalsNotification and Assessment Scheme

NTP - US Department of Health and Serices National Toxicology Program

OECD - Organisation for Economic Co-operation and Development Screening Information Data Set (SIDS)

REACH - ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - Hybrid Recipe

Chronic Exposures

Chronic Exposures					Exposure Calculations (RME)				
General Data/ Equations				Units	Ingestion of Flowback Water by Workers				
Exposure Parameters									
Exposure Frequency (EF)		days/year		20	Assume work 5 days per week for 1 month during the fracing period				
Exposure Duration (ED)		years		0.083	Maximum duration of the frac. Works will be complete in one month.				
Body Weight (BW)		kg		78	Average male and female adults as per enHealth 2012				
Averaging Time - NonThreshold (ATc)		days		25550	USEPA 1989 and CSMS 1996				
Averaging Time - Threshold (ATn)		days		30.42	USEPA 1989 and CSMS 1996				
Ingestion Rate (IRw)		L/day or L/hr		0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fracking.				
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	4.2E-09	NonThreshold			
					3.5E-06	Threshold			
<i>Daily Intake from Water = Concentration in Water x Intake Factor (ref. USEPA 1989)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water 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)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB	5.0E-01		5.0E-01	198.94	8.3E-07	7.0E-04	--	1.4E-03
1319-33-1	Boronatrocaltcite/UlexiteA	9.6E-02		9.6E-02	208.50	8.7E-07	7.3E-04	--	7.6E-03
102-71-6	Triethanol amine	1.3E+00		1.3E+00	149.92	6.3E-07	5.3E-04	--	4.2E-04
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB	5.0E-01		5.0E-01	71.05	3.0E-07	2.5E-04	--	5.0E-04
64-19-7	Acetic acid	1.2E+01		1.2E+01	65.91	2.8E-07	2.3E-04	--	1.9E-05
111-42-2	Diethanolamine	1.4E-02		1.4E-02	64.65	2.7E-07	2.3E-04	--	1.6E-02
7681-38-1	Sodium bisulfateC	1.1E+01		1.1E+01	47.49	2.0E-07	1.7E-04	--	1.6E-05
7758-19-2	Chlorous acid, sodium salt	3.9E-02		3.9E-02	45.57	1.9E-07	1.6E-04	--	4.1E-03
12008-41-2	Disodium octaborate tetrahydrateA	9.6E-02		9.6E-02	25.38	1.1E-07	8.9E-05	--	9.3E-04
104-55-2	Cinnamaldehyde	2.0E+00		2.0E+00	14.02	5.9E-08	4.9E-05	--	2.5E-05
25322-68-3	Polyethylene glycol	8.0E+00		8.0E+00	16.01	6.7E-08	5.6E-05	--	7.0E-06
111-46-6	2,2"-oxydiethanol (diethylene glycol)	3.0E-01		3.0E-01	13.65	5.7E-08	4.8E-05	--	1.6E-04
67-56-1	Methanol	3.7E-02		3.7E-02	3.98	1.7E-08	1.4E-05	--	3.8E-04
7775-27-1	Sodium persulfate	6.7E-01		6.7E-01	7.82	3.3E-08	2.7E-05	--	4.1E-05
61788-90-7	Amine oxides, cocoalkyldimethyl	8.0E-02		8.0E-02	2.97	1.2E-08	1.0E-05	--	1.3E-04
100-52-7	Benzaldehyde	3.0E-01		3.0E-01	1.95	8.2E-09	6.9E-06	--	2.3E-05
64-17-5	Ethanol	2.4E+01		2.4E+01	1.41	5.9E-09	5.0E-06	--	2.1E-07
64742-47-8	Hydrotreated light petroleum distillate	1.0E+01		1.0E+01	1.39	5.8E-09	4.9E-06	--	4.9E-07
61791-00-2	Fatty acids, tall-oil, ethoxylated	1.0E+01		1.0E+01	0.96	4.0E-09	3.4E-06	--	3.4E-07
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	5.0E-01		5.0E-01	0.81	3.4E-09	2.8E-06	--	5.7E-06
71-36-3	Butyl alcohol	1.3E+00		1.3E+00	0.71	3.0E-09	2.5E-06	--	2.0E-06
68131-39-5	Alcohols, C12-15, ethoxylatedB	5.0E-01		5.0E-01	0.71	3.0E-09	2.5E-06	--	5.0E-06
68551-12-2	Alcohols, C12-16, ethoxylatedB	5.0E-01		5.0E-01	0.77	3.2E-09	2.7E-06	--	5.4E-06
107-13-1	Acrylonitrile	2.5E-03		2.5E-03	0.08	3.3E-10	2.8E-07	--	1.1E-04
111-30-8	Glutaraldehyde	4.0E-02		4.0E-02	0.85	3.6E-09	3.0E-06	--	7.5E-05
Total Risk (mixture)									3.21E-02

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
 - Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - Hybrid Recipe

Chronic Exposures

General Data/ Equations		Units	Exposure Calculations (RME)	
Exposure Parameters			Dermal Contact with Flow Back Water by Workers	
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fracing period	
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.	
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012	
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996	
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996	
Surface Area (SAw)	cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on Australian work sites; forearms conservatively included	
Exposure Time (ET)	hr/day	1	Assume contact with flow back water for 1 hours per day	
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)	1.9E-06	NonThreshold
			1.6E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)

NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

Chemical		Non-Threshold Slope Factor	Chronic Threshold TDI	Toxicity Data Background Intake (% chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
		(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB		5.0E-01		5.0E-01	1.2E-4	198.94	4.6E-08	3.9E-05	--	7.8E-05
1319-33-1	Boronatrocacite/UlexiteA		9.6E-02		9.6E-02	9.1E-4	208.50	3.7E-07	3.1E-04	--	3.2E-03
102-71-6	Triethanol amine		1.3E+00		1.3E+00	4.9E-5	149.92	1.4E-08	1.2E-05	--	9.6E-06
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB		5.0E-01		5.0E-01	2.9E-1	71.05	3.9E-05	3.3E-02	--	6.6E-02
64-19-7	Acetic acid		1.2E+01		1.2E+01	5.6E-4	65.91	7.0E-08	5.9E-05	--	4.9E-06
111-42-2	Diethanolamine		1.4E-02		1.4E-02	4.5E-5	64.65	5.6E-09	4.7E-06	--	3.4E-04
7681-38-1	Sodium bisulfateC		1.1E+01		1.1E+01	9.3E-9	47.49	8.5E-13	7.1E-10	--	6.8E-11
7758-19-2	Chlorous acid, sodium salt		3.9E-02		3.9E-02	8.3E-9	45.57	7.2E-13	6.1E-10	--	1.6E-08
12008-41-2	Disodium octaborate tetrahydrateA		9.6E-02		9.6E-02	9.1E-4	25.38	4.5E-08	3.7E-05	--	3.9E-04
104-55-2	Cinnamaldehyde		2.0E+00		2.0E+00	5.2E-3	14.02	1.4E-07	1.2E-04	--	5.9E-05
25322-68-3	Polyethylene glycol		8.0E+00		8.0E+00	2.1E-6	16.01	6.6E-11	5.5E-08	--	6.9E-09
111-46-6	2,2'-oxydiethanol (diethylene glycol)		3.0E-01		3.0E-01	4.2E-5	13.65	1.1E-09	9.2E-07	--	3.1E-06
67-56-1	Methanol		3.7E-02		3.7E-02	3.2E-4	3.98	2.4E-09	2.0E-06	--	5.5E-05
7775-27-1	Sodium persulfate		6.7E-01		6.7E-01	7.1E-7	7.82	1.1E-11	8.9E-09	--	1.3E-08
61788-90-7	Amine oxides, cocoalkyldimethyl		8.0E-02		8.0E-02	1.0E-1	2.97	5.9E-07	4.9E-04	--	6.2E-03
100-52-7	Benzaldehyde		3.0E-01		3.0E-01	3.8E-3	1.95	1.4E-08	1.2E-05	--	4.0E-05
64-17-5	Ethanol		2.4E+01		2.4E+01	5.4E-4	1.41	1.5E-09	1.2E-06	--	5.1E-08
64742-47-8	Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	1.39	5.3E-06	4.4E-03	--	4.4E-04
61791-00-2	Fatty acids, tall-oil, ethoxylated		1.0E+01		1.0E+01	2.1E-2	0.96	3.9E-08	3.3E-05	--	3.3E-06
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)		5.0E-01		5.0E-01	7.1E-2	0.81	1.1E-07	9.3E-05	--	1.9E-04
71-36-3	Butyl alcohol		1.3E+00		1.3E+00	2.3E-3	0.71	3.1E-09	2.6E-06	--	2.1E-06
68131-39-5	Alcohols, C12-15, ethoxylatedB		5.0E-01		5.0E-01	1.5E-3	0.71	2.0E-09	1.7E-06	--	3.4E-06
68551-12-2	Alcohols, C12-16, ethoxylatedB		5.0E-01		5.0E-01	9.0E-1	0.77	1.3E-06	1.1E-03	--	2.2E-03
107-13-1	Acrylonitrile		2.5E-03		2.5E-03	1.2E-3	0.08	1.8E-10	1.5E-07	--	5.9E-05
111-30-8	Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	0.85	5.3E-10	4.5E-07	--	1.1E-05
Total Risk (mixture)											7.92E-02

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:

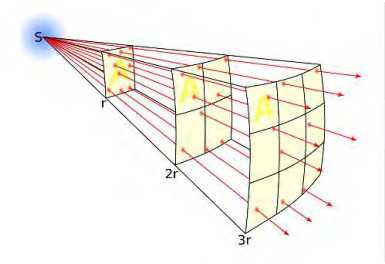
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Aerosol Exposure - Hybrid Recipe

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state
An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol} \left(\frac{L}{m^3} \right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol \left(\frac{L}{hr} \right) \times Aerosol_{driftable} (\%)}{BoxVR \left(\frac{m^3}{hr} \right)} \right)}{BoxDistance^2 (m)}$$



Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a 'spray box' of 3 m long.
Spray box width	m	3	Assume a 'spray box' of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the 'spray box'. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the 'spray box' and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the 'spray box'. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a 'spray box' dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated	198.94	71619.76796	2.500000E-03
1319-33-1	Boronatrocalsite/UlexiteA	208.50	75061.62126	2.500000E-03
102-71-6	Triethanol amine	149.92	53969.54143	2.500000E-03
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated	71.05	25578.48856	2.500000E-03
64-19-7	Acetic acid	65.91	23729.05222	2.500000E-03
111-42-2	Diethanolamine	64.65	23274.23026	2.500000E-03
7681-38-1	Sodium bisulfateC	47.49	17096.46645	2.500000E-03
7758-19-2	Chlorous acid, sodium salt	45.57	16404.17744	2.500000E-03
12008-41-2	Disodium octaborate tetrahydrateA	25.38	9138.176627	2.500000E-03
104-55-2	Cinnamaldehyde	14.02	5046.11094	2.500000E-03
25322-68-3	Polyethylene glycol	16.01	5761.962715	2.500000E-03
111-46-6	2,2"-oxydiethanol (diethylene glycol)	13.65	4915.303675	2.500000E-03
67-56-1	Methanol	3.98	1431.585551	2.500000E-03
7775-27-1	Sodium persulfate	7.82	2816.350509	2.500000E-03
61788-90-7	Amine oxides, cocoalkyldimethyl	2.97	1069.713505	2.500000E-03
100-52-7	Benzaldehyde	1.95	703.1990079	2.500000E-03
64-17-5	Ethanol	1.41	508.3231621	2.500000E-03
64742-47-8	Hydrotreated light petroleum distillate	1.39	501.7922025	2.500000E-03
61791-00-2	Fatty acids, tall-oil, ethoxylated	0.96	345.0387202	2.500000E-03
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	0.81	290.4332727	2.500000E-03
71-36-3	Butyl alcohol	0.71	254.0323025	2.500000E-03
68131-39-5	Alcohols, C12-15, ethoxylatedB	0.71	254.9143591	2.500000E-03
68551-12-2	Alcohols, C12-16, ethoxylatedB	0.77	278.0084294	2.500000E-03
107-13-1	Acrylonitrile	0.08	28.55172359	2.500000E-03
111-30-8	Glutaraldehyde	0.85	306.4351619	2.500000E-03
14808-60-7	Crystalline silica, quartz	24.60	8857.767115	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - Hybrid Recipe

Chronic Exposures

General Data/ Equations	Units	Exposure Calculations (RME) Inhalation of Mist by Workers	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.0	USEPA 1989 and CSMS 1996
$ITF_{inh,w,shwr} = \frac{EmF \times AAF \times ET_{iw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)

Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

Threshold Intake and Risk Calculations								
CAS	Chemical	Groundwater Concentration	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Adult Exposure Factor (threshold)	Adult Exposure Adjusted Air Concentration (threshold)	Hazard Index (Adult)
		mg/L	(unitless)	(L/m ³)	(mg/m ³)	(L/m ³)	(mg/m ³)	(unitless)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB	1.99E+02	1.00	2.50E-03	1.75E+00	6.85E-05	1.36E-02	7.79E-03
1319-33-1	Boronatrocalsite/UlexiteA	2.09E+02	1.00	2.50E-03	3.36E-01	6.85E-05	1.43E-02	4.25E-02
102-71-6	Triethanol amine	1.50E+02	1.00	2.50E-03	4.38E+00	6.85E-05	1.03E-02	2.35E-03
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB	7.11E+01	1.00	2.50E-03	1.75E+00	6.85E-05	4.87E-03	2.78E-03
64-19-7	Acetic acid	6.59E+01	1.00	2.50E-03	4.20E+01	6.85E-05	4.51E-03	1.07E-04
111-42-2	Diethanolamine	6.47E+01	1.00	2.50E-03	4.90E-02	6.85E-05	4.43E-03	9.04E-02
7681-38-1	Sodium bisulfateC	4.75E+01	1.00	2.50E-03	3.68E+01	6.85E-05	3.25E-03	8.85E-05
7758-19-2	Chlorous acid, sodium salt	4.56E+01	1.00	2.50E-03	1.37E-01	6.85E-05	3.12E-03	2.29E-02
12008-41-2	Disodium octaborate tetrahydrateA	2.54E+01	1.00	2.50E-03	3.36E-01	6.85E-05	1.74E-03	5.17E-03
104-55-2	Cinnamaldehyde	1.40E+01	1.00	2.50E-03	7.00E+00	6.85E-05	9.60E-04	1.37E-04
25322-68-3	Polyethylene glycol	1.60E+01	1.00	2.50E-03	2.80E+01	6.85E-05	1.10E-03	3.92E-05
111-46-6	2,2"-oxydiethanol (diethylene glycol)	1.37E+01	1.00	2.50E-03	1.05E+00	6.85E-05	9.35E-04	8.91E-04
67-56-1	Methanol	3.98E+00	1.00	2.50E-03	1.30E-01	6.85E-05	2.72E-04	2.10E-03
7775-27-1	Sodium persulfate	7.82E+00	1.00	2.50E-03	2.35E+00	6.85E-05	5.36E-04	2.29E-04
61788-90-7	Amine oxides, cocoalkyldimethyl	2.97E+00	1.00	2.50E-03	2.80E-01	6.85E-05	2.04E-04	7.27E-04
100-52-7	Benzaldehyde	1.95E+00	1.00	2.50E-03	1.05E+00	6.85E-05	1.34E-04	1.27E-04
64-17-5	Ethanol	1.41E+00	1.00	2.50E-03	8.40E+01	6.85E-05	9.67E-05	1.15E-06
64742-47-8	Hydrotreated light petroleum distillate	1.39E+00	1.00	2.50E-03	3.50E+01	6.85E-05	9.55E-05	2.73E-06
61791-00-2	Fatty acids, tall-oil, ethoxylated	9.58E-01	1.00	2.50E-03	3.50E+01	6.85E-05	6.56E-05	1.88E-06
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	8.07E-01	1.00	2.50E-03	1.75E+00	6.85E-05	5.53E-05	3.16E-05
71-36-3	Butyl alcohol	7.06E-01	1.00	2.50E-03	4.38E+00	6.85E-05	4.83E-05	1.10E-05
68131-39-5	Alcohols, C12-15, ethoxylatedB	7.08E-01	1.00	2.50E-03	1.75E+00	6.85E-05	4.85E-05	2.77E-05
68551-12-2	Alcohols, C12-16, ethoxylatedB	7.72E-01	1.00	2.50E-03	1.75E+00	6.85E-05	5.29E-05	3.02E-05
107-13-1	Acrylonitrile	7.93E-02	1.00	2.50E-03	8.75E-03	6.85E-05	5.43E-06	6.21E-04
111-30-8	Glutaraldehyde	8.51E-01	1.00	2.50E-03	1.40E-01	6.85E-05	5.83E-05	4.16E-04
14808-60-7	Crystalline silica, quartz	2.46E+01	1.00	2.50E-03	3.00E-03	6.85E-05	1.69E-03	5.62E-01
Total Threshold Risk (mixture)								0.7

Summary of Risk to Workers - Hybrid Recipe Exposure fo Target Chemicals - Theoretical Data

Receptor/Exposure Pathway	Calculated HI
	100% Mass Return
<u>Use of Stimulation Fluid in Hydraulic Fracturing</u>	
<u>HYBRID Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.03
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.08
Inhalation of mist from the evaporation units	0.74
Total Risk	0.85

Appendix B

Chemical Risk
Assessment Hydraulic
Fracture Stimulation
Fluid – HVFR

Chemical Risk Assessment
Hydraulic Fracture Stimulation Fluid HVFR Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%v/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% ww)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment
Acetic acid	64-19-7	1.05	1050.64	0.0032%	1,103	0.0032%	35	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 2	1.03E-05	2.63E-06	5.72E-05	7.01E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Acrylamide acrylate copolymer	9003-06-9	0.75	1991.54	0.0061%	1,494	0.0043%	47	Scale Inhibitor	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable.	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Acrylamide, sodium acrylate polymer	25987-30-8	0.75	19778.02	0.0603%	14,834	0.0424%	472	Corrosion Inhibitor	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subcapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Low	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	1950.67	0.0059%	1,834	0.0052%	58	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletonema costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	4.10E-04	5.41E-02	2.28E-03	5.68E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	1679.39	0.0051%	1,456	0.0042%	46	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L Green algae, EC50 (96 h) was 1.4 mg/L EC50 (3 h) for microorganisms was 140 mg/L	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 2	3.25E-04	2.21E-04	1.81E-03	2.36E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	1.25	0.0000%	1	0.0000%	0	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L Green algae, EC50 (96 h) was 1.4 mg/L EC50 (3 h) for microorganisms was 140 mg/L	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 2	2.70E-07	1.11E-04	1.51E-06	1.13E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	5461.88	0.0166%	5,134	0.0147%	163	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subcapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	1.15E-03	6.38E-05	6.39E-03	7.60E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amides, tail-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	1843.23	0.0056%	1,659	0.0047%	53	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scenedesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No based on Log Kow of 3	Tier 2	3.71E-04	1.22E-02	2.06E-03	1.46E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	6.50	0.0000%	5	0.0000%	0	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-10.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 2	6.50E-06	3.08E-04	3.62E-05	3.51E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Benzaldehyde	100-52-7	1.0415	2.94	0.0000%	3	0.0000%	0	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 2	1.14E-06	2.01E-06	6.35E-06	9.49E-06	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Butyl alcohol	71-36-3	0.81	1791.35	0.0055%	1,451	0.0041%	46	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 2	1.30E-04	1.38E-04	7.22E-04	9.90E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Choline Chloride	67-48-1	1.1	31430.04	0.0958%	34,573	0.0988%	1099	Clay Stabiliser	96-hour fish LC50 value is >100 mg/L 48-hour in vertebrate EC50 is 349 mg/L 72-hour EC50 to Pseudokirchneriella subcapitata is >1,000 mg/L 21-day Daphnia NOEC value is 30.2 mg/L	Based on Chronic: Low	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.	Not Bioaccumulative (based on a measured log Kow of -3.77 and a calculated BCF of 0.59)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Cinnamaldehyde	104-55-2	1.048	20.95	0.0001%	22	0.0001%	1	Corrosion Inhibitor	Danio rerio (Zebrafish) 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) 72 h EC50 = 4.07 mg/L. 72 h NOEC value = 2.0 mg/L Pseudokirchneriella subcapitata (Green algae)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	1.23E-06	2.93E-06	6.83E-06	1.10E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Citric acid	77-92-9	1.542	144.39	0.0004%	223	0.0006%	7	Corrosion Inhibitor	LC50/EC50 > 100 mg/L (fish, daphnia, algae) 8 day NOEC = 425 mg/L (algae)	Based on Chronic: Low	Readily biodegradable	No based on low log Kow	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Diethanolamine	111-42-2	1.1	133.12	0.0004%	146	0.0004%	5	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 2	1.17E-03	2.42E-05	6.51E-03	7.70E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).

Chemical Risk Assessment
Hydraulic Fracture Stimulation Fluid HVFR Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%w/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% ww)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment
Diethylene glycol	111-46-6	1.12	19.09	0.0001%	21	0.0001%	1	Corrosion Inhibitor	LC 50 = >100 mg/L (fish, invertebrates, algae)	Based on Acute: Low	Readily biodegradable	No based on the estimated BCF of 3	Tier 2	7.96E-06	1.53E-07	4.44E-05	5.25E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethanol	64-17-5	0.7864	3692.09	0.0113%	2,903	0.0083%	92	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 2	1.35E-05	3.34E-06	7.53E-05	9.21E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethoxylated branched C13 alcohol	68439-54-3	0.8	1019.49	0.0031%	816	0.0023%	26		96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L Daphnia magna, EC50 (48 h) was 2.5 mg/L. Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L Green algae, EC50 (96 h) was 1.4 mg/L. EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No.	Tier 2	1.82E-04	8.88E-05	1.02E-03	1.29E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethylene glycol	107-21-1	1.11	2040.97	0.0062%	2,265	0.0065%	72	Crosslinker	LC50 for fish = 22800 mg/L LC50 for Daphnia =7800 mg/L NOEC for Algae =100 mg/L	Based on Acute: Low	Readily biodegradable	No based on the measured log Kow of -1.36 and a measured BCF of 10	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	1869.83	0.0057%	1,971	0.0056%	63	Surfactant	96h-LL50 = 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 2	2.20E-05	2.14E-04	1.23E-04	3.58E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Hydrochloric acid	7647-01-0	1.152	4292.88	0.0131%	4,945	0.0141%	157	Acid	Algae = 0.492 mg/L Daphnia = 0.492 mg/L Fish = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	Acute Toxicity Only	Acute Toxicity Only	Acute Toxicity Only	Acute Toxicity Only	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Hydrotreated light petroleum distillate	64742-47-8	0.8	18843.51	0.0574%	15,075	0.0431%	479	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes 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	Tier 2	1.68E-04	1.52E-01	9.38E-04	1.53E-01	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Methanol	67-56-1	0.791	191.40	0.0006%	151	0.0004%	5	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 2	4.55E-04	6.68E-05	2.54E-03	3.06E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Polyethylene glycol	25322-68-3	1.21	341.37	0.0010%	413	0.0012%	13	Scale Inhibitor	LC50 = 100 mg/L (fish) LC50 = 1000 mg/L (invertebrates) EC 50 = 15.91 mg/L (algae)	Based on Acute: Moderate	Expected to be readily biodegradable	No based on BCF of 3.2	Tier 2	5.77E-06	5.68E-09	3.21E-05	3.79E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sorbitan, mono-9-octadecenoate, (Z)	1338-43-8	1.06	1002.94	0.0031%	1,063	0.0030%	34	Surfactant	96 h LC50 for fish = 75 mg/L	Based on Acute: Low	Readily biodegradable	No. Based on a calculated BCF of 2,832 and a BAF of 36.4	Tier 2	4.75E-06	1.10E-04	2.65E-05	1.41E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium bisulfite	7631-90-5	2.44	614.20	0.0019%	1,499	0.0043%	48	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	1.59E-05	3.05E-11	8.88E-05	1.05E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium diacetate	126-96-5	1.01	941.81	0.0029%	951	0.0027%	30	pH buffer	96 h LC 50 for fish = 184.7 mg/L 48h EC 50 for daphnia > 141 mg/L 72 h EC50 for algae = 164 mg/L	Based on Acute: Low	Readily biodegradable	No. Based on a log Kow of -3.72 and a calculated BCF of 3.16	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium hydroxide	1310-73-2	1.515	1213.57	0.0037%	1,839	0.0053%	58	pH buffer	Measured acute endpoints for fish (196 mg/L). Measured chronic endpoint for Daphnia (240 mg/L)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	Acute toxicity only (irritant and corrosive), not systemically available in body	Acute toxicity only (irritant and corrosive), not systemically available in body	Acute toxicity only (irritant and corrosive), not systemically available in body	Acute toxicity only (irritant and corrosive), not systemically available in body	Acute toxicity only (irritant and corrosive), not systemically available in body
Sodium iodide	7681-82-5	3.67	0.33	0.0000%	1	0.0000%	0	Corrosion Inhibitor	96 hour LC50 for fish is > 860 mg/L 7 days NOEC for fish is 100 mg/L 48hrs-EC50 for Daphnia magna is 1.27 mg/L NOEC for algae is 66 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium polyacrylate	9003-04-7	1.32	3013.30	0.0092%	3,978	0.0114%	126	Gelling Agent	96 hr LC50 for fish is >1000 mg/L NOEC from a chronic early life stage test for the fathead minnow is 56 mg/L 48 hr LC50 for Dapia magna is >1000 mg/L NOEC for a 21day chronic reproductive test on Daphnia magna is 5.6 mg/L EC10 for Scenedesmus is 180 mg/L	Based on Chronic: Moderate to low	Sodium polyacrylate has limited biodegradation potential and thus meets the screening criteria for persistence.	Bioaccumulation of sodium polyacrylate is unlikely due to the high molecular weight of the polymer.	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sorbitan monooleate polyoxyethylene derivative	9005-65-6	1.06	915.65	0.0028%	971	0.0028%	31	Surfactant	EC50 in algae was reported to be 100 mg/L	Based on Acute: Low	Not readily biodegradable	No. Based on a log Kow of -2.03 and a calculated BCF of 3.16	Tier 2	1.08E-05	1.77E-11	6.04E-05	7.12E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	936.32	0.0029%	890	0.0025%	28	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Crangon crangon) TLM48: 0.025 mg/l (Daphnia magna) Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 2	Acute toxicity only	Acute toxicity only	Acute toxicity only	Acute toxicity only	Acute toxicity only
Sodium perborate tetrahydrate	10486-00-7	0.65	3060.09	0.0093%	1,989	0.0057%	63	TBD	96hr LC50 for fish is estimated to be 2610 mg/L 48 hr LC50 for daphnids is estimated to be 1241 mg/L 96 hr EC50 for algae is estimated to be 444 mg/L	Based on Acute: Low	Readily biodegradable (read across)	Not bioaccumulative	Tier 2	4.44E-03	3.70E-06	2.48E-02	2.92E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Total Risk																	0.28	The calculated risks associated with potential exposure to COPC identified in flowback water, where the HVFR Recipe is used and assuming 100% mass recovery is below the target of 1, respectively. Hence, chronic health risks are considered to be low and acceptable.

Notes
Tier 1 (NICNAS) - Chemical identified as of low concern for human health, as published in the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia (NICNAS 2017).
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
TBD - To be determined
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	Oral/Dermal Exposures				Inhalation Exposures				Threshold Chronic TC or RfC (mg/m³)	NOAEC or LOAEC (mg/m³)	NOAEL or LOAEL (mg/kg bw/d)	Reference	UF	Reference
		Threshold Chronic TDI or RfD (mg/kg/day)		Dermal Permeability (cm/hr)	Reference	Inhalation Unit Risk (ug/m³) ⁻¹	Non-Threshold Slope Factor (mg/kg/day) ⁻¹								
COPC in Hydraulic Fracturing Fluid Injected into Well															
1319-33-1	Boronatrocalcite/Ulexite ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RfD		9.6	NICNAS (2017)	100	NICNAS (2017)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated ^B	0.5	D	1.21E-04	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated ^B	0.5	D	2.87E-01	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
64-19-7	Acetic acid	12	D	5.56E-04	EPI				42	converted from RfD		1200	NICNAS (2017)	100	NICNAS (2017)
25322-68-3	Polyethylene glycol	8	D	2.14E-06	EPI				28	converted from RfD		8000	REACH	1000	D
7631-90-5	Sodium bisulfite ^C	10.5	D	4.16E-09	EPI				36.75	converted from RfD		1050	NICNAS (2017)	100	NICNAS (2017)
104-55-2	Cinnamaldehyde	2	D	5.20E-03	EPI				7	converted from RfD		200	NTP (2004); REACH	100	D
67-56-1	Methanol	0.037	D	3.19E-04	EPI				0.13	converted from RfD		3.7	NICNAS (2017)	100	NICNAS (2017)
61788-90-7	Amine oxides, cocoalkyldimethyl	0.08	D	1.03E-01	EPI				0.28	converted from RfD		80	OECD (2001)	1000	D
100-52-7	Benzaldehyde	0.3	D	3.83E-03	EPI				1.05	converted from RfD		300	OECD (2002); REACH; NICNAS	1000	D
64-17-5	Ethanol	24	D	5.38E-04	EPI				84	converted from RfD		2400	NICNAS (2017)	100	NICNAS (2017)
64742-47-8	Hydrotreated light petroleum distillate	10	D	1.96E+00	EPI				35	converted from RfD		1000	NICNAS (2017)	100	NICNAS (2017)
61791-00-2	Fatty acids, tall-oil, ethoxylated	10	D	2.11E-02	EPI				35	converted from RfD		1000	REACH	100	D
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	0.5	D	7.14E-02	EPI				1.75	converted from RfD		50	USEPA (2010)	100	D
71-36-3	Butyl alcohol	1.25	D	2.31E-03	EPI				4.375	converted from RfD		125	OECD (2001)/NICNAS	100	D
68131-39-5	Alcohols, C12-15, ethoxylated ^B	0.5	D	1.48E-03	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
68551-12-2	Alcohols, C12-16, ethoxylated ^B	0.5	D	8.97E-01	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
107-13-1	Acrylonitrile	0.0025	D	1.16E-03	EPI				0.00875	converted from RfD		0.25	OECD (2005); NICNAS	100	D
111-42-2	Diethanolamine	0.014	D	4.51E-05	EPI				0.049	converted from RfD		14	REACH; OECD (2002); NICNAS	1000	D
111-30-8	Glutaraldehyde	0.04	D	3.25E-04	EPI				0.14	converted from RfD		4	NICNAS (2017)	100	NICNAS (2017)
102-71-6	Triethanol amine	1.25	D	4.93E-05	EPI				4.375	converted from RfD		125	NICNAS (2017)	100	NICNAS (2017)
7758-19-2	Chlorous acid, sodium salt	0.039	D	8.27E-09	EPI				0.1365	converted from RfD		3.9	NICNAS (2017)	100	NICNAS (2017)
12008-41-2	Disodium octaborate tetrahydrate ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RfD		9.6	NICNAS (2017)	100	NICNAS (2017)
7775-27-1	Sodium persulfate	0.67	D	7.05E-07	EPI				2.345	converted from RfD		67	NICNAS (2017)	100	NICNAS (2017)
68439-54-3	Ethoxylated branched C13 alcohol	0.5	D	1.06E-03	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)	25	JECFA	5.02E-02	EPI				87.5	converted from RfD		-	JECFA(1973); US FDA; FSANZ (2018)	-	-
9005-65-6	Sorbitan monooleate polyoxyethylene derivative	10	EFSA	3.54E-09	EPI				35	converted from RfD		-	EFSA (2017)	-	-
111-46-6	2,2"-oxydiethanol (diethylene glycol)	0.3	D	4.17E-05	EPI				1.05	converted from RfD		300	Health Council of the Netherlands (2007); NICNAS	1000	D
7681-38-1	Sodium bisulfate ^C	10.5	D	9.29E-09	EPI				36.75	converted from RfD		1050	NICNAS (2017)	100	NICNAS (2017)
14808-60-7	Crystalline silica, quartz	Not toxic via oral/dermal exposure							0.003	USEPA (2019)		-	-	-	-
10486-00-7	Sodium perborate tetrahydrate	0.05	D	1.81E-06	EPI				0.175	converted from RfD		50	REACH	1000	D

Notes:

A - Read across data from Boric Acid

B - Read across data from Alcohol ethoxylates C6-C12

C - Read across data from Sodium Sulfite

References:

D - Derived (refer to individual Toxicity Profiles)

EFSA - European Food Safety Authority

EPI - USEPA Estimation Programs Interface (EPI) Suite

FSANZ - Food Standards Australia New Zealand

J- JECFA - Joint FAO/WHO Expert Committee on Food Additives

NICNAS - National Industrial Chemicals Notification and Assessment Scheme. Assessed at <https://www.nicnas.gov.au/>

NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associatedwith coal seam gas extraction in Australia, prepared by the National Industrial ChemicalsNotification and Assessment Scheme

NTP - US Department of Health and Serices National Toxicology Program

OECD - Organisation for Economic Co-operation and Development Screening Information Data Set (SIDS)

REACH - ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - HVFR Recipe

Chronic Exposures

General Data/ Equations	Units	Exposure Calculations (RME) Ingestion of Flowback Water by Workers	
Exposure Parameters			
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fracing period
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996
Ingestion Rate (IRw)	L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fracing.
Bioavailability (B)	-	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Intake Factor = $\frac{IRw \cdot EF \cdot B \cdot ED}{BW \cdot AT}$	L/kg/day	4.2E-09 3.5E-06	NonThreshold Threshold

Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989)
NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

CAS	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/L)	(mg/kg/day)	(mg/kg/day)	(unitless)
64-19-7	Acetic acid		1.2E+01		1.2E+01	35.08	1.5E-07	1.2E-04	--	1.0E-05
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB		5.0E-01		5.0E-01	58.31	2.4E-07	2.0E-04	--	4.1E-04
68131-39-5	Alcohols, C12-15, ethoxylatedB		5.0E-01		5.0E-01	46.30	1.9E-07	1.6E-04	--	3.3E-04
68551-12-2	Alcohols, C12-16, ethoxylatedB		5.0E-01		5.0E-01	0.04	1.6E-10	1.4E-07	--	2.7E-07
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB		5.0E-01		5.0E-01	163.27	6.8E-07	5.7E-04	--	1.1E-03
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)		5.0E-01		5.0E-01	52.75	2.2E-07	1.9E-04	--	3.7E-04
61788-90-7	Amine oxides, cocoalkyldimethyl		8.0E-02		8.0E-02	0.15	6.2E-10	5.2E-07	--	6.5E-06
100-52-7	Benzaldehyde		3.0E-01		3.0E-01	0.10	4.1E-10	3.4E-07	--	1.1E-06
71-36-3	Butyl alcohol		1.3E+00		1.3E+00	46.14	1.9E-07	1.6E-04	--	1.3E-04
104-55-2	Cinnamaldehyde		2.0E+00		2.0E+00	0.70	2.9E-09	2.5E-06	--	1.2E-06
111-42-2	Diethanolamine		1.4E-02		1.4E-02	4.66	1.9E-08	1.6E-05	--	1.2E-03
111-46-6	2,2"-oxydiethanol (diethylene glycol)		3.0E-01		3.0E-01	0.68	2.8E-09	2.4E-06	--	8.0E-06
64-17-5	Ethanol		2.4E+01		2.4E+01	92.33	3.9E-07	3.2E-04	--	1.4E-05
61791-00-2	Fatty acids, tall-oil, ethoxylated		1.0E+01		1.0E+01	62.67	2.6E-07	2.2E-04	--	2.2E-05
64742-47-8	Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	479.38	2.0E-06	1.7E-03	--	1.7E-04
67-56-1	Methanol		3.7E-02		3.7E-02	4.81	2.0E-08	1.7E-05	--	4.6E-04
25322-68-3	Polyethylene glycol		8.0E+00		8.0E+00	13.14	5.5E-08	4.6E-05	--	5.8E-06
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)		2.5E+01		2.5E+01	33.81	1.4E-07	1.2E-04	--	4.7E-06
9005-65-6	Sorbitan monooleate polyoxyethylene derivative		1.0E+01		1.0E+01	30.86	1.3E-07	1.1E-04	--	1.1E-05
10486-00-7	Sodium perborate tetrahydrate		5.0E-02		5.0E-02	63.25	2.6E-07	2.2E-04	--	4.4E-03
68439-54-3	Ethoxylated branched C13 alcohol		5.0E-01		5.0E-01	25.94	1.1E-07	9.1E-05	--	1.8E-04
7631-90-5	Sodium bisulfiteC		1.1E+01		1.1E+01	47.66	2.0E-07	1.7E-04	--	1.6E-05
Total Risk (mixture)										8.90E-03

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - HVFR Recipe

Chronic Exposures

General Data/ Equations		Units	Exposure Calculations (RME)	
Exposure Parameters			Dermal Contact with Flow Back Water by Workers	
Exposure Frequency (EF)		days/year	20	Assume work 5 days per week for 1 month during the fracing period
Exposure Duration (ED)		years	0.083	Maximum duration of the frac. Works will be complete in one month.
Body Weight (BW)		kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)		days	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)		days	30.42	USEPA 1989 and CSMS 1996
Surface Area (SAw)		cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on Australian work sites; forearms conservatively included
Exposure Time (ET)		hr/day	1	Assume contact with flow back water for 1 hours per day
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-k-g-day)	1.9E-06 1.6E-03	NonThreshold Threshold
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)</i>				

CAS	Chemical	Non-Threshold Slope Factor	Chronic Threshold TDI	Toxicity Data Background Intake (% chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake NonThreshold	Daily Intake Threshold	Calculated Risk NonThreshold Risk	Calculated Risk Chronic Hazard Quotient
		(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
64-19-7	Acetic acid		1.2E+01		1.2E+01	5.6E-4	35.08	3.8E-08	3.2E-05	--	2.6E-06
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB		5.0E-01		5.0E-01	2.9E-1	58.31	3.2E-05	2.7E-02	--	5.4E-02
68131-39-5	Alcohols, C12-15, ethoxylatedB		5.0E-01		5.0E-01	1.5E-3	46.30	1.3E-07	1.1E-04	--	2.2E-04
68551-12-2	Alcohols, C12-16, ethoxylatedB		5.0E-01		5.0E-01	9.0E-1	0.04	6.6E-08	5.6E-05	--	1.1E-04
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB		5.0E-01		5.0E-01	1.2E-4	163.27	3.8E-08	3.2E-05	--	6.4E-05
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)		5.0E-01		5.0E-01	7.1E-2	52.75	7.2E-06	6.1E-03	--	1.2E-02
61788-90-7	Amine oxides, cocoalkyldimethyl		8.0E-02		8.0E-02	1.0E-1	0.15	2.9E-08	2.5E-05	--	3.1E-04
100-52-7	Benzaldehyde		3.0E-01		3.0E-01	3.8E-3	0.10	7.2E-10	6.0E-07	--	2.0E-06
71-36-3	Butyl alcohol		1.3E+00		1.3E+00	2.3E-3	46.14	2.1E-07	1.7E-04	--	1.4E-04
104-55-2	Cinnamaldehyde		2.0E+00		2.0E+00	5.2E-3	0.70	7.0E-09	5.9E-06	--	2.9E-06
111-42-2	Diethanolamine		1.4E-02		1.4E-02	4.5E-5	4.66	4.0E-10	3.4E-07	--	2.4E-05
111-46-6	2,2"-oxydiethanol (diethylene glycol)		3.0E-01		3.0E-01	4.2E-5	0.68	5.5E-11	4.6E-08	--	1.5E-07
64-17-5	Ethanol		2.4E+01		2.4E+01	5.4E-4	92.33	9.6E-08	8.0E-05	--	3.3E-06
61791-00-2	Fatty acids, tall-oil, ethoxylated		1.0E+01		1.0E+01	2.1E-2	62.67	2.5E-06	2.1E-03	--	2.1E-04
64742-47-8	Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	479.38	1.8E-03	1.5E+00	--	1.5E-01
67-56-1	Methanol		3.7E-02		3.7E-02	3.2E-4	4.81	3.0E-09	2.5E-06	--	6.7E-05
25322-68-3	Polyethylene glycol		8.0E+00		8.0E+00	2.1E-6	13.14	5.4E-11	4.5E-08	--	5.7E-09
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)		2.5E+01		2.5E+01	5.0E-2	33.81	3.3E-06	2.7E-03	--	1.1E-04
9005-65-6	Sorbitan monooleate polyoxyethylene derivative		1.0E+01		1.0E+01	3.5E-9	30.86	2.1E-13	1.8E-10	--	1.8E-11
10486-00-7	Sodium perborate tetrahydrate		5.0E-02		5.0E-02	1.8E-6	63.25	2.2E-10	1.8E-07	--	3.7E-06
68439-54-3	Ethoxylated branched C13 alcohol		5.0E-01		5.0E-01	1.1E-3	25.94	5.3E-08	4.4E-05	--	8.9E-05
7631-90-5	Sodium bisulfiteC		1.1E+01		1.1E+01	4.2E-9	47.66	3.8E-13	3.2E-10	--	3.1E-11
Total Risk (mixture)											2.19E-01

Note:

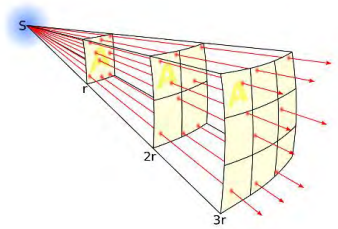
This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Aerosol Exposure - HVFR Recipe

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state concentrations
An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol} \left(\frac{L}{m^3} \right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol \left(\frac{L}{hr} \right) \times Aerosol_{driftable} (\%)}{BoxVR \left(\frac{m^3}{hr} \right)} \right)}{BoxDistance^2 (m)}$$



Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a 'spray box' of 3 m long.
Spray box width	m	3	Assume a 'spray box' of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the 'spray box'. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the 'spray box' and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the 'spray box'. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a 'spray box' dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
64-19-7	Acetic acid	35.08	12629.04069	2.500000E-03
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated	58.31	20991.25298	2.500000E-03
68131-39-5	Alcohols, C12-15, ethoxylatedB	46.30	16668.49372	2.500000E-03
68551-12-2	Alcohols, C12-16, ethoxylatedB	0.04	13.84454389	2.500000E-03
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedE	163.27	58775.50834	2.500000E-03
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	52.75	18991.02585	2.500000E-03
61788-90-7	Amine oxides, cocoalkyldimethyl	0.15	53.27067097	2.500000E-03
100-52-7	Benzaldehyde	0.10	35.01861274	2.500000E-03
71-36-3	Butyl alcohol	46.14	16610.81728	2.500000E-03
104-55-2	Cinnamaldehyde	0.70	251.2913171	2.500000E-03
111-42-2	Diethanolamine	4.66	1676.321009	2.500000E-03
111-46-6	2,2"-oxydiethanol (diethylene glycol)	0.68	244.7772451	2.500000E-03
64-17-5	Ethanol	92.33	33238.54124	2.500000E-03
61791-00-2	Fatty acids, tall-oil, ethoxylated	62.67	22561.59975	2.500000E-03
64742-47-8	Hydrotreated light petroleum distillate	479.38	172575.2226	2.500000E-03
67-56-1	Methanol	4.81	1733.209245	2.500000E-03
25322-68-3	Polyethylene glycol	13.14	4728.6147	2.500000E-03
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)	33.81	12170.50102	2.500000E-03
9005-65-6	Sorbitan monooleate polyoxyethylene deriv	30.86	11111.21667	2.500000E-03
10486-00-7	Sodium perborate tetrahydrate	63.25	22770.58133	2.500000E-03
68439-54-3	Ethoxylated branched C13 alcohol	25.94	9336.793624	2.500000E-03
7631-90-5	Sodium bisulfiteC	47.66	17156.33574	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - HVFR Recipe

Chronic Exposures

General Data/ Equations		Exposure Calculations (RME) Inhalation of Mist by Workers	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.000	USEPA 1989 and CSMS 1996
$ITF_{inh,w,shwr} = \frac{EmF \times AAF \times ET_{hw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)

Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

CAS	Chemical	Groundwater Concentration	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Threshold Intake and Risk Calculations		
		mg/L	(unitless)	(L/m ³)	(mg/m ³)	Adult Exposure Factor (threshold)	Adjusted Air Concentration (threshold)	Hazard Index (Adult)
						(L/m ³)	(mg/m ³)	(unitless)
64-19-7	Acetic acid	3.51E+01	1.00	2.50E-03	4.20E+01	6.85E-05	2.40E-03	5.72E-05
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB	5.83E+01	1.00	2.50E-03	1.75E+00	6.85E-05	3.99E-03	2.28E-03
68131-39-5	Alcohols, C12-15, ethoxylatedB	4.63E+01	1.00	2.50E-03	1.75E+00	6.85E-05	3.17E-03	1.81E-03
68551-12-2	Alcohols, C12-16, ethoxylatedB	3.85E-02	1.00	2.50E-03	1.75E+00	6.85E-05	2.63E-06	1.51E-06
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB	1.63E+02	1.00	2.50E-03	1.75E+00	6.85E-05	1.12E-02	6.39E-03
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	5.28E+01	1.00	2.50E-03	1.75E+00	6.85E-05	3.61E-03	2.06E-03
61788-90-7	Amine oxides, cocoalkyldimethyl	1.48E-01	1.00	2.50E-03	2.80E-01	6.85E-05	1.01E-05	3.62E-05
100-52-7	Benzaldehyde	9.73E-02	1.00	2.50E-03	1.05E+00	6.85E-05	6.66E-06	6.35E-06
71-36-3	Butyl alcohol	4.61E+01	1.00	2.50E-03	4.38E+00	6.85E-05	3.16E-03	7.22E-04
104-55-2	Cinnamaldehyde	6.98E-01	1.00	2.50E-03	7.00E+00	6.85E-05	4.78E-05	6.83E-06
111-42-2	Diethanolamine	4.66E+00	1.00	2.50E-03	4.90E-02	6.85E-05	3.19E-04	6.51E-03
111-46-6	2,2"-oxydiethanol (diethylene glycol)	6.80E-01	1.00	2.50E-03	1.05E+00	6.85E-05	4.66E-05	4.44E-05
64-17-5	Ethanol	9.23E+01	1.00	2.50E-03	8.40E+01	6.85E-05	6.32E-03	7.53E-05
61791-00-2	Fatty acids, tall-oil, ethoxylated	6.27E+01	1.00	2.50E-03	3.50E+01	6.85E-05	4.29E-03	1.23E-04
64742-47-8	Hydrotreated light petroleum distillate	4.79E+02	1.00	2.50E-03	3.50E+01	6.85E-05	3.28E-02	9.38E-04
67-56-1	Methanol	4.81E+00	1.00	2.50E-03	1.30E-01	6.85E-05	3.30E-04	2.54E-03
25322-68-3	Polyethylene glycol	1.31E+01	1.00	2.50E-03	2.80E+01	6.85E-05	9.00E-04	3.21E-05
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)	3.38E+01	1.00	2.50E-03	8.75E+01	6.85E-05	2.32E-03	2.65E-05
9005-65-6	Sorbitan monooleate polyoxyethylene derivative	3.09E+01	1.00	2.50E-03	3.50E+01	6.85E-05	2.11E-03	6.04E-05
10486-00-7	Sodium perborate tetrahydrate	6.33E+01	1.00	2.50E-03	1.75E-01	6.85E-05	4.33E-03	2.48E-02
68439-54-3	Ethoxylated branched C13 alcohol	2.59E+01	1.00	2.50E-03	1.75E+00	6.85E-05	1.78E-03	1.02E-03
7631-90-5	Sodium bisulfiteC	4.77E+01	1.00	2.50E-03	3.68E+01	6.85E-05	3.26E-03	8.88E-05
Total Risk (mixture)								0.050

Summary of Risk to Workers - HVFR Recipe Exposure fo Target Chemicals - Theoretical Data

Receptor/Exposure Pathway	Calculated HI
	100% Mass Return
<u>Use of Stimulation Fluid in Hydraulic Fracturing</u>	
<u>HVFR Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.0089
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.22
Inhalation of mist from the evaporation units	0.050
Total Risk	0.28

Appendix C

Chemical Risk
Assessment Hydraulic
Fracture Stimulation
Fluid – SW

Chemical Risk Assessment
Hydraulic Fracture Stimulation Fluid SW Recipe

Chemical Name	CAS Number	Density (kg/L)	Volume of Chemical (L)	Volume Fraction (%w/v)	Chemical Mass in Fluid (kg)	Mass Fraction (% w/w)	Concentration in Injected Fluid (mg/L)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
Choline Chloride	67-48-1	1.1	24720	0.0848%	27192	0.0869%	977	Clay Stabiliser	96-hour fish LC50 value is >100 mg/L 48-hour in vertebrate EC50 is 349 mg/L 72-hour EC50 to Pseudokirchneriella subcapitata is >1,000 mg/L 21-day Daphnia NOEC value is 30.2 mg/L	Based on Chronic: Low	Choline chloride is readily biodegradable and thus it does not meet the screening criteria for persistence.	Not Bioaccumulative (based on a measured log Kow of -3.77 and a calculated BCF of 0.59)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Hydrochloric acid	7647-01-0	1.152	23649	0.0811%	27244	0.0871%	979	Acid	Algae (acute) = 0.492 mg/L Daphnia (acute) = 0.492 mg/L Fish (acute) = 4.92 mg/L Daphnia (chronic) = 62 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only
Alcohols, C6-12, ethoxylated propoxylated	68937-66-6	0.94	10,206	0.0350%	9,593	0.0307%	345	Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) EC50 (96h) 0.7 mg/L (Pseudokirchneriella subapitata) NOEC 4.4 mg/L (Pimephales promelas, juvenile)	Based on Chronic: Moderate	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	2.42E-03	1.35E-04	1.35E-02	1.60E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	0.94	5,253	0.0180%	4,938	0.0158%	177	Friction Reducer, Surfactant	LC50 (96h) 0.59 mg/L (Pleuronectes platessa) EC50 (48h) 0.14 mg/L (Daphnia magna) ErC50 (48h) 0.7 mg/L (Skeletomena costatum) ErC50 (16.9h) > 10 g/L (Pseudomonas putida)	Based on Acute: Very high	Expected to be readily biodegradable based on similar substances	Not Bio accumulative (Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8)	Tier 2	1.25E-03	1.64E-01	6.94E-03	1.73E-01	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium polyacrylate	9003-04-7	1.32	3723	0.0128%	4914	0.0157%	177		96 hr LC50 for fish is >1000 mg/L NOEC from a chronic early life stage test for the fathead minnow is 56 mg/L 48 hr LC50 for Dapnia magna is >1000 mg/L NOEC for a 21day chronic reproductive test on Daphnia magna is 5.6 mg/L EC10 for Scenedesmus is 180 mg/L	Based on Chronic: Moderate to low	Sodium polyacrylate has limited biodegradation potential and thus meets the screening criteria for persistence.	Bioaccumulation of sodium polyacrylate is unlikely due to the high molecular weight of the polymer.	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium Chloride	7647-14-5	2.165	3476	0.0119%	7525	0.0241%	270	Stabiliser	EC50 = 400 to 30000 mg/L EC50 Fish = 1290 mg/L NOEC = 314 mg/L (Daphnia)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value	Low chronic toxicity, insufficient data to establish toxicity value
Acrylamide acrylate copolymer	25987-30-8	0.75	3309	0.0113%	2482	0.0079%	89	Scale Inhibitor	96 hour LC50 for fish = 1 400 mg/L 48 hour EC50 for Daphnia magna = 1 200 mg/L 21 day EC50 for Daphnia magna = 680 mg/L 21 day NOEC for algae = 380 mg/L	Based on Chronic: Low	Polymers are not readily biodegradable, hence they meet the screening criteria for persistence.	Polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable.	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Acetic acid	64-19-7	1.05	2859	0.0098%	3002	0.0096%	108	Acid	Acute endpoints: Fish = 75 mg/L, Daphnia EC50 = 32 mg/L Chronic endpoints: Daphnia = 150 mg/L	Based on Chronic: Low	Readily biodegradable	Not Bio accumulative (Based on log Kow = -0.136)	Tier 2	3.16E-05	8.07E-06	1.76E-04	2.15E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Tributyl tetradecyl phosphonium chloride	81741-28-8	0.95	2370	0.0081%	2251	0.0072%	81	Biocide	LC50: (96 hour) 0.46 mg/L (Oncorhynchus mykiss) LC50: (96 hour) 0.06 mg/l (Lepomis macrochirus) LC50: (96 hour) 0.58 mg/l (fish) TLM96: 1.6 mg/l (Cragon crangon) TLM48: 0.025 mg/l (Daphnia magna) Modelled acute endpoint: Daphnia is 16.788 mg/L Fish is 1059.2530 mg/L	Based on Acute: Very high	Not available, however it has been observed to biodegrade in sediment.	Not bioaccumulative (Based on an estimated log Kow value of 6.26)	Tier 2	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only	NA. Acute toxity only
Polyethylene glycol	25322-68-3	1.21	2059	0.0071%	2491	0.0080%	89	Scale Inhibitor	LC50 = 100 mg/L (fish) LC50 = 1000 mg/L (invertebrates) EC 50 = 15.91 mg/L (algae)	Based on Acute: Moderate	Expected to be readily biodegradable	No based on BCF of 3.2	Tier 2	3.93E-05	3.87E-08	2.19E-04	2.58E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium bisulfite	7631-90-5	1.348	1876	0.0064%	2529	0.0081%	91	Scale Inhibitor	72h-EC50 = 36.8 mg sodium sulfite/L (alga) NOEC of >8.41 mg sodium sulfite/L (Daphnia)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	3.04E-05	5.81E-11	1.69E-04	2.00E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethylene glycol	107-21-1	1.11	1558	0.0053%	1729	0.0055%	62	Crosslinker	LC50 for fish = 22800 mg/L LC50 for Daphnia =7800 mg/L NOEC for Algae =100 mg/L	Based on Acute: Low	Readily biodegradable	No based on the measured log Kow of -1.36 and a measured BCF of 10	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Cinnamaldehyde	104-55-2	1.048	1459	0.0050%	1529	0.0049%	55	Corrosion Inhibitor	Danio rerio (Zebrafish) 96 h LC50 = 3.1 mg/L; Daphnia magna (Water flea) 48 h EC50 = 3.86 mg/L; Pseudokirchneriella subcapitata (Green algae) 72 h EC50 = 4.07 mg/L. 72 h NOEC value = 2.0 mg/L Pseudokirchneriella subcapitata (Green algae)	Based on Chronic: Moderate	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	9.64E-05	2.31E-04	5.37E-04	8.64E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Diethylene glycol	111-46-6	1.12	736	0.0025%	825	0.0026%	30	Corrosion Inhibitor	LC 50 = >100 mg/L (fish, invertebrates, algae)	Based on Acute: Low	Readily biodegradable	No based on the estimated BCF of 3	Tier 2	3.47E-04	6.65E-06	1.93E-03	2.29E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Methanol	67-56-1	0.791	730	0.0025%	578	0.0018%	21	Corrosion Inhibitor, Surfactant	LC50s ranged from 15,400 to 29,400 mg/L (fish) 24-hour and 48-hour EC50s were > 10,000 mg/L (Daphnia) 28 days NOEC was 446.7 mg/L (fish) 21 days NOEC was 208 mg/L (invertebrates)	Based on Chronic: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 2	1.96E-03	2.88E-04	1.09E-02	1.32E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amine oxides, cocoalkyldimethyl	61788-90-7	0.716	483	0.0017%	346	0.0011%	12	Corrosion Inhibitor	LC50/EC50/ErC50 values: 0.60-32 mg/L for fish 0.50-10.8 mg/L for Daphnia magna 0.010-5.30 mg/L for algae NOEC/ EC20: 0.010-1.72 mg/L for algae 0.28 mg/L for Daphnia 0.31 mg/L for fish	Based on Chronic: Very High	Readily biodegradable	No based on the calculated Log Kow of <2.7 and BCF <87	Tier 2	5.45E-04	2.58E-02	3.04E-03	2.94E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium hydroxide	1310-73-2	1.515	458	0.0016%	694	0.0022%	25	pH buffer	Measured acute endpoints for fish (196 mg/L). Measured chronic endpoint for Daphnia (240 mg/L)	Based on Chronic: Low	N.A.(Inorganic)	N.A. (Inorganic)	Tier 2	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body	NA. Acute toxicity only (irritant and corrosive), not systemically available in body
Citric acid	77-92-9	1.542	336	0.0012%	518	0.0017%	19	Corrosion Inhibitor	LC50/EC50 > 100 mg/L (fish, daphnia, algae) 8 day NOEC = 425 mg/L (algae)	Based on Chronic: Low	Readily biodegradable	No based on low log Kow	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Benzaldehyde	100-52-7	1.0415	332	0.0011%	346	0.0011%	12	Corrosion Inhibitor	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L.	Based on Chronic: High	Expected to be readily biodegradable	No based on Log Pow of 1.4	Tier 2	1.45E-04	2.56E-04	8.10E-04	1.21E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethanol	64-17-5	0.7864	328	0.0011%	258	0.0008%	9	Surfactant	LC50/EC50 > 1000 mg/L (fish, daphnia, algae) NOEC for invertebrates is 9.6 mg/L (10 day reproduction), plants it is 280 mg/L (7 day study)	Based on Chronic: High	Readily biodegradable	No based on calculated logBCF=0.5	Tier 2	1.36E-06	3.36E-07	7.56E-06	9.25E-06	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Hydrotreated light petroleum distillate	64742-47-8	0.8	303	0.0010%	242	0.0008%	9	Friction Reducer, Surfactant	96 hr LL50 was 2 to 5 mg/L (fish) 48 hr EL50 was 1.4 mg/L (daphnia) 21 d NOEL = 0.48 mg/L (daphnia)	Based on Chronic: High	Readily biodegradable	Yes 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	Tier 2	3.05E-06	2.75E-03	1.70E-05	2.77E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).

Chemical Risk Assessment
Hydraulic Fracture Stimulation Fluid SW 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)	Parent Compound Purpose	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
Fatty acids, tall-oil, ethoxylated	61791-00-2	1.054	235	0.0008%	248	0.0008%	9	Surfactant	96h-LL50 > 100 mg/L (fish) 48h-EL50 = 12.41 mg/L (invertebrates) 72h-EL50 = 39.7 mg/L (algae) 72h-EL10 = 7.08 mg/L (algae)	Based on Acute: High	Readily biodegradable (read across)	No based on low BCF values of < 100 L/kg ww	Tier 2	3.12E-06	3.03E-05	1.74E-05	5.08E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	68155-20-4	0.9	125	0.0004%	112	0.0004%	4	Surfactant	LC50 (96h) 6.7 mg/L (Danio rerio) (similar substance) LC50 (21d) = 0.1 mg/L (Daphnia magna) LC50 (48h) = 2.15 mg/L EC50 (72h) 2.2 mg/L (Scenedesmus subspicatus) (similar substance)	Based on Chronic: High	Readily biodegradable (read across)	No Log Kow 3	Tier 2	2.83E-05	9.31E-04	1.58E-04	1.12E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Butyl alcohol	71-36-3	0.81	116	0.0004%	94	0.0003%	3	Surfactant	Fish, LC50 (96h) 1376 mg/l Invertebrates, EC50 (48h) 1328 mg/L Algae, EC50 (96h) 225 mg/L EC10 (17h) Pseudomonas putida = 2476 mg/L Chronic NOECrepro (21d) = 4.1 mg/L for Daphnia magna	Based on Chronic: Moderate	Readily biodegradable	No based on low log Kow values of 1	Tier 2	9.45E-06	1.00E-05	5.26E-05	7.21E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-15, ethoxylated	68131-39-5	0.867	103	0.0004%	89	0.0003%	3	Friction Reducer, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L Green algae, EC50 (96 h) was 1.4 mg/L EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 2	2.25E-05	1.53E-05	1.26E-04	1.63E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Alcohols, C12-16, ethoxylated	68551-12-2	0.97	69	0.0002%	67	0.0002%	2	Corrosion Inhibitor, Surfactant	96 h LC50 Oncorhynchus mykiss was 5 - 7 mg/L Lepomis macrochirus, NOEC (30 days) was 0.11 – 0.33 mg/L Daphnia magna, EC50 (48 h) was 2.5 mg/L Daphnia magna, NOEC (21 days) was 0.77 – 1.75 mg/L Green algae, EC50 (96 h) was 1.4 mg/L EC50 (3 h) for microorganisms was 140 mg/L.	Based on Chronic: High	Readily biodegradable	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.	Tier 2	1.68E-05	6.93E-03	9.36E-05	7.04E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium iodide	7681-82-5	3.67	47	0.0002%	171	0.0005%	6	Corrosion Inhibitor	96 hour LC50 for fish is > 860 mg/l 17 days NOEC for fish is 100 mg/L 48hrs-EC50 for Daphnia magna is 1.27 mg/L NOEC for algae is 66 mg/L	Based on Chronic: Low	N.A.(Inorganic)	N.A.(Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Acrylonitrile	107-13-1	0.806	45	0.0002%	36	0.0001%	1	Surfactant	96h LC50 for freshwater fish = 10 - 20 mg/l 96h LC50 for saltwater fish 8.6 mg/l 48h EC50 for Daphnia = 7.6 mg/l 30d NOEC for fish of 0.17 mg/l	Based on Chronic: High	Biodegradable	No based on the low log Pow (0.00-0.30)	Tier 2	1.81E-03	9.67E-04	1.01E-02	1.29E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Diethanolamine	111-42-2	1.1	43	0.0001%	48	0.0002%	2	Breaker Activiator	Fish 96-h LC50 = 1370 mg/l Invertebrates 48-h EC50 = 55 mg/l Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l Microorganisms 16-h TTC = 16 mg/l Daphnia magna, the NOEC (21 days) was 0.78 mg/l	Based on Chronic: High	Readily biodegradable	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16	Tier 2	4.29E-04	8.89E-06	2.39E-03	2.83E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Glutaraldehyde	111-30-8	1.05	23	0.0001%	24	0.0001%	1	Biocide	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 reproduct'n 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	Based on Chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 2	7.47E-05	1.12E-05	4.16E-04	5.02E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
																Total Risk	0.26	The calculated risks associated with potential exposure to COPC identified in flowback water, where the SW Recipe is used and assuming 100% mass recovery is below the target of 1, respectively. Hence, chronic health risks are considered to be low and acceptable.

Notes
Tier 1 (NICNAS) - Chemical identified as of low concern for human health, as published in the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia (NICNAS 2017).
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019)
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	Oral/Dermal Exposures				Inhalation Exposures				Threshold Chronic TC or RfC (mg/m³)	NOAEC or LOAEC (mg/m³)	NOAEL or LOAEL (mg/kg bw/d)	Reference	UF	Reference
		Threshold Chronic TDI or RfD (mg/kg/day)		Dermal Permeability (cm/hr)	Reference	Inhalation Unit Risk (ug/m³) ⁻¹	Non-Threshold Slope Factor (mg/kg/day) ⁻¹								
COPC in Hydraulic Fracturing Fluid Injected into Well															
1319-33-1	Boronatrocacite/Ulexite ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RFD		9.6	NICNAS (2017)	100	NICNAS (2017)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylated ^B	0.5	D	1.21E-04	EPI				1.75	converted from RFD		50	NICNAS (2017)	100	NICNAS (2017)
69227-22-1	Alcohols, C10-16, ethoxylated propoxylated ^B	0.5	D	2.87E-01	EPI				1.75	converted from RFD		50	NICNAS (2017)	100	NICNAS (2017)
64-19-7	Acetic acid	12	D	5.56E-04	EPI				42	converted from RFD		1200	NICNAS (2017)	100	NICNAS (2017)
25322-68-3	Polyethylene glycol	8	D	2.14E-06	EPI				28	converted from RFD		8000	REACH	1000	D
7631-90-5	Sodium bisulfite ^C	10.5	D	4.16E-09	EPI				36.75	converted from RFD		1050	NICNAS (2017)	100	NICNAS (2017)
104-55-2	Cinnamaldehyde	2	D	5.20E-03	EPI				7	converted from RFD		200	NTP (2004); REACH	100	D
67-56-1	Methanol	0.037	D	3.19E-04	EPI				0.13	converted from RFD		3.7	NICNAS (2017)	100	NICNAS (2017)
61788-90-7	Amine oxides, cocoalkyldimethyl	0.08	D	1.03E-01	EPI				0.28	converted from RFD		80	OECD (2001)	1000	D
100-52-7	Benzaldehyde	0.3	D	3.83E-03	EPI				1.05	converted from RFD		300	OECD (2002); REACH; NICNAS	1000	D
64-17-5	Ethanol	24	D	5.38E-04	EPI				84	converted from RFD		2400	NICNAS (2017)	100	NICNAS (2017)
64742-47-8	Hydrotreated light petroleum distillate	10	D	1.96E+00	EPI				35	converted from RFD		1000	NICNAS (2017)	100	NICNAS (2017)
61791-00-2	Fatty acids, tall-oil, ethoxylated	10	D	2.11E-02	EPI				35	converted from RFD		1000	REACH	100	D
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	0.5	D	7.14E-02	EPI				1.75	converted from RFD		50	USEPA (2010)	100	D
71-36-3	Butyl alcohol	1.25	D	2.31E-03	EPI				4.375	converted from RFD		125	OECD (2001)/NICNAS	100	D
68131-39-5	Alcohols, C12-15, ethoxylated ^B	0.5	D	1.48E-03	EPI				1.75	converted from RFD		50	NICNAS (2017)	100	NICNAS (2017)
68551-12-2	Alcohols, C12-16, ethoxylated ^B	0.5	D	8.97E-01	EPI				1.75	converted from RFD		50	NICNAS (2017)	100	NICNAS (2017)
107-13-1	Acrylonitrile	0.0025	D	1.16E-03	EPI				0.00875	converted from RFD		0.25	OECD (2005); NICNAS	100	D
111-42-2	Diethanolamine	0.014	D	4.51E-05	EPI				0.049	converted from RFD		14	REACH; OECD (2002); NICNAS	1000	D
111-30-8	Glutaraldehyde	0.04	D	3.25E-04	EPI				0.14	converted from RFD		4	NICNAS (2017)	100	NICNAS (2017)
102-71-6	Triethanol amine	1.25	D	4.93E-05	EPI				4.375	converted from RFD		125	NICNAS (2017)	100	NICNAS (2017)
7758-19-2	Chlorous acid, sodium salt	0.039	D	8.27E-09	EPI				0.1365	converted from RFD		3.9	NICNAS (2017)	100	NICNAS (2017)
12008-41-2	Disodium octaborate tetrahydrate ^A	0.096	D	9.14E-04	EPI (as boric acid)				0.336	converted from RFD		9.6	NICNAS (2017)	100	NICNAS (2017)
7775-27-1	Sodium persulfate	0.67	D	7.05E-07	EPI				2.345	converted from RFD		67	NICNAS (2017)	100	NICNAS (2017)
68439-54-3	Ethoxylated branched C13 alcohol	0.5	D	1.06E-03	EPI				1.75	converted from RFD		50	NICNAS (2017)	100	NICNAS (2017)
1338-43-8	Sorbitan, mono-9-octadecenoate, (Z)	25	JECFA	5.02E-02	EPI				87.5	converted from RFD		-	JECFA(1973); US FDA; FSANZ (2018)	-	-
9005-65-6	Sorbitan monooleate polyoxyethylene derivative	10	EFSA	3.54E-09	EPI				35	converted from RFD		-	EFSA (2017)	-	-
111-46-6	2,2'-oxydiethanol (diethylene glycol)	0.3	D	4.17E-05	EPI				1.05	converted from RFD		300	Health Council of the Netherlands (2007); NICNAS	1000	D
7681-38-1	Sodium bisulfate ^C	10.5	D	9.29E-09	EPI				36.75	converted from RFD		1050	NICNAS (2017)	100	NICNAS (2017)
14808-60-7	Crystalline silica, quartz	Not toxic via oral/dermal exposure							0.003	USEPA (2019)		-	-	-	-
10486-00-7	Sodium perborate tetrahydrate	0.05	D	1.81E-06	EPI				0.175	converted from RFD		50	REACH	1000	D

Notes:

A - Read across data from Boric Acid

B - Read across data from Alcohol ethoxylates C6-C12

C - Read across data from Sodium Sulfite

References:

D - Derived (refer to individual Toxicity Profiles)

EFSA - European Food Safety Authority

EPI - USEPA Estimation Programs Interface (EPI) Suite

FSANZ - Food Standards Australia New Zealand

J- JECFA - Joint FAO/WHO Expert Committee on Food Additives

NICNAS - National Industrial Chemicals Notification and Assessment Scheme. Assessed at <https://www.nicnas.gov.au/>

NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associatedwith coal seam gas extraction in Australia, prepared by the National Industrial ChemicalsNotification and Assessment Scheme

NTP - US Department of Health and Serices National Toxicology Program

OECD - Organisation for Economic Co-operation and Development Screening Information Data Set (SIDS)

REACH - ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - SW Recipe

Chronic Exposures

General Data/ Equations		Units	Exposure Calculations (RME)	
Ingestion of Flowback Water by Workers				
Exposure Parameters				
Exposure Frequency (EF)		days/year	20	Assume work 5 days per week for 1 month during the fraccing period
Exposure Duration (ED)		years	0.083	Maximum duration of the frac. Works will be complete in one month.
Body Weight (BW)		kg	78	Average male and female adults as per enHealth 2012
Averaging Time - NonThreshold (ATc)		days	25550	USEPA 1989 and CSMS 1996
Averaging Time - Threshold (ATn)		days	30.42	USEPA 1989 and CSMS 1996
Ingestion Rate (IRw)		L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fraccing.
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	4.2E-09	NonThreshold
			3.5E-06	Threshold

Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989)
NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

CAS	Chemical	Toxicity Data		Background Intake (% Chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Concentration in Water (mg/L)	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)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB		5.0E-01		5.0E-01	344.58	1.4E-06	1.2E-03	--	2.4E-03
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB		5.0E-01		5.0E-01	177.36	7.4E-07	6.2E-04	--	1.2E-03
64-19-7	Acetic acid		1.2E+01		1.2E+01	107.82	4.5E-07	3.8E-04	--	3.2E-05
25322-68-3	Polyethylene glycol		8.0E+00		8.0E+00	89.47	3.7E-07	3.1E-04	--	3.9E-05
7631-90-5	Sodium bisulfiteC		1.1E+01		1.1E+01	90.84	3.8E-07	3.2E-04	--	3.0E-05
104-55-2	Cinnamaldehyde		2.0E+00		2.0E+00	54.91	2.3E-07	1.9E-04	--	9.6E-05
111-46-6	2,2'-oxydiethanol (diethylene glycol)		3.0E-01		3.0E-01	29.63	1.2E-07	1.0E-04	--	3.5E-04
67-56-1	Methanol		3.7E-02		3.7E-02	20.75	8.7E-08	7.3E-05	--	2.0E-03
61788-90-7	Amine oxides, cocoalkyldimethyl		8.0E-02		8.0E-02	12.42	5.2E-08	4.4E-05	--	5.5E-04
100-52-7	Benzaldehyde		3.0E-01		3.0E-01	12.42	5.2E-08	4.4E-05	--	1.5E-04
64-17-5	Ethanol		2.4E+01		2.4E+01	9.27	3.9E-08	3.3E-05	--	1.4E-06
64742-47-8	Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	8.69	3.6E-08	3.1E-05	--	3.1E-06
61791-00-2	Fatty acids, tall-oil, ethoxylated		1.0E+01		1.0E+01	8.89	3.7E-08	3.1E-05	--	3.1E-06
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)		5.0E-01		5.0E-01	4.03	1.7E-08	1.4E-05	--	2.8E-05
71-36-3	Butyl alcohol		1.3E+00		1.3E+00	3.36	1.4E-08	1.2E-05	--	9.4E-06
68131-39-5	Alcohols, C12-15, ethoxylatedB		5.0E-01		5.0E-01	3.21	1.3E-08	1.1E-05	--	2.3E-05
68551-12-2	Alcohols, C12-16, ethoxylatedB		5.0E-01		5.0E-01	2.39	1.0E-08	8.4E-06	--	1.7E-05
107-13-1	Acrylonitrile		2.5E-03		2.5E-03	1.29	5.4E-09	4.5E-06	--	1.8E-03
111-42-2	Diethanolamine		1.4E-02		1.4E-02	1.71	7.1E-09	6.0E-06	--	4.3E-04
111-30-8	Glutaraldehyde		4.0E-02		4.0E-02	0.85	3.6E-09	3.0E-06	--	7.5E-05
Total Risk (mixture)										9.19E-03

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e. a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - SW Recipe

Chronic Exposures

General Data/ Equations		Units	Exposure Calculations (RME)	
Exposure Parameters			Dermal Contact with Flow Back Water by Workers	
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fracing period	
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.	
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012	
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996	
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996	
Surface Area (SAw)	cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on	
Exposure Time (ET)	hr/day	1	Australian work sites; forearms conservatively included	
Conversion Factor (CF)	L/cm ³	1.E-03	Assume contact with flow back water for 1 hours per day	
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm-kg-day)	1.9E-06	NonThreshold
			1.6E-03	Threshold
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water 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)	Dermal Permeability	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB	5.0E-01		5.0E-01	1.2E-4	344.58	8.0E-08	6.7E-05	--	1.3E-04
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB	5.0E-01		5.0E-01	2.9E-1	177.36	9.8E-05	8.2E-02	--	1.6E-01
64-19-7	Acetic acid	1.2E+01		1.2E+01	5.6E-4	107.82	1.2E-07	9.7E-05	--	8.1E-06
25322-68-3	Polyethylene glycol	8.0E+00		8.0E+00	2.1E-6	89.47	3.7E-10	3.1E-07	--	3.9E-08
7631-90-5	Sodium bisulfiteC	1.1E+01		1.1E+01	4.2E-9	90.84	7.3E-13	6.1E-10	--	5.8E-11
104-55-2	Cinnamaldehyde	2.0E+00		2.0E+00	5.2E-3	54.91	5.5E-07	4.6E-04	--	2.3E-04
111-46-6	2,2'-oxydiethanol (diethylene glycol)	3.0E-01		3.0E-01	4.2E-5	29.63	2.4E-09	2.0E-06	--	6.7E-06
67-56-1	Methanol	3.7E-02		3.7E-02	3.2E-4	20.75	1.3E-08	1.1E-05	--	2.9E-04
61788-90-7	Amine oxides, cocoalkyldimethyl	8.0E-02		8.0E-02	1.0E-1	12.42	2.5E-06	2.1E-03	--	2.6E-02
100-52-7	Benzaldehyde	3.0E-01		3.0E-01	3.8E-3	12.42	9.1E-08	7.7E-05	--	2.6E-04
64-17-5	Ethanol	2.4E+01		2.4E+01	5.4E-4	9.27	9.6E-09	8.1E-06	--	3.4E-07
64742-47-8	Hydrotreated light petroleum distillate	1.0E+01		1.0E+01	2.0E+0	8.69	3.3E-05	2.8E-02	--	2.8E-03
61791-00-2	Fatty acids, tall-oil, ethoxylated	1.0E+01		1.0E+01	2.1E-2	8.89	3.6E-07	3.0E-04	--	3.0E-05
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	5.0E-01		5.0E-01	7.1E-2	4.03	5.5E-07	4.7E-04	--	9.3E-04
71-36-3	Butyl alcohol	1.3E+00		1.3E+00	2.3E-3	3.36	1.5E-08	1.3E-05	--	1.0E-05
68131-39-5	Alcohols, C12-15, ethoxylatedB	5.0E-01		5.0E-01	1.5E-3	3.21	9.1E-09	7.7E-06	--	1.5E-05
68551-12-2	Alcohols, C12-16, ethoxylatedB	5.0E-01		5.0E-01	9.0E-1	2.39	4.1E-06	3.5E-03	--	6.9E-03
107-13-1	Acrylonitrile	2.5E-03		2.5E-03	1.2E-3	1.29	2.9E-09	2.4E-06	--	9.7E-04
111-42-2	Diethanolamine	1.4E-02		1.4E-02	4.5E-5	1.71	1.5E-10	1.2E-07	--	8.9E-06
111-30-8	Glutaraldehyde	4.0E-02		4.0E-02	3.3E-4	0.85	5.3E-10	4.5E-07	--	1.1E-05
Total Risk (mixture)										2.0E-1

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

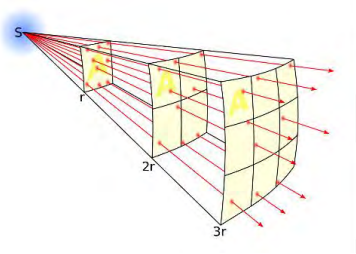
Aerosol Exposure - SW Recipe

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state concentrations were calculated. The ‘inverse square law’ was then applied to approximate the air concentration at a distance from the virtual air box. This law assumes that the density of the spray droplets is inversely proportional to the square of the distance from the source. That is, the further away a receptor is from the spray source, the density of the droplets (and therefore the concentration) will decrease.

An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol}\left(\frac{L}{m^3}\right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol\left(\frac{L}{hr}\right) \times Aerosol_{driftable}(\%)}{BoxVR\left(\frac{m^3}{hr}\right)}\right)}{BoxDistance^2(m)}$$



Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a ‘spray box’ of 3 m long.
Spray box width	m	3	Assume a ‘spray box’ of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the ‘spray box’. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the ‘spray box’ and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the ‘spray box’. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a ‘spray box’ dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
68937-66-6	Alcohols, C6-12, ethoxylated propoxyla	344.58	124049.7383	2.500000E-03
69227-22-1	Alcohols, C10-16, ethoxylated propoxyl	177.36	63849.13002	2.500000E-03
64-19-7	Acetic acid	107.82	38815.27443	2.500000E-03
25322-68-3	Polyethylene glycol	89.47	32209.40603	2.500000E-03
7631-90-5	Sodium bisulfiteC	90.84	32700.84622	2.500000E-03
104-55-2	Cinnamaldehyde	54.91	19768.14867	2.500000E-03
111-46-6	2,2"-oxydiethanol (diethylene glycol)	29.63	10665.31447	2.500000E-03
67-56-1	Methanol	20.75	7469.078692	2.500000E-03
61788-90-7	Amine oxides, cocoalkyldimethyl	12.42	4472.513177	2.500000E-03
100-52-7	Benzaldehyde	12.42	4470.713715	2.500000E-03
64-17-5	Ethanol	9.27	3338.494405	2.500000E-03
64742-47-8	Hydrotreated light petroleum distillate	8.69	3130.000401	2.500000E-03
61791-00-2	Fatty acids, tall-oil, ethoxylated	8.89	3201.205801	2.500000E-03
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyet	4.03	1452.129696	2.500000E-03
71-36-3	Butyl alcohol	3.36	1210.554971	2.500000E-03
68131-39-5	Alcohols, C12-15, ethoxylatedB	3.21	1154.770361	2.500000E-03
68551-12-2	Alcohols, C12-16, ethoxylatedB	2.39	861.0898092	2.500000E-03
107-13-1	Acrylonitrile	1.29	464.4655534	2.500000E-03
111-42-2	Diethanolamine	1.71	615.1041839	2.500000E-03
111-30-8	Glutaraldehyde	0.85	306.4351619	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - SW Recipe

Chronic Exposures

General Data/ Equations	Units	Exposure Calculations (RME) Inhalation of Mist by Workers	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.0	USEPA 1989 and CSMS 1996
$ITF_{inh, w, shwr} = \frac{EmF \times AAF \times ET_{iw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)

Hazard Quotients = (Daily Intake from Aerosol for Threshold Effects/ADI)

CAS	Chemical	Concentration in Water	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Threshold Intake and Risk Calculations		
		mg/L	(unitless)	(L/m ³)	(mg/m ³)	Adult Exposure Factor (threshold)	Adjusted Air Concentration (threshold)	Hazard Quotient (Adult)
						(L/m ³)	(mg/m ³)	(unitless)
68937-66-6	Alcohols, C6-12, ethoxylated propoxylatedB	3.45E+02	1.00	2.50E-03	1.75E+00	6.85E-05	2.36E-02	1.35E-02
69227-22-1	Alcohols, C10-16, ethoxylated propoxylatedB	1.77E+02	1.00	2.50E-03	1.75E+00	6.85E-05	1.21E-02	6.94E-03
64-19-7	Acetic acid	1.08E+02	1.00	2.50E-03	4.20E+01	6.85E-05	7.38E-03	1.76E-04
25322-68-3	Polyethylene glycol	8.95E+01	1.00	2.50E-03	2.80E+01	6.85E-05	6.13E-03	2.19E-04
7631-90-5	Sodium bisulfiteC	9.08E+01	1.00	2.50E-03	3.68E+01	6.85E-05	6.22E-03	1.69E-04
104-55-2	Cinnamaldehyde	5.49E+01	1.00	2.50E-03	7.00E+00	6.85E-05	3.76E-03	5.37E-04
111-46-6	2,2"-oxydiethanol (diethylene glycol)	2.96E+01	1.00	2.50E-03	1.05E+00	6.85E-05	2.03E-03	1.93E-03
67-56-1	Methanol	2.07E+01	1.00	2.50E-03	1.30E-01	6.85E-05	1.42E-03	1.09E-02
61788-90-7	Amine oxides, cocoalkyldimethyl	1.24E+01	1.00	2.50E-03	2.80E-01	6.85E-05	8.51E-04	3.04E-03
100-52-7	Benzaldehyde	1.24E+01	1.00	2.50E-03	1.05E+00	6.85E-05	8.51E-04	8.10E-04
64-17-5	Ethanol	9.27E+00	1.00	2.50E-03	8.40E+01	6.85E-05	6.35E-04	7.56E-06
64742-47-8	Hydrotreated light petroleum distillate	8.69E+00	1.00	2.50E-03	3.50E+01	6.85E-05	5.96E-04	1.70E-05
61791-00-2	Fatty acids, tall-oil, ethoxylated	8.89E+00	1.00	2.50E-03	3.50E+01	6.85E-05	6.09E-04	1.74E-05
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	4.03E+00	1.00	2.50E-03	1.75E+00	6.85E-05	2.76E-04	1.58E-04
71-36-3	Butyl alcohol	3.36E+00	1.00	2.50E-03	4.38E+00	6.85E-05	2.30E-04	5.26E-05
68131-39-5	Alcohols, C12-15, ethoxylatedB	3.21E+00	1.00	2.50E-03	1.75E+00	6.85E-05	2.20E-04	1.26E-04
68551-12-2	Alcohols, C12-16, ethoxylatedB	2.39E+00	1.00	2.50E-03	1.75E+00	6.85E-05	1.64E-04	9.36E-05
107-13-1	Acrylonitrile	1.29E+00	1.00	2.50E-03	8.75E-03	6.85E-05	8.84E-05	1.01E-02
111-42-2	Diethanolamine	1.71E+00	1.00	2.50E-03	4.90E-02	6.85E-05	1.17E-04	2.39E-03
111-30-8	Glutaraldehyde	8.51E-01	1.00	2.50E-03	1.40E-01	6.85E-05	5.83E-05	4.16E-04
Total Risk (mixture)								0.05

Summary of Risk to Workers - SW Recipe Exposure fo Target Chemicals - Theoretical Data

Receptor/Exposure Pathway	Calculated HI
	100% Mass Return
<u>Use of Stimulation Fluid in Hydraulic Fracturing</u>	
<u>SW Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.01
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.20
Inhalation of mist from the evaporation units	0.05
Total Risk	0.26

Appendix D

Chemical Risk Assessment – Drilling Fluid

Human Health Screening Assessment
Planned Drilling Muds

Chemical Name	CAS Number	Concentration in Injected Fluid (mg/L)	Ecotoxicity ¹	Toxicity ²	Biodegradation ^{1,3}	Bioaccumulative ¹	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
Alcohol, C11-14, ethoxylated	78330-21-9	1.5	96 h LC50, <i>Oncorhynchus mykiss</i> = 5 - 7 mg/L 30 d <i>Lepomis macrochirus</i> , NOEC = 0.11 - 0.33 mg/L. 48 h EC50 <i>Daphnia magna</i> = 2.5 mg/L. 21 d NOEC <i>Daphnia magna</i> = 0.77 - 1.75 mg/L. 96 h EC50 (green algae) = 1.4 mg/L. EC50 (3 h) for microorganisms = 140 mg/L	Based on chronic: High	Readily biodegradable	Not bioaccumulative	Tier 2	1.1E-05	6.16E-03	5.9E-05	6.2E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Proprietary	Proprietary	Proprietary	Proprietary	Proprietary	Proprietary	Proprietary	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Citric Acid, monohydrate	77-92-9	1	96 h LC50 fish = 440 to 1,516 mg/L 24 h EC50 value for invertebrates is 85 mg/L 7 d toxic limit concentration values for algae = 300 to 640 mg/L 8 d freshwater static test for the algae <i>Scenedesmus quadricauda</i> , NOEC = 425 mg/L	Based on chronic: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Distillates, hydrotreated light	64742-47-8	1.5	Lowest acute endpoint for <i>Daphnia</i> = 0.018 mg/L (modelled)	Based on acute: Very high	Readily biodegradable	Yes 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	Tier 2	5.3E-07	4.75E-04	2.9E-06	4.8E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues	68909-77-3	1	<i>Leuciscus idus</i> , Fish LC50 (96 h) = 681.2 mg/L <i>Daphnia</i> EC50 = 122 mg/L Green alga <i>ErC50</i> (72h) = 45 mg/L Microorganism > 1000 mg/L	Based on acute: Low	Not readily biodegradable.	No based on the Log Pow of 0.565	Tier 2	3.5E-06	2.23E-09	2.0E-05	2.3E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Glutaraldehyde	111-30-8	0.3	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 <i>Daphnia magna</i> LC50 = 0.35 mg/L 48 acute <i>Daphnia magna</i> LC50 = 16.3 mg/L 21 d reproduct ⁿ <i>Daphnia magna</i> LOEC = 4.3 mg/L, NOEC = 2.1 mg/L 96 h algal growth inhibition <i>Selenastrum capricornutum</i> I _m = 3.9 mg/L (median inhibitory limit) 96 h algal growth inhibition <i>Scenedesmus subspicatus</i> EC50 = 1.0 mg/L Bacterial inhibition Sewage microbes IC50 = 25-34 mg/L	Based on chronic: Moderate	Readily biodegradable	No based on the Log Pow of -0.01	Tier 2	2.6E-05	3.94E-06	1.5E-04	1.8E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Glyoxal <1%	107-22-2	1.5	96 h-LC50 fish = 215 mg/L Invertebrates EC50 > 100 mg/L NOEC fish = 119 mg/L (a.i.)	Based on chronic: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 2	4.0E-05	1.07E-06	2.2E-04	2.6E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Methanol	67-56-1	0.3	Acute LC50s = 15,400 to 29,400 mg/L Invertebrates, chronic NOEC = 32,000 mg/L.	Based on acute: Low	Readily biodegradable	No based on the Log Kow of -0.74	Tier 2	2.8E-05	4.16E-06	1.6E-04	1.9E-04	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Nitriiotriacetic acid, trisodium salt monohydrate	5064-31-3	1	Fish 96 h LC50 = 98 - 487 mg/L Fish NOEC = 54 mg/L Invertebrates NOEC = 9.3 mg/L	Based on chronic: Moderate	Readily biodegradable	No based on the Log Pow of -13.2	Tier 2	3.5E-04	1.83E-12	2.0E-03	2.3E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Plagioclase Feldspar/Kaolinite	1332-58-7	10	<i>Daphnia pulex</i> (water flea) 24- and 48-h LC50 >1.1 g/L <i>P. trilineatum</i> 12-h LC50 = 170 mg/L <i>O. fasciatus</i> 12-h LC50 = 710 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1	NA	NA	NA	NA	NA
Poly Anionic Cellulose	9004-32-4	1.5	96 h LC50 for <i>Brachydanio rerio</i> is >2,500 mg/L 48 h LC50 for <i>Daphnia magna</i> is >5,000 mg/L; 96 h EC50 for <i>Selenastrum capricornutum</i> is 500 mg/L	Based on acute: Low	Not readily biodegradable	Not bioaccumulative	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Potassium Chloride	7447-40-7	18	96 h LC50 in <i>Pimephales promelas</i> = 880 mg/L 48 h LC50 <i>Lepomis macrochirus</i> , <i>Oncorhynchus mykiss</i> and <i>Ictalurus punctatus</i> = 720 - 2010 mg/L 48 h EC50 <i>Daphnia magna</i> and <i>Ceriodaphnia dubia</i> were 660 and 630 mg/L respectively NOEC for <i>Daphnia</i> is 373 mg/L	Based on chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Potassium Hydroxide	1310-58-3	0.3	96-hour fish LC50 value = 80 mg/L 48-hr invertebrate EC50 value = 40 mg/L 120-hr algae EC50 value = 1337 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1	NA	NA	NA	NA	NA. Acute toxicity only (irritant and corrosive), not systemically available in body
Quartz/Cristobite	14808-60-7	10	acute data >10 g/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	NA. Not toxic via oral exposure as not absorbed via GI tract	NA. Not toxic via dermal exposure.	2.3E-01	2.3E-01	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Smectite	12199-37-0	10	96 hr <i>Oncorhynchus mykiss</i> (Rainbow Trout) LC50 = 19000 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1	NA	NA	NA	NA	NA
Sodium Bicarbonate	144-55-8	0.5	21 d <i>Daphnia</i> NOEC = 576 mg/L	Based on chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium Carbonate	497-19-8	0.3	96-hour LC50 Bluegill sunfish (<i>Lepomis macrochirus</i>) = 300 mg/L 96-hour LC50 to mosquitofish (<i>Gambusia affinis</i>) = 740 mg/L 48-hour EC50 to the invertebrate <i>Ceriodaphnia cf. dubia</i> = 200 to 227 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 2	1.1E-05	1.54E-10	6.1E-05	7.2E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Sodium Chloride	7647-14-5	60	acute endpoint for Fish = 1290 mg/L NOEC for <i>Daphnia</i> = 314 mg/L	Based on chronic: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium erythorbate	6381-77-7	0.2	96 h LC50 Fish > 100 mg/L 48 h EC50 <i>Daphnia magna</i> = 84 - 100 mg/L 72 h NOEC alga = 20 mg/L	Based on acute: Low	Not readily biodegradable	Not bioaccumulative	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Sodium hydroxide	1310-73-2	0.3	Measured acute endpoints for fish = 196 mg/L Measured chronic endpoint for <i>Daphnia</i> = 240 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1	NA	NA	NA	NA	NA. Acute toxicity only (irritant and corrosive), not systemically available in body
Starch	9005-25-8	4	<i>Crassostrea virginica</i> 96 h = 1000 mg/L <i>Orthopristis chrysoptera</i> 96 h = 5000 mg/L <i>Bairdiella chrysoura</i> 96 h = 5000 mg/L	Based on acute: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1	NA	NA	NA	NA	NA
Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione	533-74-4	4	<i>Daphnia magna</i> (Water flea), 48 h, static, EC50 = 0.3 mg/L <i>Salmo gairdneri</i> (Rainbow trout), 96 h, static, LC50 = 0.16 mg/L <i>Ankistrodesmus brihalanus</i> (Green alga), 72 h, static, EC50 = 1.08 mg/L <i>Colinus virginianus</i> (Bobwhite quail), 21 d, LD50 = 415 mg/kg bw <i>Colinus virginianus</i> (Bobwhite quail), 25 weeks, NOEL = 100 mg/kg food	Based on acute: Very high	Expected to be readily biodegradable	Not bioaccumulative	Tier 2	2.8E-03	6.53E-04	1.6E-02	1.9E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Xanthan Gum	11138-66-2	1.5	Acute Fish (measured) = 420 mg/L	Based on acute: Low	Expected to be readily biodegradable	Not bioaccumulative	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
Guanidine, hydrochloride (1:1)	50-01-1	7	96-h-LC50 for fish = 690 mg/L NOEC for fish = 181 mg/L EC50 for <i>Daphnia</i> = 70.2 mg/L NOEC for <i>Daphnia</i> = 2.9 mg/L EC50 for algae = 33.5 mg/L NOEC for algae = 6.3 mg/L	Based on chronic: Moderate	Expected to be readily biodegradable	Not bioaccumulative	Tier 2	2.5E-04	4.37E-09	1.4E-03	1.6E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
Polyacrylamide	38193-60-1	1.5	LC50 = 357 mg/L (fish) LC50 = 212 mg/L (invertebrates) EC 50 = >1000 mg/L (algae)	Based on acute: Low	Not readily biodegradable	Not bioaccumulative	Tier 1	NA	NA	NA	NA	NA
Calcium Carbonate	1317-65-3	15	96h EC50 for fish >100mg/L 48 h EC50 for <i>Daphnia</i> >100 mg/L 72 h ERC50 for algae >14 mg/L	Based on acute: Low	N.A. (Inorganic)	N.A. (Inorganic)	Tier 1 (NICNAS)	NA	NA	NA	NA	NA
										Total Risk	0.26	The calculated risks associated with potential exposure to COPC identified in drilling fluids is below the target of 1, respectively. Hence, chronic health risks are considered to be low and acceptable.

Notes
1 - Please refer to the individual toxicity profiles for further detail.
2 - Toxicity assessed using Commonwealth of Australia 2013 Ecotoxicity Assessment Guidelines (presented as Table 4 in the Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019))
3- Biodegradation assessed as per Northern Territory Government Draft Guideline for the Preparation of an Environment Management Plan under the Petroleum Regulations (2019) and Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS)
BCF - Bioconcentration Factor
NA - Not Applicable
MOE - Margin of Exposure
NICNAS 2017 - National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia
DOE 2017 - Draft Risk Assessment Guidance Manual: For Chemicals Associated with Coal Seam Gas Extraction, Australian Government, Department of Energy

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	Oral/Dermal Exposures				Inhalation Exposures				Threshold Chronic TC or RfC (mg/m³)	NOAEC or LOAEC (mg/m³)	NOAEL or LOAEL (mg/kg bw/d)	Reference	UF	Reference	
		Threshold Chronic TDI or RfD (mg/kg/day)	Dermal Permeability (cm/hr)	Reference	Inhalation Unit Risk (ug/m³) ⁻¹	Non-Threshold Slope Factor (mg/kg/day) ⁻¹										
COPC in Hydraulic Fracturing Fluid Injected into Well																
67-56-1	Methanol	0.037	D	3.19E-04	EPI				0.13	converted from RfD		3.7	NICNAS (2017)	100	NICNAS (2017)	
64742-47-8	Hydrotreated light petroleum distillate	10	D	1.96E+00	EPI				35	converted from RfD		1000	NICNAS (2017)	100	NICNAS (2017)	
111-30-8	Glutaraldehyde	0.04	D	3.25E-04	EPI				0.14	converted from RfD		4	NICNAS (2017)	100	NICNAS (2017)	
14808-60-7	Crystalline silica, quartz	Not toxic via oral/dermal exposure							0.003	USEPA (2019)		-				
78330-21-9	Alcohol, C11-14, ethoxylated ^B	0.5	D	1.27E+00	EPI				1.75	converted from RfD		50	NICNAS (2017)	100	NICNAS (2017)	
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues	1	D	1.38E-06	EPI				3.5	converted from RfD		1000	REACH	1000	D	
107-22-2	Glyoxal <1% (Ethanedial)	0.133	D	5.88E-05	EPI				0.4655	converted from RfD		13.3	NICNAS (2017)	100	NICNAS (2017)	
5064-31-3	Nitrilotriacetic acid, trisodium salt monohydrate	0.01	D	1.13E-11	EPI				0.035	converted from RfD		10	ADWG (2018)	1000	ADWG (2018)	
497-19-8	Sodium Carbonate	0.0967	D	3.08E-08	EPI				0.338	converted from RfD		9.67	NICNAS (2017)	100	NICNAS (2017)	
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione	0.005	D	5.05E-04	EPI				0.018	converted from RfD		0.5	NRA (1997)	100	NRA (1997)	
50-01-1	Guanidine, hydrochloride (1:1)	0.1	D	3.86E-08	EPI				0.350	converted from RfD		100	REACH	1000	D	

Notes:
A - Read across data from Boric Acid
B - Read across data from Alcohol ethoxylates C6-C12
C - Read across data from Sodium Sulfite

References:
D - Derived (refer to individual Toxicity Profiles)
EFSA - European Food Safety Authority
EPI - USEPA Estimation Programs Interface (EPI) Suite
FSANZ - Food Standards Australia New Zealand
J- JECFA - Joint FAO/WHO Expert Committee on Food Additives
NICNAS - National Industrial Chemicals Notification and Assessment Scheme. Assessed at <https://www.nicnas.gov.au/>
NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associatedwith coal seam gas extraction in Australia, prepared by the National Industrial ChemicalsNotification and Assessment Scheme
NTP - US Department of Health and Serices National Toxicology Program
OECD - Organisation for Economic Co-operation and Development Screening Information Data Set (SIDS)
REACH - ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - Drilling Fluids

Chronic Exposures

Chronic Exposures			Exposure Calculations (RME)						
General Data/ Equations		Units	Ingestion of Flowback Water by Workers						
Exposure Parameters									
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fraccing period						
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.						
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012						
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996						
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996						
Ingestion Rate (IRw)	L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fraccing.						
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	4.2E-09	NonThreshold					
			3.5E-06	Threshold					
Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989) NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor Hazard Quotients = (Daily Intake from Water 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)
67-56-1	Methanol	3.7E-02		3.7E-02	0.30	1.3E-09	1.1E-06	--	2.8E-05
64742-47-8	Hydrotreated light petroleum distillate	1.0E+01		1.0E+01	1.50	6.3E-09	5.3E-06	--	5.3E-07
111-30-8	Glutaraldehyde	4.0E-02		4.0E-02	0.30	1.3E-09	1.1E-06	--	2.6E-05
78330-21-9	Alcohol, C11-14, ethoxylatedB	5.0E-01		5.0E-01	1.50	6.3E-09	5.3E-06	--	1.1E-05
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues	1.0E+00		1.0E+00	1.00	4.2E-09	3.5E-06	--	3.5E-06
107-22-2	Glyoxal <1% (Ethanediol)	1.3E-01		1.3E-01	1.50	6.3E-09	5.3E-06	--	4.0E-05
5064-31-3	Nitrilotriacetic acid, trisodium salt monohydrate	1.0E-02		1.0E-02	1.00	4.2E-09	3.5E-06	--	3.5E-04
497-19-8	Sodium Carbonate	9.7E-02		9.7E-02	0.30	1.3E-09	1.1E-06	--	1.1E-05
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione	5.0E-03		5.0E-03	4.00	1.7E-08	1.4E-05	--	2.8E-03
50-01-1	Guanidine, hydrochloride (1:1)	1.0E-01		1.0E-01	7.00	2.9E-08	2.5E-05	--	2.5E-04
						Total Risk (mixture)		--	2.89E-05

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - Drilling Fluids

Chronic Exposures

General Data/ Equations		Units	Exposure Calculations (RME)	
Exposure Parameters			Dermal Contact with Flow Back Water by Workers	
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fracing period	
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.	
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012	
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996	
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996	
Surface Area (SAw)	cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on	
Exposure Time (ET)	hr/day	1	Australian work sites; forearms conservatively included	
Conversion Factor (CF)	L/cm ³	1.E-03	Assume contact with flow back water for 1 hours per day	
Intake Factor = $\frac{SAw \cdot ET \cdot CF \cdot EF \cdot ED}{BW \cdot AT}$		L-hr/(cm-k-g-day)	1.9E-06	NonThreshold
			1.6E-03	Threshold

Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)

NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor

Hazard Quotients = (Daily Intake from Water 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)	Dermal Permeability	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
		(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
67-56-1	Methanol		3.7E-02		3.7E-02	3.2E-4	0.30	1.8E-10	1.5E-07	--	4.2E-06
64742-47-8	Hydrotreated light petroleum distillate		1.0E+01		1.0E+01	2.0E+0	1.50	5.7E-06	4.8E-03	--	4.8E-04
111-30-8	Glutaraldehyde		4.0E-02		4.0E-02	3.3E-4	0.30	1.9E-10	1.6E-07	--	3.9E-06
78330-21-9	Alcohol, C11-14, ethoxylatedB		5.0E-01		5.0E-01	1.3E+0	1.50	3.7E-06	3.1E-03	--	6.2E-03
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine d		1.0E+00		1.0E+00	1.4E-6	1.00	2.7E-12	2.2E-09	--	2.2E-09
107-22-2	Glyoxal <1% (Ethanedia)		1.3E-01		1.3E-01	5.9E-5	1.50	1.7E-10	1.4E-07	--	1.1E-06
5064-31-3	Nitrilotriacetic acid, trisodium salt monohydrate		1.0E-02		1.0E-02	1.1E-11	1.00	2.2E-17	1.8E-14	--	1.8E-12
497-19-8	Sodium Carbonate		9.7E-02		9.7E-02	3.1E-8	0.30	1.8E-14	1.5E-11	--	1.5E-10
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione		5.0E-03		5.0E-03	5.1E-4	4.00	3.9E-09	3.3E-06	--	6.5E-04
50-01-1	Guanidine, hydrochloride (1:1)		1.0E-01		1.0E-01	3.9E-8	7.00	5.2E-13	4.4E-10	--	4.4E-09
Total Risk (mixture)											7.29E-03

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:

- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Aerosol Exposure - Drilling Fluids

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state
An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol} \left(\frac{L}{m^3}\right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol\ \left(\frac{L}{hr}\right) \times Aerosol_{driftable}\ (%) }{BoxVR\ \left(\frac{m^3}{hr}\right)}\right)}{BoxDistance^2\ (m)}$$

Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a 'spray box' of 3 m long.
Spray box width	m	3	Assume a 'spray box' of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the 'spray box'. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the 'spray box' and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the 'spray box'. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a 'spray box' dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
67-56-1	Methanol	0.30	108	2.500000E-03
64742-47-8	Hydrotreated light petroleum distillate	1.50	540	2.500000E-03
111-30-8	Glutaraldehyde	0.30	108	2.500000E-03
78330-21-9	Alcohol, C11-14, ethoxylatedB	1.50	540	2.500000E-03
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products	1.00	360	2.500000E-03
107-22-2	Glyoxal <1% (Ethanedial)	1.50	540	2.500000E-03
5064-31-3	Nitrilotriacetic acid, trisodium salt monohydrate	1.00	360	2.500000E-03
497-19-8	Sodium Carbonate	0.30	108	2.500000E-03
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazole	4.00	1440	2.500000E-03
50-01-1	Guanidine, hydrochloride (1:1)	7.00	2520	2.500000E-03
14808-60-7	Crystalline silica, quartz	10.00	3600	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - Drilling Fluids

Chronic Exposures

General Data/ Equations	Units	Exposure Calculations (RME) Inhalation of Mist by Workers	
Exposure Parameters			
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.0	USEPA 1989 and CSMS 1996
$ITF_{inh, w, shwr} = \frac{EmF \times AAF \times ET_{dw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)

Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

						Threshold Intake and Risk Calculations		
CAS	Chemical	Groundwater Concentration	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Adult Exposure Factor (threshold)	Adult Exposure Adjusted Air Concentration (threshold)	Hazard Index (Adult)
		mg/L	(unitless)	(L/m ³)	(mg/m ³)	(L/m ³)	(mg/m ³)	(unitless)
67-56-1	Methanol	0.3	1.00	2.50E-03	1.30E-01	6.85E-05	2.05E-05	1.58E-04
64742-47-8	Hydrotreated light petroleum distillate	1.5	1.00	2.50E-03	3.50E+01	6.85E-05	1.03E-04	2.94E-06
111-30-8	Glutaraldehyde	0.3	1.00	2.50E-03	1.40E-01	6.85E-05	2.05E-05	1.47E-04
78330-21-9	Alcohol, C11-14, ethoxylatedB	1.5	1.00	2.50E-03	1.75E+00	6.85E-05	1.03E-04	5.87E-05
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammo	1	1.00	2.50E-03	3.50E+00	6.85E-05	6.85E-05	1.96E-05
107-22-2	Glyoxal <1% (Ethanedial)	1.5	1.00	2.50E-03	4.66E-01	6.85E-05	1.03E-04	2.21E-04
5064-31-3	Nitritotriacetic acid, trisodium salt monohydrate	1	1.00	2.50E-03	3.50E-02	6.85E-05	6.85E-05	1.96E-03
497-19-8	Sodium Carbonate	0.30	1.00	2.50E-03	3.38E-01	6.85E-05	2.05E-05	6.07E-05
533-74-4	Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione	4	1.00	2.50E-03	1.75E-02	6.85E-05	2.74E-04	1.57E-02
50-01-1	Guanidine, hydrochloride (1:1)	7	1.00	2.50E-03	3.50E-01	6.85E-05	4.79E-04	1.37E-03
14808-60-7	Crystalline silica, quartz	10	1.00	2.50E-03	3.00E-03	6.85E-05	6.85E-04	2.28E-01
Total Threshold Risk (mixture)								0.2

Summary of Risk to Workers - Drilling Fluids Exposure fo Target Chemicals - Theoretical Data

Receptor/Exposure Pathway	Calculated HI
	100% Mass Return
<u>Use of Stimulation Fluid in Hydraulic Fracturing</u>	
<u>HYBRID Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.000029
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.0073
Inhalation of mist from the evaporation units	0.25
Total Risk	0.26

Appendix E

Chemical Risk Assessment - Tracers

Human Health Screening Assessment Chemical Tracers

Tracer Name	Concentration in Injected Fluid (mg/L)	Ecotoxicity	Toxicity	Persistence	Bioaccumulative	Tier 1 Screening Assessment	Tier 2 Assessment Worker Ingestion Risk	Tier 2 Assessment Worker Dermal Risk	Tier 2 Assessment Worker Aerosol Inhalation Risk	Hazard Quotient	Outcome of Tier 2 Worker Risk Assessment ¹
CFT (20 chemicals)	0.75	Algae EC50 = 33.1 mg/L Fish LC50 = 44.6 mg/L Daphnia EC50 > 100 mg/L Algae EC10 = 3.4 mg/L Fish NOEC 28 d = 120 mg/L Daphnia NOEC 21 d = 25 mg/L	Based on chronic: Low	Expected to be readily biodegradable	No based on calculated log Kow of 1.87	Tier 2	3.19E-06	1.01E-05	1.78E-05	3.11E-05	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
GFT (15 chemicals)	1.35	Fish 96h LC50 > 100 mg/L Invertebrates 48h EC50 > 0.1 mg/L Microorganism 3h EC50 > 100 mg/L Fish 96h NOEC = 1000 mg/L	Based on chronic: Low	Not readily biodegradable	Yes based on calculated log Kow of > 4.5	Tier 2	4.74E-06	1.04E-03	2.64E-05	1.08E-03	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
WFT (1 chemical)	200,000	LC50 fish (96 h) > 120 mg/L EC50 daphnia (48h) > 125 mg/L EC50 plants (48h) > 125 mg/L	Based on acute: Low	Not readily biodegradable	No based on log Kow of -10.7	Tier 2	2.34E-01	1.23E-02	NA. Not volatile	2.46E-01	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).
WFT (1 chemical)	200,000	Fish 96 h LC50 = 87 mg/L Daphnia 48 h EC50 = 182 mg/L Algae ErC50 > 100 mg/L	Based on acute: Low	Expected to be readily biodegradable	No based on log Kow of 0.07	Tier 2	7.02E-02	6.66E-12	NA. Not volatile	7.02E-02	Based on the calculated HQ the chemical is of low concern for workers (refer to individual toxicity profile and risk calculations for further detail).

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

CAS#	Chemical	<u>Oral/Dermal Exposures</u>				<u>Inhalation Exposures</u>				NOAEC or LOAEC (mg/m³)	NOAEL or LOAEL (mg/kg bw/d)	Reference	UF	Reference	
		Threshold Chronic TDI or RfD	Dermal Permeability	Reference	Inhalation Unit Risk	Non-Threshold Slope Factor	Threshold Chronic TC or RfC								
		(mg/kg/day)	(cm/hr)				(ug/m³)⁻¹	(mg/kg/day)⁻¹	(mg/m³)						
COPC in Hydraulic Fracturing Fluid Injected into Well															
	CFT	0.825	D	6.88E-03	EPI				2.8875	converted from RfD		825.0	OECD (2004)	1000	D
	GFT	1	D	4.79E-01	EPI				3.5	converted from RfD		1000	REACH	1000	D
	WFT	3	EFSA	1.14E-04	EPI				-	Not volatile		-	-	-	-
	WFT	10	JECFA	2.06E-13	EPI				-	Not volatile		-	-	-	-

Notes:

A - Read across data from Boric Acid

B - Read across data from Alcohol ethoxylates C6-C12

C - Read across data from Sodium Sulfite

References:

D - Derived (refer to individual Toxicity Profiles)

EFSA - European Food Safety Authority

EPI - USEPA Estimation Programs Interface (EPI) Suite

FSANZ - Food Standards Australia New Zealand

J- JECFA - Joint FAO/WHO Expert Committee on Food Additives

NICNAS - National Industrial Chemicals Notification and Assessment Scheme. Assessed at <https://www.nicnas.gov.au/>

NICNAS (2017) - Department of the Environment and Energy 2017 , National assessment of chemicals associatedwith coal seam gas extraction in Australia, prepared by the National Industrial ChemicalsNotification and Assessment Scheme

NTP - US Department of Health and Serices National Toxicology Program

OECD - Organisation for Economic Co-operation and Development Screening Information Data Set (SIDS)

REACH - ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - CFT

Chronic Exposures

Chronic Exposures					Exposure Calculations (RME)					
General Data/ Equations				Units	Ingestion of Flowback Water by Workers					
Exposure Parameters										
Exposure Frequency (EF)				days/year	20	Assume work 5 days per week for 1 month during the fraccing period				
Exposure Duration (ED)				years	0.083	Maximum duration of the frac. Works will be complete in one month.				
Body Weight (BW)				kg	78	Average male and female adults as per enHealth 2012				
Averaging Time - NonThreshold (ATc)				days	25550	USEPA 1989 and CSMS 1996				
Averaging Time - Threshold (ATn)				days	30.42	USEPA 1989 and CSMS 1996				
Ingestion Rate (IRw)				L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fraccing.				
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	4.2E-09 3.5E-06	NonThreshold Threshold				
<i>Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water 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)
	CFT		8.3E-01		8.3E-01	0.75	3.1E-09	2.6E-06	--	3.2E-06
	Total Risk (mixture)								--	3.19E-06

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - CFT

Chronic Exposures

Chronic Exposures			Exposure Calculations (RME)							
General Data/ Equations		Units	Dermal Contact with Flow Back Water by Workers							
Exposure Parameters										
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fraccing period							
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.							
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012							
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996							
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996							
Surface Area (SAw)	cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on							
Exposure Time (ET)	hr/day	1	Australian work sites; forearms conservatively included							
Conversion Factor (CF)	L/cm ³	1.E-03	Assume contact with flow back water for 1 hours per day							
Intake Factor = <u>SAw*ET*CF*EF*ED</u> BW*AT		L-hr/(cm-kg-day)	1.9E-06	NonThreshold						
			1.6E-03	Threshold						
Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)										
NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor										
Hazard Quotients = (Daily Intake from Water 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)	Dermal Permeability	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
	CFT	8.3E-01		8.3E-01	6.9E-3	0.75	9.9E-09	8.3E-06	--	1.0E-05
	Total Risk (mixture)									1.01E-05

Note:

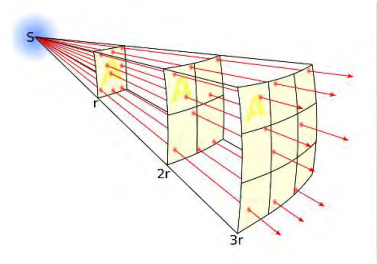
This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Aerosol Exposure - CFT

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state
An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol} \left(\frac{L}{m^3} \right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol \left(\frac{L}{hr} \right) \times Aerosol_{driftable} (\%)}{BoxVR \left(\frac{m^3}{hr} \right)} \right)}{BoxDistance^2 (m)}$$



Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a 'spray box' of 3 m long.
Spray box width	m	3	Assume a 'spray box' of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the 'spray box'. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the 'spray box' and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the 'spray box'. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a 'spray box' dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
	CFT	0.75	270	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - CFT

Chronic Exposures

General Data/ Equations		Exposure Calculations (RME)	
Exposure Parameters		Inhalation of Mist by Workers	
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.0	USEPA 1989 and CSMS 1996
$ITF_{inh, w, shwr} = \frac{EmF \times AAF \times ET_{iw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)
Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

Threshold Intake and Risk Calculations								
CAS	Chemical	Groundwater Concentration	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Adult Exposure Factor (threshold)	Adult Exposure Adjusted Air Concentration (threshold)	Hazard Index (Adult)
		mg/L	(unitless)	(L/m³)	(mg/m³)	(L/m³)	(mg/m³)	(unitless)
	CFT	0.8	1.00	2.50E-03	2.89E+00	6.85E-05	5.14E-05	1.78E-05
Total Threshold Risk (mixture)								1.78E-05

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - GFT

Chronic Exposures

Chronic Exposures					Exposure Calculations (RME)				
General Data/ Equations				Units	Ingestion of Flowback Water by Workers				
Exposure Parameters									
Exposure Frequency (EF)				days/year	20	Assume work 5 days per week for 1 month during the fraccing period			
Exposure Duration (ED)				years	0.083	Maximum duration of the frac. Works will be complete in one month.			
Body Weight (BW)				kg	78	Average male and female adults as per enHealth 2012			
Averaging Time - NonThreshold (ATc)				days	25550	USEPA 1989 and CSMS 1996			
Averaging Time - Threshold (ATn)				days	30.42	USEPA 1989 and CSMS 1996			
Ingestion Rate (IRw)				L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fraccing.			
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	4.2E-09 3.5E-06	NonThreshold Threshold			
<i>Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water 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)
GFT		1.0E+00		1.0E+00	1.35	5.6E-09	4.7E-06	--	4.7E-06
	Total Risk (mixture)						--	4.74E-06	

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - GFT

Chronic Exposures

Chronic Exposures			Exposure Calculations (RME)							
General Data/ Equations		Units	Dermal Contact with Flow Back Water by Workers							
Exposure Parameters										
Exposure Frequency (EF)	days/year	20	Assume work 5 days per week for 1 month during the fracing period							
Exposure Duration (ED)	years	0.083	Maximum duration of the frac. Works will be complete in one month.							
Body Weight (BW)	kg	78	Average male and female adults as per enHealth 2012							
Averaging Time - NonThreshold (ATc)	days	25550	USEPA 1989 and CSMS 1996							
Averaging Time - Threshold (ATn)	days	30.42	USEPA 1989 and CSMS 1996							
Surface Area (SAw)	cm ²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on							
Exposure Time (ET)	hr/day	1	Australian work sites; forearms conservatively included							
Conversion Factor (CF)	L/cm ³	1.E-03	Assume contact with flow back water for 1 hours per day							
Intake Factor = <u>SAw*ET*CF*EF*ED</u>			1.9E-06	NonThreshold						
BW*AT		L-hr/(cm-kg-day)	1.6E-03	Threshold						
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)</i>										
<i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i>										
<i>Hazard Quotients = (Daily Intake from Water 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)	Dermal Permeability	in Water	NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
	(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
	GFT	1.0E+00		1.0E+00	4.8E-1	1.35	1.2E-06	1.0E-03	--	1.04E-03
	Total Risk (mixture)									1.0E-03

Note:

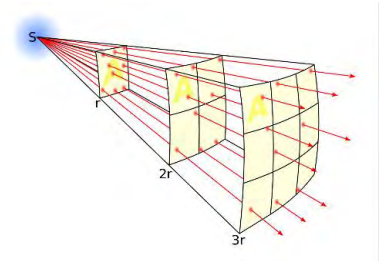
This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
 - Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Aerosol Exposure - GFT

The concentration of COPC in aerosol spray was estimated by calculating the concentration for driftable droplets using a mixed box model in which steady state
An emission factor for driftable aerosol was estimated using the algorithm presented below.

Emission Factor for Driftable Aerosol Algorithm

$$Emission\ Factor_{driftable\ aerosol} \left(\frac{L}{m^3} \right) = \frac{Box\ Centre^2(m) \times \left(\frac{Spray\ Vol \left(\frac{L}{hr} \right) \times Aerosol_{driftable} (\%)}{BoxVR \left(\frac{m^3}{hr} \right)} \right)}{BoxDistance^2 (m)}$$



Aerosol Exposure Modelling Notes:

- 1) The inhalation of chemicals in mist/aerosol resultant from irrigation activities is dependent upon the concentration in water, the amount of water used per unit time, how close a person stands to the spray generation, how long they are in a position of exposure and the extent of spray drift (determined by the size of the water droplets and speed/direction of the wind). These equations are applicable for non-volatile contaminants that are inhaled.
- 2) These equations calculate the concentration for driftable droplets using a simple well mixed box model in which steady state air concentrations are calculated. The 'Inverse square law' is then applied to approximate the air concentration at a distance from the virtual air box. This law assumes the further away a receptor is from the spray source, the density of the droplets will decrease. The density of the spray droplets is inversely proportional to the square of the distance from the source.

Parameter	Units	Value	Description
Spray box length	m	3	Assume a 'spray box' of 3 m long.
Spray box width	m	3	Assume a 'spray box' of 3 m wide.
Box Centre	m	1.5	Distance to centre of box is 1.5 m.
BoxDistance	m	2	Distance the irrigation worker is from the 'spray box'. Assumed a distance of 2 m.
Aerosol _{driftable}	unitless	0.2	Proportion of aerosol spray that drifts outside the 'spray box' and available for exposure. Assumed 0.2, based on a droplet size of 400 – 500 µm that falls approximately 0.3 m in less than 10 seconds, with a lateral drift of approximately 3.5 m in a 5 km/hr wind (i.e. a light breeze) (Grisso et al. 2013).
Spray Volume	L/hr	1800.0	1800 L/min, irrigation value adopted from NZ MtE (2011) Appendix 5A.
Wind speed	m/hr	9000	Based on windspeed of 2.5 m/sec
BoxVR	m ³ /hr	81000.0	Ventilation rate of spray in the 'spray box'. Assumed to be 81,000 m3/hr based on a wind speed of 9000 m/hr, and a 'spray box' dimension of 3 x 3 m.

CAS	Chemical	Concentration in Water	Generation rate of chemical in volume	Driftable Aerosol Emission Factor
		mg/L	mg/hr	L/m ³
	GFT	1.35	486	2.500000E-03

Exposure to Chemicals via Inhalation of Mist from the Evaporation Units - GFT

Chronic Exposures

General Data/ Equations		Exposure Calculations (RME)	
Exposure Parameters		Inhalation of Mist by Workers	
Exposure Frequency (EF)	days/year	240	Exposure for 5 days per week minus 4 weeks holidays
Exposure Duration (ED)	years	1	Maximum duration that the flowback tank will be on-site
Exposure Time (ET)	hr/day	1	Professional judgement for irrigation exposure. Assume worker to be near tank for 1 hours every working day.
Driftable aerosol emission factor (EMF)	L/m3	2.50E-03	Calculated
Aerosol Inhalation Bioavailability (AAF)	unitless	1.0	Assume 100% bioavailability
Averaging Time - Threshold (AT)	years	1.0	USEPA 1989 and CSMS 1996
$IT_{Inh, w, shwr} = \frac{EmF \times AAF \times ET_{iw} \times EF \times ED}{365 \frac{days}{year} \times 24 \frac{hours}{day} \times AT}$			

Daily Intake = Concentration in Water x Intake Factor (ref: USEPA 1989)
Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)

Threshold Intake and Risk Calculations								
CAS	Chemical	Groundwater Concentration	Aerosol Inhalation Bioavailability	Driftable Aerosol Emission Factor	RfC (Background Corrected)	Adult Exposure Factor (threshold)	Adult Exposure Adjusted Air Concentration (threshold)	Hazard Index (Adult)
		mg/L	(unitless)	(L/m³)	(mg/m³)	(L/m³)	(mg/m³)	(unitless)
64742-47-8	GFT	1.4	1.00	2.50E-03	3.50E+00	6.85E-05	9.25E-05	2.64E-05
Total Threshold Risk (mixture)								2.64E-05

Exposure to Chemicals via Incidental Ingestion of Flowback fluid - WFT

Chronic Exposures

Chronic Exposures					Exposure Calculations (RME)						
General Data/ Equations					Units	Ingestion of Flowback Water by Workers					
Exposure Parameters											
Exposure Frequency (EF)					days/year	20	Assume work 5 days per week for 1 month during the fraccing period				
Exposure Duration (ED)					years	0.083	Maximum duration of the frac. Works will be complete in one month.				
Body Weight (BW)					kg	78	Average male and female adults as per enHealth 2012				
Averaging Time - NonThreshold (ATc)					days	25550	USEPA 1989 and CSMS 1996				
Averaging Time - Threshold (ATn)					days	30.42	USEPA 1989 and CSMS 1996				
Ingestion Rate (IRw)					L/day or L/hr	0.005	Assume Incidental ingestion of 5 ml (1 tsp) of water per day during fraccing.				
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	4.2E-09	NonThreshold				
						3.5E-06	Threshold				
<i>Daily Intake from Water = Concentration in Water x Intake Factor (ref: USEPA 1989)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water 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)	
	WFT		3.0E+00		3.0E+00	200000	8.4E-04	7.0E-01	--	2.3E-01	
	WFT		1.0E+01		1.0E+01	200000	8.4E-04	7.0E-01	--	7.0E-02	
	Total Risk (mixture)							--	3.04E-01		

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:
- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Dermal Exposure to Chemicals via Contact with Flow Back Water - WFT

Chronic Exposures

Chronic Exposures			Exposure Calculations (RME)								
General Data/ Equations			Units	Dermal Contact with Flow Back Water by Workers							
Exposure Parameters											
Exposure Frequency (EF)		days/year	20	Assume work 5 days per week for 1 month during the fracing period							
Exposure Duration (ED)		years	0.083	Maximum duration of the frac. Works will be complete in one month.							
Body Weight (BW)		kg	78	Average male and female adults as per enHealth 2012							
Averaging Time - NonThreshold (ATc)		days	25550	USEPA 1989 and CSMS 1996							
Averaging Time - Threshold (ATn)		days	30.42	USEPA 1989 and CSMS 1996							
Surface Area (SAw)		cm²	2300	Hands and forearms exposed (enHealth 2012) Occupational HSE would require long pants and closed shoes on							
Exposure Time (ET)		hr/day	1	Australian work sites; forearms conservatively included							
Conversion Factor (CF)		L/cm³	1.E-03	Assume contact with flow back water for 1 hours per day							
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)	1.9E-06	NonThreshold						
				1.6E-03	Threshold						
<i>Daily Intake from Water = Concentration in Water x Dermal Permeability x Intake Factor (ref: USEPA 1989, 2004)</i> <i>NonThreshold Risk = Daily Intake from Water for NonThreshold Effects x Slope Factor</i> <i>Hazard Quotients = (Daily Intake from Water for Threshold Effects/ADI)</i>											
Chemical		Non-Threshold Slope Factor	Chronic Threshold TDI	Toxicity Data Background Intake (% chronic TDI)	Chronic TDI Allowable for Assessment (TDI-Background)	Dermal Permeability	Concentration in Water	Daily Intake		Calculated Risk	
								NonThreshold	Threshold	NonThreshold Risk	Chronic Hazard Quotient
		(mg/kg-day) ⁻¹	(mg/kg/day)		(mg/kg/day)	(cm/hr)	(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
	WFT		3.0E+00		3.0E+00	1.1E-4	200000.00	4.4E-05	3.7E-02	--	1.2E-02
	WFT		1.0E+01		1.0E+01	2.1E-13	200000.00	7.9E-14	6.7E-11	--	6.7E-12
Total Risk (mixture)											1.23E-02

Note:

This scenario is deemed protective of the following scenarios due to the less frequent and short duration of exposures:

- Worker exposure during a spill (i.e.a couple breaks on a tank and releases product onto the worker) or leak scenarios

Summary of Risk to Workers - Chemical Tracers Exposure to Target Chemicals - Theoretical Data

Receptor/Exposure Pathway	Calculated HI
	100% Mass Return
<u>Use of Chemical Tracers in Hydraulic Fracturing</u>	
<u>CFT Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.0000032
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.000010
Inhalation of mist from the evaporation units	0.000018
Total Risk	0.00003
<u>GFT Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.0000047
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.0010
Inhalation of mist from the evaporation units	0.000026
Total Risk	0.001
<u>WFT Recipe</u>	
Workers	
Ingestion of Chemicals via Incidental Contact with Flowback Water	0.30
Dermal Exposure to Chemicals via Incidental Contact with Flowback Water	0.012
Inhalation of mist from the evaporation units	-
Total Risk	0.3

Appendix F

Toxicological Profiles for
SW, HYBRID and HVFR
Recipes

Toxicity Summary - 2-hydroxy-N,N,N-trimethylethanaminium (Choline Chloride)

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	67-48-1
Molecular formula	C ₅ H ₁₄ NOCl
Molecular weight	139.63 g/mole
Solubility in water	Very soluble in water and alcohol
Melting point	247°C
Boiling point	Decomposition upon heating
Vapour pressure	6.57 x 10 ⁻⁸ Pa at 25°C
Henry's law constant	2.06*10E-11 Pa*m ³ /mole at 25°C
Explosive potential	Not explosive
Flammability potential	Combustible. Gives off irritating or toxic fumes (or gases) in a fire.
Colour/Form	white crystalline solid
Overview	Choline chloride is a quaternary amine salt, it dissociates in water into the corresponding positively charged quaternary hydroxyl alkylammonium ion and the negatively charged chloride ion. Choline chloride has neither explosive nor oxidizing properties due to its molecular structure. Choline is a dietary component and found in foods as free choline and as esterified forms such as phosphocholine, glycerophosphocholine, sphingomyeline, and phosphatidylcholine. It functions as a precursor for acetylcholine, phospholipids, and the methyl donor betaine and is important for the structural integrity of cell membranes, methyl metabolism, cholinergic neurotransmission, transmembrane signalling, and lipid and cholesterol transport and metabolism. Evidence from animal studies and from human exposure indicates that choline chloride has low toxicity, is not mutagenic and has no developmental toxicity. This is not unexpected in view of its presence in the diet and its production in metabolic processes in the body; it fulfils key roles in nerve transmission, cell membrane integrity, and lipid metabolism. Only limited animal data are available on effects on fertility, but the normal exposure of humans to appreciable amounts of choline chloride both from the diet and formed from normal metabolic processes, would argue against it having any significant adverse effects on fertility. This is supported by the fact that it has been widely used as an animal feed additive for decades with no apparent adverse effects being noted on fertility. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health.
Environmental Fate ^{1,3,4}	
Soil/Water/Air	Distribution modelling using Mackay Level I indicates water (100 %) to be the main target compartment. The amount in the other compartments is with < 0.0001 % negligible. Choline chloride is readily biodegradable according to OECD-criteria (MITI-I Test; BOD measurements) reaching 93 % degradation within 14 days. Due to the chemical structure hydrolysis can be excluded. In the atmosphere choline chloride will be rapidly degraded according to a half-life time (t_{1/2}) of about 6.9 hours for hydroxyl-radicals based on a 12 hours day. Due to the measured and calculated logK_{ow} of -3.77 and -5.16 both at 25°C, respectively, and a calculated logK_{oc} of 0.37 a bio- or geoaccumulation is not to be expected.

Human Health Toxicity Summary ^{1,3,4,5}	
Chronic Repeated Dose Toxicity	A 72-week feeding study was conducted to investigate the impact of choline chloride on the liver tumour promoting activity of phenobarbital and DDT in diethylnitroamineinitiated Fischer 344 rats (Shivapurkar <i>et al.</i> , 1986). Animals received approximately 500 mg/kg-day choline chloride. Following the end of the exposure period, the animals were kept on the same untreated diet as the control group until study termination at week 103. Histopathology was limited to the liver and organs that developed gross abnormalities. There were no significant differences between treated and control animals on survival rates, body weights, and relative liver weights. Neither was there any increased number of neoplastic liver nodules, hepatocellular carcinomas, lung tumours, leukaemia nor other tumours between treated and control animals. The NOAEL for choline chloride in this study is 500 mg/kg/day. In humans, oral administration of 10,000 mg/day choline chloride in a pilot study treating a small number of patients with Alzheimer's disease, resulted in a slight hypotensive effect (Boyd <i>et al.</i> , 1977). This dose was regarded as a LOAEL by the Standing Committee on the Scientific Evaluation of Dietary Reference Intake (2000).
Carcinogenicity	No studies were located.
Mutagenicity/ Genotoxicity	Choline chloride was not mutagenic to bacteria in reverse mutation assays (Haworth <i>et al.</i> , 1984; JETOC, 1997; Litton Bionetics, 1977). A small, but statistically significant, and dose-related increase in sister chromatid exchanges (SCEs) in Chinese Hamster Ovary (CHO) cells was reported at 50 and 500 µg/ml choline chloride in the absence of S9 only (Bloom <i>et al.</i> , 1982). No higher concentrations were examined. These results could not be confirmed in another study using CHO cells at concentrations of choline chloride up to 5,000 µg/ml. (Galloway <i>et al.</i> , 1985). In a gene conversion assay with <i>Saccharomyces cerevisiae</i> strain D4, choline chloride was negative in the presence and absence of metabolic activation (Litton Bionetics, 1977). No <i>in vivo</i> genotoxicity studies were available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Pregnant female mice were given in their feed 1,250 to 20,000 mg/kg choline chloride during gestational days 1 to 18 (BASF AG, 1966). Maternal body weight gain was reduced in all treated groups except for the 1,250 mg/kg group. Determination of maternal weight gain of dams with embryonic/foetal absorptions showed that there was no All foetuses were resorbed in the 20,000 mg/kg group. Embryonic/foetal lethality of 35% and 69% were seen in the 4,160 and 10,800 mg/kg groups, respectively. No resorptions occurred in the 1,250 mg/kg group. Developmental toxicity was seen in all but the 1,250 mg/kg group. No statistically significant increases in malformations were observed in any dose group. The NOAELs for maternal and developmental toxicity is 1,250 mg/kg/day.
Acute Toxicity	The oral LD50 in rats was reported to be between 3,150 and 5,000 mg/kg (BASF AG, 1963a, 1969).
Irritation	Application of a 70% aqueous solution to the skin of rabbits for 20 hours under occlusive conditions resulted in only minor skin irritation (BASF AG, 1963b). Slight eye irritation was seen in the eyes of rabbits after instillation of a 70% aqueous solution of choline chloride; no effects were seen one day after exposure (BASF AG, 1963c).
Sensitisation	No data are available in animals. In a Human Repeated Insult Patch Test, there was no evidence of dermal sensitization in two hundred subjects given 0.5% (w/v) aqueous solution of choline chloride during the induction phase and 0.2% (w/v) aqueous solution during the challenge phase (Colgate-Palmolive, 2003).
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 Standing Committee on the Scientific Evaluation of Dietary Reference Intakes selected hypotension as the critical effect from the study by Boyd <i>et al.</i> (1977) when deriving a Tolerable Upper Intake Level. Boyd <i>et al.</i> (1977) reported a LOAEL of 10,000 mg/day choline chloride (7,500 mg/day choline). An uncertainty factor of 2 was chosen because of the limited data regarding hypotension and the inter-individual variation in response to cholinergic effects. Thus, the value for the Tolerable Upper Intake Value for repeated exposure of adults to choline is 3,500 mg/day choline. The oral RfD for choline chloride is derived by using the LOAEL of 10,000 mg/day from the Boyd <i>et al.</i> (1977) study, which is divided by an uncertainty factor of 2, to obtain a value of 5,000 mg/day or 71 mg/kg/day for a 70 kg person. Oral RfD = 71 mg/kg/day Drinking water guideline value = 248 ppm
Ecological Toxicity ⁴	
Aquatic Toxicity	The 96-hour fish LC50 value is >100 mg/L (nominal and measured) in <i>Oryzias latipes</i> (MOE Japan, 1999a), and the 48-hour in vertebrate EC50 is 349 mg/L (nominal and measured) in <i>Daphnia magna</i> (MOE Japan, 1999b). The 72-hour EC50 to <i>Pseudokirchneriella subcapitata</i> is >1,000 mg/L (nominal and measured) based on growth rate; the 72-hour NOEC is 32 mg/L (MOE Japan, 1999c). In a 21-day <i>Daphnia magna</i> reproduction test, the nominal and measured NOEC was reported to be 30.2 mg/L (MOE Japan, 1999d).
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for three trophic levels. Acute E(L)C50 values are available for fish (>100 mg/L), invertebrates (349 mg/L), and algae (>1,000 mg/L). Results from chronic studies are available for invertebrates (21-day NOEC = 30.2 mg/L) and algae (72-hour NOEC = 32 mg/L). On the basis that the data consists of chronic studies on two trophic levels, an assessment factor of 10 has been applied to the lowest reported NOEC of 30 mg/L for Daphnia. The PNECaquatic is 3.02 mg/L.
Current Regulatory Controls	
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?	Choline chloride 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 -3.77 and a calculated BCF of 0.59, choline chloride does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	The chronic toxicity data on choline chloride show NOECs of >0.01 mg/L. Thus, choline chloride does not meet the screening criteria for toxicity.
Overall conclusion	Not a PBT substance (based on screening data).
Revised	December 2018

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Toxicity Summary - Acetic acid

Chemical and Physical Properties ^{1,6}	
CAS number	64-19-7
Molecular formula	C ₂ H ₄ O ₂
Product name	Acetic Acid 60%
Molecular weight	60 g/mol
Solubility in water	1000 g/L at 25°C
pH	1.38
Melting point	16.6 °C
Boiling point	117.9 °C
Vapour pressure	1.5 kPa at 20°C
Henry's law constant	0.0101 Pa m ³ /mol
Explosive potential	Above 39°C explosive vapour mixtures may be formed. Risk of fire and explosion on contact with strong oxidants.
Flammability potential	Flammable. Flashpoint = 39°C
Colour/Form	Clear colourless liquid with a pungent vinegar smell
Overview	Acetic acid is naturally occurring as the acid in apple cider vinegar and other fruit derived products. Acetic acid is recognised by Food Standards Australia New Zealand (FSANZ) and the US Food and Drug Administration (FDA) as safe as a food additives (e.g. flavouring agent, preservative).
Environmental Fate ¹	
Soil/Water/Air	When released into the environment, acetic acid is not expected to adsorb onto suspended solids or sediments. Acetic acid dissociates in aqueous media to H ⁺ and the acetate anion (CH ₃ CO ₂ ⁻). The compound is expected to be present in the dissociated form, where volatilisation is not an important process. Based on the range of expected Koc values, acetic acid is expected to have a very high to moderate mobility in soil. In air acetic acid will exist solely in the vapour phase where it is degraded with photochemically produced hydroxyl radicals with a half-life for this reaction in air of approximately 22 days. Acetic acid is readily biodegradable, and biodegrades rapidly under aerobic and anaerobic conditions. Based on an estimated bioconcentration factor of 3.2, the potential for bioaccumulation is low.

Human Health Toxicity Summary^{1,2,5,6}

Chronic Repeated Dose Toxicity

In a six-month repeat dose oral toxicity study (Lamb and Evard 1919), pigs were initially fed acetic acid at 155 mg/kg bw/day with the dose was raised every 10 to 30 days until a final dose of 380 to 450 mg/kg bw/day was reached after 60 days. There was no mortality and no effects on body weight or acid-base balance noted in this study (REACH 2013). A NOAEL was not established in this study. Repeated intra-gastric administration of the chemical at 3% concentration in animals (unspecified) for six months resulted in chronic inflammation of the oesophageal mucosa (HSDB 2013). Similarly, intra-gastric administration to rats of 3 mL of a 10% solution for 90 days produced a drop in haemoglobin concentration and erythrocyte count (HSDB 2013). In another similar study, pigs were fed daily diets containing the chemical at 0, 240, 720, 960 and 1200 mg/kg bw/day for successive 30-day periods for a total of 150 days (HSDB 2013). There were no significant differences in growth rate, weight gain, early morning urinary ammonia and terminal blood pH between controls and test groups. A NOEL or NOAEL was not indicated by the authors. Based on the available information and taking a conservative approach, the NOAEL in the study is considered to be 1200 mg/kg bw/day, the highest tested dose with no adverse effects. This NOAEL will be used for human health risk assessment.

In the only available dermal repeat dose toxicity study (Slaga et al. 1975), acetic acid was applied dermally to mice at doses of 1 to 40 mg/animal, one to three times/week for 32 weeks. Single dermal applications of acetic acid at doses of up to 40 mg/animal did not induce mortality. However, more than one application per week of 10 mg acetic acid or more caused excessive mortality. 33% of mice died when 10 mg acetic acid/animal was applied dermally three times/week and approximately 50% of mice died when 20 mg was applied twice a week. No biochemical or histopathological effects were reported. A LOAEL of 10 mg/animal was suggested by the authors, however it was expressed in terms of 'mg/animal' rather than 'mg/kg bw/day' and it therefore cannot be adopted. Dermal NOAEL or LOAEL for acetic acid are not available.

Repeated oral, inhalation and dermal exposure of humans to pure acetic acid has been reported to have effects on the gastrointestinal tract and to cause digestive disorders including heartburn and constipation, chronic inflammation of the respiratory tract, pharyngitis, catarrhal bronchitis, darkening of skin, skin dermatitis and erosion of the exposed front teeth enamel. In addition, skin on the palms of hands can become dry, cracked and hyperkeratotic. These observed effects were not associated with any systemic findings, suggesting the effects observed could be due to its corrosive action (EC 2012; HSDB 2013).

Carcinogenicity

In a carcinogenicity study (Slaga et al. 1975), acetic acid was tested as the promoter for tumour development in mice. Acetic acid was applied dermally to mice initiated with a carcinogenic agent, dimethylbenz(a)anthracene (DMBA) at doses of 1 to 40 mg/animal, one to three times/week for 32 weeks. Control animals received acetic acid dermally once per week. No further details were provided about the exposure duration. Single dermal application of acetic acid at doses of up to 40 mg/animal did not induce mortality. However, more than one application per week of 10 to 40 mg acetic acid caused excessive mortality. Thirty three per cent of mice died when 10 mg acetic acid/animal was applied dermally three times/week and approximately 50% of mice died when 20 mg was applied twice a week. No biochemical or histopathological effects were reported. Acetic acid did not produce any carcinogenic effects in mice (REACH 2013).

In another study, oral administration of the chemical as a 3% solution in rats, three times/week for eight months did not induce tumours in the oesophagus and fore-stomach, although epithelial hyperplasia was observed. When dosed in combination with the known carcinogen, N-nitrososarcosine ethyl ester (positive control), there was an increase in oesophageal/stomach tumour formation (REACH 2013).

Based on the limited available data, acetic acid is not likely to be a carcinogen.

Mutagenicity/ Genotoxicity	Acetic acid was not mutagenic in bacterial reverse mutation assays using <i>Salmonella typhimurium</i> strains TA100, TA1535, TA97 and TA98 with and without metabolic activation (Ishidate et al. 1984). Acetic acid was negative in the chromosome aberration assay using Chinese hamster lung fibroblasts at concentrations of up to 1 mg/mL with or without metabolic activation. In one study using Chinese hamster ovary KI cells, acetic acid induced chromosomal aberrations at the initial pH of 6.0 or below (about 10 to 14 mM of acid) both with and without S9 mix (REACH 2013). However, when the culture medium was neutralised to pH 7.2 with sodium hydroxide, no clastogenic activity was observed. Moreover, pH lower than 6.0 (pH 5.7 or below) were also found to be cytotoxic. Chromosomal aberrations induced at these high concentrations were therefore considered to be artefacts due to acidification of the culture medium. Acetic acid was concluded not to be clastogenic when tested in cultured Chinese hamster K1 cells (REACH 2013; HSDB 2013). It was concluded that acetic acid is not mutagenic.
Reproductive Toxicity	No data available
Developmental Toxicity/Teratogenicity	In two developmental toxicity studies conducted according to the EU Method B.31 (prenatal developmental toxicity study), acetic acid was administered by gavage to pregnant female Wistar rats and CD-1 mice at 16, 74.3, 345, and 1600 mg/kg bw/day during gestation days 6 to 15 (10 consecutive doses) (REACH 2013). In a similar study, the chemical was administered by gavage to female Dutch rabbits at 16, 74.3, 345, and 1600 mg/kg bw/day during gestation days 6 to 18 (13 consecutive doses) (REACH 2013). There were no clearly discernible effects on implantation, maternal survival or foetal survival in any species at any of the doses. The number of abnormalities seen in either soft or skeletal tissues of the test groups did not differ significantly from those occurring spontaneously in the controls. No NOAEL could be established for maternal toxicity or foetal developmental effects. Based on the available data, the chemical does not show developmental toxicity.
Acute Toxicity	Acetic acid was of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) observed in two rat studies is greater than 2000 mg/kg bw (REACH2013). In one study, groups of unfasted rats were fed 2239, 2512, 2859, 3100, 3500, 4000, 4467 mg/kg bw sodium acetate and observed for six days (REACH 2013). The acute oral median lethal dose (LD50) of the sodium salt of acetic acid was found to be 3310 mg/kg bw for rats. Acetic acid was of moderate acute toxicity in rabbits following dermal exposure. The LD50 in rabbits was 1060 mg/kg bw (HSDB 2013). Details regarding the concentration of the administered test substance were not provided. The moderate acute dermal toxicity is believed to be due to its local corrosive effects rather than any systemic toxicity. Acetic acid was of low acute toxicity in animal tests following inhalation exposure. In an acute inhalation study, mice were exposed to various concentrations of acetic acid (experimental details and concentration range not provided) (HSDB 2013). Clinical signs of respiratory irritation were evident at concentrations of 2.46 mg/L and higher. Animals exposed to concentrations higher than 11.07 mg/L died within 27 hours of exposure. Surviving mice recovered quickly and showed no abnormalities three days after exposure. The median lethal concentration (LC50) was determined by the Weil's method and was estimated to be 13.8 mg/L in the mouse. Severe health effects have been reported in humans following accidental exposure to acetic acid by different routes, mainly due to the local corrosive effects of the chemical leading to systemic effects (HSDB 2013).

Irritation	Pure acetic acid is corrosive to skin. In animal studies, severe skin burns were reported in guinea pigs following application to intact or abraded skin of patches of 80% solution of the chemical, moderate to severe burns at 50 to 80% solution, mild injury at 50% solution, and no effect at 10% solution (HSDB 2013). In a study with rabbits, the chemical was considered to be slightly irritating at concentrations of 3.3% and 10% (REACH 2013). In another study with rabbits, a concentration of 2.5% of the chemical was not irritating while concentrations of 10 to 25% caused moderate to severe erythema, slight to severe oedema, skin lesions over the application site and eschar formation (REACH 2013). A 10% solution was therefore considered a skin irritant. As part of a study to select the optimum testing conditions for predicting hazard to the human eye, 3% and 10% aqueous acetic acid were tested in rabbit eyes (REACH 2013). Materials were applied directly to the central corneal surface. Irritation was followed for up to 21 days and scored according to the Draize scale. The 3% acetic acid gave moderate irritation and 10% acetic acid was severely irritating or corrosive. In other studies, instillation of 0.5 mL of a 1% acetic acid solution in the eyes of rabbits caused a severe burn (Smyth et al. 1951). Solutions of 5% induced injury in eyes of rabbits which healed by 14 days, while a 10% solution resulted in severe permanent damage (Henschler 1973). Based on the results of the studies pure acetic acid is considered to be corrosive to eyes. In an acute inhalation study in mice, clinical signs of respiratory irritation were evident at concentrations of 2.46 mg/L and higher (see Section A28.5.2.3). Acetic acid vapours were reported to cause damage to nose, throat and lungs in humans (SCOEL 2012). Acetic acid is considered to be a respiratory tract irritant. Chemical burns and eye and nasal irritation have been reported in humans following exposure
Sensitisation	No experimental data were available, however the US National Institute of Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards mentions skin sensitisation as one of the symptoms of acetic acid exposure (NIOSH 2010). A 1994 report (Kivity et al. 1994) describes a late asthmatic response to inhaled glacial acetic acid by an asthma patient. Based on reports of patients with bronchial asthma reacting to acetic acid challenge, it is believed that acetic acid may cause allergic reactions in humans (HSDB 2013). Some researchers consider acetic acid capable of causing a syndrome known as 'reactive airways dysfunction', which resembles bronchial asthma. Symptoms include dyspnoea, wheezing, and cough.
Health Effects Summary	Acetic acid has low acute oral and inhalation toxicity but moderate dermal toxicity. LD50 for oral, dermal and inhalation routes were >3100 mg/kg bw, 1060 mg/kg bw and 13.8 mg/L, respectively in laboratory animals. It is corrosive to skin, eyes and respiratory tract. Acetic acid has low repeat dose toxicity by oral and dermal routes. Information on toxicity by the inhalation route is not available. It is not genotoxic or carcinogenic and does not have any developmental effects in animals. Information on effects on fertility is not available. The critical health effect of acetic acid for risk characterisation is its corrosivity.
Key Study/Critical Effect for Screening Criteria	A NOEL or NOAEL was not established in any of the repeat dose studies. Based on the available information and taking a conservative approach, the highest tested dose with no adverse effects in the repeat dose oral study (1200 mg/kg bw/day) was taken as the NOAEL for human health risk assessment.
Ecological Toxicity ²	
Aquatic Toxicity	Acute endpoints: Fish = 75 mg/L (measured), Daphnia EC50 = 32 mg/L (Dept. Env. (2013a) in LMC, 2012 Chronic endpoints: Daphnia = 150 mg/L (measured)
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for Daphnia, an assessment factor of 10 has been applied to the lowest reported effect concentration of 150 mg/L. The PNECaquatic is determined to be 15 mg/L.

Current Regulatory Controls	
Australian Hazard Classification	Acetic acid is classified as hazardous, with the following risk phrase for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013): C; R35 (Corrosive, causes severe burns). Mixtures containing the chemical are classified as hazardous with the following risk phrases based on the concentration (Conc) of the chemical in the mixtures: Conc $\geq$90%: C; R35 (Corrosive, causes severe burns) $\geq$25% Conc <90%: C; R34 (Corrosive, causes burns) $\geq$10% Conc <25%: Xi; R36/38 (Irritant, Irritating to eyes and skin).
Australian Occupational Exposure Standards	The chemical has an exposure standard of 25 mg/m ³ (10 ppm) Time Weighted Average (TWA) and 37 mg/m ³ (15 ppm) Short-Term Exposure Limit (STEL) (Safe Work Australia 2013).
International Occupational Exposure Standards	The following exposure standards are identified in Galleria Chemica (2013). Occupational Exposure limit (TWA): 10 to 25 mg/m³ [China, Canada, Denmark, Germany, Ireland, South Africa, Spain, Sweden, Switzerland, and the US]. An exposure limit (STEL): 15 to 50 mg/m³ [China, Canada, France, Ireland, Singapore, South Africa, Spain, Sweden, Switzerland, and the US].
Australian Food Standards	Acetic acid is allotted the following International Numbering System of food additives number: INS 260 (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	No. The acetate ion of acetic acid is readily biodegradable and thus it does not meet the screening criteria for persistence.
B/vB criteria fulfilled?	The log Kow for acetic acid is reported to be -0.136. Acetate is also found in the body and is metabolized as part of the body's biochemical pathways. Thus, acetic acid (specifically, the acetate ion) does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The NOECs from the chronic aquatic toxicity data on acetic acid are >1 mg/L, hence does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

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Toxicity Summary - Acrylamide polymers: Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer and Polymer of 2-acrylamido-2-ethylpropanesulfonic acid sodium salt and methyl acrylate

Chemical and Physical Properties ^{2, 3, 4}	
CAS number	38193-60-1, 136793-29-8, 9003-06-9, 25987-30-8
Molecular formula	38193-60-1: (C ₇ H ₁₃ NO ₄ S.C ₃ H ₅ NO.Na) _x 136793-29-8: C ₁₁ H ₁₈ NNaO ₆ S
Molecular weight	Likely >1000 MW
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	No studies are available for the Acrylamide polymers. Information for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt will be referenced in the following sections. 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salts are generally incorporated into polymers. As such, the fate of the monomer is tied to the polymer and no hydrolysis, movement, biodegradation or bioaccumulation of the polymer is expected. A Tier 1 Human Health Assessment for Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health.
Environmental Fate ²	
Soil/Water/Air	The polymers are not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weights and the low water solubilities of the polymers. Due to their high molecular weight, the polymers are not expected to bioaccumulate.
Human Health Toxicity Summary ²	
Chronic Repeated Dose Toxicity	A repeat dose 28 day oral toxicity study carried out in rats with a 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicated no treatment related toxic effects.
Carcinogenicity	No information available.
Mutagenicity/ Genotoxicity	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt did not induce a mutagenic response in bacteria and no clastogenicity was observed when a 50% solution of the notified chemical was tested in albino mice cells in vitro.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.

Acute Toxicity	Aqueous solutions containing 50% of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt exhibited low acute oral and dermal toxicity in rats (LD50 > 5 000 mg/kg, and 2 000 mg/kg respectively).
Irritation	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt was non-irritant to rabbit skin and a slight eye irritant in rabbits.
Sensitisation	A 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt showed minimal sensitisation potential when tested in guinea pigs.
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	No data available
Ecological Toxicity ²	
Aquatic Toxicity	Limited information is available. The polymers are expected to be a low concern for toxicity to aquatic organisms. Due to their poor solubility and high molecular weights, they are not expected to be bioavailable. The polymers do not contain any reactive functional groups. Ecotoxicity data for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicate that it is practically non-toxic to fish, water fleas and algae.
Determination of PNEC aquatic	No PNEC values were calculated.
Current Regulatory Controls⁵	
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	Based on health considerations, the concentration of acrylamide in drinking water should not exceed 0.0002 mg/L.
Aquatic Toxicity Guidelines	No data available
PBT Assessment ^{1, 2}	
P/vP Criteria fulfilled?	The polymers are not readily biodegradable, hence they meet the screening criteria for persistence.
B/vB criteria fulfilled?	The polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable, hence the polymers do not meet the criteria for bioaccumulation.
T criteria fulfilled?	There are no aquatic toxicity studies on the polymers. They are expected to have low aquatic toxicity because of their very high molecular weights and poor water solubility. As such, the polymers do not meet the criteria for toxicity.
Overall conclusion	Not PBT substances
Revised	December 2018

References

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2. National Industry Chemicals Notification and Assessment Scheme. 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt, July 1997.
3. U.S National Library of Medicine, Toxicology Data Network, ChemIDplus, CAS#38193-60-1. Accessed 2017 at <https://chem.nlm.nih.gov/chemidplus/rn/38193-60-1>
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Toxicity Summary - Acrylonitrile

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	107-13-1
Molecular formula	C ₃ H ₃ N
Molecular weight	53.06
Solubility in water	73 g/L at 20 °C
Melting point	– 88.55 °C
Boiling point	77.3 °C
Vapour pressure	12.4 kPa at 20 °C
Henry's law constant	9.0 Pa · m ³ /mole at 20 °C
Explosive potential	Sax (1989) presents that acetonitrile forms explosive mixtures with air. The lower explosive limit is 3.05% in volume and the upper explosive limit 17% in volume.
Flammability potential	Acetonitrile is highly flammable, with a lower flammability limit of 4.4% in volume and an upper flammability limit of 16% in volume.
Colour/Form	Volatile, colourless liquid with a sweet ether-like odour
Overview	Acrylonitrile was first prepared in 1893 but had no significant technical or commercial applications until the late 1930s when a synthetic rubber based on a co-polymer of butadiene and acrylonitrile was introduced in Germany (Langvardt, 1984). In USA, projects relating to nitrile rubber received special support during World War II because of their strategic importance and acrylonitrile became established as a monomer of commercial importance. Demand for acrylonitrile began to soar following the introduction of acrylic fibres in 1950. Today, acrylonitrile is an industrial intermediate used predominantly in the production of polymeric materials, with acrylic fibres accounting for 60% and plastics for 25% of world consumption (SRI, 1995). Other uses include the production of adiponitrile and acrylamide monomers and the co-polymerisation with other monomers to produce polymer emulsions, elastomers and nitrile rubber. From the early 1940s to the mid-1960s, acrylonitrile was mainly manufactured by the dehydration of ethylene cyanohydrin produced from ethylene oxide and aqueous hydrocyanic acid. Nowadays, all acrylonitrile is produced by direct catalytic conversion of propene, oxygen (as air) and ammonia (SRI, 1995). Processes based on propane or ethylene have been developed and may become commercially viable in the future where propane or ethylene feedstock is readily available. In 1995, global acrylonitrile capacity amounted to 4.5 million metric tonnes (t) (SRI, 1995).
Environmental Fate ¹	
Soil/Water/Air	Acrylonitrile is readily to fairly degradable in water, soil and in the troposphere. Its toxicity to aquatic vertebrates and invertebrates, algae and aquatic plants is slight to moderate. Bioaccumulation is expected to be slight to negligible. As there are no readily hydrolysable groups on the acrylonitrile molecule, hydrolysis is not expected to be an environmentally significant process. The vapour pressure of acrylonitrile puts it in the category of highly volatile chemicals (Mensink et al., 1995). However, the water solubility is also high. The Henry's Law constant can provide an indication of the volatility characteristics of compounds (Lyman et al., 1982). The characteristics of acrylonitrile indicate that although the volatilisation from aquatic systems is not rapid, it may be a significant removal process in the environment. Therefore, the high vapour pressure is mediated by the high water solubility. The volatilisation half-life of acrylonitrile in a typical pond, river and lake has been estimated at 6, 1.2 and 4.8 days respectively (Howard, 1989). The US EPA has previously suggested that although acrylonitrile is quite volatile, large spillages of the substance could lead to groundwater contamination (DoE, 1993).
Human Health Toxicity Summary ^{1,2,3}	

Chronic Repeated Dose Toxicity	Repeated-dose toxicity studies involving inhalation, ingestion or subcutaneous or intraperitoneal injection of acrylonitrile for 1-12 months in rats, mice, guinea pigs, rabbits, cats, dogs and monkeys showed a narrow range between lethal and no observed adverse effect levels. The most consistently observed effects were decreased body weight gain, irritation of the respiratory tract, kidney damage and reversible ataxia or paralysis. Retching and vomiting, adrenal hyperplasia, increased liver weight, hyperplasia of the gastric mucosa and biochemical effects such as small reductions in haemoglobin, haematocrit and erythrocyte counts and small increases in alkaline phosphatase were observed in some studies.
Carcinogenicity	The carcinogenic potential of acrylonitrile has been investigated in three strains of rats exposed to 5-80 ppm in air (2 studies), 1-500 ppm in drinking water (5 studies), or 0.1-10 mg/kg by gavage (2 studies). Exposure-related tumours were found in all studies. The most common forms were astrocytomas of the CNS and carcinomas of the zymal gland, both of which rarely occur spontaneously in experimental animals. Tumours of the mammary gland, tongue, small intestine and forestomach (oral exposure only) were less consistent across studies. A 2-year bioassay in mice, where metabolism via CNEO plays a greater role than in rats, is currently underway within the US National Toxicology Program. Acrylonitrile has also been evaluated by the International Agency for Research on Cancer (IARC). In 1979 and 1987, IARC concluded that there was limited evidence of carcinogenicity of acrylonitrile in humans and sufficient evidence of carcinogenicity in animals and therefore assigned the chemical to group 2A: agents that are probably carcinogenic to humans (IARC, 1979, 1987). In February 1998, all published literature on acrylonitrile was re-evaluated by an IARC working group comprising 30 experts from 12 countries. The group concluded that although additional studies confirmed that acrylonitrile is a potent multi-site carcinogen in rats, the combined epidemiological evidence did not support a credible association between acrylonitrile exposure and cancer. As such, IARC determined that there was inadequate evidence in humans but sufficient evidence in experimental animals for the carcinogenicity of acrylonitrile and re-classified the chemical in group 2B: agents that are possibly carcinogenic to humans (IARC, 1999).
Mutagenicity/ Genotoxicity	The genetic toxicity of acrylonitrile has been investigated in numerous in vitro and in vivo test systems. In vitro, it was weakly positive in several bacterial, fungal and mammalian mutagenicity assays and mammalian and fungal cytogenetic tests, particularly in the presence of metabolic activation. Where CNEO was tested in parallel assays, it was mutagenic in the absence of metabolic activation. In vivo, acrylonitrile tested negative in several dominant lethal, micronucleus and chromosome aberration assays. Studies in <i>Drosophila</i> using various genetic markers gave positive results. In vitro and in vivo assays for DNA binding and unscheduled DNA synthesis yielded negative results in tests using the most reliable techniques. On balance, it appears that acrylonitrile has little affinity for DNA, whereas the metabolite CNEO is a direct-acting mutagen in vitro. It is conceivable that the lack of genotoxicity of acrylonitrile in several in vivo tests is due to limited formation and/or rapid degradation of CNEO in intact mammals.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a 3-generation rat study, up to 35 mg/kg/day had no effect on fertility. In sub-acute studies in rats and mice, there was evidence of defective spermatogenesis at oral doses approaching acutely toxic levels, whereas several long-term studies found no abnormalities in male reproductive organs. In developmental toxicity studies in rats, hamsters, and rat embryos exposed in vitro, acrylonitrile showed some potential to cause foetal toxicity, but developmental effects in vivo occurred only at exposure levels associated with marked maternal toxicity.
Acute Toxicity	Acrylonitrile is acutely toxic by all routes of administration. In the rat, the LD50 is 72-186 mg/kg from oral and 148-282 mg/kg from skin exposure, and the 4 h LC50 from inhalation is 138-558 ppm (0.47-1.2 mg/L). The acute toxicity is roughly similar in other species, including mice, guinea pigs, rabbits, cats and dogs. Irrespective of route or test species, a lethal dose causes central nervous system (CNS) excitation followed by paralysis and respiratory arrest. The target organs are the gastrointestinal tract (bleeding), adrenals (haemorrhagic necrosis), brain (oedema) and lungs (oedema).
Irritation	Acrylonitrile is irritating to the skin and eyes. Repeated airborne exposure induces inflammatory and hyperplastic changes in the nasal mucosa, indicating a potential for irritation of the respiratory system.

Sensitisation	A guinea pig maximisation test for skin sensitisation was strongly positive. There are no data on respiratory sensitisation.
Health Effects Summary	Acrylonitrile is acutely toxic to humans by inhalation, in contact with skin and if swallowed. It is also a severe eye irritant and may cause sensitization by skin contact. Repeat dose toxicity studies in animals have shown treatment related changes in the gastrointestinal tract, central nervous system and adrenal gland. There are occasional reports of liver and kidney damage. It is a rodent carcinogen, tumours being observed in the brain, Zymbal gland, gastrointestinal tract and mammary gland. Detailed, recent epidemiological studies do not however provide evidence of human carcinogenicity. Acrylonitrile is an in vitro mutagen, indicating that the mechanism of carcinogenicity may be genotoxic. This is not however supported by the results of in vivo mutagenicity studies. It is concluded that there is a need for active management of the identified risk and further consideration of the risk management measures currently being applied in relation to workers, consumers and the population exposed via the environment.
Key Study/Critical Effect for Screening Criteria	In animals repeated exposure to acrylonitrile results in damage to the gastrointestinal tract, central nervous system and adrenal gland. There are occasional reports of liver and kidney damage. The respiratory tract is also affected following inhalation exposure, based on histopathological changes in the nasal turbinates of rats in the Quast et al., (1980) two year study. A LO(A)EL of 20 ppm was established in the study, treatment-related nasal changes being evident at this exposure level, and this was used as a starting point in the risk assessment in relation to inhalation exposure. A No Adverse Effect Level (NAEL) of 4 ppm for the inhalation route was been derived from the LO(A)EL of 20 ppm, by application of a safety factor of 5. In relation to oral administration of acrylonitrile, the N(A)OEL is estimated to be 3 ppm (0.25 mg/kg/day) in drinking water, based on the information from the Biodynamics study (1980) study in rats which showed systemic toxicity, probably attributable to metabolic release of cyanide.
Ecological Toxicity ⁶	
Aquatic Toxicity	The data set for acrylonitrile includes a wide range of information on short and long term toxicity in fish, Daphnia and other aquatic invertebrates. Acrylonitrile is moderately toxic to fish, with 96-hour LC50 for fresh water fish generally lying in the range of 10 - 20 mg/l (nominal). A recent short term study in the saltwater species <i>Cyprinodon variegatus</i> , carried out in full compliance with current protocols, reported a 96-hour LC50 of 8.6 mg/l. The lowest 48 hour EC50 for Daphnia was 7.6 mg/l. The fish early life stage toxicity test in <i>Pimephales promelas</i> , using flow-through conditions, provided a LOEC/NOEC of 0.34 mg/l, while a 30 day flow through test in mature fish of the same species provided a long-term LC50 of 2.6 mg/l. If the value of 0.34 mg/l is taken as a LOEC, a NOEC may be derived by application of safety factor of 2, giving a NOEC of 0.17 mg/l.
Determination of PNEC aquatic	Applying an assessment factor of 10 to the NOEC (0.17 mg/l) derived from the fish early life stage toxicity test gives a PNEC of 17 µg/l.
Current Regulatory Controls ^{1,7}	
Australian Hazard Classification	The chemical is classified as hazardous, with the following risk phrases for human health in the Hazardous Chemical Information System (HCIS) (Safe Work Australia): H225 (Highly flammable liquid and vapour) H350 (May cause cancer) H331 (Toxic if inhaled) H311 (Toxic in contact with skin) H301 (Toxic if swallowed) H335 (May cause respiratory irritation) H315 (Causes skin irritation) H318 (Causes serious eye damage) H317 (May cause an allergic skin reaction) H411 (Toxic to aquatic life with long-lasting effects)
Australian Occupational Exposure Standards	The current national occupational exposure standard for acrylonitrile in Australia is 2 ppm (4.3 mg/m ³) expressed as an 8 h TWA airborne concentration, Carcinogen Category 2, with a 'skin' notation (NOHSC, 1995a).

International Occupational Exposure Standards	The following exposure standards are identified: 8h TWA: Austria 2 ppm (4.5 mg/m³) Belgium 2 ppm (4.3 mg/m³) Denmark 2 ppm (4.0 mg/m³) Finland 2 ppm (4.3 mg/m³) France 2 ppm (4.0 mg/m³) Germany 3 ppm (7.0 mg/m³) Hungary 0.23 ppm (0.5 mg/m³) India 2 ppm (4.3 mg/m³) Ireland 2 ppm (4.5 mg/m³) Japan 2 ppm (4.3 mg/m³) Netherlands 4 ppm (9 mg/m³) Philippines 20 ppm (43 mg/m³) Poland 5 ppm (10 mg/m³) Russia 0.23 ppm (0.5 mg/m³) Spain 2 ppm (4.5 mg/m³) Sweden 2 ppm (4.5 mg/m³) Turkey 20 ppm (43 mg/m³) United Kingdom 2 ppm (4 mg/m³) USA (NIOSH) 1 ppm (2.2 mg/m³) USA (OSHA) 2 ppm (4.3 mg/m³) Short-term exposure limits (STEL): Finland 4 ppm (9 mg/m³) France 15 ppm (32.5 mg/m³) Netherlands 10 ppm (22 mg/m³) Sweden 6 ppm (14 mg/m³) USA (NIOSH) 10 ppm (22 mg/m³) USA (OSHA) 10 ppm (22 mg/m³)
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	A freshwater low reliability trigger value of 160 µg/L was calculated for acetonitrile using an AF of 1000. In the absence of marine data, this was adopted as a marine low reliability trigger value.
PBT Assessment	
P/vP Criteria fulfilled?	No. Acrylonitrile is readily to fairly degradable in water, soil and in the troposphere
B/vB criteria fulfilled?	No. The low log Pow (0.00-0.30) measures for acrylonitrile suggest bioaccumulation will not occur.
T criteria fulfilled?	Yes. Chronic toxicity data <1 mg/L in fish, thus acrylonitrile meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

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5. ANZECC & ARMCAZ (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality
6. OECD (2005) SIDS Initial Assessment Profile on Acrylonitrile

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<http://hcis.safeworkaustralia.gov.au/>

Toxicity Summary - Alcohols, C10-16, ethoxylated propoxylated

Chemical and Physical Properties ¹	
CAS number	69227-22-1
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
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	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate ¹	
Soil/Water/Air	This substance is expected to be readily biodegradable (84% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/ Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity ¹	

Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (<i>Pleuronectes platessa</i>) (similar substance) LC50 (96h) 1.6 mg/L (<i>Pimephales promelas</i>) (similar substance) LC50 (96h) 3 mg/L (<i>Brachydanio rerio</i>) (similar substance) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (<i>Daphnia magna</i>) (similar substance) EC50 (48h) 2 mg/L (<i>Daphnia magna</i>) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (<i>Pseudokirchnerella subcapitata</i>) (similar substance) ErC50 (48h) 0.7 mg/L (<i>Skeletonema costatum</i>) EC10 9.79 mg/L (<i>Selenastrum capricornutum</i>) (similar substance) ErC50 1.1 mg/L (<i>Scenedesmus subspicatus</i>) (similar substance) Toxicity to microorganisms: ErC50 (16.9h) > 10 g/L (<i>Pseudomonas putida</i>) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for <i>Daphnia</i> . The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
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. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	No. The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Alcohols, C6-12, ethoxylated propoxylated

Chemical and Physical Properties ¹	
CAS number	68937-66-6
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
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	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate ¹	
Soil/Water/Air	This substance is expected to be readily biodegradable (60% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/ Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity ¹	

Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (<i>Pleuronectes platessa</i>) (similar substance) LC50 (96) 1.4 mg/L (<i>Pimephales promelas</i>) (similar substance) NOEC 4.4 mg/L (<i>Pimephales promelas</i>, juvenile) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (<i>Daphnia magna</i>) (similar substance) EC50 (48h) 0.39 mg/L (<i>Cerodaphnia dubia</i>) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (<i>Pseudokirchnerella subcapitata</i>) (similar substance) EC50 (96h) 0.7 mg/L (<i>Pseudokirchneriella subcapitata</i>) (similar substance) CD10 8 mg/L (<i>Pseudokirchneriella subcapitata</i>) EC10 2 mg/L (<i>Brachionus calyciflorus</i>) Toxicity to microorganisms: EC50 (48h) 0.39 mg/L (<i>Cerodaphnia dubia</i>) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for <i>Daphnia</i> . The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
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. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Ethoxylated of aliphatic alcohols (>C6)

Chemical and Physical Properties ^{1,2,3}	
CAS number	112-59-4, 3055-93-4, 3055-94-5, 3055-95-6, 3055-97-8, 4536-30-5, 5274-68-0, 25190-05-0, 9002-92-0, 9004-95-9, 9004-98-2, 9005-00-9, 9043-30-5, 31726-34-8, 24938-91-8, 26183-52-8, 26468-86-0, 27252-75-1, 27306-79-2, 31943-12-1, 32128-65-7, 37281-47-3, 37702-39-9, 39587-22-9, 52292-17-8, 61723-78-2, 68439-45-2, 68439-46-3, 68439-49-6, 68439-50-9, 68439-54-3, 61791-13-7, 61791-28-4, 61827-42-7, 64425-86-1, 66455-14-9, 66455-15-0, 69227-20-9, 67254-71-1, 68002-97-1, 68131-39-5, 68131-40-8, 68155-01-1, 68213-23-0, 68526-94-3, 68551-12-2, 97953-22-5, 68920-66-1, 68991-48-0, 78330-21-9
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)
Melting point	7.2 °C at 101.3 kPa (CAS 68131-39-5) -20 °C at 101.3 kPa (CAS 68439-46-3)
Boiling point	271.11 - 516.11 °C (CAS 68131-39-5) 260 °C (CAS 68439-46-3)
Vapour pressure	< 1 Pa at 25 °C (CAS 68131-39-5) 0.004 - 117 Pa at 20 °C (CAS 68439-46-3)
Henrys law constant	No data available.
Explosive potential	Non explosives
Flammability potential	Non flammable
Colour/Form	Organic liquid, colourless to light yellow
Overview	The chemicals in this group are structurally related alcohol ethoxylates (AEs), ethoxylated ethers of aliphatic alcohols, where the alkyl chain length is six carbons or higher. Ethoxylates of shorter chain alcohols (C<6) do not show the same degree of surfactancy compared to the chemicals in this group. Commercially available AEs generally consist of a mixture of various AE homologues of varying carbon chain lengths and degree of ethoxylation. The chemicals contain a hydrophobic alkyl chain attached via an ether linkage to a hydrophilic ethylene oxide (EO) chain that gives them their characteristic surfactant properties. The hydrophobic alkyl and the hydrophilic EO chains can vary in length depending on method of production and source of the precursor chemicals (HERA, 2009). Although most of chemicals of this group are polymers according to the definition in the Industrial Chemicals (Notification and Assessment) Act (1989), the individually named members do not necessarily meet the polymer of low concern (PLC) criteria as the number-average molecular weight (NAMW) >1000 Da. Lower molecular weight forms of these chemicals (MW <500) are expected to be used in commercial, domestic and cosmetic products. The chemicals are used extensively as non-ionic surfactants in a wide range of cosmetic and domestic products. The chemicals in this group are expected to have similar physicochemical and toxicological properties, which depend on the alkyl chain length and the number of EO units.
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 Summary¹	
Chronic Repeated Dose Toxicity	The chemicals in this group are not expected to cause serious damage to health fr In several 90-day oral feeding studies in rats (similar to OECD TG 407), the NOAEL was established between 50 and 700 mg/kg bw/day (calculated from dietary levels) for group members (CAS Nos. 68439-50-9 and 68131-39-5, ranging from C12–15 with EO7). Effects observed at higher concentrations included reduction in mean body weights, and increases in relative liver and kidney weights. These changes were considered to be adaptive and related to the poor palatability of the test chemicals. No treatment related histopathological changes were reported (SCCS, 2007; HERA 2009; CIR, 2012). Similar effects were seen in longer-term studies. Alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were given to rats in one- and two-year chronic feeding studies at levels between 0.1 and 1 %. The NOAEL was established between 50 and 192 mg/kg bw/day (calculated from dietary level). Effects observed at higher levels included reduction in mean body weights, and increase in relative liver and kidney weights. These changes were considered to be adaptive and may be due to poor palatability of the test chemicals. No treatment related lesions were observed (SCCS, 2007; HERA, 2009; CIR, 2012).om repeated oral and dermal exposure. In a 90-day study (OECD TG 411), Fischer rats were exposed to the chemical (C9–11 with 6 EO units, CAS No. 68439-46-3) at 1, 10 or 25 % concentration, 3 days/week. The application site was shaved but not covered. There were no significant treatment related effects at any concentration. Dry and flaky skin was observed in the 10 and 25 % dose groups. Increased relative kidney weights were observed in the 25 % dose groups. However, no histological lesions were observed. The NOAEL was established at 10 %, equivalent to 80 mg/kg bw/day (HERA, 2009).
Carcinogenicity	Based on the data available, the chemicals in this group are not considered to be carcinogenic. Two chemicals, alcohols, C12-13, ethoxylated (CAS No. 66455-14-9; EO6.5) and alcohols, C14-15, ethoxylated (CAS No. 68951-67-7, EO7, not listed on AICS) were administered at up to 1 % in the diet to rats for one and two years, respectively. No treatment related histopathological effects or increased tumour incidences were observed in either study (HERA, 2009; CIR, 2012). The chemicals are synthesised through processes which may result in 1,4-dioxane as an impurity. This impurity is classified as a Carcinogen—Category 3 (R40—Limited evidence of a carcinogenic effect). However, it is reported that cosmetic industry uses additional purification steps to remove the 1,4-dioxane residual in PEG before blending into cosmetic formulations (CIR, 2012).

Mutagenicity/ Genotoxicity	Based on the data available, the chemicals in this group are not considered to be genotoxic. The group members (CAS Nos. 68439-50-9, 68131-39-5 and 64425-86-1) and several analogue chemicals (ranging from C12–18 and EO3–21) produced negative results in several in vitro and in vivo tests for gene mutation and clastogenicity. Negative results were reported in bacterial reverse mutation tests for mutagenicity against <i>Salmonella typhimurium</i> (strains TA98, TA100, TA102, TA104, TA1535, TA1537 and TA1538) and <i>Escherichia coli</i> (strains WP2 and WP2uvrA pKM101), with or without metabolic activation. Negative results were also reported in chromosomal aberration tests in Chinese hamster V79, Chinese hamster ovary, mouse lymphoma and rat liver cell lines (SCCP, 2007; HERA, 2009; CIR, 2012). These chemicals did not induce chromosomal damage in Chinese hamster or Tunstall Wistar rat bone marrow cells after acute oral doses ranged between 250 and 3400 mg/kg bw (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. In a two-generation reproductive and developmental toxicity study, the chemical (C14-15EO7) was administered in the diet of Charles River CD rats (n=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 % of the diet). No treatment related effects were reported with respect to fertility, gestation, or viability indices or other histopathological parameters. The NOAEL for developmental toxicity was established as 50 mg/kg bw/day based on reduced pup body weights in the second generation at 250 mg/kg bw/day (HERA 2009; CIR, 2012). In a two-generation reproductive and developmental toxicity study, the chemical (C9-11EO6) was applied dermally to Fischer 344 rats (n=30/sex/group, at doses of 0, 10, 100 or 250 mg/kg bw/day, 3 times a week except mating periods). No treatment related effects were reported with respect to mating, fertility, gestation, or viability indices and mean gestational length in both generations. No effects on testicular weights or sperm counts were observed in the male rats. The NOAEL for reproductive toxicity was established as 250 mg/kg bw/day. The NOAEL for developmental toxicity was >250 mg/kg bw/day, based on no effects seen in growth and development in the offspring up to the highest dose tested (HERA 2009; CIR, 2012). In a two generation study, the chemical (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 and 200 mg/kg bw/day, indicating maternal toxicity. 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 implantations, number of live fetuses and spontaneous abortions. The NOAEL for maternal toxicity was reported as >50 mg/kg bw/day (HERA, 2009). Although certain short chain monoethylene glycol ethers such as 2-ethoxyethanol (CAS No. 110-80-5) are known reproductive toxicants, the ability of the glycol ethers to cause testicular toxicity decreases with increasing chain length, with effects not observed with chain lengths greater than C2 (OECD, 2004).

Acute Toxicity	Based on the available animal (rats, mice and guinea pigs) studies, the chemicals in this group are expected to have low to moderate acute oral toxicity (REACHa-h; OECD, 2005; HERA, 2009; CIR, 2012). The LD50 in rats ranged from 600 mg/kg bw to greater than 20 g/kg bw. Observed sublethal effects for the chemical with the highest toxicity (C15–16 and EO10) included diarrhoea, pilo-erection, ataxia, abnormal posture, difficult laboured breathing, salivation, lacrimation, bloody noses and lethargy. Data from HERA assessment studies show that the chemicals with ethoxylate chains (EO) between 5 and 15 units were more toxic by the oral route than those with less than 4 or greater than 21 units. No relationship between the alcohol chain length and toxicity was observed (HERA, 2009). The chemicals of this group exhibit low acute dermal and inhalation toxicity. The chemicals (C9 to C15 with 3–13 EO units) were of low acute toxicity in rats and rabbits following dermal exposure. The LD50 ranged from 2000 to 5000 mg/kg bw. Sub-clinical effects included wet appearance of the fur, little or no urine, laboured breathing, lethargy, diarrhoea, ataxia, muscle tremours and decreased activity. There was no relationship between the alcohol chain length or number of ethoxylate groups and toxicity. Very high dermal doses of the chemicals (>16000 mg/kg bw) applied dermally for 24 hours in rabbits led to severe skin irritation, ataxia and lung lesions (HERA, 2009; CIR, 2012). In a guideline study (Test Guideline (TG) 403), a single static inhalation exposure to substantially saturated vapour (equivalent to 131.58 ppm - calculated) of C6EO1-2.5 (CAS No. 112-59-4), resulted in no mortality or other signs of inhalation toxicity in Sprague- Dawley (SD) rats (REACHa).
Irritation	The chemicals in this group are reported to be moderate to severe skin irritants in animal studies. The degree of irritation was reported to be dependent on the type of patch (occluded vs semi-occluded), exposure time (ranging from 4 hours up to 4 weeks) and the concentration used. Undiluted chemicals were moderately to severely irritating, 1–10 % was mildly irritating and 0.1 % and 0.5 % were non-irritating. There was also a general trend between the severity of irritation and the degree of ethoxylation. Chemicals with three and less ethoxylate units appeared to be more irritating than chemicals with higher degree of ethoxylation. No trend in irritation potential with respect to the length of carbon chain could be established. Available data indicates that undiluted AEs can produce varying degrees of eye irritation ranging from moderate to severe irritancy. The severity of irritation was found to be concentration dependent, with up to 1 % minimally irritating and concentrations in the range of 1 to 10 % slightly to moderately irritating. In most cases, following exposure, the eyes of the treated animals recovered a few days after exposure. Further tests showed that rinsing the eye 30 seconds after application with tap water may reduce the severity of the effects. No clear relationship could be established between the number of EO units or carbon chain length and eye irritation potency.
Sensitisation	Based on available data, the chemicals in this group are not skin sensitisers.
Health Effects Summary	The chemicals in this group are synthesised from linear alcohols (primary or secondary) or branched alcohols. The commercial AEs may also contain un-reacted alcohol as reaction by-products at about 5 % but with variations between different commercial products (HERA, 2009). Available data on linear and branched chain alcohols show that they have low acute and systemic toxicity and exhibit similar patterns of absorption, metabolism, and excretion to alcohol ethoxylates. They are also shown to have no skin sensitisation potential. A potential for skin and eye irritation exists with alcohols >11 carbon chain length (OECD, 2006; OECD, 2006a).
Key Study/Critical Effect for Screening Criteria	The critical human health effects for risk characterisation are acute oral toxicity and skin and eye irritation. The irritant effects are similar to those produced by other surfactants, and the severity of irritation appears to increase directly with concentration and generally decrease with an increasing number of ethoxylate units.

Ecological Toxicity ^{2,3}	
Aquatic Toxicity	The 96 h LC50 value for Alcohols, C9-11, ethoxylated with <i>Oncorhynchus mykiss</i> was 5 - 7 mg/L based on nominal concentrations. In the long term toxicity test to <i>Lepomis macrochirus</i>, 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	
Australian Hazard Classification	No data available.
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
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Ethoxylates of aliphatic alcohols (>C6);, Retrieved 2019: <https://www.nicnas.gov.au>
2. ECHA REACH, Alcohols, C9-11 ethoxylated, < 2.5 EO, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>
3. ECHA REACH, Alcohols, C12-15 ethoxylated, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>

Toxicity Summary - Alcohols, C6-12, ethoxylated propoxylated

Chemical and Physical Properties ¹	
CAS number	68937-66-6
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	Soluble in water
Melting point	-3 °C
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	Yellow liquid, mild odour
Overview	Principle Route of Exposure: Eye or skin contact, inhalation Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Environmental Fate ¹	
Soil/Water/Air	This substance is expected to be readily biodegradable (60% @ 28d) (similar substances). Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative. Mobility in soil: KOC = >4
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	No data available to indicate product or components present at greater than 0.1% are chronic health hazards.
Carcinogenicity	Did not show carcinogenic effects in animal experiments (similar substances)
Mutagenicity/Genotoxicity	In vitro tests did not show mutagenic effects. In vivo tests did not show mutagenic effects. (similar substances)
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Animal testing did not show any effects on fertility.
Acute Toxicity	LD50 Oral: 600 mg/kg (Rat) (similar substance) LD50 Dermal: > 5200 mg/kg (Rabbit) (similar substance) LD50 Inhalation: > 0.22 mg/L (saturated concentration) (Rat) (similar substance)
Irritation	May cause mild respiratory irritation. Causes severe eye irritation which may damage tissue. Causes skin irritation.
Sensitisation	Did not cause sensitization on laboratory animals (guinea pig) (similar substances)
Health Effects Summary	Causes severe eye irritation which may damage tissue. Causes skin irritation. Harmful if swallowed.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity ¹	

Aquatic Toxicity	Toxicity to fish: LC50 (96h) 0.59 mg/L (<i>Pleuronectes platessa</i>) (similar substance) LC50 (96) 1.4 mg/L (<i>Pimephales promelas</i>) (similar substance) NOEC 4.4 mg/L (<i>Pimephales promelas</i>, juvenile) Toxicity to invertebrates: EC50 (48h) 0.14 mg/L (<i>Daphnia magna</i>) (similar substance) EC50 (48h) 0.39 mg/L (<i>Cerodaphnia dubia</i>) (similar substance) Toxicity to algae: EC50 (72h) 0.75 mg/L (<i>Pseudokirchnerella subcapitata</i>) (similar substance) EC50 (96h) 0.7 mg/L (<i>Pseudokirchneriella subcapitata</i>) (similar substance) CD10 8 mg/L (<i>Pseudokirchneriella subcapitata</i>) EC10 2 mg/L (<i>Brachionus calyciflorus</i>) Toxicity to microorganisms: EC50 (48h) 0.39 mg/L (<i>Cerodaphnia dubia</i>) (similar substance)
Determination of PNEC aquatic	On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 0.14 mg/L for <i>Daphnia</i> . The PNEC aquatic is 0.14 µg/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	H302 - Harmful if swallowed H315 - Causes skin irritation H318 - Causes serious eye damage
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. Expected to be readily biodegradable based on similar substances.
B/vB criteria fulfilled?	No. Based on an estimated log Kow value of 4.3 – 5.36, and BCF value of 1.1 – 1.8, it is not expected to be bioaccumulative.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. Redacted

Toxicity Summary - Amides, tall-oil fatty, N,N-bis(hydroxyethyl)

Chemical and Physical Properties ^{1,2}	
CAS number	68155-20-4
Molecular formula	UVCB
Molecular weight	370 (typical C18 monounsaturated)
Solubility in water	Dispersible
Melting point	<25 °C (liquid)
Boiling point	>300 °C (estimated)
Vapour pressure	<1.0×10 ⁻¹⁰ (estimated)
Henry's law constant	<1.0×10 ⁻¹⁰ (estimated)
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Liquid
Overview	Non-confidential information in the IUR indicated that the industrial processing and uses of the chemical include other basic organic chemical manufacturing as surface active agents and intermediates; pesticide and other agricultural chemical manufacturing as surface active agents; soap and cleaning compound manufacturing as surface active agents; support activities for mining as surface active agents; and petrochemical manufacturing as surface active agents. Non-confidential commercial and consumer uses of this chemical include lubricants, greases and fuel additives.
Environmental Fate ^{1,2}	
Soil/Water/Air	The members of the fatty nitrogen derived amides category are long-chain alkyl substituted amides used in commercial product mixtures. The category consists of three subcategories: Subcategory I, fatty acid amides; Subcategory II, fatty alkanolamides; and Subcategory III, fatty acid reaction products with amines. For the purpose of this discussion only, a one-member Subcategory, Subcategory IV, which contains CASRN, 61790-63-4, has been considered as part of Subcategory II. The components of Subcategory I are solids possessing low vapor pressure and low water solubility. The substances in Subcategory II contain solids and liquids with negligible to low vapor pressure and tend to be dispersible in water. The substances in Subcategory III also contain solids and liquids possessing negligible to low vapor pressure that tend to be dispersible in water. The fatty acid amides (Subcategory I) and the fatty acid reaction products with amines (Subcategory III) are expected to possess low mobility in soil. The fatty alkanolamides (Subcategory II) are expected to possess moderate to high mobility in soil. Volatilization is low to moderate for the fatty acid amides and low for the fatty alkanolamides and the fatty acid reaction products with amines. The rate of hydrolysis is considered negligible for all category members. The rate of atmospheric photooxidation is considered moderate to rapid for members of each subcategory; however, this is not expected to be an important environmental fate process since these substances are not expected to exist in the vapor phase in the atmosphere. The overall weight of evidence suggests that the members of the fatty nitrogen derived amides category should possess low persistence (P1) and low bioaccumulation potential (B1) with the exception of two members of subcategory III. Fatty acids, tall-oil, reaction products with tetraethylenepentamine and fatty acids, tall-oil, reaction products with polyethylenepolyamines are expected to possess low persistence (P1), but moderate bioaccumulation potential (B2).
Human Health Toxicity Summary ^{1,2,3}	

Chronic Repeated Dose Toxicity	Based on read-across from CAS 120-40-1, an oral repeated dose toxicity study reported NOEL = 0.1% which corresponds to 50 mg/kg/day. No rats died as a result of being treated with the test substance. Two males treated with diet containing 1.0% test substance were euthanized on Days 23 and 58 because of weight loss and respiratory distress. Extensive lung abscess formation was seen at autopsy and bronchopneumonia was confirmed histologically. Growth was inhibited significantly in males and females at and above the 0.5% dietary concentration. Food intake was reduced at all dietary levels except 0.1%, and was attributed to an effect of the test substance on palatability of the diet. The rats in the palatability study showed exclusive preference to the control feed than the treated feed, virtually no test diet was consumed at any dietary levels incorporated. Hematological examination revealed statistically significant reductions in hemoglobin levels and red cell counts in females at the 2.0 and 1.0% dietary concentration and in hemoglobin levels in males at the 2.0% level. Examination of the femoral bone marrow smears showed not deviation from normality. Serum chemistry revealed significantly high serum levels of glutamic-oxaloacetic transaminase in females at the 0.5% level and higher, but only at the 0.5% level in males. Urinalysis was comparable across all groups for males and females. Gross examinations were unremarkable. Statistically significant increases in relative kidney weight in all test groups except at 0.1% in females and at 2.0 and 1.0% in males; and increases in relative liver weight in females at 2.0 and 1.0% were seen. These were attributed to the decreases in body weight. Types and incidence of pathological lesions seen histologically were comparable in control and test groups. Gonads were examined histologically, thus this study meets SIDS requirements for a reproductive screen.
Carcinogenicity	Not regarded as carcinogenic.
Mutagenicity/ Genotoxicity	Based on read-across from CAS 120-40-1, the test substance did not induce reverse mutations in the tested strains of Salmonella typhimurium in the presence or absence of S-9 activation.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on read-across from CAS 68603-42-9, the results from a developmental toxicity study showed that repeated oral administration of COMPERLAN KD to pregnant rats on day 6 through 15 of gestation, caused no symptoms of cumulative toxicity up to a dose level of 1000 mg/kg/day. With the exception of salivation and propulsion of the head during the dose administration, there were no treatment-related effects. Also, COMPERLAN KD does not reveal any embryotoxic or teratogenic potential at dose levels up to 1000 mg/kg/day (author of the report).
Acute Toxicity	Acute oral and dermal toxicities of CASRN 68140-00-1 in rat and rabbit, respectively, are low. Based on read-across from CAS 68140-00-1, an oral acute toxicity test on rats reported LD50 > 5 g/kg. All animals survived the 8-day observation period and no adverse effects were observed. With respect to the determined LD50 value, it is assumed that the LD50 value for female rats also exceeds the limit dose of > 2000 mg/kg body weight. In a dermal acute toxicity test on rabbits, LD50 > 2 g/kg was reported. All animals survived. All animals appeared normal through day 14. Two females that had abraded skin lost weight (0.01 and 0.25 kg) over the 14-day post-exposure period. All remaining rabbits gained weight through day 14. Swiss-Webster mice (4 males/dose) were administered "Alkanolamide #1", identified in the robust summary as CASRN 68144-20-4, via whole body exposure for 3 hours. Doses were 86- 219 mg/m3 (0.086 – 0.219 mg/L). Animals were observed for several days. No mortality was observed. LC50 > 0.219 mg/L
Irritation	The test article produced sensory irritation later in the exposure at low concentrations. Pulmonary irritation also occurred later in these exposures.
Sensitisation	Did not cause sensitization on laboratory animals (similar substances)

Health Effects Summary	Acute oral and dermal toxicities of CASRN 68140-00-1 in rat and rabbit, respectively, are low. CASRNs 142-78-9 and 68140-00-1 were negative for gene mutations in bacteria in vitro. No data are available for the repeated-dose/reproductive/developmental toxicity and genetic toxicity (chromosomal aberrations) endpoints. The repeated-dose/reproductive/developmental toxicity and genetic toxicity (chromosomal aberrations) endpoints are identified as data gaps
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity ^{1, 3}	
Aquatic Toxicity	Based on read-across for CAS No: 68603-42-9 Daphnia: EC50 (24-hour): 3.3 mg active matter/l Daphnia: 48-hour LC50 = 2.15 and 2.64 mg/l Based on read-across for CAS No: 112-84-5 The experiment measured the survival and reproduction of Daphnia magna over a 21-day exposure to the test and control substances. Daphnids were cultured in the laboratory using Elendt M7 medium and a daily feeding regiment of green algal cells (<i>Chlorella vulgaris</i>). Four experimental groups: control (Elendt M7 medium), solvent control (0.1 ml methanol/l), 33 µg/l, and 100 µg/l (nominal concentrations) were used in a static-renewal exposure system. All test solutions were prepared with Elendt M7 medium. Replicate test vessels consisted of 4 oz glass bottles containing 100 ml of test solution. There were 10 replicates per experimental group. On the day of test initiation, neonate daphnids were removed from cultures and placed in a crystallizing dish containing Elendt M7 medium. One daphnid was placed in each replicate test vessel, and each vessel was randomly placed in the testing area. Light intensity was not measured, but ambient laboratory lighting was provided with a photoperiod of 16 hours light/8 hours dark. Each day, test solutions were renewed, and the daphnids were fed 1.7 x 10(5) cells/ml of <i>Chlorella vulgaris</i>. Adult survival and reproduction was assessed each day and neonates were removed daily. The pH, dissolved oxygen (DO) and total hardness (as mg/l CaCO(3)) were measured on test days 0, 1, every Tuesday and Friday and on day 21. Means and ranges for temperature, water pH, DO and total hardness were 19.7 °C (14.5 - 25.0 °C), 7.6 (7.2 - 8.1), 8.2 mg/l (4.5 - 9.3 mg/l) and 245 mg/l (234 - 256 mg/l) as CaCO(3), respectively. Concentrations of the test substance in exposure solutions were measured on test days 0, 1, 5, 9, 12, 16 and 19 in both the old and the new solutions. Effect concentrations were based on mean measured concentrations. 21 d NOEC = 0.08 mg/L
Determination of PNEC aquatic	Applying an assessment factor of 1000 to the NOEC (0.08 mg/l) gives a PNEC of 0.08 µg/l.
Current Regulatory Controls	
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. Expected to be readily biodegradable based on similar substances.

B/vB criteria fulfilled?	No. Based on BAF = 108 and log Kow of 3 (estimated)
T criteria fulfilled?	No. Acute toxicity data was >1 mg/L.
Overall conclusion	Not PBT
Revised	January 2019

References

1. OECD, Amides, tall-oil fatty, N,N-bis(hydroxyethyl), Retrieved 2019: <http://www.echemportal.org>
2. USEPA Hazard Characterization Document, Fatty Nitrogen Derived (FND) Amides Category, September 2010
3. Redacted

Toxicity Summary - Amine oxides, cocoalkyldimethyl

Chemical and Physical Properties	
CAS number	61788-90-7
Molecular formula	CH ₃ .(CH ₂) _R .N(CH ₃) ₂ O, where R is 9-17
Molecular weight	237 (70% C12: 30% C14) (molecular weight will vary depending on structure)
Solubility in water	409.5 g/L
Melting point	Average: 130.5
Boiling point	Decomposes before boiling
Vapour pressure	Predicted vapour pressure values are < 4.6E-7 hPa
Henry's law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Surfactants known as amine oxides (AO) contain even numbered linear alkyl chains ranging from C8 to C20. Also known as fatty alkyl dimethyl AOs, they are usually produced by reacting alkyl dimethyl amines with hydrogen peroxide in water. The AOs are produced, transported and used in water solutions, typically at a 25-35% activity level. The AOs are produced and used either as single chain length substances (e.g., C12) or as a mixture of different chain lengths (e.g., C12 to C18). All of the substances in this category are surfactants, consisting of a polar "head" (the amine oxide) and a relatively inert, hydrophobic "tail" (the long alkyl substituent). AOs are used in cleaning and personal care products as foam stabilizers, thickeners, emollients, emulsifying and conditioning agents. Primary uses are in liquid hard surface cleaners, laundry and dishwashing detergents, shampoos and hair conditioning products.
Environmental Fate ¹	
Soil/Water/Air	AOs are highly water soluble (C10-16 AO = 409.5g/L). AO is fully biodegradable under both aerobic and anaerobic conditions and is effectively removed during wastewater sewer transport ("pipe loss" >90%) and in biological wastewater treatment (~98%). It has low potential for bioaccumulation (BCF <87 L/kg). These characteristics help to minimize the potential for environmental exposure, and for indirect human exposures via drinking water and/or fish consumption.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	In four repeated-dose studies with rats and mice exposed to AO via oral and dermal routes (all with CAS No 70592-80-2), three dermal studies were designed to assess the effect of repeated exposure on skin at maximum doses of 1.5 mg AO/kg-bw/day. Higher doses were tested in a 90-day dietary study with rabbits. No treatment-related clinical chemistry, hematology and histopathological changes were observed. In these studies, LOAELs ranged from 87 to 150 mg AO/kg bw/day with the highest oral NOAEL below the lowest LOAEL as 80 mg AO/kg bw/day. Signs of toxicity observed in the oral study included suppressed mean body weight gain, lenticular opacities and diarrhoea; in the dermal studies, local dermal irritation was evident.
Carcinogenicity	The carcinogenic potential of amine oxides has been thoroughly investigated in three carcinogenicity studies in rats or mice by dermal, dietary, or drinking water routes. In all cases the substances demonstrated no evidence of a carcinogenic response.

Mutagenicity/ Genotoxicity	In five in vitro bacterial (Salmonella) mutagenicity studies, AO shows no evidence of mutagenicity either with or without S9 metabolic activation at concentrations up to 250 ug/plate (higher concentrations caused cytotoxicity). Three in vivo studies investigated clastogenic effects on a close structural analog of the category, 1-(methyldodecyl)dimethylamine-N-oxide including: a mouse micronucleus, a Chinese hamster micronucleus and a Chinese hamster cytogenetics study. These studies were all negative showing no increase in micronuclei or chromosome aberrations. An in vivo mouse dominant lethal assay showed no evidence of heritable effects. Two AOs (CAS No 1643-20-5 and CAS No 3332-27-2) were negative in an in vitro cell transformation assay tested at concentrations up to 20 ug/ml.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No evidence of reproductive toxicity or fertility effects was observed in a study in which rats were given dietary doses of AO in the diet over two generations (CAS No 1643-20-5). No macroscopic or histopathological changes were attributable to treatment with the test substance. The maternal NOAEL from this reproductive study was >40 mg AO/kg bw/day, which was the highest dose tested. At all treatment levels, the rate of bodyweight gain for the F1 and F2 offspring was reduced during the lactation period, however, this reduction was not greater than 10%. This effect appeared to be dose-related, but was not statistically significant until after weaning in the mid and high dose levels. This was not considered an adverse effect since the body weight change only reached statistical significance when the rat pups were getting the majority of their calories from solid food (Developmental NOAEL >40 mg/kg bw/day). In three developmental toxicity studies via gavage in rats and rabbits (with CAS No 1643-20-5 & 70592-80-2), effects such as decreased fetal weight or delayed ossification, were most often observed only at maternally toxic doses and were associated with the irritation effects of AO on the gastrointestinal tract. No decreases in litter size, no changes in litter parameters, no malformations or significant differences in skeletal defects were observed at oral doses up to 25 mg/kg bw/day in rats (based on decreased fetal weight at 100 mg/kg bw/day) and >160 mg/kg bw/day in rabbits (the highest dose tested).
Acute Toxicity	In rat oral acute toxicity limit tests, no deaths occurred at single doses of 600 mg C10-16 AO/kg bw or less (for CAS No 70592-80-2). In multi-dose studies, acute oral LD50 values for rats ranged from 846 mg AO/kg bw to 3873 mg AO/kg bw (both values for CAS No 61788-90-7), with several other AO's having rat oral LD50's falling within this range. In single dose acute dermal toxicity limit tests, no deaths occurred at a dose of 520 mg AO/kg bw (CAS No 70592-80-2). This dose was equivalent to 2 mL/kg of a 30% formulation. There were no deaths observed in a rat acute inhalation study to aerosol droplets of a consumer product providing a dose of 0.016 mg AO/L.
Irritation	In a series of studies on rabbits, AO's of varying chain length showed consistent results and all 1) were not irritating to the skin or eyes at low concentrations (1%), 2) were moderately irritating at 5%, and 3) more severely irritating when tested as produced (e.g., ~30% aqueous solutions). In studies that included rinsing, eye irritation effects diminished with rinsing after 30 seconds of exposure and were slight with rinsing after 4 seconds of exposure. In Draize rabbit eye irritation tests using ~30% AO solutions, rabbits experienced severe to moderate irritation. (The maximum concentration of AO is 10% active in consumer products.) Accidental eye exposure in manufacturing employee incidents and consumer incidents established that eye irritation effects of exposure during manufacturing and use of products containing AO and other surfactants are moderate, transient and reversible
Sensitisation	There is no indication of skin sensitization for the AO category based on the available animal and human data.
Health Effects Summary	The chemicals in this category present properties indicating a hazard for human health (skin and eye irritation). However, these hazards do not warrant further work as they are related to reversible, transient and non-lasting effects. Nevertheless, these hazards should be noted by chemical safety professionals and users.
Key Study/Critical Effect for Screening Criteria	Skin and eye irritation.

Ecological Toxicity ^{1,2,3}	
Aquatic Toxicity	Extensive aquatic toxicity data are available for commercially representative amine oxides (C10 to C18) that are single chain length as well as mixtures. Based on hazard data, freshwater green algae are considered the most sensitive species, for acute and chronic endpoints. Acute toxicity is affected by chain length for fish and invertebrates. Chain length affects hydrophobicity, wherein longer chain-lengths increase the rate of uptake and decrease depuration. All but four supporting AO's have been tested for acute toxicity in fish, daphnia, and algae. The range of acute LC50/EC50/ErC50 values based on a review of the aquatic toxicity data on AO were 0.60-32 mg/L for fish, 0.50-10.8 mg/L for Daphnia magna and 0.010-5.30 mg/L for algae. Chronic toxicity data were normalized to a chain length of 12.9 carbon atoms, as this average chain length represents the largest volume product for North America (CAS No 70952-80-2). Chronic toxicity (NOEC, EC20) for an amine oxide of average chain length of C12.9 ranged as follows for the different trophic levels: 0.010-1.72 mg/L for algae, 0.28 mg/L for Daphnia (flow through) and 0.31 mg/L for fish (flow through). These are based on geometric mean values, and a dataset of 21 chronic toxicity studies. Based on a chronic periphyton microcosm bioassay that included 110 taxa of algae (most sensitive species), a NOEC value of 0.050 mg/L was derived when normalized for a C12.9 amine oxide.
Determination of PNEC aquatic	Chronic toxicity values are reported for fish, aquatic invertebrates, and freshwater algae. Since there is valid chronic toxicity data for three trophic levels, an assessment factor of 10 is used (in accordance with EU guidance). Based on the NOEC for freshwater algae (the most sensitive species), the aquatic PNEC is 0.01 µg/L.
Current Regulatory Controls ⁴	
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. AOs are highly removed by conventional sewage treatment systems and biodegrade rapidly and completely under aerobic and anaerobic conditions.
B/vB criteria fulfilled?	No. BCFWIN predictions using the calculated logKow value of < 2.7 as input parameters (derived for C10-16 AO), calculated bioconcentration factor < 87 for C12-14 AO (The Procter & Gamble Company, 2002C). Thus the potential for bioaccumulation of AOs in aquatic organisms is considered to be low.
T criteria fulfilled?	Yes. Chronic toxicity data < 1 mg/L fish, aquatic invertebrate and/or algae, thus AO does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. OECD (2001) SIDS Initial Assessment Profile for Amine Oxides (AO)

Toxicity Summary - Benzaldehyde

Chemical and Physical Properties ^{1,2,3}	
CAS number	100-52-7
Molecular formula	C ₇ H ₆ O
Molecular weight	106.12
Solubility in water	6.55 g/L at 25°C
Melting point	-26°C
Boiling point	179.2°C
Vapour pressure	0.130 kPa (0.97 mmHg) at 20°C
Henry's law constant	2.85 Pa.m ³ .mol ⁻¹ @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless or yellow liquid with an almond-like odour.
Overview	Benzaldehyde is a colourless liquid that becomes yellowish with age. It smells a little like almond and has a burning, aromatic taste. Benzaldehyde is very soluble in water. Benzaldehyde occurs naturally in plants. It can be formed in the atmosphere from the reaction of some chemicals with sunlight. It has been detected in air associated with volcanoes. Benzaldehyde is an important commercial chemical that is used to make other chemicals. It is also used as a preservative in cosmetics, personal care products, food and select car detailing products. It is used as a solvent for oils, flavouring, and in synthetic perfumes. It may be a tobacco additive. It was formerly used as an insecticide.
Environmental Fate ^{2,3}	
Soil/Water/Air	The test substance is readily biodegradable. The test substance was shown to degrade under influence of light with a DT50 of 9.4 hours. In addition under anaerobic conditions complete biodegradation is expected. As the logKow is 1.4, the potential for bioaccumulation and sorption of the test substance is considered to be low. The Henry Constant was calculated to be 2.85 Pa m³/mol. A calculation with Simple Treat shows that the test substance will degrade in the Sewage Treatment Plant for > 88% with at maximum about 12% to end up in the water compartment.

Human Health Toxicity Summary ¹

Chronic Repeated Dose Toxicity

Based on the data available, the chemical is not considered to cause serious damage to health from repeated oral and inhalation exposure.

In a repeated dose oral toxicity study, Fischer rats (male/female, 10/sex/dose) were administered the chemical by oral gavage at doses of 0, 50, 100, 200, 400 or 800 mg/kg bw/day, five days a week, for 13 weeks. Mortalities and histopathological changes including lesions in the brain (degeneration and necrosis of the cerebellum and necrosis in the hippocampus), renal tubular necrosis, hyperplasia and/or hyperkeratosis of the forestomach, and degeneration of the liver were observed in both sexes at the highest tested dose level. Depressed body weights (26 % lower than controls) were also observed for male rats at this dose. A no observed adverse effect level (NOAEL) of 400 mg/kg bw/day was established (NTP, 1990; OECD, 2002; CIR, 2006; REACH).

A similar repeated dose oral toxicity study on B6C3F1 mice (male/female, 10/sex/dose) was also conducted. The mice were administered the chemical by oral gavage at doses of 0, 75, 150, 300, 600 or 1200 mg/kg bw/day, five days a week, for 13 weeks. Within the first week of dosing, 9/10 males and 1/10 females died at the highest tested dose. Mild to moderate renal tubular degeneration in all males was observed in the high dose group and 1/10 males in the 600 mg/kg/day group. Depressed body weights (9 % lower than controls) were also observed for the males at 600 mg/kg bw/day. The NOAEL was determined to be 300 mg/kg bw/day for male mice and 600 mg/kg bw/day for female mice (NTP, 1990; OECD, 2002; CIR, 2006; REACH).

In another repeated dose oral toxicity study, similar to OECD TG 408, groups of Osborne–Mendel rats (male/female, five/sex/dose) were fed a powdered diet containing the chemical at concentrations of 1000 ppm for 28 weeks, or 10000 ppm (approximately 500 mg/kg bw/day) daily for 16 weeks. No effects on body weight or haematological parameters and no macroscopic/microscopic changes in selected organs were noted at 10000 ppm (CIR, 2006; REACH).

In a repeated dose inhalation toxicity study conducted similarly to OECD TG 412, groups of Sprague Dawley (SD) rats (male/female, 14/sex/dose) were exposed (whole body) to the vapours of the chemical at 0, 500, 750 and 1000 ppm, six hours a day for 14 days. Significant reduction in body weight was observed for all males but only at 1000 ppm for females. Mortalities occurred in the two higher dose groups. All groups exhibited clinical toxicity symptoms including reduced motor activity, hypothermia, respiratory problems and nasal and ocular irritation. With increased concentrations, the severity of nasal and ocular irritation increased. At the two highest doses, the rats displayed aggressive behaviour and central nervous system symptoms (tremors, piloerection, diuresis, seizures and sensitivity to noise). The most prominent histopathological observation was goblet cell metaplasia in the respiratory epithelial lining of the nasal septum, which was found in males at doses 500 and 1000 ppm, but not in females. A no observed adverse effect concentration (NOAEC) could not be determined due to the clinical observations (indicative of neurotoxicity), hypothermia, and goblet cell metaplasia which were seen at concentrations of 500 ppm and above. The lowest observed adverse effect concentration (LOAEC) was reported to be 500 ppm in this study (CIR, 2006; HSDB; REACH).

In another repeated dose inhalation toxicity study with limited documentation (non-guideline), rats were exposed to the chemical at 186 ppm (803 mg/m³), four hours a day, five days a week for two weeks. Respiratory irritation was observed during exposure. No other effects were reported (EC, 2000; OECD 2002).

Carcinogenicity	Although the chemical has been reported to have 'some evidence of carcinogenic activity' in B6C3F1 mice, there was 'no evidence of carcinogenic activity' in Fischer 344 rats receiving 200 or 400 mg/kg bw/day (NTP, 1990). It was further concluded that the increased incidences of pancreatic acinar cell neoplasms in male rats and squamous cell papillomas of the forestomach in mice were probably due to the high concentrations of corn oil (mild irritant and mitogen) used as a vehicle in these studies (US EPA, 2001). The chemical is also considered not to have mutagenic or genotoxic potential (see Genotoxicity). Therefore, the chemical is not considered to have carcinogenic potential. In a combined chronic toxicity–carcinogenicity study (OECD TG 451), groups of eight-week-old Fischer 344 rats (male/female, 50/sex/dose) were administered (gavage) the chemical in corn oil at doses of 200 or 400 mg/kg bw, five days a week for two years. At the highest dose, mortality in male rats was significantly higher than the controls. No dose-related effects on body weight and clinical signs were observed. As squamous cell papillomas of the forestomach were seen in only two female rats in the high dose group and there was a lack of supporting hyperplasia, these were not considered to be due to the administration of the chemical. Significant increases in the incidences of pancreatic acinar cell hyperplasia and tumours were observed in male rats only at the high dose. Unpublished National Toxicology Program (NTP) studies indicated that pancreatic acinar cell tumours found in rats gavaged with corn oil were not autonomous as these tumours failed to transplant. Therefore, based on the facts that these tumours failed to transplant, were present in variable numbers in control animals, and increased only at the high dose, it was concluded that pancreatic acinar cell hyperplasia and tumours were not considered as evidence of carcinogenic activity for the chemical (NTP, 1990; EC, 2000; HSDB; REACH). It was further concluded that the increased incidence of tumours specific to male rats in this study was probably due to the use of corn oil as a vehicle in this study (US EPA, 2001). In the same carcinogenicity study, groups of eight-week-old B6C3F1 mice (male and female, 50/sex/dose) were administered (gavage) the chemical in corn oil at doses of 200 or 400 mg/kg bw (in males), 300 or 600 mg/kg bw (in females), five days a week for two years. Although no significant differences in mean body weights and survival were observed between any groups of mice, effects were noted in the forestomach of mice. The incidences of uncommonly occurring squamous cell papillomas of the forestomach in both exposure groups were significantly greater as compared to the controls (male: vehicle control, 1/50; low dose, 2/50; high dose, 5/50; female: 0/50; 5/50; 6/50). The increased incidences of papillomas were accompanied by significantly increased incidences of focal hyperplasia in the forestomach in both sexes of the 400 mg/kg bw group and in females of the 200 mg/kg bw group, compared with vehicle controls. The NTP considered that the increase in papillomas was due to a concurrent increase in hyperplasia following treatment with the chemical and concluded that there was 'some evidence of carcinogenicity' in mice. It was also concluded male and female mice might have been able to tolerate higher doses (NTP, 1990; REACH).

Mutagenicity/ Genotoxicity	Overall, the data indicate that the chemical has no mutagenic or genotoxic potential. Although there is no mutagenic activity in bacterial systems, the chemical does have weak clastogenic effects in some mammalian cell assays. There are also no in vivo data available. The chemical gave negative results in several in vitro bacterial reverse mutation assays with <i>Salmonella typhimurium</i> at concentrations up to 3333 mg/plate. Induction of chromosomal aberrations was also not observed in Chinese hamster ovary (CHO) cells, treated with the chemical up to 500 mg/mL in the absence of S9 or with up to 1600 µg/mL with S9 (NTP, 1990; REACH). In an in vitro chromosomal aberration assay (OECD TG 473) in the Chinese hamster cell line B241, a significant percentage (13 %; 21/162) of the cells displayed abnormalities following exposure to a concentration of 5.3 nM of the chemical for 24 hours (CIR, 2006). Cytogenetic tests with CHO cells reported an increased number of sister chromatid exchanges at doses of 50 mg/ml and 160 mg/ml in the absence of S9 or at 1600 mg/mL with S9 (NTP, 1990; HSDB; REACH). The chemical gave positive results in a mouse lymphoma forward mutation assay (OECD TG 476) with mouse lymphoma L5178Y cells. The concentrations of the chemical tested in this assay were 0, 50, 100, 200, 400, and 800 mg/mL. Although significant increases in mutant fractions were observed at a dose of 400 mg/mL, the positive response was noted to be close to the cytotoxic dose of 640 mg/ml (HSDB; REACH). Negative results were obtained with the chemicals in an in vivo sex-linked recessive lethal test with <i>Drosophila melanogaster</i> (NTP, 1990; OECD, 2002; HSDB; REACH).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Although limited data are available, the available information indicates that the chemical does not show specific reproductive or developmental toxicity. Benzyl derivatives, including benzaldehyde, have been reported to produce no evidence of reproductive and developmental toxicity during various studies. It was also stated that as benzyl derivatives generally follow similar metabolic pathways, studies conducted on benzyl derivatives provide adequate evidence for benzaldehyde (US EPA, 2001). As part of reviewing the reproductive toxicity and teratogenicity of benzaldehyde and related compounds (benzyl acetate, benzyl alcohol, and benzoic acid and its salts), the Joint Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) Expert Committee on Food Additives concluded that 'delayed development and reduced foetal and postnatal pup body weights were observed in developmental toxicity studies in rats, mice, hamsters and rabbits, but only at doses that were toxic to the mother' (CIR, 2006). In a poorly-documented one-generation reproductive toxicity study (non-guideline), male and female rats were administered the chemical by oral gavage at doses of 0 or 5 mg/kg bw/day in oil, once every second day for 32 weeks. Dosing commenced at 75 days before breeding with untreated males; two pregnancies per rat were studied, one at 75 days and one at 180 days. The number of gestating females, number of live-born offspring, pup weights at birth and on postnatal days 7 and 21, and pup viability were recorded. The incidences of pregnancy were reported to be lower for treated females compared with controls. All other parameters were reported to be similar between the treatment and control groups. It was concluded that the treatment did not cause a significant change in any of the reproductive parameters measured. (US EPA, 2001; OECD, 2002; CIR, 2006; REACH).

Acute Toxicity	In an acute oral toxicity study conducted similar to the Organisation for Economic Co-operation and Development (OECD) Test Guideline (TG) 401, groups of male Wistar rats were administered (by gavage) the chemical at doses of 0.8, 1.0, 1.1, 1.2, 1.3, 1.5, and 1.8 mL/kg bw and observed twice daily for 14 days. The acute median lethal dose (LD50) was reported to be 1.43 mL/kg bw (1430 mg/kg bw), with a mortality rate of 100 % (10/10) at the highest tested dose. Observed sub-lethal effects included sedation, staggering, weight loss and a rough coat (REACH). In another acute oral toxicity study with limited data, male and female rats were administered the chemical at doses of 1100–1540 mg/kg bw. An LD50 of 1300 mg/kg bw was established (OECD, 2002; REACH). Although limited information is available, the chemical is likely to have low acute dermal toxicity in animal tests following dermal exposure. In an acute dermal toxicity study in rabbits with limited available data, an LD50 of >1250 mg/kg bw was reported (OECD, 2002; HSDB; REACH). Although limited data are available, the available information indicates that the chemical has moderate acute toxicity in animal tests following inhalation exposure and is recommended for classification. In an acute inhalation toxicity study conducted according to OECD TG 436, Wistar rats (male/female) were exposed (nose only) to the vapours of the chemical at 1 and 5 mg/L for four hours and observed up to 14 days. Clinical effects were observed in most animals following exposure at 5 mg/L including lethargy, flat/hunched postures, ventrolateral recumbency, respiratory difficulties and piloerection. Four animals out of six (one male and three females) died following exposure at 5 mg/L. A median lethal concentration (LC50) of <5mg/L was established, based on mortalities at the highest tested dose (REACH). An increased incidence of respiratory symptoms was noted among workers exposed to vapour of the chemical at atmospheric concentrations of >5 mg/m³ (OECD, 2002).
Irritation	Although limited data are available, the available information indicates that the chemical is not likely to be a skin irritant. In two skin irritation studies (non-guideline) with limited data, the undiluted chemical (500 mg) was applied to the intact or abraded skin of New Zealand White rabbits for 24 hours with observation up to seven days. Although the exact details were not provided, slight skin irritation was observed (EC, 2000). Although limited data are available, the chemical had been reported to be an eye irritant in animal studies. The available information is not sufficient to support a classification. In an eye irritation study (non-guideline), one drop of the undiluted chemical was applied to the conjunctival sac of a rabbit. Observations were made at one, 24 and 48 hours following application. Immediate irritation effects were noted at one hour and within 24 hours, the anterior portion of the cornea was damaged. The cornea was cleared within 48 hours and only erythema of the conjunctiva and nictitating membrane was noted at this stage. Although the rabbit died on the sixth day, the death was not related to the application of the chemical (CIR, 2006; REACH). In another eye irritation study (non-guideline) with limited data, the chemical (100 µL, concentration not stated) was instilled into the eyes of two rabbits and observed for seven days. The chemical was observed to be slightly irritating to the eyes (REACH).

Sensitisation	Although the chemical has produced skin sensitisation reactions in some tests, based on the weight of evidence, the chemical is not likely to be a skin sensitiser. It is also noted that the chemical is rapidly metabolised to benzoic acid in the skin. Clinical reports of allergy to the chemical are rare and benzoic acid has also been reported not to produce sensitisation in clinical trials in humans (CIR, 2006). In a Magnusson-Kligman skin sensitisation test conducted by the US EPA, guinea pigs (10/group) were initially exposed to the chemical intradermally by a 0.1 mL injection of 3 % chemical in paraffin oil followed by topical application to a patch of skin (occluded for 48 hours) of 15 % chemical in petrolatum. The skin was later challenged by a topical application (occluded for 24 hours) of 7 % chemical in petrolatum on a patch of skin. As the chemical failed to induce erythema in either group, the chemical was concluded not to be a skin sensitiser (CIR, 2006). In a skin sensitisation study that compared four testing methods of 32 fragrance materials on Himalayan guinea pigs, the chemical tested positive for allergenicity in the Draize test (DT), the maximisation test (MT) and Freund's complete adjuvant (FCA) test. The guinea pigs were injected intradermally with the chemical at doses of 0.05 mL (0.1 % solution), 0.1 mL (5 % solution) and 0.05 mL (undiluted) for DT, MT and FCA, respectively (EC, 2000; CIR, 2006; REACH). The chemical was reported to be non-sensitising in the open epicutaneous test (OET) for the same study as reported above. The guinea pigs were exposed to the chemical (undiluted, 0.03, 0.1, 0.3, 1, 3, 10, or 30 %) at a dose of 0.1 mL on an 8 cm² area of shaved skin on the flank. Applications were repeated once a day for 21 days and the sites were scored for signs of irritation 24 hours following each treatment. The acute minimum irritating concentration was 10 % and after 21 exposures was 3 %. The animals were challenged with 3 % (minimum irritating concentration for day 21) or an unspecified lower concentration on a 2 cm² area of shaved skin at two weeks post-exposure. The sites were scored at 24, 48 and 72 hours. No sensitisation effects were observed (CIR, 2006; REACH). In a guinea pig skin maximisation test (OECD TG 406), animals were injected intradermally with 2.7 % of the chemical and followed by three epidermal challenges with 2.1, 2.1 and 0.64 % of the chemical. It was noted that only one intradermal induction was performed and no additional topical induction. Also, there were three challenge reactions instead of one. The time between induction and challenge applications was also not stated. No sensitisation effects were observed (REACH).
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity from oral and inhalation exposure).
Key Study/Critical Effect for Screening Criteria	The chemical has been reported to possibly cause respiratory failure, depression of the CNS and convulsions at high concentrations (HSDB). A young woman died after ingesting 50–60 ml (700–2000 mg/kg) of the chemical. At autopsy, yellowish-white pulp with a strong odour of bitter almond was found in the stomach. The time between consumption and death was not specified. In another case, a man had to be revived from near death following ingestion of 40 ml of a derivative of the chemical (o-hydroxybenzaldehyde). Based on these two studies, a lethal oral dose of 600–900 mg/kg bw was calculated for the chemical in the absence of prompt treatment (NTP, 1990; EC, 2000; CIR, 2006). In a case study, workers exposed to vapour of the chemical at atmospheric concentrations of >5 mg/m³ reported an increased incidence of respiratory symptoms (OECD, 2002). In an inhalation toxicity study, human volunteers were exposed to 4.5 ppm (19.5 mg/m³) of the chemical for one minute. Irritation of the eyes and upper respiratory tract were observed. In an occupational study, workers exposed to the chemical vapour at atmospheric concentrations of >5 mg/m³ reported symptoms of slight eye irritation and considerable skin irritation (OECD, 2002).

Ecological Toxicity ^{2,3}	
Aquatic Toxicity	Acute LC50 for freshwater fish is 1.07 mg/L, freshwater invertebrates is 16.2 mg/L and EC10 for freshwater algae is 20 mg/L. Chronic NOEC for freshwater fish is 0.12 mg/L. The overall acute dataset on aquatic organisms yields a lowest LC50 value for fish of 1.07 mg/L and a NOEC of 0.12 mg/L. However, the substance is readily biodegradable and has a low potential for bioaccumulation. Based on the second ATP to CLP the test substance was classified as Chronic category 3 for aquatic toxicity.
Determination of PNEC aquatic	Ecotoxicological data indicate that benzaldehyde is acutely toxic to fish, harmful to daphnia and very slightly toxic to algae. Using an uncertainty factor of 100 on the lowest LC50 to fish a PNEC (Predicted No Effect Concentration) of 10.7 ug/L is calculated, for aquatic organisms.
Current Regulatory Controls ¹	
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): Harmful if swallowed, Xn; R22 (Acute toxicity)
Australian Occupational Exposure Standards	No specific exposure standards are available.
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica). The chemical has an exposure standard of 5 mg/m³ time weighted average (TWA) in Bulgaria, Hungary, Latvia and Russia; 10 mg/m³ in Poland; and 2 ppm in the USA. Short-term exposure limits (STEL) of 4 ppm in the USA and Canada; 10 mg/m³ in Hungary; and 40 mg/m³ in Poland have been reported.
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. Expected to be readily biodegradable.
B/vB criteria fulfilled?	No. As the Log Pow is 1.4 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	No. The chronic aquatic toxicity of the chemical is > 0.01 mg/L. Hence the substance does not fulfil 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 Benzaldehyde: Retrieved 2019: <https://www.nicnas.gov.au>
2. ECHA REACH, Benzaldehyde, Retrieved 2019: <https://echa.europa.eu/>
3. OECD (2002) SIDS Initial Assessment Profile for Benzaldehyde

Toxicity Summary - Butyl alcohol

Chemical and Physical Properties ^{1,2,3}	
CAS number	71-36-3
Molecular formula	C ₄ H ₁₀ O
Molecular weight	74.12
Solubility in water	77 g/l at 20 °C
Melting point	-89.9 °C
Boiling point	117.6 °C
Vapour pressure	0.56 kPa at 20 °C
Henry's law constant	0.054 Pa m ³ /mol
Explosive potential	Non-explosive
Flammability potential	Flammable
Colour/Form	Colourless liquid with a mildly alcoholic odour.
Overview	n-Butyl alcohol is used as a solvent in surface coatings. These can include varnishes, resins, waxes and gums. It is also used in the manufacture of other butyl compounds. n-Butyl alcohol is a product of fermentation. It has also been detected in the volatiles of foods such as cheese, muskmelon and cooked rice. People that work in industries where products containing n-butyl alcohol are used will have the highest exposure. These could include varnishing of automobiles, painting shops and fabric coating. Exposure will happen by eating foods containing n-butyl alcohol and breathing in fumes from cooking certain foods. n-Butyl alcohol can be found in surface water and air. It is often found in indoor air of new construction. It breaks down in air by reaction with radicals. It is expected to evaporate from soil and water surfaces. n-Butyl alcohol that remains in soil or water will be broken down by microorganisms. It is not expected to build up in aquatic organisms.
Environmental Fate ¹	
Soil/Water/Air	Based on level III fugacity modelling, BA will partition 83.5% in air, 5.9% in soil, 10.6% in water, <0.1% in suspended solids, and <0.1% in biota and in sediment. BA degrades in air by reaction with hydroxyl radicals, having a half-life in air of 1.2 to 2.3 days. The volatilization half-life for BA in water is estimated to be 2.4 hours for streams, 3.9 hours for rivers and 126 days for lakes.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	A no observed adverse effect level (NOAEL) of 125 mg/kg bw/day and a lowest observed adverse effect level (LOAEL) of 500 mg/kg bw/day in male and female CD rats was reported based on results from a repeat dose oral study using the chemical (OECD 2001). Groups of male and female rats (30/sex/group) were administered the chemical via gavage at 0, 30, 125 or 500 mg/kg/day for 13 weeks. It was reported that ataxia (impaired muscle coordination) and hypoactivity were observed at the highest dose during the final six weeks of the study. No treatment related effects were reported in the 30 and 125 mg/kg/ bw/day dose groups (OECD 2001). In a non-guideline study, the chemical was applied to the skin of rabbits under occlusive conditions over a period of 21 days. Local effects were reported such as drying of the skin, cracking, wrinkling and exfoliation of the epidermis. However, no systemic toxicity was reported (REACH). In another non-guideline repeat dose dermal study on rabbits, 42 to 55 mL/kg of the chemical applied to the skin of rabbits over four consecutive days resulted in 100 % mortality. However, the same study reported that 30 applications of 20 mL/kg of the chemical over six weeks did not produce any deaths (OECD 2001).

Carcinogenicity	OECD (2001) reported that based on the number of negative mutagenicity and clastogenicity findings, the chemical is not expected to be a carcinogen. A weight of evidence study reported that the chemical is not expected to have carcinogenic potential as it does not contain structural components to support carcinogenicity (REACH, HSDB).
Mutagenicity/ Genotoxicity	The chemical is not expected to be genotoxic. The chemical tested negative in a number of tests for genotoxicity. These included several in vitro tests (OECD Guideline 473: mammalian chromosome aberration test on Chinese hamster lung fibroblasts V79; OECD Guideline 471: bacterial reverse mutation assay on <i>S. typhimurium</i> TA 98, TA 100, TA 98, TA 1535 and TA 1537; OECD Guideline 476: mammalian cell gene mutation test on Chinese hamster lung fibroblasts V79) and in vivo tests (OECD Guideline 474: mouse micronucleus) (OECD 2001, REACH).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The chemical is not expected to be toxic to reproduction (OECD 2001). In a non-guideline study, male and female Sprague Dawley (SD) rats were exposed to the chemical via inhalation at 0, 3000 or 6000 ppm for seven hours/day. Female rats were exposed to the chemical throughout gestation, while males were exposed to the chemical for six weeks prior to mating. No harmful effects on fertility or pregnancy rate were reported at any of the dose levels. In another non-guideline study, no testicular toxicity (effect on testes weight or histopathology) was reported in SD male rats that were administered the chemical via oral intubation at 533 mg/kg bw/day over six days (OECD 2001). Any developmental effects were only reported to be observed secondary to maternal toxicity, so the chemical is not expected to be a developmental toxin. OECD (2001) reported that the chemical showed mild foetotoxicity and developmental variations in offspring only at or near the maternally toxic and, in some cases, lethal dose of 8000 ppm. Offspring of female SD rats exposed via inhalation to 0, 3500, 6000 or 8000 ppm of the chemical on gestations days 1 to 19, reported a reduction of foetal weights at 6000 and 8000 ppm and a slight increase in skeletal malformations at 8000 ppm but not at the lower dosage levels. At a maternally toxic dose of 8000 ppm, decreased weight gain, food consumption and dam deaths were reported. The NOAEL for offspring and dams was 3500 ppm as there was a slight decrease in foetal weight at the 6000 ppm dose level. In another 20 day study in male and female SD rats exposed to 0, 3000 or 6000 ppm of the chemical via inhalation, a small number of behavioural and neurochemical variations in offspring at 6000 ppm were reported. No maternal toxicity was reported throughout gestation for females or for six weeks prior to mating for males as a result of maternal or paternal exposure. However, the effects observed in offspring were not regarded as biologically significant by the authors due to inconsistencies between dose-response patterns.
Acute Toxicity	The chemical is reported to be slightly acutely toxic via the oral route of exposure. Oral median lethal doses (LD50s) in rats were reported between 790 and 4360 mg/kg bw (OECD 2001). The chemical is reported to have low toxicity via the dermal route of exposure. The lowest LD50 in rabbits was reported to be 3402 mg/kg bw (OECD 2001). The chemical is reported to be of low acute toxicity via the inhalation route of exposure. The median lethal concentration (LC50) in rats was reported to be greater than 5000 ppm (OECD 2001).

Irritation	Based on an inhalation study in mice, it was reported that 1268 ppm (3909 mg/ m³) of the chemical was predicted to be intolerable in humans, 127 ppm (390.9 mg/ m³) would be uncomfortable in humans and 13 ppm (40 mg/ m³) was expected to have no effect on humans (OECD 2001). Moderate irritation was reported in a 24 hour patch test (non-guideline study) where 405 or 500 mg of the chemical was applied to the skin of the rabbits. It was reported that these effects may be due to the chemical's defatting (chemical dissolving of dermal lipids from the skin) and drying characteristics (OECD 2001). Another non-guideline study reported the chemical was a skin irritant in several Vienna white rabbits exposed to 0.5 mL of the chemical for five minutes, one hour or two hours under occlusive conditions. The animals were observed for eight days. The authors concluded that exposure for two hours under occlusive conditions resulted in higher Draize scores and observed superficial necrosis (death of tissue). However, there was no full thickness destruction of the skin (REACH). The chemical was reported to be a severe eye irritant when tested according to OECD Test Guideline (TG) 405 using 0.1 mL of the chemical applied to three New Zealand white rabbits. Severe ocular lesions were present at the end of the seven day observation period, indicating severe eye damage and irreversible effects on the eye (REACH). The chemical was reported to be a severe eye irritant in rabbits in non-guideline studies where 1.62 or 20 mg of the chemical was applied into rabbit eyes over a 24 or 72 hour period (OECD 2001). An additional non-guideline study reported severe corneal irritation when 0.005 mL of the chemical was applied into rabbit eyes.
Sensitisation	Based on available repeat dose dermal studies, the chemical is not expected to be a skin sensitiser. OECD (2001) reported that human studies and experience show that the chemical is not likely to be a skin sensitiser.
Health Effects Summary	The critical health effects for risk characterisation include local effects (serious damage to the eyes and respiratory irritation). The chemical also possesses hazardous properties such as skin irritation, harm if ingested and chemical vapours causing drowsiness and dizziness.
Key Study/Critical Effect for Screening Criteria	n-Butyl alcohol was only slightly toxic to experimental animals following acute oral, dermal, or inhalation exposure. The acute oral LD50 values for female rats ranged from 790 to 4360 mg/kg.
Ecological Toxicity³	
Aquatic Toxicity	Results on acute aquatic toxicity are available for fish (Pimephales promelas, LC50 (96h) 1376 mg/l), invertebrates (Daphnia magna, EC50 (48h) 1328 mg/L), and algae (Selenastrum capricornutum, EC50 (96h) 225 mg/L). EC10 (17h) as determined for Pseudomonas putida was 2476 mg/L. Furthermore, based on the chronic NOECrepro (21d) of 4.1 mg/L for Daphnia magna butan-1-ol is very likely not harmful to aquatic organisms. Thus, no adverse effects were observed.
Determination of PNEC aquatic	A PNECaqua = 0.082 mg/L can be calculated based on the lowest chronic toxicity value (21 day NOEC = 4.1 mg/L) for aquatic invertebrates (Daphnia) with the assessment factor of 50.
Current Regulatory Controls⁴	
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 (Harmful if swallowed) Xi; R37/38-41 (Irritating to respiratory system and skin. Risk of serious damage to eyes) R67 (Vapours may cause drowsiness and dizziness)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 152 mg/m ³ (50 ppm) Peak limitation Time Weighted Average (Ceiling TWA).

International Occupational Exposure Standards	The following exposure standards were identified (Galleria Chemica): Ceiling TWA: 150- 152 mg/m³ (50 ppm). India, Indonesia, Japan (OEL), Malaysia and USA [National Institute for Occupational Safety and Health (NIOSH)]. Ceiling TWA: 90 mg/m³ (30 ppm). Canada (British Colombia), Estonia, Russia and Sweden. TWA: 150- 154 mg/m³ (50 ppm). Canada (Yukon), Chile, Denmark, Egypt, Iceland, Poland and Switzerland. TWA: 300- 310 mg/m³ (100 ppm). Germany, Greece, Taiwan and USA [Occupational Safety and Health Administration (OSHA)]. TWA: 45- 75 mg/m³ (15-25 ppm). Canada (Alberta, British Colombia, Saskatchewan), Estonia, Hungary, Ireland, Japan [Workplace Exposure Standards (WES) and Working Environment Evaluation Standards (WEES)], Norway and Sweden.
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. n-Butanol is considered readily biodegradable.
B/vB criteria fulfilled?	No. Due to the low log Pow (1.0), accumulation in organisms is not to be expected.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus butyl alcohol does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. NICNAS (2017) Human Health Tier II Assessment for 1-Butanol: Retrieved 2019: <https://www.nicnas.gov.au>
2. OECD (2005) SIDS Initial Assessment Profile on 1-Butanol
3. ECHA REACH, 1-Butanol, Retrieved 2019: <https://echa.europa.eu/>

Toxicity Summary - Chlorous acid, sodium salt

Chemical and Physical Properties ^{1,2,3}	
CAS number	7758-19-2
Molecular formula	ClHO ₂ .Na
Molecular weight	90.4
Solubility in water	571 g/L at 20 °C
Melting point	234 °C
Boiling point	Decomposes > 170 °C. Poor purity of test substance, accurate value cannot be obtained.
Vapour pressure	1.1 x 10 ⁻⁷ Pa at 25°C
Henry's law constant	No data available.
Explosive potential	At normal temperature and pressure, the natural form of chlorine dioxide is unstable, highly reactive (an oxidizing agent) and explosive. It is explosive when its concentration in air exceeds 10% v/v when it is easily detonated by sunlight, heat, contact with mercury or carbon monoxide (O'Neil et al. 2001).
Flammability potential	Non-flammable
Colour/Form	White crystals or crystalline powder, odourless
Overview	The commercial production of sodium chlorite is carried out in two steps: firstly, sodium chlorate is reacted with an acid to generate chlorine dioxide (gas) and secondly, chlorine dioxide is reacted with caustic soda, catalysed by hydrogen peroxide, to form sodium chlorite. The industrial product formed is a solution of 34.5%; the commercial grade is obtained by dilution with water. Chlorine dioxide may also be produced from sodium chlorate. The total amount of sodium chlorite (as 100%) sold on average in the EU Member States (15) for the years 1998-2000 was 11 800 tonnes per year. This includes use as preservatives for liquid cooling and processing systems; food and feed area disinfectants; food or feedstocks; molluscicides; and slimicides and other non-defined biocidal use. The estimated annual total consumption of sodium chlorite in Japan is 4000 tonnes.
Environmental Fate ²	
Soil/Water/Air	Irradiation of sodium chlorite solutions indicated a photodegradation half-life of about 30 minutes with a steady increase in pH (pH 8 to 12.6) and major products identified as hydroxide, chlorine dioxide and chloride with chlorate and hypochlorite as minor products and trace amounts of chlorine. The radiation dose (9000 J/m²) needed to produce a 50% reduction in chlorite concentration suggests that the doses (200-250 J/m²) used for drinking water disinfection would not result in a significant reduction in chlorite concentrations (Cosson and Ernst, 1994; Leitner et al., 1992). It is not considered technically appropriate to perform a ready biodegradation test on sodium chlorite. As ready biodegradation studies measure oxygen consumption or carbon dioxide production, none of these techniques can be used to analyse mineralization of this compound. However, sodium chlorite is expected to be rapidly reduced to sodium chloride in the environment, especially in anaerobic conditions. Due to its extremely low lipophilicity and high instability in water, sodium chlorite and hence chlorine dioxide are not expected to bioaccumulate in fish.

Human Health Toxicity Summary^{1,2}

Chronic Repeated Dose Toxicity

In a study used by the World Health Organization (WHO) to establish a drinking water guideline for chlorite in 1993, rats were administered sodium chlorite at doses of 0, 10, 50, 100, 250 and 500 mg/L (equivalent to 0, 1, 5, 10, 25 and 50 mg/kg bw/day) via drinking water for 30, 60 or 90 days (Heffernan et al. 1979). After 30 days, haematological parameters were depressed indicating slight anaemia at 10 and 25 mg/kg bw/day. These were correcting at 60 days and returned to near normal levels by 90 days. Decreases in erythrocyte glutathione levels were observed at 5 mg/kg bw/day and above, but given the magnitude of variations normally seen in mammals, the toxicological significance of these changes was uncertain. The No Observed Adverse Effect Level (NOAEL) established from this study was 5 mg/kg bw/day.

In a 14-day range finding study conducted to OECD TG 407, rats were administered sodium chlorite daily by gavage at doses of 0, 25, 50, 100 or 200 mg/kg bw day (CMA 1992a; Harrington et al. 1995a). At 200 mg/kg bw/day, 3 of 10 animals died. At 100 mg/kg bw/day, changes in haematological parameters were seen and body weight gains were reduced. At 50 mg/kg bw/day, body weights in males were reduced and at both 25 and 50 mg/kg bw/day haematocrits were slightly reduced.

A follow-up 90-day study was performed in which rats were administered sodium chlorite daily by gavage at doses of 0, 10, 25 or 80 mg/kg bw day (CMA 1992b; Harrington et al. 1995a). At 80 mg/kg bw/day, four of 30 animals died and surviving animals displayed hypoactivity, piloerection and hunched posture. At 25 mg/kg bw/day, one of 30 animals died. Increased salivation was observed at both doses. Treatment-related haematological changes consisting of reduced erythrocyte counts, reduced associated erythrocyte parameters and morphological changes in erythrocytes were observed at 80 mg/kg bw/day. These were accompanied by increases in absolute and relative spleen weights, histopathological abnormalities in the spleen and evidence of irritation of the gastric mucosa. At 25 mg/kg bw/day, minor clinical signs and occasional histopathological abnormalities in the stomach mucosa were seen. There were no haematological changes considered treatment related at this dose. A NOAEL was established at 10 mg/kg bw/day.

Data on repeat dose toxicity were also available from a two-generation reproductive toxicity study in rats conducted to OECD TG 416 (Chlorine Dioxide Panel of the Chemical Manufacturers Association 1996; Gill et al. 2000). This study was used by the WHO to revise an earlier drinking water quality guideline for chlorite and chlorate (WHO 2005). A NOAEL of 35 ppm (approximately 3.9 mg/kg bw/day) was derived based on decreased liver weights in two generations.

Repeated dose toxicity studies have also been performed in mice. Mice were treated for 30 days with doses equivalent to 0, 0.19, 1.9 and 19 mg/kg bw/day sodium chlorite in drinking water (Moore and Calabrese 1980). Slight changes in haematological parameters suggestive of effects on erythrocyte cell membranes were seen at 19 mg/kg bw/day. A NOAEL of 1.9 mg/kg bw day was established.

Similarly, in more limited studies, mice were administered sodium chlorite in drinking water at doses up to approximately 17 mg/kg bw/day for 30, 90 or 180 days. No effects on water consumption, body weight gain, kidney weights or kidney histology were seen (Connor et al. 1985). Also, no dose-related immunomodulatory effects were seen in a study of immunotoxicity in mice receiving sodium chlorite in drinking water at levels up to 30 mg/L for 28 days (Karrow et al. 2001).

In conclusion, several rodent studies of 30 to 90 days' duration have reported haemotoxicity from repeated doses of sodium chlorite. A guideline 90-day repeated dose toxicity study in rats reported reduced erythrocyte counts, reduced associated erythrocyte parameters and morphological changes in erythrocytes at 80 mg/kg bw/day. At lower doses, minor clinical signs and occasional histopathological abnormalities in the stomach mucosa were seen. A NOAEL for repeated dose oral toxicity was established from this 90-day study at 10 mg/kg bw/day.

Carcinogenicity	A limited number of carcinogenicity studies indicated that sodium chlorite is not carcinogenic in laboratory animals. In an oral carcinogenicity study conducted similarly to OECD TG 451, groups of 50 male and 50 female rats were exposed to sodium chlorite in drinking water at concentrations of 0, 300 or 600 mg/L (estimated to be 0, 18 or 32 mg/kg bw/day for males and 0, 28 or 41 mg/kg bw/day for females) for 85 weeks. The original study envisaged an exposure period of 104 weeks, but was stopped at 85 weeks due to infections in all groups. At this time there were no significant changes in organ weights and haematological or clinical chemistry findings between groups. Tumours developed in the testis, uterus, pituitary gland, thyroid gland (males) and adrenal gland (males) of both treated and control rats. However, the incidences of tumours and non-neoplastic lesions in the three groups were not significantly different. There were no findings suggestive of a carcinogenic effect of sodium chlorite (Shimoyama et al., 1985). In another oral carcinogenicity study conducted similarly to OECD TG 451, groups of 50 male and 50 female B6C3F1 mice were exposed to sodium chlorite in drinking water at concentrations of 0, 250 or 500 mg/L (estimated to be 0, 36 and 71 mg/kg bw/day) for 85 weeks (Yokose et al., 1987). After 85 weeks, surviving animals were euthanised and histopathological examinations were performed. Although tumours developed in a variety of organs in all animals including controls, the only significant change was an increase in lung adenomas in highest dose males: 5/43 (12 %) in this group, compared with 0/35 (0 %) in the control group. Based on an absence of dose-related increases in the incidence of lung adenomas and the lack of increased incidence of lung adenocarcinomas, the authors concluded that sodium chlorite had no carcinogenic potential.
Mutagenicity/ Genotoxicity	Sodium chlorite is not mutagenic or genotoxic. In vitro genotoxicity test results for sodium chlorite are not available. In the three in vivo tests that looked at chromosomal damage or sperm head abnormality, sodium chlorite gave negative results for genotoxicity (Meier et al., 1985). In vitro tests using chlorine dioxide have been reported in the literature. Chlorite (and chlorate) ions are produced following dissolution of chlorine dioxide in aqueous media. Therefore, in vitro test results for chlorine dioxide are regarded as relevant to sodium chlorite. Two of the three in vitro tests, the mouse lymphoma forward mutation assay and in vitro transformation of BALB/3T3 cells, were negative for chlorine dioxide, whereas the chromosome aberration frequencies test in Chinese hamster ovary cells was positive (Scopas, 1986a, Scopas, 1986b and Scopas, 1986c). Across all available studies, data suggest that sodium chlorite (and chlorine dioxide) has low genotoxic potential.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on a series of studies of fertility and sperm parameters in rats, sodium chlorite is not considered to be toxic to the reproductive system. Studies in rats and rabbits did not show any effect of sodium chlorite on development. In a rabbit study conducted according to US EPA guidelines, sodium chlorite was administered via drinking water to groups of 16 pregnant New Zealand White rabbits at concentrations of 0, 200, 600 or 1200 mg/L during gestation days (GD) 7–19 (Harrington et al., 1995b). At 600 and 1200 mg/L, dose-related reductions in water consumption (due to palatability problems), food consumption and body weight gain were observed. No treatment-related abnormalities were observed at maternal necropsy. Overall, data indicate that sodium chlorite does not cause developmental toxicity at doses below those associated with maternal toxicity. In a two-generation reproduction study in rats conducted according to OECD TG 416 (Gill et al. 2000), groups of 30 male and 30 female Sprague-Dawley rats were administered sodium chlorite via drinking water at doses of 0, 35, 70 or 300 ppm (approximately 0, 4, 7.6 or 28.2 mg/kg bw/day for males and 0, 3.9, 8 and 38.7 mg/kg bw/day for females) (Chlorine Dioxide Panel of the Chemical Manufacturers Association 1996; Gill et al. 2000). Dosing was conducted in the parental F0 generation commencing 10 weeks prior to mating, until weaning of the F2 generation. Males were exposed through mating and then sacrificed. Females were exposed through mating, pregnancy and lactation and were sacrificed following weaning of litters. F1 pups were continued on the same treatment regime as the parents. At 14 weeks they were mated to produce the F2 generation. Reductions in food and water consumption and body weight gain were observed for all generations, attributed to unpalatability of the formulated drinking water. At 35 and 70 ppm, minor reductions in several haematological parameters were observed in F1 female pups. These appeared within the range of historical control data and were not regarded as toxicologically significant. At 70 ppm, a reduction in liver weight was also observed in F0 females and F1 males and females. A slight decrease in the maximum response to auditory startle stimulus was also observed in F2 pups. At 300 ppm, reductions in haematological parameters were seen in F1 male and female pups and adults. Reduced liver weights were seen in F0 adult males, F1 adult males and females and F1 pups. Reduced thymus and spleen weights were also seen in both generations. A slight decrease in absolute brain weight was seen in F1 male pups at post-natal day (PND) 11 but not at PND 25. In F2 pups at this dose, there was a slightly lowered incidence of normal righting reflexes and a slight decrease in the maximum response to auditory startle stimulus. Reduced pup body weight at birth and during lactation in F1 and F2 generations were also observed. Delays in preputial separation and vaginal openings were reported for F1 pups. Despite systemic toxicity, the authors reported no treatment-related changes to oestrous cyclicity, sperm motility, sperm morphology, or mating, fertility or gestational indices. Also, there were no treatment-related changes in number of pups born, sex ratios, live birth index or pup survival indices. There were no treatment-related changes in serum T3 or T4 in F1 pups or F1 adults. On the basis of historical data, delays in preputial separation and vaginal openings reported for F1 pups were attributed to reduced body weight rather than a direct treatment-related effect. Similarly, slight decreases in brain weight in male pups were consistent with decreased body weight. The toxicological significance of decreases in auditory startle stimulus response at 70 and 300 ppm was unclear. The magnitude of responses was small compared to known neuroactive chemicals, dose response to the stimulus was weak, there was a lack of corroborative evidence from neuropathology or other test of motor function or arousal, and the decreases in response were not replicated upon later examination of the same animals at PND 60 (Gill et al. 2000). A NOAEL of 35 ppm (approximately 3.9 mg/kg bw/day) with a LOAEL at 70 ppm (approximately 7.6 mg/kg bw/day) were derived based on decreased liver weights.

Acute Toxicity	Sodium chlorite has moderate acute oral toxicity. An acute oral toxicity study in rats, similar to OECD Test Guideline TG 401, derived a lethal median dose (LD50) of 284 mg/kg bw for sodium chlorite. At doses of 250 mg/kg bw and above, the main clinical signs were prostration and cyanosis (Atochem, 1984). Sodium chlorite has high acute dermal toxicity. In a dermal toxicity study in rabbits, conducted according to US EPA test guidelines, various doses of an aqueous slurry (80 %) of sodium chlorite were administered under semi-occlusive dressings to over 10 % of the body surface area for 24 hours. Animals were observed for clinical signs immediately after dosing, at one and four hours and then once daily for 14 days following exposure. Slight depression and dose-related dermal irritation consisting of skin thickening, epidermal scaling, necrosis and sloughing were noted in all animals. The study reported a dermal LD50 of 134 mg/kg bw (Degussa Corporation, 1984).
Irritation	Sodium chlorite is a severe skin irritant. Necrosis was observed in rabbits in the skin irritation studies. In one skin irritation study conducted according to US EPA test guidelines, 0.5 g sodium chlorite powder (80 % pure) was applied to three male and three female New Zealand White rabbits under occlusive conditions for four hours. Dermal responses were assessed at 30–60 minutes on day one, and once daily for 21 days after application. Irritation consisted of erythema (grades 1–3) in all sites at 30–60 minutes and 24 hours after dosing, persisting through day seven at two sites. Oedema (grade one) was observed at one site at 30–60 minutes and at two sites at 48 hours. Other dermal effects included blanching, thickening, necrosis, sloughing, and blackened areas (REACH, 2014). In another study in rabbits, edema cutis and subcutis were observed immediately after patch removal followed by formation of eschar within 24–48h. Dose and other details of the test were not provided (REACH, 2014) A 34.5 % solution of sodium chlorite, applied to rabbit skin for four hours under semi-occlusive conditions, did not elicit any irritation effects. Only one of three animals displayed slight erythema and dryness of the skin (Elf Atochem SA, 1994). In the only eye irritation study available and conducted according to US EPA test guidelines, sodium chlorite was found to be a severe eye irritant. A 31.5 % sodium chlorite solution was applied to the eyes of rabbits. Six of the nine rabbits showed corneal opacity that did not reverse by rinsing the eyes 30 seconds after instillation. All animals showed iris damage and exhibited moderate to severe redness and chemosis which was also not abolished by rinsing. Superficial corneal vascularisation and transient cases of haemorrhaging and adhesion of conjunctivae to cornea were also seen (Atochem, 1985).
Sensitisation	Sodium chlorite is not considered to be a skin sensitiser. A guinea pig maximisation test conducted according to OECD TG 406 reported no clinical signs and no cutaneous reactions upon a challenge application of 1 % sodium chlorite in normal saline. Sodium chlorite was concluded not to be a skin sensitiser (CEFIC sodium chlorite sector group, 2002).
Health Effects Summary	The critical health effects for risk characterisation include acute effects from oral and dermal exposure, and severe skin and eye irritation and repeated dose toxicity from oral exposure.
Key Study/Critical Effect for Screening Criteria	A guideline two-generation reproductive toxicity study in rats also reported haemotoxicity, as well as hepatotoxicity and slight neurobehavioural changes at doses below those associated with no effects in repeated dose studies. The study reported no effects on fertility or development. Accordingly, a NOAEL for hepatotoxicity was established from this 2- generation study at 3.9 mg/kg bw/day. The LOAEL was approximately 7.6 mg/kg bw/day. This NOAEL is used for this human health risk assessment.
Ecological Toxicity ²	

Aquatic Toxicity	Sodium chlorite, in general, shows low acute toxicity to fish with LC50 values above 100 mg/l for zebrafish, sheepshead minnow and rainbow trout and slightly lower for bluegill sunfish. Due to extremely low lipophilicity and high instability in water, sodium chlorite is not expected to bioaccumulate in fish. Sodium chlorite is more toxic to invertebrates with high toxicity to <i>Daphnia magna</i> (sodium chlorite, LC50 48-hour = 0.063 mg/l) and the crustacean, <i>Mysidopsis bahia</i> (sodium chlorite LC50 96-hour = 0.65 mg/l). However, the mollusc, <i>Crassostrea virginica</i> was much less sensitive (sodium chlorite 96 hours NOEC was 70.6 mg/l and the EC50 (shell growth) was 129 mg/l). The green algae were more sensitive to sodium chlorite than fish or oyster and toxicity increased with time (ECr50 value at 72 hours was recorded as 1.2 mg/l).
Determination of PNEC aquatic	Using an uncertainty factor of 100 on the lowest LC50 to <i>Daphnia</i> a PNEC (Predicted No Effect Concentration) of 0.63 ug/L is calculated, for aquatic organisms.
Current Regulatory Controls¹	
Australian Hazard Classification	The chemical is not listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Australian Occupational Exposure Standards	There is no specific exposure standard for sodium chlorite. However, the permissible exposure limits for dusts apply: · Time Weighted Average (TWA): 10 mg/m³ measured as inspirable dust.
International Occupational Exposure Standards	There are no specific exposure standards for sodium chlorite. However, the following exposure standards for particulates are identified (Galleria Chemica 2013). TWA: · 10 mg/m³ [Canada, Ireland, Spain] · 5 mg/m³ [US] · 1 mg/m³ [Latvia].
Australian Food Standards	Sodium chlorite has the following listings in the Australia New Zealand Food Standards Code – Standard 1.3.3 Processing Aids (Food Standards Australia and New Zealand 2013): · As a permitted bleaching agent, washing and peeling agent (maximum level 1 mg/kg available chlorine) · As a permitted processing aid with miscellaneous functions (anti-microbial agent for meat, fish, fruit and vegetables; maximum level is the limit of determination for chlorite, chlorate, chlorous acid and chlorine dioxide).
Australian Drinking Water Guidelines	The National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines lists chlorite under microbial, chemical and physical characteristics as a by-product of chlorine dioxide disinfection. The guideline value for chlorite based on health considerations is 0.8 mg/L (NHMRC 2011).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment³	
P/vP Criteria fulfilled?	No. Not expected to be persistent due to its instability.
B/vB criteria fulfilled?	No. There is no concern for potential bioaccumulation from chlorine chlorite.
T criteria fulfilled?	Yes. Acutely toxic to aquatic invertebrates.
Overall conclusion	Not PBT
Revised	January 2019

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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
Henry's 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 α,β-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 sternalbrae 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 $\mu\text{g/L}$. 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 Controls ⁴	
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 applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and hydroxide ions are ubiquitous and are present in most water, soil and sediment.
T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - Citric acid

Chemical and Physical Properties ^{2,3,5}	
CAS number	77-92-9
Molecular formula	C ₆ H ₈ O ₇
Product name	--
Molecular weight	192.124
Solubility in water	1000000 mg/L
pH	2 to 2.2
Melting point	Decomposition > 175 C
Boiling point	152 to 159 C
Vapour pressure	White powder or granules
Henry's law constant	1.7 x 10 ⁻⁸ mm Hg at 25 deg C
Explosive potential	4.39 x 10 ⁻⁰⁹ Pa.m ³ /mol
Flammability potential	Dust explosion possible if powder or granular form, mixed with air
Colour/Form	Melts and decomposes in fire, a non-hazardous reaction.
Overview	Citric acid is a water soluble organic solid. It is a natural substance that appears as an intermediate in the basic physiological citric acid or Krebs cycle in every eukaryote cell. Citric acid has been produced for many years in high volumes. It has wide dispersive use, being added to processed food and beverages, used in pharmaceutical preparations and in household cleaners as well as in special technical applications. Citric acid is recognised by Food Standards Australia New Zealand (FSANZ) and the WHO JECFA as safe as a multipurpose food additive. No upper limit of concentrations has been established in food products. 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 ^{2,5}	
Soil/Water/Air	Citric acid is highly mobile in the environment and is extremely soluble in water. The pKa of citric acid is 2.79, indicating that this compound will exist almost entirely in the anion form in the environment. The compound does not sorb to soil or particles in the water column and is readily and rapidly degraded in surface waters and in soil. (OECD, hsdB)

Human Health Toxicity Summary ^{1,2,4,5}	
Chronic Repeated Dose Toxicity	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed (approx. 2 resp. 1.2 g/kg/d) found slightly decreased growth in the higher dosage group but no tissue abnormalities in the major organs. From the lower dosage a NOAEL of 1200 mg/kg/d results. Similarly, NOAELs of 1500 mg/kg/d (rabbit) and of 1400 mg/kg/d (dog) have been determined. In general, citric acid is a strong chelating agent, the dietary uptake of which may interfere with biological availability, absorption and excretion of metals. Further, loss of superficial enamel and erosion of teeth as well as local irritation result from frequent ingestion of citric acid in beverages including natural fruit juices; citric acid fumes were reported to apparently affect the teeth of exposed workers. The average daily intake of citric acid from natural sources in the diet and food additives was estimated at about 40 mg/kg for women, 130 mg/kg for infants and 400 mg/kg for individuals on slimming diets; maximum daily intake is reported to reach levels of 500 mg/kg. No formal ADI (acceptable daily intake) level has been specified for citric acid and its common salts by the Joint FAO/WHO Expert Committee on Food Additives nor by the EC Scientific Committee for Food.
Carcinogenicity	Citric acid has not been classified by the IARC.
Mutagenicity/ Genotoxicity	In several in vitro and in vivo tests citric acid was not mutagenic. The substance was not mutagenic either in bacterial tests with <i>Salmonella typhimurium</i> (Ames test, 2 studies) and <i>Escherichia coli</i> , with and without metabolic activation.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a two-generation 90 days study with male and female rats fed 1.2 % citric acid no adverse effect on reproductive parameters nor any teratogenicity of dietary citric acid was seen. There were no indications of teratogenic or other adverse effects in three shorter term reproductive studies in rats with dietary dosage of either 5% citric acid (approx. 2.5 g/kg/d) previous, during and after mating (NOEL = 2500 mg/kg/d), or 295 mg/kg/d (route unspecified) during days 6–15 of pregnancy
Acute Toxicity	Citric acid has a low acute toxicity by oral application in both rat (LD50 = 3,000–12,000 mg/kg, 3 different values) and mouse (LD50 = 5,400 mg/kg). General effects comprised physiological disturbances (acidosis and calcium deficiency), while “high” doses caused nervous system effects as well as severe damage to the stomach mucosa.
Irritation	Local effects of citric acid to the skin (rabbit) are reported as slightly irritating in two studies and as not irritating in a third study using a 30% aqueous solution. In an acute eye irritation/corrosion test in rabbits according to OECD 405 citric acid was highly irritating.
Sensitisation	The sensitising potential is low.
Key Study/Critical Effect for Screening Criteria	A 2-year chronic oral study in rats being given 5% or 3% citric acid in feed resulted in a NOAEL of 1200 mg/kg/d. Uncertainty factors: 10 (interspecies variability) and 10 (intraspecies variability). Drinking water guideline = 4.7 ppm
Ecological Toxicity ^{1,5}	
Aquatic Toxicity	The 96-hour LC50 values for citric acid to fish are from 440 to 1,516 mg/L. The acute toxicity 24 hour EC50 value for invertebrates is 85 mg/L. The 7 day toxic limit concentration (TLC) values for algae range from 300 to 640 mg/L. In an 8 day freshwater static test for the algae <i>Scenedesmus quadricauda</i>, the NOEC is 425 mg/L. In freshwater, citric acid appears to be of low toxicity to aquatic acute test standard organisms, fish, daphnia and algae, with consistent LC50/EC50 values of several hundred milligrams per litre.

Determination of PNEC aquatic	PNEC_{aquatic}: Experimental results are available for three trophic levels. Acute E(L)C₅₀ values are available for fish (440 mg/L), Daphnia (85 mg/L). A TLC value of 300 mg/L was obtained for algae from which no dependable EC₅₀ can be derived. Even though a NOEC was obtained from the algae study, 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 85 mg/L for Daphnia Magna. The PNEC_{aquatic} was calculated to be 0.085 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	
Australian Occupational Exposure Standards	
International Occupational Exposure Standards	
Australian Food Standards	
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
Australian Hazard Classification	
PBT Assessment¹	
P/vP Criteria fulfilled?	Citric acid is expected to be readily biodegradable and does not persist in the environment
B/vB criteria fulfilled?	Based on the low Log Kow and widespread natural occurrence, citric acid is not expected to have potential for bioaccumulation.
T criteria fulfilled?	Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not a PBT substance (based on screening data).

References

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3. IPCS Citric Acid, Retrieved 2015: <http://www.inchem.org>
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Toxicity Summary - Crystalline silica-cristobalite, crystalline silica-quartz

Chemical and Physical Properties ^{1,3}	
CAS number	Crystalline Silica (Cristobalite) : 14464-46-1 Crystalline Silica (Quartz): 14808-60-7 Diatomaceous Earth (Calcined silica): 91053-39-3
Molecular formula	Crystalline Silica (Cristobalite): SiO ₂ Crystalline Silica (Quartz): SiO ₂ Diatomaceous Earth (Calcined silica): SiO ₂
Molecular weight	60.09 g/mol
Solubility in water	Insoluble/negligible
pH	-
Melting point	1713°C (Cristobalite) 1610°C (Quartz)
Boiling point	2230 °C
Vapour pressure	NA
Henrys law constant	NA
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 (SiO ₂) 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	
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/m ³ 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/m ³ France: 0.05 mg/m ³ Japan: 0.03 mg/m ³ Sweden: 0.05 mg/m ³ US (ACGIH): 0.025 mg/m ³ US (NIOSH): 0.05 mg/m ³ US (OSHA): 0.1 mg/m ³ US: 0.3, 0.9, 1.5, 500 mg/m ³ 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
Revised	April 2018

References

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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 - Diethanolamine

Chemical and Physical Properties ^{1,2,4}	
CAS number	111-42-2
Molecular formula	C ₄ H ₁₁ NO ₂
Molecular weight	105.14
Solubility in water	1,000 g/L @ 20 °C
Melting point	27 °C at 101.3 kPa
Boiling point	269.9 °C at 101.325 kPa
Vapour pressure	0.0028 hPa (25 °C)
Henry's law constant	3.97 x 10 ⁻⁶ Pa·m ³ /mol
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Colourless crystals or a white syrupy liquid with a mild ammonical odour.
Overview	2,2'-Iminodiethanol (diethanolamine, DEA) belongs to the ethanolamines group that includes monoethanolamine (MEA), diethanolamine (DEA) and triethanolamine (TEA). Large-scale production of DEA is carried out by the reaction of ethylene oxide and excess ammonia, followed by fractionation of the three ethanolamines (mono-, di- and triethanolamine). Ethanolamines are used widely as intermediates in the production of anionic and non-ionic surfactants, which have become commercially important as detergents, textile and leather chemicals, and emulsifiers. Their uses range from drilling and cutting oils to medicinal soaps and high-quality toiletries. DEA is an important additive of corrosion inhibitors, particularly in coolants for automobile engines. DEA is also employed as an additive in lubricants and in cement/concrete production. Large amounts of DEA are used as such in closed systems for absorptive gas purification to remove weakly acidic components. In the production of detergents, cleaners, fabric softeners and metalworking fluids DEA is used for acid neutralization and to prevent soil deposition. DEA is also used as an intermediate in the production of morpholine, photographic chemicals and polyurethanes. In addition, DEA is used as a building block for agrochemicals.
Environmental Fate ⁴	
Soil/Water/Air	The colourless solid DEA is completely miscible with water at ambient temperature and has a negligible vapour pressure of 0.0028 hPa (25 °C). The measured log KOW of -2.18 (25 °C) and the calculated BCF of 3.16 indicate a low potential for bioaccumulation. The Henry's law constant of 3.97 x 10 ⁻⁶ Pa·m ³ /mol (uncharged) is considered as an indication for low volatility. The calculated Koc of uncharged DEA is 1 (corrected log Koc = 0). Thus, the potential for adsorption to soil, sediment, and suspended solid may be low. However, binding of the substance to the matrix of soils (and sediments) with high capacities for cation exchange (e.g. clay) cannot be excluded for the charged molecule. The measured pKa value of 8.92 (23 °C) indicates that at environmentally relevant conditions of pH 6 – 8, the molecule will predominantly occur in the charged (cationic) form. At pH values > 9, DEA will predominantly be present as the uncharged species. According to Mackay Level I modelling, uncharged DEA will distribute almost completely into water (99.99 %). DEA is readily biodegradable according to OECD criteria. Potential for anaerobic degradation of DEA was also observed. In the atmosphere, it will be photodegraded by reactions with OH radicals (calculated half-life of the uncharged molecule for a 12-hour day and 1.5E06 OH/cm ³ : 2.4 hours = 0.1 day; for a 24-h day and 0.5E06 OH/cm ³ : 4.2 hours = 0.2 days). At environmental pH conditions hydrolysis is not expected to be a relevant degradation process due to the absence of hydrolysable groups
Human Health Toxicity Summary ^{1,2}	

Chronic Repeated Dose Toxicity	In a 90 day oral gavage study conducted similarly to OECD TG 408 in F344 rats, lowest observed adverse effect levels (LOAEL) of 320 and 160 ppm (equivalent to 25 and 14 mg/kg bw/day, respectively) was reported in male and female rats, respectively. These were the lowest doses tested. Mortality was observed in males (2/10 animals) at the highest dose (5000 ppm) before the completion of the study (REACH; OECD, 2008). Signs of toxicity were observed across all dose groups (160 - 2500 ppm), and included tremors, extreme weight loss, abnormal posture and a dose dependent increase in microcytic anaemia. Dose related (≥ 320 ppm in males and ≥ 160 ppm in females) changes in kidney weights were associated with an increase in nephropathy and renal cell necrosis. Dose related (≥ 320 ppm in males and ≥ 630 ppm in females) increase in liver weight was associated with a moderate increase in serum bile acid concentration (REACH; OECD, 2008). Based on treatment-related effects reported with a LOAEL of 32 and 80 mg/kg bw/day in rat and mouse studies, respectively, the chemical is considered to cause serious damage to health from repeated oral exposure. In a 90 day dermal application study conducted similarly to OECD TG 411 in F344 rats, a LOAEL of 32 mg/kg bw/day was reported in male and female rats. Mortality occurred in one male and two female rats administered the highest dose of 500 mg/kg bw/day (REACH; OECD, 2008). Ulceration, inflammation, hyperkeratosis, and acanthosis occurred at all administered doses (32 - 500 mg/kg bw/day). Other signs of toxicity included reductions in body weight gain, anaemia, renal function changes and liver weight increases. Demyelination in the brain, nephropathy and renal tubular necrosis were also observed (REACH; OECD, 2008). In a similar study conducted similarly to OECD TG 411 in B6C3F1 mice, a LOAEL of 80 mg/kg bw/day was reported in male and female mice. Effects on the skin were noted at all doses (80 - 1250 mg/kg bw/day) and consisted of acanthosis at the lower doses and a dose-dependent increase in ulcerations, inflammation and hyperkeratosis at higher dose levels (630 and 1250 mg/kg bw/day in males and females, respectively) (REACH; OECD, 2008). Further signs of toxicity included dose dependent increases in liver and kidney weights. The increase in liver weight was associated with hepatocellular changes consisting of enlarged hepatocytes and, at the higher dose levels, the presence of multinucleated, giant hepatocytes. Liver damage (hepatocellular necrosis) was observed in male mice only (REACH; OECD, 2008). Based on the available data no adverse systemic toxicity was evident. Local effects were observed at a lowest observed adverse effect concentration (LOAEC) of 0.15 mg/L in one study. The available data do not warrant a hazard classification for repeated dose inhalation toxicity. However, a classification for respiratory irritation is warranted. In a 90 day inhalation study conducted according to OECD TG 413 in Wistar rats, a LOAEC of 0.15 mg/L was reported in male and female rats. Local inflammation (focal squamous metaplasia and hyperplasia) was evident in the larynx (0.15 mg/L) and trachea (0.4 mg/L) in a concentration dependent manner (REACH, SIDS, 2008). Marginal increases in liver weight and serum alkaline phosphatase levels occurred at the mid - high doses (0.15 and 0.4 mg/L, respectively), although, no histopathological changes were noted. In females, erosions of the glandular stomach occurred in a dose dependent manner (0.15 mg/L and 0.4 mg/L) (REACH; OECD, 2008). A further study conducted according to OECD TG 413 in male and female Wistar rats using lower doses (0.0015, 0.003 or 0.008 mg/L) showed similar local irritation effects (focal squamous metaplasia) after 90 days of exposure. After 90 days of exposure to the chemical, a group of 10 animals were given three months of recovery. At the end of the recovery period, no treatment related systemic effects were observed, indicating reversibility in the laryngeal epithelium up to the highest dose administered (0.008 mg/L) (REACH, OECD, 2008).

Carcinogenicity	Limited data are available on the carcinogenicity of DEA. A two-year carcinogenicity study was conducted by the United States National Toxicology Program (NTP, 1999). Based on the pattern of occupational and consumer exposure, dermal administration was considered the most appropriate route for the carcinogenicity study in rats and mice. Groups of 50 male F344/N rats were administered dermal doses of 0, 16, 32, or 64 mg/kg bw DEA in ethanol solutions, 5 days per week for 103 weeks. Female rats were administered 0, 8, 16, or 32 mg/kg bw, and male and female B6C3F1 mice were administered 0, 40, 80, or 160 mg/kg bw DEA dermally, 5 days per week for 103 weeks. Mean body weights of treated rats were generally lower than those of the control rats. The only clinical finding attributed to DEA administration was irritation of the skin at the site of application. This effect was dose-related. Exudate, consisting of focal accumulations of serum and cellular debris on the epidermal surface, occurred at significantly increased incidences in 64 mg/kg bw males and in all dosed female groups. In rats, the main histopathological effects were noted in kidneys of female rats with nephropathy, renal tubular epithelial cell necrosis and/or mineralisation, which increased in incidence and/or severity in a dose-dependent manner. The incidence of nephropathy in dosed female groups was significantly greater than that in the vehicle controls; but no such effects were seen in male rats. There was no neoplastic response in the skin or any organ associated with DEA exposure during the two-year study. The incidence of basophilic foci was significantly decreased in all dosed groups of males and females. The incidence of fibroadenoma in mammary glands in female rats occurred with a negative trend, being lower in all dosed groups compared to the historical control range. In mice, mean body weights of treated groups were depressed, more so in female mice than in male mice. The liver was clearly the most affected organ, and female mice were more sensitive than males. Exposure to diethanolamine for two years produced a marked neoplastic response in the liver characterised by significant increases in the incidences and multiplicity of hepatocellular adenomas (males: 31/50, 42/50, 49/50, 45/50 and females: 32/50, 50/50, 48/50, 48/50) and hepatocellular carcinoma (males: 12/50, 17/50, 33/50, 34/50 and females: 5/50, 19/50, 38/50, 42/50) at 0, 40, 80 and 160 mg/kg bw/day, respectively. The microscopic appearance of these liver neoplasms was typical of those usually observed spontaneously in B6C3F1 mice. There was a morphologic continuum from adenoma to carcinoma, with less differentiation and typical trabecular formations in the carcinomas. Increased mortality was noted in female mice and this, along with reduced body weights, was considered to be a consequence of the presence of liver neoplasms. The incidence of hepatoblastomas, uncommon phenotypic variants of hepatocellular carcinoma, was significantly increased in male mice, but not in females. In addition, the incidence of syncytial alteration, a non-neoplastic lesion characterised by the presence of hepatocytes containing multiple (three or more) nuclei, was increased in all groups of dosed mice; this lesion was not present in the controls. Centrilobular cytoplasmic alteration was increased in treated males but was not present in females. There were no neoplasms of the skin in mice. Effects in the kidneys included increased organ weights and increased incidence of tubular epithelial cell necrosis. The incidences of renal tubule adenoma and renal tubule adenoma or carcinoma (combined) occurred with a positive trend in male mice, but renal tubule carcinoma did not follow the same pattern. Detailed evaluation of the renal neoplasms indicated a treatment- and dose-related increase in the incidences of renal tubule adenoma (1/50, 4/50, 6/50 and 6/50) and adenoma or carcinoma (combined) (3/50, 5/50, 6/50 and 8/50 at 0, 40, 80 and 160 mg/kg, respectively). Diethanolamine is eliminated in urine as the parent compound. The data on the mode of action are insufficient to conclude that diethanolamine-induced tumours in mice are relevant for humans and, therefore, based on the available information, diethanolamine is not classified for carcinogenicity.

Mutagenicity/ Genotoxicity	The chemical tested negative in several in vitro (Ames test with and without metabolic activation, reverse mutation assay, cytogenic assay and the mouse lymphoma assay) and in vivo (micronucleus assay and the alkaline elution assay) tests for gene mutation and clastogenicity (NICNAS; OECD, 2008).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No reproductive toxicity studies are available for diethanolamine. Repeated dose studies were conducted in F344/N rats and B6C3F1 mice of both sexes for 13 weeks (10/sex/species/dose) to characterise the effects of oral and dermal exposure (NTP, 1992). No reproductive toxicity in male or female rats was reported following dermal administration of the chemical for 13 weeks. There were no morphological effects on male or female reproductive organs or in sperm parameters (NTP, 1992). It is likely that testicular degeneration in a 90-day drinking water study is a direct toxic effect of diethanolamine. However, no effect on the reproductive organs of the female rats was noted. The NOAEL for reproductive effects in males is 630 ppm (48 mg/kg bw/day). In an inhalation study, conducted according to OECD TG 413, male and female Wistar rats were exposed to the chemical via inhalation (0.015, 0.15 or 0.4 mg/L), five times a week for 90 days. Reproductive effects in males were reported at the highest concentration (0.4 mg/L) and these included testicular atrophy and slight atrophy of the prostate. No changes were observed in female rats (OECD, 2008). The effects of diethanolamine on the male reproductive system are indicative of a potential to impair reproductive capability. However, more detailed reproductive toxicity studies are needed to confirm the potential effects on fertility observed in male rats. The current information is insufficient to classify diethanolamine for reproductive toxicity. Developmental effects were tested following exposure of dams to diethanolamine by oral, dermal and inhalation routes. In almost all the rodent studies, developmental effects were seen only at higher doses, at which maternal effects were also noted. In a dermal study in rabbits, the overall incidence of malformation was similar to the incidence seen in control animals. The current data therefore do not allow for a clear delineation of reproductive and developmental toxicity of diethanolamine in experimental animals. Classification of diethanolamine for reproductive and developmental toxicity is, therefore, not recommended at this stage.

Acute Toxicity	The reported oral median lethal dose (LD50) values in rats ranged from 780 - 3540 mg/kg bw (OECD, 2008). In one study male Sprague Dawley (SD) rats administered a single oral dose of aqueous DEA (100 – 6400 mg/kg bw) resulting in 90 % mortality at the highest dose. Doses greater than 100 mg/kg bw resulted in an increase in liver weight. An increase in the relative kidney weight was observed at doses greater than 1600 mg/kg bw. Clinical chemistry changes were reported for the liver at doses greater than 200 mg/kg bw and for the kidney at greater than 400 mg/kg bw (OECD, 2008). The chemical was of low acute toxicity in animal tests following dermal exposure. The median lethal dose (LD50) in rabbits is greater than 12000 mg/kg bw (IUCILID, 2000). The chemical was of low acute toxicity in animal tests following inhalation exposure. The median lethal concentration (LC50) in rats is 6.4 mg/L. The available data do not warrant hazard classification. Acute inhalation exposure to the chemical for 1.5 – 4 hours at concentrations between 30 – 1476 ppm (0.13 - 6.4 mg/L) caused mortality in 5/8 rats after 105 minutes of exposure to 6.4 mg/L. Exposure to 3.35 mg/L (768 ppm) for up to 4 hours resulted in no mortality. It was reported that the exposure was to vapours or aerosols (most likely at the higher concentration). Observed sub-lethal effects included lethargy, increased breathing, increased blood pressure, congestion in the lung and discolouration in the kidney and thymus (REACH; OECD 2008).
Irritation	The chemical on unabraded rabbit skin produced skin irritation after 1 - 15 minutes and marked irritation after 20 hours. Over 72 hours, erythema increased and oedema decreased (REACH). After 20 hours of exposure the mean Draize scores for erythema and oedema formation were 2 and 1.33, respectively. While the Draize scores for erythema and oedema returned to normal after 8 days, severe desquamation of the skin persisted. The chemical is also reported to cause ulceration, inflammation and hyperkeratosis following repeated exposure. In an eye irritation study in Vienna White rabbits, 0.05 mL of the chemical was instilled into the rabbit's eyes and observed for eight days. The chemical caused signs of severe irritation consisting of superficial corrosion, corneal opacity, conjunctival bleeding, conjunctivitis and oedema (OECD, 2008; REACH). Extensive corrosion was evident at the end of the observation period. In a further study, 0.1 g of the chemical was applied into the conjunctival sac of New Zealand White rabbits. This resulted in strong irritation of the cornea, iris and conjunctiva, which did not completely resolve over seven days of observation (OECD, 2008).
Sensitisation	The chemical was not found to induce dermal sensitisation in the Guinea pig maximization test conducted according to OECD Test Guideline (TG) 406 (OECD, 2008).
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity by the oral route of exposure) and local effects (skin, eye and respiratory irritation). The chemical may also cause harmful effects following repeated exposure through oral and dermal routes.
Key Study/Critical Effect for Screening Criteria	The lowest observed adverse effect levels (LOAEL) of 320 and 160 ppm (equivalent to 25 and 14 mg/kg bw/day, respectively) were reported in male and female rats, respectively, based on kidney and liver weights in the drinking water study (US NTP, 1992). In mice, the LOAEL was 630 ppm (104 mg/kg bw/day for males and 142 mg/kg bw/day for females) based on liver weight changes. It is reported that the fatal oral dose of the chemical is 20g in humans (HSDB).
Ecological Toxicity ^{3,4}	

Aquatic Toxicity	The lowest reliable acute toxicity values for aquatic species were as follows: Pimephales promelas (fish) 96-h LC50 = 1370 mg/l (nominal) Daphnia magna (invertebrates) 48-h EC50 = 55 mg/l (nominal) Pseudokirchneriella subcapitata 96-h ErC50 = 2.2 mg/l (nominal) Pseudomonas sp. (microorganisms) 16-h TTC = 16 mg/l (nominal) In a chronic toxicity test on reproduction of the water flea Daphnia magna, the NOEC (21 days) was 0.78 mg/l (nominal, based on analytical verification).
Determination of PNEC aquatic	Using an uncertainty factor of 50 on the lowest NOEC to Daphnia a PNEC (Predicted No Effect Concentration) of 0.02 mg/L is calculated, for aquatic organisms.
Current Regulatory Controls ¹	
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; R38/41 (Irritation) Xn; R48/22 (Repeated dose toxicity)
Australian Occupational Exposure Standards	The chemical has an exposure standard of 13 mg/m ³ (3 ppm) time weighted average (TWA).
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica): An exposure limit (TWA) of 2 - 15 mg/m ³ (0.46 – 3 ppm) in different countries such as USA (Alaska, Hawaii), Canada (Yukon), Norway and Switzerland.
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?	No. DEA is readily biodegradable according to OECD criteria.
B/vB criteria fulfilled?	No. Based on a measured log Kow of -2.18 and a calculated BCF of 3.16, this chemical does not meet the screening criteria for bioaccumulation.
T criteria fulfilled?	No. The chronic aquatic toxicity of the chemical is > 0.01 mg/L. Hence the substance does not fulfil the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

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Toxicity Summary - 2,2''-oxydiethanol (Diethylene glycol)

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	111-46-6
Molecular formula	C ₄ H ₁₀ O ₃
Molecular weight	106.1 g/mol
Solubility in water	Miscible
Melting point	-10°C
Boiling point	245°C
Vapour pressure	It has a low vapour pressure (<0.01 kPa at 25°C).
Henrys law constant	2.0X10 ⁻⁹ atm-cu m/mol at 25 °C
Explosive potential	Not explosive
Flammability potential	Combustible
Colour/Form	Odourless, colourless, viscous and hygroscopic liquid with a sharply sweetish taste
Overview	Diethylene glycol (DEG) is produced via a non-catalytic reaction between ethylene oxide and water at high pressure temperature. The resulting crude ethylene glycols (EG) are dried. The water-free glycol mixture is subsequently fractionated by vacuum distillation into mono, di and triethylene glycol. Biodegradation of polyethylene glycols results in chain shortening with concomitant formation of ethylene glycol and diethylene glycol in nature DEG is a widely used chemical in industrial and household applications. It is also used in cosmetics for topical use. DEG is not an approved food additive in Australia. However, DEG is allowable in food in Australia as an impurity in polyethylene glycol (PEG) used as a processing aid or miscellaneous food additive. PEG used for this purpose must contain no more than 0.25% w/w DEG.
Environmental Fate ^{1,4}	
Soil/Water/Air	EGs emitted to the atmosphere readily undergo hydroxyl radical induced photodegradation, with half-lives ranging from about 2 to 15 hours. Particulate-phase EGs may be physically removed from the atmosphere by wet deposition (SRC, 2003). EGs have limited volatility, decreasing with increasing molecular weight. Level III fugacity modelling and Henry's Law constants ranging from 1.31×10^{-7} to 7.62×10^{-15} atm-m ³ /mole indicate that volatilization from water to the atmosphere is limited. EGs are inherently to readily biodegraded in water. Since these substances are resistant to water hydrolysis, abiotic degradative processes in water are not major elimination pathways. Fugacity modelling indicates that EGs have a high affinity for soil as well as water. Low soil/sediment coefficients (Koc = 1 to 10) suggest that these substances are highly mobile in soil, have limited tendency to adsorb onto suspended solids and sediment, and are therefore subject to biodegradative elimination in either soil or water. Overall, the data suggest that EGs do not persist in the environment and that they have limited potential for bioaccumulation.

Human Health Toxicity Summary ^{1,2,3,4,5}	
Chronic Repeated Dose Toxicity	Two well-conducted studies were identified from which effect levels from long-term oral DEG administration could be derived (OECD, 2004; Health Council of the Netherlands 2007). In these two studies by Gaunt et al. (1976*) using DEG doses in food of 0%-4% (0.3-3.7 g/kg bw/d) for 98 days and 0%-2% (0.05-1.5 g/kg bw/d) for 225 days in Wistar rats (10-15/sex/dose), kidney effects were reported consisting of oxalate crystalluria, increased urine volumes and histopathological evidence of hydropic degeneration and tubular necrosis. For the crystalluria and increased urine volumes, there were inconsistent findings between male and female rats and questionable dose-response relationships. For example, the number of male rats with urinary oxalate crystals was not increased at the highest male dose of 1.2 g/kg bw/d in the 225 day study. In addition, the observed increase in urinary volumes was possibly caused by the osmotic diuretic effect of DEG and the oxalate crystalluria could not be explained in view of oxalic acid being a minor metabolite of DEG in rats. Therefore, the significance of elevated production of oxalate was regarded as unclear (Health Council of the Netherlands, 2007) and was viewed as a biomarker and not an indication of toxicity (OECD, 2004). OECD (2004) identified a LOAEL for kidney effects of 230 mg/kg bw/d from the 225 day study based on increases in urine volume. The NOAEL was 100 mg/kg bw/d. Health Council of the Netherlands (2007) regarded a NOAEL based on renal histopathological findings as more relevant than a NOAEL based on increased urine volumes. From the 98 day study, a LOAEL based on renal hydropic degeneration was established at 1.6 g/kg bw/day with the NOAEL at 300 mg/kg bw/d (Health Council of the Netherlands, 2007).
Carcinogenicity	The International Agency for Research on Cancer (IARC) has not evaluated DEG as a carcinogen. Urinary bladder calculus and tumour responses were recorded in some long-term oral studies in the rat. Bladder tumours were found associated with the formation of oxalate containing bladder stones in a 2-year feeding study by Fitzhugh and Nelson (1946*). On the other hand, Weil et al. (1965*, 1967*) found that DEG did not induce bladder tumours in rats unless a foreign body or lesion was present, such as an oxalate-containing bladder stone or a surgery-induced bladder lesion. These authors concluded that the bladder tumours seen were due to mechanical irritation by oxalate-containing bladder stones rather than the carcinogenic response to DEG. In more recent studies such as Ito et al. (1988*), Masui (1988*) and Hiasa et al. (1990* and 1991*), DEG did not demonstrate any evidence of carcinogenic effects after oral administration. Several studies in mice also showed that DEG is not carcinogenic after dermal application. No information was found in the literature concerning the occurrence of bladder stones in humans after ingestion of DEG. Overall, although some human carcinogenicity information are available, data are insufficient (e.g. lack of a quantitative estimate of DEG exposure and sound methodology) to evaluate the carcinogenic potential of DEG.
Mutagenicity/ Genotoxicity	DEG was shown to be negative in the majority of gene mutation and chromosome aberration studies in vitro. Some indications of chromosomal damage were seen in vivo only at high doses. Taken together, DEG is considered non-genotoxic.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In oral studies, adverse effects on fertility were seen in mice and foetal abnormalities occurred in rats and mice. Inhalation and injection studies in rabbits and hamsters also revealed foetal abnormalities and other adverse effects on the foetus. However, reduced fertility was observed only at high doses of DEG, up to 6.1 g/kg bw/d in mice with maternal toxicity. With regard to developmental toxicity, a significant decrease in mean foetal body weight in mice was seen at 10 g/kg bw/d in the presence of maternal toxicity. In addition, at an oral dose of 6.1 g/kg bw/d in a 2-generation study in mice, craniofacial malformations, including exencephaly and cleft palate, and related mortality were observed in the presence of maternal toxicity. In rats, a decreased foetal body weight with increased skeletal variations was seen at 4.5 g/kg bw/d in the presence of maternal toxicity. Foetal malformations were not observed at dose levels up to 8.9 g/kg bw/d. From these studies, the NOAEL for fertility and developmental effects is established at 3.1 g/kg bw/d with a LOAEL of 6.1 g/kg bw/d based on reductions in litters/pair, live pups/litter and live pup weight
Acute Toxicity	In animals, the acute oral, dermal and inhalational toxicity of DEG are low. Oral toxicity is similar for both rats and mice with LD50 values ranging 13-30 g/kg bw across both species. A single study of dermal toxicity in rabbits derived an LD50 value of 12.5 or 13.3 g/kg bw. Acute inhalational toxicity has also been tested in rats and mice. The 4-hour LC50 in rats was 4600 mg/m³. In humans, mortality and morbidity are high in cases of inadvertent DEG ingestion, with most deaths occurring within the first 2 weeks post exposure. Neurological impairments observed after exposure include encephalopathy, demyelinating neuropathy, optic neuritis, facial paralysis, cerebral oedema and haemorrhages. Acute anuric renal failure with metabolic acidosis and concomitant severe neurological abnormalities progressing to coma and finally death were also noted during severe intoxications after uptake of DEG in patients with burns. A median lethal oral dose of 1.49 g/kg bw DEG (range 0.25-4.9 g/kg bw) was estimated from large-scale intoxication of Haitian children with a paracetamol syrup contaminated with DEG. However, large overlaps in ranges of lethal and non-lethal doses have been observed for adults and children. Accidents in humans following acute DEG exposure have been recorded. A large number of mass poisonings in humans involving substitution of DEG for more expensive, non-toxic, glycols in medicinal preparations have been documented over the past 70 years. Typical features of acute toxicity include neurological impairment, metabolic acidosis and acute renal failure. Early mortality and morbidity are high, with most deaths occurring within the first two weeks following DEG exposure. Humans appear to be 10 times more susceptible to acute oral toxic effects of DEG compared with experimental animals, with median lethal dose of 1490 mg/kg bw in humans compared with > 15000 mg/kg bw in rats (NICNAS, 2009).
Irritation	Overall, available data indicate that DEG causes no or only minimal skin and eye irritation in laboratory animals. Respiratory depression was reported in mice although the characteristics were reported as not typical of a pure airway irritant (OECD, 2004). No other information on respiratory irritation was available. Similar to experimental animals, DEG causes no or only minimal skin irritation in humans. Data for eye irritation in humans were not available.
Sensitisation	DEG does not cause skin sensitisation in guinea pigs. In humans, there is a single case study reporting skin sensitisation 2-4 weeks after a man had started smoking a brand of cigarettes containing DEG. However, overall, available data indicate that DEG is not a skin sensitizer in humans.
Health Effects Summary	The critical health effects for risk characterisation include systemic acute effects (acute toxicity from oral exposure).

Key Study/Critical Effect for Screening Criteria	The effects of diethylene glycol on the liver and kidneys after prolonged oral exposure are considered as the critical effects. Key study is the oral exposure study in rats carried out by Gaunt <i>et al.</i> (1976). the NOAEL for hydropic degeneration is 300 mg/kg bw/day (0.4% diethylene glycol in food) in the male rats (Health Council of the Netherlands, 2007). Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (sub-chronic to chronic) Oral RfD = 300/1000 = 0.3 mg/kg/day Drinking water guidance value = 1.17 mg/L
Ecological Toxicity^{1,4}	
Aquatic Toxicity	Fish acute toxicity (measured as LC50 in mg/L) for DEG ranges from >1000 mg/L to 77900 mg/L. The lowest acute toxicity (LC50) to invertebrates (Daphnia) value was >100 mg/L (48hr LC50). Algal toxicity has been tested for DEG with an EC50 of >1000 mg/L. Chronic toxicity to fish was also tested which resulted in a 7 day LC50 of 61,000 mg/L and chronic toxicity data on pentaEG are available for algae (NOEC – 100 mg/L)
Determination of PNEC aquatic	On the basis that short term results from three trophic levels and long term results from two trophic levels, an assessment factor of 50 has been applied to the lowest reported NOEC for algae (100 mg/L). The PNEC aquatic is 2.0 mg/L.
Current Regulatory Controls⁶	
Australian Hazard Classification	The chemical is classified as hazardous with the following risk phrase for human health in HSIS (Safe Work Australia): Xn; R22 (Harmful if swallowed)
Australian Occupational Exposure Standards	TWA (time weighted average) = 100 mg/m³ (Safe Work Australia).
International Occupational Exposure Standards	TWA = 101 mg/m³ [UK] (HSE, 2013).
Australian Food Standards	No data available
Australian Drinking Water Guidelines	No data available
Aquatic Toxicity Guidelines	No data available
PBT Assessment^{1,4}	
P/vP Criteria fulfilled?	DEG is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low.
T criteria fulfilled?	The acute aquatic toxicity of DEG is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T).
Overall conclusion	Not a PBT substance (based on screening data).
Revised	December 2018

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Toxicity Summary - Boric acid/sodium tetraborate / boronatrocalcite / boron sodium oxide

Chemical and Physical Properties ^{1,3,5,8}	
CAS number	Boric Acid: 10043-35-3 Sodium Tetraborate: 1330-43-4 Boronatrocalcite: 1319-33-1 Boron sodium oxide: 12008-41-2
Molecular formula	Boric acid: H_3BO_3 Sodium Tetraborate: $Na_2B_4O_7$ Boronatrocalcite: $CaNaH_{12}(BO_3)_5 \cdot 2H_2O$ Boron sodium oxide: $B_8Na_2O_{13}$
Molecular weight	Boric acid: 61.833 g/mol Sodium Tetraborate: 201.220 g/mol Boronatrocalcite: 405.23 g/mol Boron sodium oxide: 340.47
Solubility in water	Boric acid: 49.20 g/l @ 20± 0.5 °C Sodium Tetraborate: 3.1% at 25 °C Boronatrocalcite: no data found Boron sodium oxide: 223.65 g/L @ 20 °C
pH	Boric acid: 6.1 in a 0.1% (wt) solution Sodium Tetraborate: 9.3 at 20 °C (3% solution) Boronatrocalcite: no data found Boron sodium oxide: no data found
Melting point	Boric Acid: 170.9 °C Sodium Tetraborate: 743 °C Boronatrocalcite: no data found Boron sodium oxide: 813 °C
Boiling point	Boric Acid: 300 °C Sodium Tetraborate: 1,575 °C (decomposes) Boronatrocalcite: no data found Boron sodium oxide: no data found
Vapour pressure	Boric acid: 9.9×10^{-6} Pa @ 25 °C Sodium Tetraborate: Negligible at 20 °C Boronatrocalcite: no data found Boron sodium oxide: 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. Boron sodium oxide: Solid white powder. Odourless.

Overview	Limited toxicity data is available for sodium tetraborate (Borax anhydrous) and boronatrocaltite (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	All of the chemical in this group will transform into boric acid in the aquatic environment. This simple mononuclear boron compound is highly water soluble and is the predominant form of dissolved boron in surface waters. It is a mobile species in the environment and is to be found in all major environmental compartments.

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); 10 (subacute to chronic). 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	
Australian Hazard Classification	Boric acid and borax are classified as hazardous for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013) with the following risk phrases: · Toxic to reproduction (Repr.) Cat. 2; R60 (May impair fertility) · Repr. Cat. 2; R61 (May cause harm to the unborn child) Mixtures containing boric acid and borax are classified as hazardous with the following risk phrases based on the concentration (conc) of the chemicals in the mixtures. · Boric acid: Conc ≥5.5%: Toxic (T); R60; R61 · Borax: Conc ≥8.5%: T; R60; R61.
Australian Occupational Exposure Standards	There are no specific exposure standards for boric acid or disodium octaborate anhydrate. 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). The exposure standard for borax is 5 mg/m ³ TWA (Safe Work Australia 2013a).
International Occupational Exposure Standards	The following exposure standards were identified (Galleria Chemica 2013): · Boric acid – Canada 2 mg/m³ TWA, 6 mg/m³ Short-term exposure limit (STEL) (borate compounds) – Germany 10 mg/m³ TWA; 1 mg/m³ STEL – Spain 10 mg/m³ TWA (insoluble particles) – US 2 mg/m³ TWA; 6 mg/m³ STEL (borate compounds), 5 mg/m³ TWA (particulates, respirable fraction) · Disodium octaborate anhydrate – Canada 10 mg/m³ TWA, (insoluble particles) – Spain 10 mg/m³ TWA (particulates, inhalable fraction) – US 5 mg/m³ TWA (particulates, respirable fraction) · Borax – Canada 1 to 5 mg/m³ TWA, 6 mg/m³ STEL (inorganic borate compounds) – Denmark 1 to 2 mg/m³ TWA – Germany 0.5 mg/m³ TWA – Spain 5 mg/m³ TWA – Sweden and UK 2 mg/m³ TWA – US 2 mg/m³ TWA (inorganic borate compounds); 5 to 10 mg/m³ TWA.
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	No aesthetic or health-related guidance values exist specifically for boric acid, disodium octaborate anhydrate or borax. However, the guidelines note that 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
Revised	April 2018

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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	

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 (≥2) 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 ≥2 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	While exposure to the chemical through consuming alcoholic beverages is associated with an increased risk of carcinogenicity and reproductive and developmental toxicity, these risks increase in a dose-dependent manner and are not considered relevant at doses relating to occupational exposure and using consumer products containing the substance such as mouthwash. Therefore the critical health effect for risk characterisation from industrial use of the chemical is a local effect: eye irritation.
Key Study/Critical Effect for Screening Criteria	Overall, the most sensitive endpoint for ethanol is repeat dose toxicity. The oral NOAEL was 2,400 mg/kg bw/day. This NOAEL is used in this human health risk assessment.
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}	
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/m³ (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/m³ (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/m³ (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 & ARMCANZ, 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

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3. ECHA REACH, Ethanol, Retrieved 2019: <https://echa.europa.eu/>
4. OECD (2005) SIDS Initial Assessment Profile for Ethanol
5. ANZECC & ARMCANZ (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Toxicity Summary - Ethylene glycol

Chemical and Physical Properties ^{1,2}	
CAS number	107-21-1
Molecular formula	C ₂ H ₆ O ₂
Molecular weight	62.07 g/mol
Solubility in water	Miscible with water.
pH	No data found
Melting point	-12.69 °C
Boiling point	197.3 °C
Vapour pressure	0.092 mm/Hg at 25C
Henry's law constant	Low. 6.00X10 ⁻⁸ atm-cu m/mol at 25 deg C
Explosive potential	Not explosive
Flammability potential	Lower flammable limit of 3.2% by volume; Flashpoint of 232 deg F (111 deg C). Not combustible.
Colour/Form	Colourless odourless liquid
Overview	Ethylene glycol is a clear, colourless, syrupy liquid with a sweet taste but no odour. It has low volatility. It is miscible with water and some other solvents, slightly soluble in ether, but practically insoluble in benzene, chlorinated hydrocarbons, petroleum ethers, and oils. As a small molecular weight alcohol, ethylene glycol readily passes through biological membranes and will be effectively absorbed from the gastrointestinal tract and via inhalation exposure. It is rapidly distributed in body water. The chemical has numerous domestic and commercial uses, and is found in cleaning products, cosmetics, hydraulic brake fluids, anti-freeze agents and corrosion inhibitors. Ethylene glycol has been assessed by NICNAS to be of low environmental concern when used in coal seam gas extraction.
Environmental Fate ^{1,3,5}	
Soil/Water/Air	Ethylene glycol released to the atmosphere will be degraded by reaction with hydroxyl radicals; the half-life for the compound in this reaction has been estimated at between 0.3 and 3.5 days. No hydrolysis of ethylene glycol is expected in surface waters. The compound has little or no capacity to bind to particulates and will be mobile in soil. The low octanol/water partition coefficient and measured bioconcentration factors indicate low capacity for bioaccumulation. Ethylene glycol is readily biodegradable in standard tests using sewage sludge. Rapid degradation has been reported in surface waters (less in salt water than in fresh water), groundwater, and soil.

Human Health Toxicity Summary ^{1,2,3,4,6,7}

Chronic Repeated Dose Toxicity

Considering the lowest observed adverse effect levels (LOAELs) available from 13–104 week studies (300–3000 mg/kgbw/d) (ATSDR, 2010), 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. However, there is evidence of cumulative effects, as the nephropathy observed at high doses in acute toxicity studies also occurs after repeated exposure at lower doses. The National Toxicology Program (NTP) conducted a 13 week and a two year study in B6C3F1 mice. In the 13 week study, 10 male and 10 female mice were administered 0, 3200, 6300, 12500, 25000 or 50000 ppm ethylene glycol incorporated into feed. There were no reported deaths and no chemical-related clinical findings were reported. Histopathology showed chemical-related kidney and liver lesions, which were significantly elevated in the 25000 and 50000 ppm male mice. These lesions included nephropathy and centrilobular hepatocellular hyaline degeneration (NTP, 1993). The two year study used 60 male mice dosed with the chemical at 0, 6250, 12500 or 25000 ppm and 60 females dosed at 0, 12500, 25000 or 50000 ppm in feed. The doses in ppm were reported as being equivalent to: males - 0, 1500, 3000 or 6000 mg/kg bw/d and females - 0, 3000, 6000 or 12000 mg/kg bw/d. There were no significant differences in survival although male mice in the high dose (6000 mg/kg bw/d) group had to be housed separately after week 54 due to excessive fighting. Survival of mice was not affected by ethylene glycol administration at all doses. As with the 13 week study, mice did not show any adverse clinical signs. Histopathology showed hepatocellular degeneration in the mid and high dose male and high dose female mice. Pulmonary arterial hyperplasia occurred at a higher incidence in female mice than male mice exposed to the chemical. Some male mice in the high dose group had oxalate-like crystals and/or calculi in the renal system (NTP, 1993).

Mice appear to be less sensitive than rats to ethylene glycol. A two-year study conducted in Fischer-344 (F344) rats found that administration of the chemical (40, 200 or 1000 mg/kg bw/d) resulted in excessive mortality in male rats in the high dose group after nine months. All male rats in the high dose group (1000 mg/kg bw/d) were reported dead by 15 months of the study. Survival was significantly reduced in male rats in the 1000 mg/kg bw/d group only. (Cruzan et al., 2004; DePass et al., 1986). Pathology investigation of the male rats concluded that extensive kidney damage was the reason for increased mortality in the 1000 mg/kg bw/d group. The NOAEL for male rats was reported as 200 mg/kg bw/d in this study (DePass et al., 1986).

A further study indicates that the Wistar rat strain is more sensitive than the F344 strain. In a 16-week study, 10 male rats of each strain were exposed to the chemical (0, 50, 150, 500 or 1000 mg/kg bw/d) by incorporation in a normal diet. Mortality was reported in two Wistar rats at the highest dose and significant weight loss was observed in Wistar rats administered 500 and 1000 mg/kg bw/d, respectively. Both strains of rats treated with ≥ 500 mg/kg bw/d had increased calcium oxalate crystals in the kidney tubules as well as crystal associated nephropathy; this was reported as being more severe in the Wistar rat strain (Cruzan et al., 2004).

Further repeated dose studies conducted in rodents have reported no observed adverse effect levels (NOAELs) in the range of 150–2000 mg/kg bw/d depending on species and strain studied. Overall, repeated oral exposure to ethylene glycol is consistently associated with adverse effects on the kidney such as crystal nephropathy in rodents (ATSDR, 2010).

	In a study conducted according to OECD TG 410, five male Beagle dogs per group were dermally exposed (60 % of the total body surface area) to 0.5, 2.0 or 8 mL/kg bw/d Glysantin G 105 (automotive coolant which contains ≥ 92.5 % ethylene glycol and ≥1.4 % p-tert.-butyl benzoate (PTBBA)) daily for four weeks. Mortality (4/5 animals) was reported at the highest dose (8 mL/kg). Prior to death, animals showed signs of toxicity including staggering gait, vomiting, diarrhoea and reduced food intake. Clinical analysis showed increased creatinine and urea levels and increased incidence of calcium oxalate crystals. Pathology investigation reported oxalate nephrosis, testicular atrophy and uraemic gastroenteritis. Similar pathology findings were reported at the mid dose (2 mL/kg), but only in one animal. No mortality or any further clinical or pathological adverse effects were reported at the mid and lower doses. Further studies conducted comparing pure ethylene glycol to Glysantin G105 showed that the testicular atrophy was associated with the presence of PTBBA in Glysantin G105 and not ethylene glycol (REACH). PTBBA has known testicular toxicity (NICNAS). Mortality was reported in 1/15 rats, 3/15 guinea pigs, 1/3 rabbits, 0/3 dogs and 0/3 monkeys after exposure to 12 mg/m³ of ethylene glycol aerosol for 90 days. Apart from mortality, no specific signs of clinical toxicity were reported. In a further study, no mortality or toxicity was observed in the same range of animal species exposed to either 10 or 57 mg/m³ ethylene glycol. The authors noted that as the exposure was whole body, further oral intake from grooming may have occurred, and therefore a reliable LOAEL could not be established (ATSDR, 2010).
Carcinogenicity	Based on the available data, ethylene glycol is not considered to be a carcinogen. Histopathological investigations showed no evidence of carcinogenicity in studies conducted in various rodent species. No tumours were reported in SD rats administered up to 3000 mg/kg bw/day in the diet for two years, F344 rats administered 1000 mg/kg bw/day in the diet for one year, B6C3F1 mice administered up to 12000 mg/kg bw/day in the diet for two years and CD-1 mice administered up to 1000 mg/kg bw/day in the diet for two years (NTP, 2004; WHO, 2002). A limited number of epidemiological studies have reported that exposure to the chemical does not increase the risk of cancer. Ethylene glycol exposure (inhalation) in 1666 chemical plant employees was not found to increase the odds ratio (OR) for any type of cancer (ATSDR, 2010).
Mutagenicity/ Genotoxicity	Based on the weight of evidence from the available in vitro and in vivo genotoxicity studies the chemical is not considered to be genotoxic. An Ames assay conducted according to OECD TG 471 reported that the chemical did not induce bacterial mutations in Salmonella typhimurium strains TA 1535, TA 1537, TA 98, TA 100 and Escherichia coli WP2 at a concentration up to 5000 µg/plate with or without metabolic activation (REACH). Further in vitro genotoxicity tests conducted with bacterial and mammalian cell lines were all negative for gene mutations and DNA strand breaks respectively (ATSDR, 2010). An in vivo study in mice reported no chromosomal aberrations in Swiss mice exposed to 638 mg/kg bw/day for two days (WHO, 2002). Negative results were found for dominant lethal mutations in F344 rats after administration of up to 1000 mg/kg bw/d ethylene glycol in a 155-day multi-generational study.

Reproductive Toxicity Developmental Toxicity/Teratogenicity	The available data from rat studies suggest that developmental effects were only observed secondary to maternal toxicity, so the chemical does not show specific developmental toxicity. The chemical is not toxic to reproduction. Having reviewed the available data the Centre for the Evaluation of Risks to Human Reproduction (CERHR) expert panel concluded that there are sufficient data to conclude that the chemical is not toxic to reproduction in rats orally exposed to 1000 mg/kg bw/day in diet (NTP, 2004). A study in mice gave negative results at doses up to 2826 mg/kg bw/day via drinking water. The expert panel also concluded that exposure of CD-1 mice to the chemical by the dermal route for 6 hours/d on gestation days (GD) 6-15 resulted in no evidence of developmental toxicity up to a dose of 3549 mg/kg bw/d. Developmental toxicity was also not observed in rabbits exposed orally via gavage on GD 6-19 to doses as high as 2000 mg/kg bw/d. Severe maternal toxicity was observed at the high dose with maternal deaths as well as oxalate crystals in the kidney. Data suggested that oral exposure to high doses of the chemical (≥ 500 mg/kg bw/d in CD-1 mice and ≥ 1000 mg/kg bw/d in SD rats) on GD 6-15 causes developmental effects in mice and rats such as axial skeletal malformations, external malformations, reduced body weights and increased post-implantation loss (NTP, 2004). The CERHR expert panel concluded that developmental toxicity may not be attributed directly to the chemical but from the accumulation of glycolic acid, which is a metabolic breakdown product of ethylene glycol. The developmental effects are seen at doses that exceed saturation of glycolic acid metabolism. Observations from rat studies suggest that oral doses resulting in developmental toxicity (1000 mg/kg bw/d) are greater than those associated with maternal and renal toxicity at 500 mg/kg bw/d.
Acute Toxicity	Ethylene glycol has low acute toxicity via oral, inhalation, or dermal exposure. LD50s for the oral administration of ethylene glycol in rats range from 4000 to 10 020 mg/kg body weight, while reported values in guinea-pigs and mice are 6610 mg/kg body weight and 5500–8350 mg/kg body weight, respectively. The minimum lethal oral dose in rats is 3.8 g/kg body weight (Clark et al., 1979). Oral LD50s of 5500 and 1650 mg ethylene glycol/kg body weight have also been reported in dogs and cats, respectively. A dermal LD50 of 10 600 mg/kg body weight has been reported for rabbits. In rats and mice, the lethal concentration following 2-h inhalation exposure has been reported to be >200 mg/m ³ .
Irritation	The available data show that the chemical is a mild skin irritant in animals. Mild dermal irritation was reported in rabbits and guinea pigs. No dermal effects were reported in female CD-1 mice exposed to 3549 mg/kg bw/day ethylene glycol under occlusive conditions for 6 hours/day on gestation days 6-15 (NTP, 2004; WHO, 2002). The available data indicate that the chemical is a mild eye irritant in animals. In a study conducted in six New Zealand White rabbits, 0.05 mL of the chemical (4 or 40 %) applied to one eye (while the other eye served as a control) at 10 minute intervals for a total of 35 applications in a six hour period was reported to cause chemosis, swelling and conjunctival redness. All eyes exposed to the chemical were reported to be normal on day seven of observation and no evidence of systemic toxicity was reported (REACH).
Sensitisation	The chemical was not found to induce dermal sensitisation when tested according to OECD Test Guideline (TG) 406 (REACH).
Health Effects Summary	Ethylene glycol demonstrates acute oral toxicity, is a mild skin and eye irritant and a respiratory irritant in humans. The chemical is not a skin sensitiser. Consistent adverse effects associated with repeated exposure to ethylene glycol in animals are the kidney effects, characterised by calcium oxalate crystal deposition and consequent renal lesions.

Key Study/Critical Effect for Screening Criteria	The key study chosen for the determination of a drinking water guidance value is the one-year rat feeding study by Wilson et al. (2005). No adverse chronic renal effects from ethylene glycol dosing were seen in animals exposed below 150 mg/kg/day. The oral RfD for ethylene glycol is thus based on the NOAEL of 150 mg/kg/day. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Oral RfD = 150/100 = 1.5 mg/kg/day Drinking water guideline value = 0.59 ppm
Ecological Toxicity^{3,8}	
Aquatic Toxicity	The aquatic toxicity of the 'ethylene glycol and higher glycols' (mono-, di-, tri-, tetra- and pentaethylene glycol) is evaluated as a category. Fish acute toxicity (measured as LC50 in mg/L) has been tested for all category members and ranges from 22800 for EG to greater than 50000 for pentaEG. Toxicity to Daphnia (measured as LC50 in mg/L) is greater than 20,000 for all category members except tetraEG (LC50=7800 mg/L) indicating low toxicity, but the toxicity was not as uniform as in fish. Toxicity evaluations in another invertebrate, brine shrimp (<i>Artemia salina</i>) were imprecise, but appear to be more consistent than the measured Daphnia toxicity values (no toxicity observed at the highest tested dose, 20g/l for EG, 10 g/l for DEG, TEG and tetraEG). Algal toxicity has been tested for EG, DEG, TEG, and PentaEG, and no toxicity was found at concentrations less than or equal to 100 mg/L. As a worst case assumption the limit test concentration of 100 mg/L was used as NOEC value for the PNEC derivation.
Determination of PNEC aquatic	PNECaquatic: An assessment factor of 10 has been applied to the lowest reported effect concentration of 100 mg/L. The PNECaquatic is determined to be 10 mg/L.
Current Regulatory Controls⁷	
Australian Hazard Classification	Xn (Harmful); R22 (Harmful if swallowed) (Safe Work Australia 2013) Acute Toxicity: Harmful if swallowed – Cat 4 (H302) (NICNAS)
Australian Occupational Exposure Standards	Ethylene glycol has an exposure standard of 10 mg/m ³ time weighted average (TWA). A further exposure standard for ethylene glycol (vapour) is 52 mg/m ³ (20 ppm) TWA and a short-term exposure limit (STEL) of 104 mg/m ³ (40 ppm) (Safe Work Australia 2013)
International Occupational Exposure Standards	TWA: 50 mg/m ³ (20 ppm) [Belgium, Hungary, UK, Finland] 26 mg/m ³ (10 ppm) [Denmark, Iceland, Sweden] 25 to 50 mg/m ³ (63 to 125 ppm) [Mexico, Norway] 5 mg/m ³ [Russia] STEL: 20 to 40 mg/m ³ (50 to 104 ppm) [Belgium, Hungary, UK, Finland, Peru, Sweden] 10 mg/m ³ [Russia]
Australian Food Standards	No data found.
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment^{1,3,5}	
P/vP Criteria fulfilled?	Ethylene glycol is readily biodegradable both aerobically and anaerobically and as such not persistent in the environment.
B/vB criteria fulfilled?	Based on the measured log Kow of -1.36 and a measured BCF of 10, Ethylene glycol is not bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of Ethylene glycol is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data).
Revised	April 2018

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Toxicity Summary - Fatty acids, tall-oil, ethoxylated

Chemical and Physical Properties ¹	
CAS number	61791-00-2
Molecular formula	C(18-50)H(34-98)O(3-8)
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 sings 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 sings 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.
Health Effects Summary	Possible sensitiser.
Key Study/Critical Effect for Screening Criteria	
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	
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 xx 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
Revised	January 2019

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1. ECHA REACH, Fatty acids, tall-oil, ethoxylated, Retrieved 2019: <https://echa.europa.eu/>

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 subcidal 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 reproduct'n 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 for faunal species
Current Regulatory Controls ^{1,2,4}	
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
Revised	January 2019

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Toxicity Summary - Guar gum

Chemical and Physical Properties ^{1,2,7}	
CAS number	9000-30-0
Molecular formula	NA.
Product name	
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 ^{1,2,3,5,6,7,8,9}	
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).

Key Study/Critical Effect for Screening Criteria	The key studies for the determination of a drinking water guidance value is the NTP two year chronic bioassays. The LOAELs are based on decreased mean body weights in female mice and rats fed 50,000 ppm guar gum in diet for 103 weeks. The NOAELs for these studies are 25,000 ppm guar gum. Rat: NOAEL (mg/kg/day) = 25,000 ppm * 0.05 = 1,250 mg/kg/day Mouse: NOAEL (mg/kg/day) = 25,000 ppm * 0.13 = 3,250 mg/kg/day Where 0.05 and 0.13 are the fraction of body weight that rats and mice, respectively, consume per day as food (U.S. EPA). The lowest NOAEL of 1,250 mg/kg/day for the rat will be used to derive a drinking water guidance value. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability) Oral RfD = 1,250/100 = 12.5 mg/kg/day Drinking water guideline = 49 ppm
Ecological Toxicity ^{1,7}	
Aquatic Toxicity	The lowest measured ecotoxicity endpoint for fish was reported to be 218 mg/L.
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.
Current Regulatory Controls	
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.
Australian Hazard Classification	No data available.
PBT Assessment	
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.

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Toxicity Summary - Hydrochloric acid

Chemical and Physical Properties ^{1,2}	
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
Henrys law constant	2.04 x106 mol/L atm
Explosive potential	Reacts with most metals producing explosive hydrogen gas
Flammability potential	Not combustible
Colour/Form	liquid
Overview	CAS Registry number. Since the gas becomes the acid in aqueous systems and volatilization of the gas can occur from aqueous systems, it is often difficult to determine which is being considered in a specific item in the literature. If released to water, hydrogen chloride dissociates readily in water to chloride and hydronium ions, decreasing the pH of the water. The solution in water is a strong acid, it reacts violently with bases and is corrosive. Reacts violently with oxidants forming toxic gas (chlorine). Attacks many metals in the presence of water forming flammable/explosive gas (hydrogen). 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 ^{3,4}	
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 CO ₂ , HCO ₃ ⁻ and CO ₃ ²⁻ in the aquatic ecosystem is mainly responsible for the buffer capacity of receiving water.

Human Health Toxicity Summary ^{1,2,3,8}	
Chronic Repeated Dose Toxicity	Frequent contact with aqueous solutions of hydrochloric acid may lead to dermatitis. For repeated dose toxicity, local irritation effects were observed in the groups of 10 ppm and above in a 90-day inhalation study. Rats were fed diets containing 280 to 1,250 mmol/kg hydrochloric acid (10.2 to 45.6 mg/kg) for 7-12 weeks. There was increased water intake in all treated groups. All animals fed diet containing 937 mmol/kg and above for 9 weeks, and half of the animals fed diet containing 900 mmol/kg for 12 weeks died. Also at doses >937 mmol/kg, there was decreased body weight, food consumption, blood pH, femur length, rate of ash in bone (Upton and L'Estrange, 1977). In another study with rats, hydrochloric acid was administered via drinking water at pH 2-3 (study duration not provided). Decreased protein levels in urine and decreased urine volumes were observed in the treatment groups (Clausing and Gottschalk, 1989).
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.

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 ⁸	
Australian Hazard Classification	C (Corrosive); R34 (Causes burns) Xi (Irritant); R37 (Irritating to respiratory system).
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
Revised	April 2018

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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 C₉-C₁₄ 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 10⁴ to 1.67 x 10⁶ Pa·m³/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 10⁶ •OH/cm³. 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 a2μ-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 ($\leq 2\%$ 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	
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	
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
Revised	January 2019

Human Health Risk Assessment

Occupational Exposure

Table 2 presents the calculated internal doses for adult workers associated with drilling chemical exposure/hydraulic fracturing chemical exposure.

Table 2 Calculated Internal Doses for Adult Workers

Occupational Activity	E_{derm} (mg/kg bw/day)	E_{inh} (mg/kg bw/day)	E_{total} (mg/kg bw/day)
Transport and storage	Negligible*	Negligible*	Negligible*
Mixing/blending drilling of hydraulic fracturing chemicals	0.06	0.750	0.810
Injection of drilling chemicals	Negligible*	Negligible*	Negligible*
Cleaning and maintenance (hydraulic fracturing)	0.012	0.150	0.162
Combined exposure Mixing/blending and cleaning and maintenance			0.972
Transport and storage of drilling muds	Negligible*	Negligible*	Negligible*

E_{derm} - Internal dose from dermal exposure; E_{inh} – Internal dose from inhalation exposure; E_{total} – Total internal dose from all routes.

* In the absence of accidents/incidents, repeated occupational exposures during transport and storage, or during injection of mixed/blended chemicals, are negligible. Similarly, repeated occupational exposures to the chemical via the transport and storage of drilling muds are negligible (NICNAS 2017).

Human Health Risk Characterisation

Uncertainty Factors

Using the Margin of Exposure (MOE) approach, conservative default uncertainty factors for intra- and inter-species variability are assumed to be 10 each. A MOE of less than 100 is considered a concern (NICNAS 2017).

Acute Health Risks

Acute exposure to the chemical is unlikely to result in adverse health effects. In addition, given the low concentration in the drilling fluids, exposure to the chemical via these fluids is of low concern for workers.

Chronic long-term health risks

The critical (most sensitive) adverse health effect is maternal toxicity (decreased bodyweight gain). The NOAEL established for this effect is 1000 mg/kg bw/day from a reproductive toxicity study. There are no adverse effects observed from repeated exposures to the chemical at any dose tested, up to 1000 mg/kg bw/day. This highest no-effect dose is applicable for a general worker. Margins of Exposure (MOE) for adverse health effects from repeated occupational exposures are calculated by comparing the NOAEL with exposures estimated for different occupational activities and combined activities. **Table 3** presents Margin of Exposure calculated for Adult Workers associated with drilling

chemical exposure/hydraulic fracturing chemical exposure. Risk characterisation calculations are presented in **Attachment A**.

Table3 Margins of exposure calculated for adult workers

Adult worker exposure scenario	E _{total} (mg/kg bw/day)	NOAEL (mg/kg bw/day)	Critical effect	MOE (NOAEL / E _{total})	Chemical is of concern? (MOE < 100)
Occupational Activity					
Mixing/blending drilling of hydraulic fracturing chemicals	0.810	1000	Maternal toxicity in rats	1235	No
Cleaning and maintenance (hydraulic fracturing)	0.162			6173	
Combined exposure Mixing/blending and cleaning and maintenance	0.972			1029	

Based on uncertainty factors derived for this risk characterisation, the MOEs indicate that the chemical is of low concern for workers from repeated exposures during certain operations.

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
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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 - 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
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.
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 cm ³ /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/m ³) 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	A PNECaqua = 3.20E+03 mg/L can be calculated based on the lowest chronic toxicity value for aquatic invertebrates (Daphnia) with the assessment factor of 10.
Current Regulatory Controls ⁴	
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/m ³ (200 ppm) Time Weighted Average (TWA) and 328 mg/m ³ (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 Assessment	
P/vP Criteria fulfilled?	No. Methanol is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. The Log Kow for methanol is -0.82 to -0.64. 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
Revised	January 2019

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>
5. IPCS Acetic Acid, Retrieved 2015: <http://www.inchem.org>

Toxicity Summary - Polyethylene glycol

Chemical and Physical Properties	
CAS number	25322-68-3
Molecular formula	(C ₂ H ₄ O) _n H ₂ O
Molecular weight	UVCB
Solubility in water	40 g/L @ 30 °C
Melting point	-10 °C at 101.3 kPa
Boiling point	870 °C at 101.3 kPa
Vapour pressure	0 Pa @ 25 °C
Henry's law constant	
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Odourless, viscous transparent organic liquid
Overview	Polyethylene glycols, also known as PEGs, are clear, colourless, thick liquids to waxy solids, depending on the molecular weight. The molecular weight of PEGs ranges from 200 to over 6000. Some may have a faint odour and bitter taste. PEGs mix easily with water. PEGs are important commercial chemicals. They are used to make other chemicals, paper coatings, solvents, plasticizers and used in many household products, cosmetics and pharmaceuticals. One formulation, PEG 3500, is used as a laxative. PEGs are also used as food and animal feed additives.
Environmental Fate ¹	
Soil/Water/Air	Koc value of PEG was estimated as 10 L/kg by means of MCI method. This indicates that PEG will have a negligible tendency of sorption to soil and sediment and therefore have rapid migration potential to groundwater. The estimated half-life of the substance indicates that the substance is rapidly hydrolysable.

Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	The substance PEG exhibits repeated dose toxicity by oral, dermal and inhalation route. A study was designed to investigate the subacute repeated dose toxicity effects of Polyethylene Glycols (PEG 400) in Wistar rats (male/female) by oral route, in an overall study period of 90 days. Dose group (5 animals per group) was fed a solution of PEG400 equivalent to 0, 2000, 4000, 8000, 16000 or 24000 mg/kg/day in the diet. The control group received no polyethylene glycol. During the study period, body weight as a ratio to the amount of nutrient consumed, body weight, liver weight, kidney weight, micro pathology of liver and kidneys were examined. No effects upon male and female rats were observed when PEG 400 was present in the diet at a level up to 8000 mg/kg/day (8% concentration) for 90 days study period. But at 16000 mg/kg/day it showed effects on organ weight (liver and kidney heavier than that of control rats); and a decrease in weight gain was observed. Thus, from overall conclusion of the study the NOAEL (no observed adverse effect level) for repeated dose oral toxicity was considered to be 8000 mg/kg/day. And the LOAEL (low observed adverse effect level) for subacute repeated dose toxicity was considered to be 16000 mg/kg/day. Rats were exposed to airborne concentrations of 100 mg/m³ and 1000 mg/m³ of PEG-200 for periods up to 13 weeks. Toxicological, physiological, hematological, blood chemical, and pathological effects were evaluated during the course of the exposures. No significant lesions observed in this study occurred exclusively in exposed animals and the severity of lesions which were found was not dose-related. It is our impression that there were no PEG 200 induced lesions in rat tissue at the dosage level and exposure/post exposure periods evaluated in this study. Organ:body weight ratios in rats at all concentrations and for the 6- and 13-week exposure periods and the 30-day post exposure period showed no pattern of significance that could be related to PEG 200. The mice organ:body weights for the 6-week exposure period are unavailable. No pattern of significance could be related to PEG 200 exposure for the 13-week or the 30-day post exposure periods. There were no consistently significant changes in rat blood chemistry at the end of the 6- or 13-week exposures or the 30-day post exposure period. It appears that PEG-200 produced no positive effects in the rodents at the 100 and 1000 mg/m³ PEG 200 concentrations over the 13 weeks of exposure used in this study. Thus it is concluded that the NOAEC value of PEG-200 in rats was observed at dose level of 1000 mg/m³. The NOAEL value of PEG in rabbit was observed at dose level of 760 mg/kg bw/day. The supporting study indicates the TDLo (TDLo - Lowest published toxic dose) of PEG was observed at a dose concentration of 30 mL/kg (30000 mg/kg) in a 30 days study period where the dosage of PEG was intermittently given to rodent-rabbit by the dermal route (full study is not available). Considering the above results it is concluded that PEG is non-toxic by dermal route.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	PEG was found to be non-genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	The one generation reproductive toxicity NOAEL (no observed adverse effect level) of PEG in rat was observed at a dose concentration of 1698.09 mg/kg bw/day. On the basis of this NOAEL value it indicates that PEG does not exhibit toxic effects to rat below the above mention dose.
Acute Toxicity	Acute toxicity of PEG to mouse by the oral route indicates that the substance does not exhibit acute toxicity by the oral route. Similarly the acute values of inhalation also indicate that the substance does not exhibit acute toxicity by the inhalative route. Thus, it can be inferred that the target substance is non-toxic to any of the oral, dermal and inhalation route of exposure.
Irritation	The available studies indicate that the substance PEG is not classified as a skin and eye irritant according to CLP regulation within the dose levels mentioned in the study.
Sensitisation	In the human repeat insult patch test 216 subjects were enrolled and 200 subsequently completed the study. PEG 200 caused some degree of sensitization response in 1 of the 200 subjects. This subject was a 61 year old white woman.

Health Effects Summary	PEG is non acute toxic to oral, dermal and inhalation route, shows no irritation effect to skin and eye, is not genotoxic and is not developmental and reproductive toxic.
Key Study/Critical Effect for Screening Criteria	Oral: In chronic repeated dose toxicity study by polyethylene glycols (PEG) 400 showed no effect upon male and female dogs when present in the diet at a level of 500 mg/kg/day (2% concentration) for one year. Thus NOAELs (no observed adverse effect level) for repeated dose oral toxicity was considered to be 500 mg/kg/day. Inhalation: The NOAEC value of PEG-200 in rats was observed at dose level of 1000 mg/m³. Dermal: The NOAEL value of PEG in rabbit was observed at dose level of 760 mg/kg bw/day.
Ecological Toxicity ¹	
Aquatic Toxicity	The toxicity values of fish, invertebrates and algae are LC50 = 100 mg/L, LC50 = 1000 mg/L and EC 50 = 15.91 mg/L, respectively.
Determination of PNEC aquatic	Acute LC50 values are reported for fish, aquatic invertebrates, and freshwater algae. Since there is valid acute toxicity data for three trophic levels, an assessment factor of 1000 is used (in accordance with EU guidance). Based on the EC50 for freshwater algae (the most sensitive species in short term tests), the aquatic PNEC is 15.91 µg/L.
Current Regulatory Controls	
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 ¹	
P/vP Criteria fulfilled?	No. PEG is non persistent in nature and so is considered to have rapid biodegradation in the environment.
B/vB criteria fulfilled?	No. The calculated BCF of PEG is 3.2 dimensionless and below the threshold of 2000.
T criteria fulfilled?	No. Acute toxicity data >1 mg/L in fish, invertebrates and algae, thus PEG does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

1. ECHA REACH European Chemicals Agency Database: <http://apps.echa.europa.eu>

Toxicity Summary - Sodium bisulfite

Chemical and Physical Properties ¹	
CAS number	7631-90-5
Molecular formula	H ₂ O ₃ S.Na
Molecular weight	104.06
Solubility in water	724 g/L @ 20 °C
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	Sulfites in aqueous solutions involve complex equilibria among the different species of sulfur oxidation state IV. The composition of their mixture in solutions depends on the pH and temperature. Sulfur dioxide may be produced from sulfites at low pH. At a pH closer to 7, the concentration ratio of bisulfite (HSO₃⁻) to sulfur dioxide (SO₂) is very high (Gunnison and Jacobsen, 1987). Sulfites occur naturally in some foods and beverages as a result of fermentation (e.g. in beer and wine). A small percentage of the population (up to 1 %) is sensitive to sulfites (FDA, cited in Grotheer et al., 2005), as sulfur dioxide may be generated from sulfites in the stomach at low pH (Simon, 1986). The sensitivity to sulfur dioxide can cause a wide range of reactions in humans ranging from mild to severe dermatological, pulmonary, gastrointestinal, or cardiovascular symptoms (Grotheer et al., 2005).
Environmental Fate ¹	
Soil/Water/Air	The substance has a very low vapour pressure, and also does not sublime. Therefore, the substance will not be present as a gas and no radical reactions can be expected. According to its chemical properties, hydrolysis is not expected/probable. Photodegradation in water is not relevant because it dissociates rapidly into ions and decomposes in water, and it not susceptible to visible light. The substance is an inorganic compound which does not undergo biodegradation. The substance readily dissociates in aqueous solution, as with soil moisture. Bioaccumulation is not to be expected. a low log Kow underlines this statement. Due to the ionic salt-character and other physico-chemical properties (negligible vapour pressure, very high water solubility and decomposition in water), the Henry constant is near to zero. Because of its ionic nature, sodium hydrogensulfite as well as its dissociation products are not volatile from aqueous solutions. Relevant adsorption onto soils, sediments or suspended matter is not expected.

Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	Based on the data available for sodium metabisulfite, Sulfites are not considered to cause serious damage to health by repeated oral and inhalation exposure. In an 8-week study, SD rats (normal and sulfite oxidase enzyme—which oxidises sulfite to sulfate—deficient) were exposed to sodium metabisulfite (CAS No. 7681-57-4) or a mixture containing sodium metabisulfite and acetaldehyde hydroxysulfonate, in drinking water at doses of 0, 7, 70 or 175 mg/kg bw/day (as SO₂). A no observed effect level (NOEL) for sodium metabisulfite was established as 70 mg/kg bw/day (as SO₂) for all treated rats (normal and enzyme deficient), based on severe gastric lesions, significant body weight reduction and increased urine excretion with sulfites observed at the highest dose. The NOEL for the mixture was 7 mg/kg bw/day (as SO₂) for enzyme-deficient rats, based on severe gastric and hepatic lesions at higher doses. At necropsy, lung oedema was observed in sodium metabisulfite treated, enzyme-deficient rats (Hui et al., 1989 cited in CIR, 2003). Groups of six rats (Sprague Dawley) were exposed to sodium sulfite (CAS No: 7757-83-7) aerosols with a particle size of approximately 1 µm at concentrations of 0.1, 1, 5 or 15 mg/m³ for three days. Mild pulmonary oedema at 5 mg/m³ and irritation of the tracheal epithelium at 15 mg/m³ were observed (CIR, 2003). In a repeated dose study, eight dogs (beagle) were exposed to 1 mg/m³ of sodium metabisulfite (CAS No: 7681-57-4) aerosols with a mass median aerodynamic diameter (MMAD) of 0.63 µm for 290 days. Severe epithelial changes were observed with hyperplastic foci in the respiratory region of the nasal cavity. An increase in the nonciliated cell numbers in the membranous portion of the trachea of the animals was also observed. No other effects were reported (CIR, 2003).
Carcinogenicity	Based on a 104-week repeated dose toxicity study in rats, with up to 2 % sodium bisulfite in the diet, sodium bisulfite is not considered carcinogenic to rats (OECD, 2001).
Mutagenicity/ Genotoxicity	Based on the data available, Sulfites are not considered to be genotoxic. A mixture of sodium bisulfite (CAS No. 7631-90-5) and sodium sulfite (1:3) was tested at concentrations of 0.05–1 mmol/L in human peripheral lymphocytes. Positive results were obtained for chromosomal aberrations: micronucleus formation, and sister chromatid exchange (WHO, 1999). In an in vitro unscheduled DNA synthesis test with rat hepatocytes (OECD TG 486), and in an in vivo micronucleus test (OECD TG 474), sodium bisulfite (CAS No. 7631-90-5) did not show any evidence of mutagenicity (SCCNFP, 2003). Sodium bisulfite gave both positive and negative results in the mutagenicity testing. The positive results in Salmonella typhimurium strains containing his-G46 and his-D6610 mutations, and in some E.coli strains were suggested to be due to the presence of sulfurous acid under acidic conditions. At a neutral pH and lower concentrations, sodium bisulfite was not mutagenic to these strains. However, sodium bisulfite alone gave negative results in all in vivo studies with mammalian systems (rats and mice) (CIR, 2003).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the data available, Sulfites are not considered to cause reproductive or developmental toxicity. Pregnant rats (Wistar) were exposed by gavage to sodium bisulfite (CAS No. 7631-90-5) at 0, 1, 5, 24, or 110 mg/kg bw/day on days 6–15 of gestation. The NOAEL for maternal toxicity or embryo foetotoxicity was 110 mg/kg bw/day. A NOAEL of 123 mg/kg bw/day was established in a study with pregnant rabbits (Dutch belted) exposed to sodium metabisulfite (CAS No. 7681-57-4) at 0, 1.23, 5.71, 26.5 or 123 mg/kg bw/day on days 6–18 of gestation. In both these studies, there were no treatment related effects reported on nidation (nesting behaviour), maternal or foetal survival. The number of abnormalities in soft or skeletal tissues of the treated groups were similar to controls (OECD, 2001).

Acute Toxicity	Sodium bisulfite has an oral LD50 of 2000 mg/kg bw in rats (ChemIDplus). Based on the limited data available, sulfites are considered to be of low acute dermal toxicity. The LD50 for sodium metabisulfite in rats is >2000 mg/kg bw. Sulfites exhibit low acute toxicity in animal tests (US EPA, 2007). Based on the limited data available, no conclusion can be made on the acute inhalation toxicity of the chemicals in this group. A group of guinea pigs was exposed (whole body) for one hour to 0.204, 0.395 or 1.152 mg/m³ of sodium sulfite (CAS No. 7757-83-7) aerosols with a mass median aerodynamic diameter (MMAD) of 0.36 µm. The chemical caused dose-related changes in the lung capacity parameters (bronchoconstriction) with a lowest observed adverse effect concentration (LOAEC) of 0.204 mg/m³ (Chen et al., 1987 cited in CIR, 2003). Sodium bisulfite are classified as hazardous with the risk phrase 'Contact with acid liberates toxic gas' (Xi; R31) in the Hazardous Substances Information System (HSIS) (Safe Work Australia).
Irritation	No data are available on respiratory tract irritation from a single exposure. A 3-day repeated dose study indicated irritation of the tracheal epithelium in rats from exposure to sodium sulfite (CAS No. 7757-83-7) aerosols at 15 mg/m³ (CIR, 2003). In acute dermal irritation studies (OECD TG 404) with sodium sulfite, sodium bisulfite and potassium sulfite, no skin irritation was observed in albino rabbits (SCCNFP, 2003). In acute eye irritation studies (OECD TG 405) with sodium sulfite and sodium bisulfite in rabbits, slight to severe effects in the cornea and the iris in most of the exposed animals persisted during the observation periods (eight and 15 days, respectively). Slight to moderate conjunctival effects (erythema and oedema) were also observed up to the end of the observation periods. Due to the persistency of eye effects, especially of increased corneal opacity, both chemicals were considered as severe eye irritants (SCCNFP, 2003).
Sensitisation	Based on the available data, Sulfites are not likely to be skin sensitisers.
Health Effects Summary	Severe eye irritation effects; acute oral toxicity; and the possibility of liberating toxic gas when the chemical is in contact with acids. Sensitivity to sulfites that causes allergic reactions in a small percentage of the population should also be considered.
Key Study/Critical Effect for Screening Criteria	The main critical effects to human health are severe eye irritation and acute oral toxicity. The chemicals in this group will liberate toxic gas when in contact with acid and therefore may cause effects in individuals with a high acid content in the stomach. A small percentage of the population (up to 1 %) are sensitive to sulfites (FDA, cited in Grotheer et al., 2005). Those who have asthma are most at risk to sulfite sensitivity and other forms of sulfite reactions. This sensitivity can cause a wide range of allergic reactions ranging from mild to severe.
Ecological Toxicity ²	
Aquatic Toxicity	Acute and chronic toxicity data were available for the three main aquatic trophic levels that are considered for classification purposes. Classification is based on the lowest acute and chronic value, referred to as the acute and chronic toxicity reference value (TRV). The lowest acute effect concentration was observed for the alga <i>S. subspicatus</i> (72h-EC50), and was 36.8 mg sodium sulfite/L. Translating this value to HNaSO₃ results in an acute TRV of 47.9 mg/L for this substance. For sulfite/disulfite compounds, the lowest chronic value was a NOEC of >8.41 mg sodium sulfite/L for the invertebrate <i>D. magna</i>. Translating this value to HNaSO₃ results in a chronic TRV of 10.9 mg/L for this substance, i.e., > 1 mg/L.

Determination of PNEC aquatic	The lowest value for chronic toxicity was an unbounded NOEC of 8.41 mg sodium sulfite/L. Applying the AF of 10 results in a PNECaquatic of 0.84 mg sodium sulfite/L. Translating this value to HNaSO₃ gives a PNECaquatic of 1.09 mg test substance/L. As the lowest NOEC-value is an unbounded value (i.e., no effect was noted at the highest test concentration), this value can be considered as a worst-case estimate. Further refinement of the NOEC-value for daphnids could increase the PNECaquatic up to a maximum value of 2.8 mg sodium sulfite/L (i.e., an assessment factor of 10 on the algal 72h-EC₁₀ value), which is equivalent to 3.64 mg test substance/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	Sodium bisulfite is classified as hazardous with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): Sodium bisulfite (CAS No. 7631-90-5): Xn; R22 (acute toxicity) Xi; R31 (contact with acid liberates toxic gas)
Australian Occupational Exposure Standards	Sodium bisulfite has an exposure standard of 5 mg/m³ time weighted average (TWA). The exposure standard for sulfur dioxide of 5.2 mg/m³ (2 ppm) (TWA) is also relevant to uses of these chemicals that may generate sulfur dioxide.
International Occupational Exposure Standards	An exposure limit (OEL, TWA, STEL, PEL or STV) of 5–10 mg/m³ in different countries such as USA, United Kingdom, Canada, Ireland, Spain, Norway and Switzerland.
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment ²	
P/vP Criteria fulfilled?	Not applicable (inorganic substance)
B/vB criteria fulfilled?	Not applicable (inorganic substance)
T criteria fulfilled?	Not applicable (inorganic substance)
Overall conclusion	Not PBT
Revised	January 2019

References

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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 25oC
pH	In aqueous solution is neutral
Melting point	1 mm Hg at 865oC
Boiling point	1670 °C
Vapour pressure	No data found
Henrys 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	Sodium is an essential mineral for the regulation of body fluid balance. 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 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.
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	
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
Revised	April 2018

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. 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

Toxicity Summary - Sodium hydroxide

Chemical and Physical Properties	
CAS number	1310-73-2
Molecular formula	Na-O-H
Product name	40 g/mol
Molecular weight	1.11E+06 mg/L at 20C
Solubility in water	13
Melting point	318 °C
Boiling point	1388 °C
Vapour pressure	Negligible at 25 deg C
Henrys law constant	No data found.
Explosive potential	No
Flammability potential	No
Colour/Form	Anhydrous (pure) NaOH is a solid – <i>refer melting point above</i> . However it is a hygroscopic, ionic solid, and will absorb water from air and is highly soluble
Incompatibility	Avoid contact of solid NaOH with water due to strong exothermic reaction, leather, wood, acids, organic halogen compounds or organic nitro compounds. Carbon monoxide gas can form upon contact with reducing sugars, food and beverage products in enclosed spaces. NaOH is neither explosive, flammable, nor oxidising.
Overview	Vegetable oil refining, regenerating iron exchange resins, organic fusions, peeling of fruits and vegetables in the food industry, etching and electroplating.
Environmental Fate ¹	
Soil/Water/Air	Sodium hydroxide is highly soluble, not volatile and unlikely to materially adsorb to soil and is therefore predominately found in the aquatic environment if released to the environment. NaOH will readily dissociate to be present in the environment as sodium and hydroxyl ions, both being ubiquitous in the environment. NaOH is a strong alkali, so it's dissolution in water may locally raise the pH of the affected environment. The dissolution reaction is also strongly exothermic.

Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	No animal data are available on repeated dose toxicity studies by oral or dermal routes for sodium hydroxide. In a repeat dose inhalation study, twenty seven white rats died within a month, mostly from bronchopneumonia, after being exposed twice weekly to an aerosol of unknown airborne concentration of sodium hydroxide, generated from an aqueous 40% sodium hydroxide solution (NIOSH 1975). When exposed to an aerosol generated from a 20% sodium hydroxide solution, the bronchi were dilated, the epithelial cover was thin and frequently desquamated, and the septa were dilated and cracked. A light round cell infiltration of the sub-mucus membrane tissue was also observed. Few changes occurred in a group of rats exposed to aerosols from 10% sodium hydroxide, but rats exposed to an aerosol of 5% sodium hydroxide had dilation of the bronchi and a slight degeneration of the mucus membrane and thickened strata of lymphadenoid tissue surrounding the bronchi. A NOAEL could not be established in this study. Workers exposed to 0.24 to 1.86 mg/m³ sodium hydroxide for 2 to 15 minutes reported throat irritation and watery eyes (NIOSH 1975). Based on the observations of the irritant effects on workers exposed to 1 to 40 mg/m³ sodium hydroxide, it was concluded that 2 mg/m³ represented a concentration that is 'noticeably but not extensively irritant' (NIOSH 1975). Obstructive airway disease has been reported following chronic occupational exposure to sodium hydroxide mist (IPCS 1996). The patient developed cough, dyspnoea and tachypnoea after a 20-year exposure to sodium hydroxide.
Carcinogenicity	IARC Category 3 - not classifiable as to human carcinogenicity
Mutagenicity/ Genotoxicity	In vitro and vivo genetic toxicity testing reported no evidence of mutagenic activity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No valid studies were identified regarding reproduction toxicity after oral, dermal or inhalation exposure to NaOH. Sodium hydroxide is not expected to be systemically available to the body under normal handling and use conditions.
Acute Toxicity	Exposure to the solid or concentrated liquid can cause severe burns to the eyes, skin and gastrointestinal tract which may cause death. An oral LD50 of a 1-10% solution of NaOH in rabbits was 325 mg/kg bw (as 100% NaOH). An oral LD50 of 140 to 340 mg/kg in rats has also been reported (National Research Council 2011), however details of the study are not available. In an acute dermal study, mice were treated dermally with 50% sodium hydroxide, and the treated area was irrigated with water at various intervals (OECD 2002). The mortality of mice was 20, 40, 80 and 71% when they were irrigated at 30 minutes, one hour, two hours or not at all after the application. All animals developed rapidly progressive burns. No mortality or burns were observed when the treated area was irrigated immediately after the application. A 5% aqueous solution of sodium hydroxide produced severe necrosis when applied to the skin of rabbits for four hours (Clayton and Clayton 1993). A dermal LD50 of 1350 mg/kg has been reported in rabbits (National Research Council 2011), however details of the study are not available. Caustic dusts are irritating to the upper respiratory system. Prolonged exposure to high concentrations may cause discomfort and ulceration of nasal passages. Cases of fatality due to ingestion of liquid sodium hydroxide have been reported in humans.
Irritation	Sodium hydroxide is a corrosive irritant to skin, eyes and mucous membranes. A NaOH solution of 8% can be considered corrosive based on animal data. Human data indicate that concentrations of 0.5 to 4% were irritating.
Sensitisation	Sodium hydroxide has no skin sensitisation potential.

Health Effects Summary	An oral LD50 of 325 mg/kg in rats and a dermal LD50 of 1350 mg/kg in rabbits were reported for sodium hydroxide. Lethality has been reported in animals at oral doses of 240 mg/kg bw. Inhalational LC50 is not available. Sodium hydroxide is corrosive to skin, eyes and gastrointestinal and respiratory tracts. Based on human data, concentrations of 0.5 to 4.0% are irritating to the skin, while a concentration of 8.0% is corrosive. Sodium hydroxide is not a skin sensitiser. No animal data were available on repeated dose toxicity by oral or dermal routes for sodium hydroxide. In the single reported repeat dose inhalation study, a NOAEL could not be established. Both in vitro and in vivo genetic toxicity tests indicated no evidence of a mutagenic activity. Information is not available on reproductive and developmental toxicity and carcinogenicity of sodium hydroxide. Due to dissociation into ions which are subject to homeostatic controls in the human body, systemic effects from repeated exposures to sodium hydroxide are not expected. The critical health effect of sodium hydroxide is its corrosive effect.
Key Study/Critical Effect for Screening Criteria	No oral TRV apply. Acute toxicity only (irritant and corrosive), not systemically available in body. The Australian drinking water guideline value for pH may apply to sodium hydroxide.
Ecological Toxicity ^{1,2,3}	
Aquatic Toxicity	Measured acute endpoints were available for fish (196 mg/L). Measured chronic endpoint were available for Daphnia (240 mg/L)
Determination of PNEC aquatic	An assessment factor of 10 has been applied to the lowest reported NOEC of 240 mg/L for Daphnia. The PNECaquatic is 24 mg/L.
Current Regulatory Controls ⁴	
Australian Hazard Classification	C: R35 (Corrosive, causes severe burns)
Australian Occupational Exposure Standards	Sodium hydroxide has an exposure standard of 2 mg/m ³ , Time Weighted Average (Safe Work Australia 2013).
International Occupational Exposure Standards	Occupational Exposure Limit (OEL) or limit values in working environment of 2 mg/m³ [Argentina, Belgium, Bulgaria, Canada, China, India, Japan and the US (NIOSH 1975)]. Occupational exposure standard: 2 mg/m³ [Korea] Occupational exposure limit values: 0.5 mg/m³ [Latvia] Short Term Exposure Limit (STEL): 2 mg/m³ [UK] US Department of Energy Temporary Emergency Exposure Limits (TEELs) = 0.5 mg/m³ (TEEL-0 and TEEL-1), 5 mg/m³ (TEEL-2) and 50 mg/m³ (TEEL-3).
Australian Food Standards	Processing aids - Generally permitted - permitted for use as acidity regulator (FSANZ 2013). Sodium hydroxide is allotted an International Numbering System (INS) of food additives number: INS 524 (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found. However, since sodium hydroxide readily dissociates in water into sodium and hydroxyl ions, the Australian Drinking Water Guidelines for sodium state that, based on aesthetic considerations (taste), the concentration of sodium in drinking water should not exceed 180 mg/L (National Health and Medical Research Council (NHMRC) 2011). No health-based guideline value is proposed for sodium.
Aquatic Toxicity Guidelines	No data found.
Occupational Exposure Limits	Peak limitation – 2 mg/m ³
PBT Assessment	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and hydroxide ions are ubiquitous and are present in most water, soil and sediment.

T criteria fulfilled?	Not applicable. Chronic toxicity data >1 mg/L in invertebrates, thus sodium hydroxide does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT

References

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2. HSDB (n.d.). *Hazardous Substances Data Bank*. Retrieved March 2015, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
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4. Safe Work Australia, Hazardous Substances System, sodium hydroxide

Toxicity Summary - Sodium iodide

Chemical and Physical Properties ^{1,2,3}	
CAS number	7681-82-5
Molecular formula	INa
Molecular weight	149.92
Solubility in water	165 – 1,800 g/L @ 25 °C
Melting point	651 - 659 °C at 101.3 kPa
Boiling point	1,304 °C at 101.3 kPa
Vapour pressure	-1.301 @ 25 °C
Henrys law constant	0.015 Pa.m ³ .mol ⁻¹ @ 25 °C
Explosive potential	Non explosive
Flammability potential	Non flammable
Colour/Form	Solid, colourless cubic crystals, odourless
Overview	Iodides are used by the thyroid gland in hormone production. Iodides have been utilized to treat iodine disorders, hyperthyroidism, bacterial, fungal or protozoal infections and also were traditionally as expectorants because of their stimulatory effects on bronchial secretions. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate ²	
Soil/Water/Air	Sodium iodide is very stable under ordinary conditions of use and storage. The phototransformation in air is irrelevant to sodium iodide, because few sodium iodide can be distributed in air for the low vapour pressure and high water solubility. Hydrolysis is not a concern to such inorganic substance which can be completely ionized in water phase. sodium iodide will completely dissociate in water giving sodium ion and iodide anion. The sodium iodide is readily absorbed by organisms as Na⁺ and I⁻, which are both small (an)ions and well known to not likely to be bioaccumulative. Based on the intrinsic prosperities of sodium iodide, the substance can be expected to have a low potential for adsorption (completely ionized to small ions in water phase). The sodium ion and iodide anion are uniformly distributed in water phase. In the air, these two basic (an)ions is negligible, due to high water solubility and low vapour pressure. To sediment and soil phases, these two (an)ions are mostly distributed in the pore water.
Human Health Toxicity Summary ¹	

Chronic Repeated Dose Toxicity	The most likely route for human exposure is via digestion, so the dermal and inhalation route are irrelevant in the repeated toxicity assessment. Boyages et al. (1989) compared thyroid status in groups of children 7–15 years of age who resided in two areas of China where drinking-water iodide concentrations were either 462.5 µg/l (n = 120) or 54 µg/l (n =51). Urinary iodine concentrations were 1236 µg/g creatinine in the high-iodine group and 428 µg/g creatinine in the low-iodine group. Although the subjects were all euthyroid, with normal values for serum thyroid hormones and TSH concentrations, TSH concentrations were significantly higher ($P < 0.05$) in the high-iodine group. The high-iodine group had a 65% prevalence of goitre and a 15% prevalence of Grade 2 goitre compared with 15% for goitre and 0% for Grade 2 goitre in the low-iodine group. To transform the measured urinary iodine levels into estimates of iodine intakes, steady state baseline dietary intakes of iodide were assumed to be equivalent to the reported 24 h urinary iodine excretion rates. Assuming a body weight of 40 kg and lean body mass of 85% of body weight, the urinary iodine/creatinine ratios reported by Boyages et al. (1989) can be converted to approximate equivalent intake rates of 1150 µg/day (0.029 mg/kg body weight per day) and 400 µg/day (0.01 mg/kg body weight per day) for the high- and low-iodine groups, respectively. Thus, the NOAEL for this study is considered to be 0.01 mg/kg body weight per day. From the Boyages et al. (1989) study, supported by the studies of Gardner et al. (1988), Paul et al. (1988), and others, a TDI of 0.01 mg/kg body weight, based upon reversible subclinical hypothyroidism, can be established by dividing the NOAEL of 0.01 mg/kg body weight per day by an uncertainty factor of 1.
Carcinogenicity	A chronic toxicity and carcinogenicity study, in which male and female F344/DuCrj rats were administered iodide (KI) in the drinking water at concentrations of 0, 10, 100 or 1000 ppm for 104 weeks was conducted. In the test, neither focal hyperplasias, adenomas nor carcinomas derived from the follicular epithelium were increased, despite the fact that iodide was administered for 2 yr. It was therefore concluded that long-term treatment of iodide per se does not result in thyroid tumour induction in rats. In contrast, SCCs were observed in the submandibular gland in the 1000 ppm groups of both sexes, along with focal acinar atrophy and/or ductular proliferation, frequently accompanied by squamous metaplasia. Based on the fact that the cell proliferation of these proliferating ductules was higher in cases with metaplasia, and the evidence of a morphological continuum from meta-plasias to squamous cell carcinomas, a histogenetic relationship is suspected, which was also described in previous investigation (Takegawa et al., 1998). Based on these findings, it suggests that excess iodide has a thyroid tumour-promoting effect, but iodide per se does not induce thyroid tumours in rats. In the salivary gland, iodide was suggested to have carcinogenic potential via an epigenetic mechanism, only active at a high dose (1000 ppm in drinking water). The default value of volume of drinking water for rat is well accepted of 10 ml/100g bw·day, and the average body weight for rat is 250g. Based on these the LOAEL for salivary glands for carcinogenicity is proposed to be 100 mg/kg bw·day of iodide by drinking water

Mutagenicity/ Genotoxicity	The mutagenic potential for iodide (in potassium iodide) was studied using the L5178Y mouse (TK+/-) lymphoma assay (Kessler et al., 1980), The established mutagens ethylmethanesulphonate (EMS) and dimethylnitrosamine (DMN)were highly active in this assay, whereas iodide (KI) was inactive. Using the BALB/c 3T3 transformation assay well assessed the transformational capacities of these same agents and the positive mutagen N-ethyl-N-nitro-N-nitrosoguanidine (MNNG). All concentrations of the iodide tested were inactive in this assay it can be concluded that KI did not possess any biologically significant mutagenic cell transforming ability. Another study (J.M. Poul, and P. Sanders, 2004) on genotoxic effects of potassium iodide was conducted in vitro using the alkaline comet assay at concentration of 0.625, 1.25, 2.5, 5 and 10 mM. Additionally in the test cell viability was also measured using the Trypan blue exclusion method and expressed as proportion of total cells. The test results showed that potassium iodide did not induced DNA damage or cytotoxicity in the alkaline comet assay for doses up to 10 mM. In the same study, the chromosome damage effects of potassium iodide were evaluated in vitro using cytokinesis-block micronucleus test at concentration of 0.625, 1.25, 2.5, 5 and 10 mM. Additionally in the test cytotoxicity was also measured by the binucleated (BN) cell ratio between treated and control slides. The test results showed that potassium iodide did not induce chromosome damage or cytotoxicity in the alkaline comet assay for doses up to 10 mM. In an in vivo chromosome aberration test on embryonic hepatocytes, Stable iodine of 10 mg/kg is administered to the rats 7 days after fertilization. Then the embryonic liver was homogenated and the cells in metaphase were stained and checked under metaphase. The chromosome aberration cells were counted respectively for the concentration group and control group. The chromosome aberration rate in the concentration group was compared with that in the control group. The result showed there was no significant difference between iodide dosed group with the control group. Therefore, it can be concluded that the iodide has neither genetic toxicity nor cytotoxicity to mammalian cells.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Iodide (KI) was fed to male and female rats before and during breeding, to females only during gestation and lactation, and to their offspring after weaning (day 21 after birth) through to day 90, at levels of 0, 0.025, 0.05 or 0.1% (w/w) of the diet. There was no evidence suggesting that potassium iodide was embryotoxic. Litter size was significantly reduced, but birth weights and external morphology among those born alive were not significantly altered. No change in thyroid weight was observed indicating that these doses were not overtly thyrotoxic. Thyroid hormones were not assessed, however, and it is possible that thyroid function could have been altered in these animals. Nevertheless, the data are consistent with a picture of impaired thyroid function. Several tests of post-weaning behaviour showed effects at the lowest dose, 0.025 % potassium iodide. M-maze errors were increased at this dose and rotorod performance decreased. However, because these effects were not found at the higher doses it appears unlikely that they were related to potassium iodide. At present, these effects can only be described as 'false positives'. The only effect on post-weaning behaviour that appeared to be consistently related to potassium iodide exposure was the reduction in nocturnal running-wheel activity found among the tested females. It may be that female cyclicity makes them more sensitive to the influence of chronic moderate iodide exposure than males and this could explain the contrast with the results of an acute test of activity and exploration, the open-field test, on which no consistent iodide-related effects were found. According to REACH guidance "R 10.8 of Guidance on information requirements and chemical safety assessment Chapter R.10: Characterisation of dose [concentration]-response for environment" The NOAEL can be calculated with the equation $R\ 10-7: NOAEL(mg/kg\ bw\ day) = NOEC\ (mg/kg\ food)/CONV$ Where NOEC (mg/kg food) is 0.1, and CONV for <i>Rattus norvegicus</i> (> 6 weeks) is 20, and 10 for <i>Rattus norvegicus</i> (≤6 weeks). Therefore under this study the NOAEL for rats is 50 mg/kg bw day (developmental). In another study, twenty-five thyroiditis-prone BB/W rats were prenatally and postnatally exposed to iodine in drinking-water at dosages equivalent to 0, 0.059, or 59 mg/kg body weight per day for about 12 weeks. An increase in the number of lysosomes and lipid droplets was observed in the treated animals, especially in the higher exposure group. However, the test organism is not healthy, as well as not enough information in the study, the effects cannot be considered to be dose related. Additionally, old studies were conducted with rabbits hamsters, rats and swine (Arrington LR, et al., 1965) to determine the effects of excess iodine intake. Females were bred to normal males, potassium or sodium iodide was added to the diet during the latter portion of gestation and the females were permitted to litter normally. Observations were made for length of gestation, parturition time, lactation and survival of young. 250 to 1000 ppm iodide fed for 2 to 5 days caused increasing mortality of new born rabbits. Hamsters were not affected by 2500 ppm iodine except for slightly reduced feed intake and decreased weaning weight of the young. Gestation time for rats and hamsters was not affected by iodine. Female rats and rabbits re-bred after removal from dietary iodine produced and nursed litters normally. Swine were not affected by dietary levels of iodine which were toxic to rabbits and rats. In conclusion, the iodide is not reproductive, embryonic toxicity, but the developmental toxicity was showed under concentration of 0.1% in diet, corresponding NOAEL as 50 mg/kg bw day (developmental).

Acute Toxicity	The most relevant study on vertebrates by oral route is a company study (A. Hausner, G. Weise, and A. Hofmann, 1980). In the test the effects of iodide were studied in male and female Wistar rats. 10 male and 10 female in each dose and control groups were administrated with potassium iodide for 14 days at dose of 0 (control), 2000, 2500, 2800 3200, 3600, and 4000 mg/kg body weight mg/kg bw respectively. The key value of LD50 was calculated by Probit-analysis (Fink und Hund 1965). It shows the 24 hour and 7-14 days of LD50 to rats (male/female) was respectively 3118 and 2779 mg/kg bw under test conditions. Therefore the key value which is used in the hazard classification and chemical safety assessment is 3118 mg/kg bw.
Irritation	Iodine has been used for dermal application in human as disinfectant (as Iodine and Povidine Iodine) for long time. The mechanism of disinfecting is oxidizing bactericide by iodine; meanwhile the iodine is reduced to iodide. It means after application of iodine on skin, the iodide is left on skin. In addition, based on information from assessment report of WHO, in a human assay, five patients were applied with potassium iodide in concentrations ranging from 5% to 20% in petrolatum, the reactions were negative. With such evidence, it can be concluded that iodide has no effect to the human skin.
Sensitisation	No adverse effect observed (not sensitising) for skin and respiratory sensitisation.
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	TDI of iodide is 0.01 mg/kg body weight.
Ecological Toxicity ²	
Aquatic Toxicity	The 96 hours acute toxicity test to Rainbow Trout (Laverock, M.J., M. Stephenson, and C.R. MacDonald, 1995) was conducted according to Protocol to determine the acute lethality of liquid effluents to fish, which was established by Ontario Ministry of the Environment. The results showed that the 96 hour LC50 is over 860 mg/l. The acute toxicity to daphnia of iodide was determined (INERIS Parc Technologique ALATA, 2012) according to OECD test guideline 202 following GLP procedure to give a result of 48hrs-EC50 as 1.27 mg/L (95%CL, 1.19 -1.38 mg/L). There is another data on daphnia acute toxicity (Laboratoire d'Ecotoxicologie Parc technologique ALATA, 1996) of KI according to method of "French standard", which was similar to OECD test guideline 202, which is 48 hrs- EC50 as 7.5 mg/l. As the study for NaI gives lower tolerance value for daphnia and the test itself is more reliable (Klimisch score 1), the 48 hrs- EC50 of 1.27 mg/l is taken as the key value. One study of acute toxicity of iodide to algae was published in well-known journal "water research" (Bringmann, G., and R. Kuhn, 1980). It was not a standard test and without declaration of GLP compliance, and in the test the 7 days cell multiplication inhibition test was applied to the model organism, Scenedesmus quadricauda (green algae) for iodide, but fulfilled basically scientific principles. The results showed the toxicity threshold (≥3% inhibition of the biomass of green algae) of iodide to green algae is 2370 mg/l.
Determination of PNEC aquatic	PNECaquatic: On the basis of the acute results for Daphnia, an assessment factor of 100 has been applied to the lowest reported effect concentration of 1.27 mg/L. The PNECaquatic is determined to be 1.27 µg/L.
Current Regulatory Controls	
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 ²	
P/vP Criteria fulfilled?	Not applicable (inorganic salt, ionic species ubiquitous in environment).
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions; sodium and iodide ions are ubiquitous and are present in most water, soil and sediment.
T criteria fulfilled?	Not applicable. Acute toxicity data >0.01 mg/L in invertebrates, thus sodium iodide does not meet the screening criteria for toxicity.
Overall conclusion	Not applicable.
Revised	January 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>
2. ECHA REACH, Sodium iodide, Retrieved 2019: <https://echa.europa.eu/>
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>

Toxicity Summary - Sodium Persulfate

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	7775-27-1
Molecular formula	Na ₂ O ₈ S ₂
Molecular weight	238
Solubility in water	730 g/l at 25 °C
Melting point	Decomposes at > 180°C
Boiling point	No data available
Vapour pressure	0 Pa at 25 °C (negligible)
Henry's law constant	No data available
Explosive potential	Non-explosive
Flammability potential	Non-flammable
Colour/Form	White crystals or powder
Overview	The persulfates category includes molecules with similar chemical structure and similar physical-chemical properties. Substances of the persulfate category are inorganic salts sharing the persulfate anion moiety. The inorganic substances differ only by the cationic portion of the salt, which is not expected to influence the hazardous properties of the molecule. The anionic part is identical and is expected to display the same environmental, ecotoxicological and toxicological behaviour based on the available data.
Environmental Fate ^{1,3}	
Soil/Water/Air	Substances of the persulfate category are not stable in the environment. Persulfates are not expected to adsorb to soil due to their dissociation properties, instability (hydrolysis) and high water solubility. They 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	
Chronic Repeated Dose Toxicity	The persulfates have low repeat dose toxicity. Twenty-eight-day repeated dose oral (dietary) toxicity studies were conducted in rats with three persulfate salts. The oral doses for the three salts were 0, 100, 316, 1000 ppm (equivalent to 0, 12.6, 41.2, 131.5 mg/kg bw/day for the potassium salt). Tests were performed in male rats only. The no observed adverse effect levels (NOAEL) for sodium and potassium salts were 137 and 131.5 mg /kg bw/day, respectively (the highest doses tested), while the NOAEL for ammonium persulfate was 41 mg/kg bw/day, based on decreased relative adrenal weight at the highest dose (FMC, 1979a; FMC, 1979b; FMC1979c). Another oral (dietary) subchronic toxicity study using sodium persulfate was conducted in rats. Rats (20/sex/group; strain not provided) were fed rodent chow containing 0, 300, 1000 or 3000 ppm sodium persulfate (0, 23, 100 or 225 mg/kg bw/day) for 90 days. On day 48 of the study, the concentration of the group receiving 1000 ppm was increased to 5000 ppm for the remainder of the study. At the two high dose levels body weight was decreased during the last 6 weeks of treatment (FMC 1979e).
Carcinogenicity	Based on the limited data available, there is no evidence of carcinogenicity of any of the persulfate salt. In a non-guideline study, female SENCAR mice were exposed dermally twice weekly to 0.2 mL of a 200 mg/mL solution of ammonium persulfate for 51 weeks. The investigators concluded that ammonium persulfate is neither a tumour promoter nor a complete carcinogen when applied to the skin (Kurokawa et al., 1984).

Mutagenicity/ Genotoxicity	Based on the limited available data, sodium persulfate was not mutagenic. An in vitro unscheduled DNA synthesis test was also negative for sodium persulfate (FMC, 1990d). The ammonium salt was not clastogenic in Chinese hamster fibroblasts in the absence of metabolic activation in a chromosome aberration test (Ishidate et al., 1988). Sodium persulfate was negative in two in vivo genotoxicity studies. Doses of sodium persulfate up to 338 mg/kg injected into mice intraperitoneally did not increase the incidence of micronuclei in bone marrow polychromatic erythrocytes (FMC, 1990c). Sodium persulfate was found to be non-genotoxic when tested up to 820 mg/kg in an in vivo unscheduled DNA synthesis test in rats (FMC, 1991c).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the limited data available for ammonium persulfate, the sodium persulfate is not toxic to reproduction or development. In a well conducted fertility/developmental study (OECD 421), groups of rats (CrI:CD (SD)IGS BR, 12/sex/group) were administered ammonium persulfate in the diet at doses of 0, 40, 100 and 250 mg/kg bw/day (Weaver, 2004). Animals (both sexes) were dosed two weeks prior to and during mating. Females were administered the substance following mating, throughout gestation and until lactation day 4. In the parental generation group, there were no treatment related clinical signs, effects on body and organ weights or gross lesions. There were no significant adverse effects on the gonads and progression of spermatogenesis, although a non-significant decrease in pregnancy rates was reported at = 100 mg /kg bw/day. On this basis, it was concluded that the NOAEL for fertility indices and reproductive performance was the top dose of 250 mg /kg bw/day. There were no treatment-related clinical signs, mortality or necropsy findings among pups (live birth and viability indices were similar across all groups). There was a slight transient depression in mean pup body weight; however it was not considered adverse. The developmental toxicity NOAEL determined was the highest dose of 250 mg /kg bw/day (Weaver, 2004).
Acute Toxicity	Persulfate salts are considered to have moderate acute toxicity by the oral route. The acute oral median lethal dose (LD50) values for sodium persulfate (in rats) was reported as 895-930 mg/kg bw (Degussa AG, 1979). Clinical signs were ocular and oral discharge, irregular breathing and loss of muscle control. Persulfate salts have low acute dermal toxicity. The acute dermal LD50 was greater than 10,000 mg/kg bw (rabbits) for sodium persulfates (FMC, 1979c). Ocular and nasal discharge and slight irritation were reported in animals dermally exposed to high levels of persulfates (FMC, 1979b). Persulfates have low acute inhalation toxicity. Acute inhalation studies with sodium persulfates performed according to OECD guidelines in rats, indicated median lethal concentration (LC50) values of greater than the maximum attainable concentrations, 5.1 mg/L. Following exposure to high concentrations of persulfates, animals exhibited dyspnoea, respiratory distress and increased nasal, ocular and oral secretion (FMC 1987, FMC, 1979b; FMC 1995).

Irritation	The chemicals are classified as hazardous with the risk phrase 'Irritating to Respiratory system' (Xi; R37) in the HSIS (Safe Work Australia). Groups of male ND4 Swiss Webster mice were exposed, head-only, to sodium persulfate dust for 30 minutes at concentrations of 0.26 to 3.22 mg/L. Mortality was observed in all except the lowest exposure group during the 7-day post-exposure period with clinical signs that included ocular and nasal discharge and decreased respiratory rate. Abnormal gait and whole body tremors were observed in animals exposed to the highest concentration of dust. The concentration of dust which produced a 50 % decrease in respiratory rate (RD50) was 2.25 mg/L, indicating that sodium persulfate was a respiratory system irritant (FMC, 1994). Sodium persulfates were not found to be skin irritants in animal studies. However human observations support the existing classification as skin irritants. Three brief study reports submitted by industry on sodium persulfate showed at most a slight skin irritant potential in rabbits (FMC, 1979d; FMC, 1980). The chemicals are classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in the HSIS (Safe Work Australia). In a single unpublished study, sodium persulfate was instilled into the eyes of 8 rabbits. Eye irritation was scored by the Draize method at 24, 48 and 72 h. Slight conjunctivitis was noted at 48 h (FMC, 1979c).
Sensitisation	There was evidence of delayed contact hypersensitivity in two maximisation tests (OECD TG 406) using ammonium and sodium persulfate in guinea pigs. All test animals reacted positively following challenge by intradermal injection of 0.1 % ammonium persulfate and 80 % of animals were positive following dermal challenge with 1 % ammonium persulfate 14 days later. The corresponding figures for sodium persulfate were 90 % positive for test animals positive following an (non-standard) intracutaneous challenge and 60 % of the test animals were positive following topical challenge (CIR, 2001; BIBRA International, 1997). Sodium persulfate was not sensitising when applied to the skin of guinea pigs in an unpublished Buehler Test, conducted to guideline standards (FMC, 1990b). In a murine local lymph node assay (LLNA), investigators concluded that both ammonium and sodium persulfate were moderate to strong sensitisers with EC3 values (amount of chemical required to elicit a stimulation index of 3) calculated to be 1.9 % and 0.9 % respectively (Cruz et al., 2009 cited in HSDB).
Health Effects Summary	Although the persulfate salts are harmful by the oral route, potential for acute toxicity was generally not demonstrated via the dermal or inhalation routes. The persulfate salts were irritating to eyes and respiratory system but not skin irritants in animal studies, while studies in humans indicate that persulfates can cause skin irritation. The persulfates are capable of inducing skin and respiratory sensitisation in animals and these are also the major chronic effects observed in humans. Mouse LLNA results for ammonium and sodium persulfate suggest that persulfates are moderate to strong sensitisers. Overall, the main critical effects to human health are skin and respiratory sensitisation and irritation.
Key Study/Critical Effect for Screening Criteria	
Ecological Toxicity ²	
Aquatic Toxicity	The LC50 values for acute toxicity to fish ranged between 163 to 771 mg/L for sodium persulfate. The acute toxicity EC50 values for invertebrates were between 133 and 519 mg/L for sodium persulfate. In algae, the EC50 for sodium persulfate 116 mg/L.
Determination of PNEC aquatic	A PNECaquatic of 116 µg/L was calculated using the lowest endpoint of EC50 of 116 mg/L for algae. An assessment factor of 1000 was used.
Current Regulatory Controls	

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. Biodegradation is not applicable to substances of the Persulfate Category, as the substances are inorganic. Upon contact with water or water vapour substances of the persulfate category hydrolyse into cation and persulfate anion. The persulfate anion, independent of the cation, undergoes further decomposition in normal water or acid conditions, readily oxidizing water to oxygen, producing sulphate and hydrogen ions. All final persulfate degradation products are ubiquitous to the environment.
B/vB criteria fulfilled?	No. Persulfates are very soluble in water and are not expected to bioaccumulate in soil or aqueous solutions.
T criteria fulfilled?	Based on measured acute toxicity endpoints of greater than 1 mg/L, sodium persulfate does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	January 2019

References

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2. OECD (2005) SIDS Initial Assessment Profile on Persulfates
3. ECHA REACH, Disodium peroxodisulphate, Retrieved 2017: <https://echa.europa.eu/information-on-chemicals/registered-substances>
4. ICSC Sodium Persulfates, Retrieved 2017: <http://www.inchem.org>

Toxicity Summary - Sodium sulphate

Chemical and Physical Properties ^{1,3,4,5}	
CAS number	7757-82-6
Molecular formula	Na ₂ SO ₄
Product name	142.04 g/mol
Molecular weight	161 g/l at 20 °C
Solubility in water	No data found.
Melting point	884 °C
Boiling point	Decomposition occurs above 884°C.
Vapour pressure	Solid
Henry's law constant	Expected to be extremely low
Explosive potential	No data found.
Flammability potential	No data found.
Colour/Form	Not combustible. Gives off irritating or toxic fumes/gases in a fire.
Overview	Sodium sulfate is widely distributed in nature; it occurs as mineral salts (e.g. thenardite, mirabilite), it is present in almost all fresh and salt waters and sulfate as such is normally present in almost all natural foodstuffs. Both sodium and sulfate ions are among the most common ions found in all living organisms. In mammals, sulfate is a normal metabolite of sulfur-containing amino-acids, it is normally incorporated in a variety of body compounds and it plays an important role in detoxification/ excretion processes due to sulfoconjugation Sodium sulfate has been produced for many years in high volumes for use in detergents, glass and paper manufacture and a variety of smaller industrial uses National Industrial Chemicals Notification and Assessment Scheme (NICNAS) has performed an IMAP environment Tier 1 summary which concluded that sodium sulphate is an inorganic substance comprising ions 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.
Environmental Fate ^{1,4,5}	
Soil/Water/Air	Sodium sulphate is a solid inorganic salt well soluble in water. In water solutions it is fully dissociated to sodium and sulfate ions. In anaerobic environments sulfate is biologically reduced to (hydrogen) sulphide by sulfate reducing bacteria, or incorporated into living organisms as source of sulphur, and thereby included in the sulphur cycle. The BCF of sodium sulfate is very low (0.5) and therefore bioconcentration is not expected. Sodium and sulfate ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. However some plants (e.g. corn and <i>Kochia Scoparia</i>), are capable of accumulating sulfate to concentrations that are potentially toxic to ruminants.
Human Health Toxicity Summary ^{1,2,4,5}	
Chronic Repeated Dose Toxicity	Valid oral repeated dose toxicity studies with 21, 28 and 35 day studies in hens and pigs are available. Toxicity was confined to changes in bodyweight, water and feed intake and diarrhoea. These changes occurred only at very high doses of sodium sulfate. In ruminants, high concentrations of sulfate in food may result in the formation of toxic amounts of sulfites by bacterial reduction in the rumen, leading to poly-encephalomalacia. The available data do not allow the derivation of a NOAEL. Based on available consumer data, a daily dose of around 25 mg/kg/day is well tolerated by humans

Carcinogenicity	There is no valid oral carcinogenicity study. Limited data from experimental studies support the notion that a substance that is abundantly present in and essential to the body is unlikely to be carcinogenic.
Mutagenicity/ Genotoxicity	Sodium sulfate has been shown to be without effect in the Ames test using various strains of <i>S. typhimurium</i> (TA1535, TA1537, TA100, TA98) both with and without S9 activation in a GLP standardised test Based on the natural intra- and extracellular occurrence of the substance it can be concluded that sodium sulfate is highly unlikely to be mutagenic
Reproductive Toxicity	Limited data of poor validity did not provide an indication of toxicity to reproduction.
Developmental Toxicity/Teratogenicity	No data were found.
Acute Toxicity	The acute toxicity (LD50) of sodium sulfate has not been reliably established but is probably far in excess of 5000 mg/kg. In an inhalation study with an aerosol, no adverse effects were found at 10 mg/m ³ . Also human data indicate a very low acute toxicity of sodium sulfate. Human clinical experience indicates that very high oral doses of sodium sulfate, 300 mg/kg bw up to 20 grams for an adult, are well tolerated, except from (intentionally) causing severe diarrhoea. WHO/FAO did not set an ADI for sodium sulfate. There is no data on acute dermal toxicity, but this is probably of no concern because of total ionisation in solution.
Irritation	Sodium sulfate is not irritating to the skin and slightly irritating to the eyes. Respiratory irritation has never been reported.
Sensitisation	Sodium sulphate is not a skin or respiratory sensitiser
Key Study/Critical Effect for Screening Criteria	The Australian Drinking Water Guidelines for sodium and sulphate may apply to sodium sulphate.
Ecological Toxicity ^{3,4,5}	
Aquatic Toxicity	Algae were shown to be the most sensitive to sodium sulfate; EC50 120h = 1,900 mg/l. For invertebrates (<i>Daphnia magna</i>) the EC50 48h = 4,580 mg/l and fish appeared to be the least sensitive with a LC50 96h = 7,960 mg/l for <i>Pimephales promelas</i> . No data were found for long term toxicity. The acute studies all show a toxicity of sodium sulfate higher than 100 mg/l, no bioaccumulation is expected
Determination of PNEC aquatic	An assessment factor of 1000 has been applied to the lowest reported effect concentration of 1900 mg/L for Daphnia. The PNEC aquatic is 1.9 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	The chemical is not listed in the Hazardous Substance Information System (HSIS) (Safe Work Australia 2013).
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	The Australian Drinking Water Guideline for sulphate is 250 mg/L (aesthetic) and sodium is 180 mg/L (aesthetic).
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	Sodium sulphate is an inorganic salt that dissociates completely to sodium and sulphate ions in aqueous solutions. The persistent criterion is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	The BCF of sodium sulfate is very low (0.5) and therefore bioconcentration is not

	expected.
T criteria fulfilled?	The acute aquatic toxicity of sodium sulfate is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data).

References

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2. National Health and Medical Research Council, Natural Resources Management Ministerial Council, national Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.3 Updated November 2016.
3. National Industrial Chemicals Notification and Assessment Scheme (NICNAS), IMAP Environment Tier I Summary all tranches, 2016.
4. OECD (2005a) Screening Information Dataset (SIDS) Initial Assessment Report for Sodium Sulfate, CAS Number 7757-82-6, UNEP Publications
5. OECD (2005b) SIDS Initial Assessment Profile for Sodium Sulfate, CAS Number 7757-82-6, UNEP Publications

Toxicity Summary - Tributyl tetradecyl (TTPC)

Chemical and Physical Properties	
CAS number	81741-28-8
Molecular formula	C ₂₆ H ₅₆ P.Cl
Product name	BE9
Molecular weight	435.15 g/mol
Solubility in water	miscible
Melting point	45 °C
Boiling point	439 °C (estimated)
Vapour pressure	Solid
Henry's law constant	1.04 x 10 ⁻⁸ kPa at 25 °C (estimated)
Explosive potential	No data found
Flammability potential	No data found
Colour/Form	No data found
Overview	Limited toxicity information was located for this alkyl phosphonium salt.
Environmental Fate ¹	
Soil/Water/Air	No data found
Human Health Toxicity Summary ^{1,2}	
Chronic Repeated Dose Toxicity	No data were found.
Carcinogenicity	No data were found.
Mutagenicity/ Genotoxicity	No data were available for TTPC. A brief report for TBPB noted that the chemical tested negative in an Ames bacterial mutagenicity assay, a Chinese hamster ovary (CHO) chromosome aberration test and a cell transformation test using Hamster Embryo Cells (HEC) although further details were not provided (Dunn et al. 1982). Therefore, TBPB is not mutagenic under the conditions tested and, on the basis of this limited evidence; it is assumed that TTPC is not genotoxic.
Reproductive Toxicity	No data were found.
Developmental Toxicity/Teratogenicity	No data were found.
Acute Toxicity	An inhalation study (EPA Office of Prevention, Pesticides and Toxic Substances (OPPTS) 870.1300) in rats exposed nose-only to TTPC (particle size 1.7 to 2.1 µm) reported hypoactivity, gasping, irregular respiration, red nasal discharge, ano-genital staining and abdominal distension at 0.05 mg/L (US EPA 2012b). Six of the 10 animals died within three days of a four-hour exposure. Gross necropsy revealed red coloured lungs, distension of stomach and / or intestines and / or mottled liver. The single exposure acute inhalation LC₅₀ for this study was identified as <0.05 mg/L. This study shows that TTPC is highly toxic by the inhalation route in rats. No oral or dermal information was available for TTPC. However, based on analogue data available for THPB, TBPC and TBPB from animal studies, acute toxicity of TTPC by oral and dermal route is likely to be moderate

Irritation	No information was available for TTPC but data were available for the analogues THPB and TBPC for skin irritation. Overall, the effects observed with the analogues THPB and TBPC, albeit after a 24-hour exposure period compared with the four-hour exposure specified by the equivalent OECD TG, demonstrate the likely corrosive potential of TTPC to the skin. No information was available for TTPC but data were available for the analogues THPB, TBPC and TBPB for eye irritation. The effects observed in all tests with the analogues THPB, TBPC and TBPB demonstrate the likely corrosive potential of TTPC to the eyes. In an inhalation study with TTPC in rats, a red nasal discharge and facial staining was noted (US EPA 2012b). While the information in the study is limited based on the analogues being corrosive to the skin it is likely that the chemicals are also irritant to the respiratory mucosa. TTPC is therefore likely to be a respiratory irritant.
Sensitisation	No data were available for TTPC. TBPC at 0.1% concentration in normal saline solution was determined as not sensitising to the skin following dermal applications (undisclosed induction and one challenge treatment) in guinea pigs (US EPA 1978). TBPC is not a skin sensitizer in guinea pigs and therefore a sensitisation potential for TTPC is not expected. No data were available for respiratory sensitisation.
Health Effects Summary	TTPC demonstrates high acute toxicity by the inhalation route. Based on read across data available from THPB, TBPC and TBPB, the chemical has moderate acute toxicity by oral and dermal routes and is corrosive to the skin and eye and is a respiratory irritant. Data available for TBPC and TBPB indicate that the chemical is not a skin sensitizer or genotoxic, respectively. No repeat dose, carcinogenicity or reproductive toxicity data were available for the chemical or suitable analogues. Chronic exposure may be considered as inappropriate given the nature of TTPC and analogues as direct acting corrosives mediating severe adverse effects at the site of contact. In conclusion, the critical health effect of TTPC is its acute inhalation toxicity.
Key Study/Critical Effect for Screening Criteria	No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.
Ecological Toxicity ^{1,2}	
Aquatic Toxicity	The modelled acute endpoint for Daphnia is 16.788 mg/L and Fish is 1059.2530 mg/L.
Determination of PNEC aquatic	PNECaquatic: On the basis that the modelled data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 16.788 mg/L for Daphnia. The PNECaquatic is calculated to be 0.0168 mg/L.
Current Regulatory Controls	
Australian Hazard Classification	The chemical is not listed in the Hazardous Substance Information System (HSIS) (Safe Work Australia 2013).
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found

Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment	
P/vP Criteria fulfilled?	No information is available on biodegradation.
B/vB criteria fulfilled?	Not Bioaccumulative (Based on an estimated log Kow value of 6.26)
T criteria fulfilled?	No chronic toxicity data are available for TTPC. The lowest modelled acute endpoint of TTPC is 16.788 mg/L in invertebrates. Since this value is >0.1 mg/L, TTPC does not meet the screening criteria for toxicity.
Overall conclusion	Inconclusive.

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1. Material Safety Data Sheet for Bellacide 350, BWA Water Additives, SDS No. 10794
2. National Information System of the Regional Integrated Pest Management (IPM) Centers, U.S. Department of Agriculture and National Institutes of Food and Agriculture (www.ipmcenters.org).

Toxicity Summary - 2,2',2"- Nitrilotriethanol

Chemical and Physical Properties ^{1,2, 3,6}	
CAS number	102-71-6
Molecular formula	C ₆ H ₁₅ NO ₃
Molecular weight	149.19 g/mol
Solubility in water	Miscible with water.
pH	10.5
Melting point	17-21.6 °C
Boiling point	153 °C at 0.1007 kPa 192.87 °C at 0.7996 kPa 236.69 °C at 5.01 kPa 320 °C at 101 kPa
Vapour pressure	3.59x10 ⁻⁶ mm Hg at 25 °C
Henry's law constant	7.05x10 ⁻¹³ atm-cu m/mole at 25 °C
Explosive potential	No data found.
Flammability potential	Combustible, when exposed to heat or flame. Gives off irritating or toxic fumes (or gases) in a fire.
Colour/Form	Pale yellow to colourless viscous liquid with a slight ammonia odour.
Overview	Triethanolamine is a member of the ethanolamines family that combines the properties of amines and alcohols. Triethanolamine is typically supplied as a pale colourless to yellow liquid with an ammonia-like odor. Triethanolamine is primarily used in detergents, personal-care products, and textile finishing. Triethanolamine may also be used as in other applications including adhesives, agricultural products, concrete additives, gas treating processes, rubber, surfactants, photographic chemicals, and urethane foams. Contact with triethanolamine may cause slight to severe eye irritation. Brief contact is essentially nonirritating to the skin, but repeated exposure may cause irritation and burns. Skin contact may cause an allergic skin reaction. At room temperature, exposure to vapour is minimal due to low volatility; single exposure is not likely to be hazardous. This product has very low toxicity if swallowed. Harmful effects are not anticipated from swallowing small amounts, but swallowing larger amounts may cause injury. This product has been toxic to the fetus in laboratory animals at doses toxic to the mother. Findings from a study by the National Toxicology Program suggest an increased incidence of liver tumors in mice, but their relevance to humans is not clear. Triethanolamine is water soluble and biodegradable according to the OECD 301A test for biodegradation. It is not expected to bioaccumulate or persist in the environment. Triethanolamine is practically non-toxic to aquatic organisms on an acute basis. However large releases may increase the pH of aquatic systems to levels that may be toxic to aquatic organisms.

Environmental Fate ^{1,3,4,6}

Soil/Water/Air

If released to soil, triethanolamine is expected to have very high mobility based upon an estimated Koc of 7. However, the pKa of triethanolamine is 7.8, indicating that this compound will primarily exist in cation form; and cations generally adsorb to organic carbon and clay more strongly than their neutral counterparts. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 7.1×10^{-13} atm-cu m/mole. If released into water, triethanolamine is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Triethanolamine biodegraded in a biochemical oxygen demand (BOD) test at an initial concn 50 ppm. After 10 days, the ThOD (theoretical oxygen demand) was 70% using acclimated water as seed and sewage as inoculum. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low. Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyze under environmental conditions

Human Health Toxicity Summary ^{1,2,3,4,5,6}	
Chronic Repeated Dose Toxicity	Fischer 344 rats and B6C3F1 mice were administered 0, 500, 1000, 2000, 4000 or 8000 mg/100 mL triethanolamine in drinking water (NTP 1990). Water consumption was reduced at the top two doses. No other details were provided. In a 91-day study conducted in accordance with OECD TG 408, Cox CD rats were administered 88.5% triethanolamine in the diet at doses of 0, 250, 500 or 1000 mg/kg bw/day (REACH 2013). There were no significant dose-dependent changes in bodyweight, organ weight, histopathology, pathology and haematology. No Lowest Observed Adverse Effect Level (LOAEL) or No Observed Adverse Effect Level (NOAEL) can be established for this study. In a 90-day study, rats (strain not specified) were administered doses of 5 to 2610 mg/kg bw/day triethanolamine in the diet (Smyth et al. 1951). The study reported microscopic lesions and mortality at doses of 730 mg/kg bw/day and above. The authors indicated the NOAEL as 80 mg/kg bw/day. No other details were provided. In 60- and 120-day studies in rats (strain not specified) given 200 to 1800 mg/kg bw/day triethanolamine, effects observed included liver changes at all treatment doses after 60 and 120 days administration, kidney changes at 400 mg/kg bw/day after 60 and 120 days administration, and kidney damage at >800 mg/kg bw/day after 60 and 120 days administration (Kindsvatter 1940). The specific changes in the liver and kidney were not described. No other details were provided. The LOAEL for this study was 200 mg/kg bw/day. Repeated dermal dose toxicity with triethanolamine application was consistently associated with inflammation at the treatment site. Systemic effects included changes in bodyweight and organ to bodyweight ratios. The critical study for determining the effects of repeated dermal exposures to the chemical is the 90-day study cited in REACH (2013) conducted similarly to OECD TG 411. The NOAELs for this study are 125 mg/kg bw/day for males and 250 mg/kg bw/day for females. In an inhalation study, Fischer 344 rats were exposed to 0, 125, 250, 500, 1000 or 2000 mg/m³ triethanolamine for 16 days (NTP 1985b). The effects observed included decreased bodyweight at 2000 mg/m³ for both sexes, increased liver weight in males at 2000 mg/m³, increased kidney weight in males at concentrations ≥500 mg/m³, and increased kidney weight in females at concentrations ≥250 mg/m³. Minimal to slight acute inflammation of the larynx was reported but the doses for which this effect was seen were not specified. The LOAECs are 500 mg/m³ in males and 250 mg/m³ in females. The NOAECs are 250 and 125 mg/m³ in males and females, respectively. Wistar rats were exposed through the head and nose to 0, 0.02, 0.1 or 0.5 mg/L aerosolised triethanolamine in a 28-day study conducted in accordance with OECD TG 412 (Gamer et al., 2008). There were no treatment-related effects seen on bodyweight, haematology, clinical chemistry and neurobehavioural parameters. Local effects, such as minimal to moderate focal inflammation in the submucosa of the larynx region, were reported at all treatment concentrations. The LOAEC and NOAEC for systemic effects cannot be established. The LOAEC for local effects is 0.02 mg/L. B6C3F1 mice exposed to 0, 125, 250, 500, 1000 or 2000 mg/m³ triethanolamine for 14 days showed minimal acute inflammation of the laryngeal submucosa (NTP 1985a). The doses for which this effect was seen were not specified.
Carcinogenicity	The International Agency for Research on Cancer (IARC) has classified the chemical as 'not classifiable as to its carcinogenicity to humans' (Group 3), based on inadequate evidence for carcinogenicity in humans and experimental animals (IARC, 2000). There was no evidence of carcinogenicity by oral (up to 1000 mg/kg/day for 104 weeks, and up to 3334 mg/kg/day for 82 weeks amongst rats and mice respectively) or dermal routes (dose unknown) in studies of 14-18 months duration using rats and mice. No inhalation data were available.

Mutagenicity/ Genotoxicity	Triethanolamine was not genotoxic in a number of in vitro studies (bacterial reverse mutation, mammalian cell cytogenetics, and unscheduled DNA synthesis). On the basis of the negative results observed in a range of in vitro studies, in vivo genotoxicity is not anticipated.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	Triethanolamine is not considered to be toxic to fertility and not considered to be a developmental toxicant. There were no effects observed in the reproductive organs of the animals treated with the chemical from repeated oral, dermal and inhalation toxicity studies. In a reproduction/developmental toxicity screening test conducted in accordance with OECD TG 421, Wistar rats were administered 0, 100, 300 or 1000 mg/kg bw/day triethanolamine by gavage (REACH 2013). The animals were treated during pre-mating (two weeks for both sexes), mating (maximum of two weeks for both sexes), post-mating (one week in males), and the entire gestation period and four days of lactation in females. There were no parental systemic effects reported in all of the treated animals. Most of the animals treated at the top dose showed transient salivation, which could be attributed to the unpalatability of the chemical or local irritation of the upper digestive tract. There were no effects on fertility observed in any of the treated animals. The parental LOAEL and NOAEL for local effects are 1000 and 300 mg/kg bw/day, respectively. The developmental LOAEL and NOAEL are 1000 and 300 mg/kg bw/day, respectively. The LOAEL and NOAEL for fertility cannot be established. A dye formulation containing 0.15, 1.5 or 2% triethanolamine was applied to the shaved skin of CD-1 rats (Burnett et al. 1976). The application occurred seven times during the gestation period. There were no systemic or local effects observed. No developmental effects were reported.
Acute Toxicity	The chemical was of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in experimental rats studies ranged from is 4190–11300 mg/kg bw triethanolamine. Two studies in mice (strain not specified), two studies in rabbits (strain not specified), and three studies in guinea pigs (strain not specified) reported acute oral LD50s of 5400 to 7800, 2200 to 5200, and 2200 to 8000 mg/kg bw, respectively. Observed sub-lethal effects included agitation, elevated respiration and reduced grooming (NIWL, 2003; CIR, 2011). The chemical was of low acute toxicity in animal tests following dermal exposure. The median lethal dose (LD50) in rabbits is greater than 2000 mg/kg bw. Observed sublethal effects included mild erythema 24 hours after exposure, resolving after 6 –10 days (REACH; CIR, 2011). Due to the low vapour pressure of the chemical, the highest attainable vapour concentration is 1.8 mg/m ³ . In a study conducted in rats (strain not specified) exposed to the chemical (1.8 mg/m ³), no deaths were reported. One out of 12 rats exposed showed signs of chronic bronchitis (REACH).
Irritation	Based on the available data, the chemical is considered a respiratory and eye irritant. In two studies conducted similarly to OECD TG 405 the average Draize scores for corneal opacity, redness of the conjunctivae and chemosis were 1, 2 and 1.75 respectively (REACH). In one study, the corneal opacity in one animal had not fully resolved by day eight of the observation period. However, based on the results seen in the other animals, it is expected that the corneal opacity would fully resolve had the observation period continued for 21 days. The chemical was not irritating to skin in studies that were performed in accordance with OECD Test Guideline (TG) 404 (REACH). In one study, three Vienna White Rabbits were dermally exposed to the chemical (85 % concentration of triethanolamine and 15 % diethanolamine) through a occlusive patch for four hours. Neither oedema nor erythema was observed throughout the observation period (REACH). In animal studies with repeated exposures, the chemical was applied to rabbit ears over 10 open applications, with 10 unoccluded applications to abdominal intact skin, or with three semi-occluded 24-hour applications to abraded skin. These exposures resulted in slight to moderate irritation (CIR, 2013). In a two-year repeated dose dermal study, the chemical caused lesions consisting of acanthosis (thickened skin), ulceration and chronic active inflammation at the application site. In the repeated dose inhalation studies, minimal to slight acute inflammation of the larynx was observed in rats and mice (NTP 1985a, 1985b). In a more recent 28-day inhalation study, minimal to moderate focal inflammation in the submucosa of the larynx was observed in rats (Gamer et al. 2008).

Sensitisation	Triethanolamine is not a skin sensitizer in animals. The negative results observed for the chemical in several guinea pig maximisation tests and one local lymph node assay support a conclusion that the chemical is not a skin sensitiser (REACH; CIR, 2013).
Health Effects Summary	Triethanolamine has low acute oral and dermal toxicity but may cause eye and respiratory irritation. Triethanolamine was non-irritating to the skin in rabbit studies, whilst studies in humans indicate that the chemical can cause skin irritation. The chemical is not a skin sensitiser. The chemical is neither genotoxic, carcinogenic nor a reproductive toxicant.
Key Study/Critical Effect for Screening Criteria	The most appropriate NOAELs for risk assessment, determined from the 90-day repeat dermal dose toxicity study cited in REACH (2013) are 125 (males) and 250 (females) mg/kg bw/day based on systemic effects. Uncertainty factors: 10 (interspecies variability); 10 (intraspecies variability); 10 (subchronic to chronic) Oral RfD = $125/1000 = 0.125$ mg/kg/day Drinking water guideline value = 0.49 ppm

Ecological Toxicity ^{1,3, 4,6}	
Aquatic Toxicity	Triethanolamine is of low acute toxicity to fish and aquatic invertebrates. The most sensitive fish species tested was the fathead minnow <i>Pimephales promelas</i> for which a 96h-LC50 of 11,800 mg/l was determined. Triethanolamine was slightly more toxic to <i>Daphnia</i> , which had a 24h-EC50 of 1,390 mg/l. In a 21 day reproduction test with <i>Daphnia magna</i> , a NOEC of 16 mg/l and an EC50 of 2,038 mg/l were determined in a semi-static test (concentrations measured twice during the test). Triethanolamine appears to be more toxic to algal species. Toxicity tests have been carried out at both constant pH and allowing the pH to increase with increasing triethanolamine concentration. In two cases triethanolamine appears to be more toxic when the test is carried out allowing the pH to increase. In one case, using the green algae <i>Scenedesmus quadricauda</i> , the 7-8 day toxicity threshold (defined as the concentration which just caused an effect of cell multiplication of around 3% compared with controls - can be considered as a NOEC) for triethanolamine was found to be much lower at constant pH (toxicity threshold = 1.8 mg/l) than when the pH was allowed to vary (toxicity threshold = 715 mg/l). The EC50 was reported as 910 mg/l for <i>Scenedesmus subspicatus</i> (algae) for 96 hour exposure under test conditions where the test media was neutralised.
Determination of PNEC aquatic	PNECaquatic: 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 NOEC of 1.8 mg/L for <i>Scenedesmus quadricauda</i> mg/L for invertebrates. The PNECaquatic is 0.18 mg/L.
Current Regulatory Controls ²	
Australian Hazard Classification	Triethanolamine is listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia 2013) with a recommended Exposure Standard.
Australian Occupational Exposure Standards	Time Weighted Average (TWA) of 5 mg/m ³ (Safe Work Australia 2013).
International Occupational Exposure Standards	TWA: 5 mg/m ³ [Belgium, Finland, Iceland, New Zealand, Peru] 0.5 mg/m ³ [Denmark].
Australian Food Standards	Triethanolamine is listed as a permitted processing aid in bleaching agents, washing and peeling agents, water used as an ingredient in other foods, and miscellaneous functions under the conditions of Good Manufacturing Practice (GMP) (Food Standards Australia New Zealand 2013).
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
PBT Assessment ^{1,3,4,6}	
P/vP Criteria fulfilled?	There are conflicting findings from standard ready biodegradability tests regarding the rate of biodegradation of triethanolamine. Some studies indicate relative rapid biodegradation, whereas some closed bottle studies indicate slow biodegradation under the test conditions (OECD 1995). However, the chemical is inherently biodegradable. The results of a test using OECD test guideline 302B showed that 89% of the chemical is degraded after 14 days (OECD 1995). Thus, Triethanolamine is categorised as Persistent.
B/vB criteria fulfilled?	Based on the measured log Kow of -1.0 and a measured BCF of <3.9 L/kg in fish, triethanolamine has low bioaccumulation potential and is considered not bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of triethanolamine is > 0.01 mg/L. Hence the substance does not fulfill the screening criteria for toxic (T)
Overall conclusion	Not a PBT substance (based on screening data). Further assessment of the environmental risks from the use of this chemical is not required as identified by DoEE.
Revised	April 2018

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3. OECD (1995) SIDS Initial Assessment Report for Triethanolamine, CAS Number 102-71-6
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5. International Agency for Research on Cancer (IARC) – Summaries & Evaluations, Triethanolamine, 2000
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 - Sodium perborate tetrahydrate

Chemical and Physical Properties	
CAS number	10486-00-7
Molecular formula	NaBO ₃ . 4H ₂ O / NaBO ₂ . H ₂ O ₂ . 3H ₂ O
Molecular weight	153.9
Solubility in water	g/100ml at 20°C: 2.3
Melting point	ca. 60-65.5°C
Boiling point	Decomposes.
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	Perborates are salts of perboric acid. Sodium perborate degrades into sodium metaborate and water with the generation of hydrogen peroxide and oxygen. Sodium metaborate is the salt of a strong base (sodium hydroxide) and a weak acid (boric acid). Undissociated boric acid is the main species present in the blood of mammals following exposure to these chemicals. Sodium perborate tetrahydrate (CAS No. 10486-00-7) have reported domestic use as bleaching agents.
Environmental Fate ¹	
Soil/Water/Air	Perborates have high water solubility. Perborates dissociate to borates and hydrogen peroxide in aqueous environments. The most important borate species, which will be formed in aqueous solutions, is boric acid (H₃BO₃). At relevant environmental pH values of ≤ 7 no significant adsorption of boron compounds in soil and the aquatic compartments are to be expected (EPA, 1975; Koehnlein, 1972).
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	In a repeated dose toxicity study, sodium perborate tetrahydrate (CAS No. 10486-00-7) was administered (by gavage) to rats at 1000 mg/kg bw/day (70 mg boron/kg bw/day) for 28 days. Acanthosis and hyperkeratosis in the forestomach, and hyperplasia of the fundic mucosa were noted. At the end of the study, the red blood cell count, haemoglobin, haematocrit and number of lymphocytes were significantly decreased; the number of platelets was significantly increased. The spleen size and splenic parenchyma were reduced. Although a significant (18 %) decrease in absolute testicular weights was recorded, the authors attributed this to a generalised weight reduction of 15 %; histological examination of the testes revealed no adverse effects. The lowest observed adverse effect level (LOAEL) was 1000 mg/kg bw/day (70 mg boron/kg bw/day), based on effects on the stomach, spleen and the haematopoietic system. It was concluded that the no observed adverse effect level (NOAEL) for males or females was below 1000 mg/kg bw/day (EU RAR, 2007; SCCS, 2010; REACH). In a repeated dose toxicity study, sodium perborate tetrahydrate (CAS No. 10486-00-7) was applied at 200 mg/kg bw/day (as a 10 % aqueous solution) to the abraded skin of New Zealand White rabbits for three weeks. After exposure, the skin was near normal (signs of mild irritation in some cases) and there were no adverse microscopic findings in different organs. A NOAEL of 200 mg/kg bw/day was established, being the highest tested dose (EU RAR, 2007; SCCS, 2010; REACH). In another repeated dose toxicity study, sodium perborate tetrahydrate (CAS No. 10486-00-7) was applied at 50 mg/kg bw (as a 2.5 % aqueous solution) to the

	intact skin of New Zealand White rabbits (three/sex), five days/week for 13 weeks. The treatment caused no skin irritation and there were no adverse effects on blood parameters or on the gross histopathology of selected organs. An NOAEL of 50 mg/kg bw/day was established, being the highest tested dose (EU RAR, 2007; SCCS, 2010; REACH).
Carcinogenicity	Not likely to have any carcinogenic potential.
Mutagenicity/ Genotoxicity	Not considered to have mutagenic or genotoxic potential.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	In a repeated dose toxicity study, sodium perborate tetrahydrate (CAS No. 10486-00-7) was administered (by gavage) to rats at 1000 mg/kg bw/day (70 mg boron/kg bw/day) for 28 days. The authors recorded a significant (18 %) decrease in absolute testicular weights but this was attributed to a generalised weight reduction of 15 %. A histological examination of the testes revealed no adverse effects. It has also been argued that more sensitive methods of histopathology than used in this study (fixed with formalin) could have revealed more subtle effects. Therefore, using reduced testes weights as early signs of testicular toxicity cannot be dismissed in view of the known testicular toxicity of the borates. It was concluded that the NOAEL for males or females was below 1000 mg/kg bw/day (EU RAR, 2007; SCCS, 2010; REACH). In a developmental toxicity study, sodium perborate tetrahydrate (CAS No. 10486-00-7) was administered (by gavage) to 25 pregnant CrI:CD (SD) rats on gestation days (GD) 6–15 at doses of 0, 100, 300 and 1000 mg/kg bw/day. The NOAEL for maternal toxicity was established as 100 mg/kg bw/day (7 mg boron/kg bw/day), based on significant reductions in body weight gain at the two highest doses. It is also noted that even though reduced maternal weight gain might partly be due to an increased number of resorptions and reduced foetal weights, other toxicological studies have supported the view that doses above 100 mg/kg bw/day administered via gavage are toxic to the dams. A dose-related effect was found on the ossification and bone system. While various incomplete ossifications and wavy ribs occurred at 300 mg/kg bw/day, malformations (fused ribs) were observed at 1000 mg/kg bw/day. The NOAEL for developmental toxicity was established as 100 mg/kg bw/day (7 mg boron/kg bw/day) (EU RAR, 2007; SCCS, 2010; REACH).
Acute Toxicity	The reported oral LD50 for sodium perborate tetrahydrate is 2567 mg/kg bw (CAS No. 10486-00-7). The chemical is likely to have low acute toxicity following dermal exposure. It is also noted that the dermal absorption through intact skin is very low. The available data (median lethal concentration—LC50, inhalation) for sodium perborate tetrahydrate is 1.65 mg/L. Reported signs of toxicity included gasping, red nasal discharge, and compound-covered faeces (EU RAR, 2007; SCCS, 2010; REACH).
Irritation	The chemicals in the group are classified as hazardous, with hazard category Specific Target Organ Toxicity (Single Exposure) – Category 3 and hazard statement 'May cause respiratory irritation' (H335) in the HCIS (Safe Work Australia). Although slight skin irritant effects were reported in animal studies, the effects were not sufficient to warrant a hazard classification for the chemicals in this group. The sodium perborates are classified as hazardous with hazard category 'Eye Damage – Category 1' and the hazard statement 'Causes serious eye damage' (H318) in the HCIS (Safe Work Australia). In an eye irritation study conducted according to Federal Hazardous Substances Act Regulations 191.12 (1964-09) of the USA, 0.1 mL of sodium perborate tetrahydrate (CAS No. 10486-00-7) was placed once into the right eyes of six albino rabbits. The chemical was judged to be corrosive as severe corneal damage, severe iritis and severe conjunctivitis were observed in all animals (EU RAR, 2007; SCCS, 2010; REACH).
Sensitisation	Not likely to be skin and respiratory sensitisers.
Health Effects Summary	The critical health effects for risk characterisation include systemic long-term effects (reproductive toxicity, developmental toxicity), systemic acute effects

	(acute toxicity from oral/inhalation exposure) and local effects (respiratory and eye irritation).
Key Study/Critical Effect for Screening Criteria	The lowest NOAEL of 50 mg/kg bw/day from the repeated dose dermal study will be used for risk assessment.
Ecological Toxicity³	
Aquatic Toxicity	The following aquatic toxicity endpoints are based on modelled estimates of sodium perborate (CAS 7632-04-4) from ECOSAR: The 96hr LC50 for fish is estimated to be 2610 mg/L The 48 hr LC50 for daphnids is estimated to be 1241 mg/L The 14 day LC50 for earthworms is estimated to be 164.5 mg/L The 96 hr EC50 for algae is estimated to be 444 mg/L
Determination of PNEC aquatic	In a recent publication Dyer (2001) used a probabilistic approach to derive a PNEC0.05 (Predicted No Effect Concentration for 95% of the species) from chronic studies that were available for boron for all trophic levels. Mean toxicity levels per taxa were determined and then converted to a cumulative probability term and curve-fit assuming a log-logistic distribution. The PNEC 0.05 derived from this analysis was 3.45 mg B/l when all species data with uniform chronic toxicity endpoints (NOEC, LC10) were considered.
Current Regulatory Controls⁴	
Australian Hazard Classification	Reproductive toxicity – category 1B Acute toxicity – category 4 Specific target organ toxicity (single exposure) – category 3 Eye damage – category 1
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. Expected to be biodegradable based on Ecosar prediction using sodium perborate.
B/vB criteria fulfilled?	No. Estimated log Kow for sodium perborate: 0.08 (Log Kow < 4.5)
T criteria fulfilled?	No. Acute toxicity values > 1 mg/L.
Overall conclusion	Not PBT
Revised	October 2019

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Appendix G

Toxicological Profiles for Drilling Fluids

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.
Henrys 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	The chemical is not expected to be readily biodegradable. The chemical achieved 56% degradation in 28 days according to test guidelines OECD 301E. However, the degradation after 28 d was not yet finished as a plateau is not yet visible in the degradation curve; thus, a further degradation of the product seems to be possible.
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 ^{1,2}	
Aquatic Toxicity	The acute toxicity of the sodium erythorbate to the freshwater fish rainbow trout (<i>Oncorhynchus mykiss</i>) has been investigated and gave a 96-Hour LC50 of greater than 100 mg/L (semi-static). The acute toxicity of sodium erythorbate to <i>Daphnia magna</i> gave an EC50 (48 h) of 84 - 100 mg/L. The effect of the test item on the growth of <i>Pseudokirchneriella subcapitata</i> has been investigated over a 72-Hour period. The EC50 (72 h) was 160 mg/L while the NOEC (72 h) was 20 mg/L.
Determination of PNEC aquatic	A PNECaquatic of 84 µg/L was calculated using the lowest endpoint of EC50 of 84 mg/L for <i>Daphnia magna</i> . An assessment factor of 1000 was used.
Current Regulatory Controls ⁴	
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?	Could potentially be persistent as it is not readily biodegradable.
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
Revised	April 2019

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Toxicity Summary - Starch

Chemical and Physical Properties ^{1,2,4,6}	
CAS number	9005-25-8
Molecular formula	(C ₆ H ₁₀ O ₅) _n
Molecular weight	UVCB
Solubility in water	In cold water, starch absorbs water reversibly and swells slightly. In hot water, irreversible swelling occurs, producing gelatinisation.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henry's law constant	No data available.
Explosive potential	Combustible
Flammability potential	No data available.
Colour/Form	White powder, tasteless and has no smell
Overview	Starch is a high –polymeric carbohydrate material primarily composed of amylopectin and amylose. It is usually derived from cereal grains such as corn, wheat and sorghum and from roots and tubers such as potatoes and tapioca. It includes starch which has been pregelatinized by heating in the presence of water. This chemical has been identified by NICNAS to be of low concern to human health and thus required no further assessment.
Environmental Fate ⁷	
Soil/Water/Air	Based on information from NICNAS (2006): In a ready biodegradation test, the notified polymer (Potato Starch Modified) showed an 86.87% degradation during a Modified Sturm Test (OECD Test Guideline 301B) indicating that it was readily biodegradable. The test was verified using a sodium benzoate standard which showed 93.77% degradation at the end of the study. In addition a toxicity control consisting of a mixture of the test substance and sodium benzoate showed 83.49% degradation at the end of the study period, indicating that the test material did not inhibit the microbial activity. The notified polymer does potentially contain cationic and anionic functional groups, however based on the typical dissociation constants for the functionalities and their ratio within the polymer it is expected to have a net anionic charge throughout most of the environmental pH range, becoming slightly cationic only at the low end of the range. In landfill and the sewer, the notified chemical is expected to be relatively readily degraded by biotic and abiotic pathways to ultimately yield water and oxides of carbon and nitrogen and salts of chlorine and sodium. Any incineration of the notified polymer would result in its destruction and the formation of carbon dioxide and water and ash containing salts of chlorine and sodium. The notified polymer has a high molecular weight not expected to bioaccumulate.

Human Health Toxicity Summary ^{2,3}	
Chronic Repeated Dose Toxicity	A long-term study was carried out on the effects of inoculating 1.5 g of starch powder into the peritoneal cavity of rats. After an initial considerable inflammatory reaction, the intense vascular reaction subsided, leaving firm adhesions that were still present in animals sacrificed at 18 months (EII90). Feeding of unmodified cornstarch and potato starch to groups of rats at dietary levels up to 30% (equivalent to 27.4-33.6 g/kg bw/d) in a 2-year test and 10% (food intake not indicated) in a 3-generation test did not result in distinct toxicologically significant effects (Gro74). Rats fed a cooked diet containing 62% unmodified maize starch (equivalent to 51.1 g/kg bw/d*) for 2 years also did not show significant toxicological effects, including reproductive effects over 3 generations (Tru79). Slight growth retardation was seen in rats exposed for 4 weeks to raw potato starch at a dietary level of 40% (equivalent to 46.0-52.8 g/kg bw/d) (Fer73).
Carcinogenicity	Not classifiable as a human carcinogen (A4)
Mutagenicity/ Genotoxicity	There were no indications for significant toxicity, carcinogenicity or reproduction toxicity of starch in rats fed 27.4-52.8 g/kg bw/day.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	There were no indications for significant toxicity, carcinogenicity or reproduction toxicity of starch in rats fed 27.4-52.8 g/kg bw/day.
Acute Toxicity	Toxicity of starch given orally to albino rats were studied. Experiments were performed upon CBL albino rats weighing 140 ± 15 (mean $\pm$ S.D.). Starch was given daily for 14 consecutive days in total daily oral doses of 36, 72, 120 and 168 g/kg and in animals which did not succumb to gastric rupture in doses gradually increasing to 204, 240 and 288 g/kg. Gastric rupture appeared in 50 – 75% of rats given starch in amounts of 168 g/kg and over. Of the survivors of gastric rupture, 5% died of pneumonia and 20% from bowel obstruction during the 14 days of starch administration. Doses of one tenth body weight and above produced some inhibition of growth, doses of one fifth body weight and above increased the susceptibility to pneumonia and bowel obstruction owing to the inability of the animal to evacuate the starch calculi. It was noted that doses of this order could not readily be taken by humans and smaller doses had insignificant toxicity. Acute respiratory effects after exposure to dust from the refining process of potato starch have been described (personal sampling: 3.9-56.0 mg/m³, total dust). The responsible agent could not be identified although the authors suspected endotoxin to be the causative agent (Hol94). Millers and bakers occupationally exposed to grain and flour dusts (personal sampling: 1.1-14.3 mg/m³, total dust) showed significantly higher incidences of coughing and chronic bronchitis compared to a non-exposed reference group (Mas95, Mas96). A dose-response relationship was observed between dust exposure levels and chronic respiratory symptoms (Mas95). Although flour is a complex product that is mainly made up of starch (70%) and gluten (12%), it may also contain mite dust and endotoxins. The causative role of starch in the observed respiratory symptoms is therefore not clear. The intraperitoneal LD50 of starch in mice is 6600 mg/kg (ACG99).
Irritation	Skin contact with a total dose of 300 µg of starch, intermittently applied over a 3-day period, resulted in a mild erythema and slight oedema of the skin in humans (ACG99).
Sensitisation	No data available.
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 intraperitoneal LD50 of starch in mice is 6600 mg/kg (ACG99).

Ecological Toxicity ⁷	
Aquatic Toxicity	Based on QSAR modelling: Crassostrea virginica 96 h = 1000 mg/L Orthopristis chrysoptera 96 h = 5000 mg/L Bairdiella chrysoura 96 h = 5000 mg/L
Determination of PNEC aquatic	Based on the lack of ecotoxicity data, PNECaquatic was not determined.
Current Regulatory Controls ^{2,4}	
Australian Hazard Classification	No data available.
Australian Occupational Exposure Standards	TWA = 10 mg/m ³
International Occupational Exposure Standards	TLV: 10 mg/m ³ , as TWA The current administrative occupational exposure limit (MAC) for starch in the Netherlands is 10 mg/m ³ , 8-hour TWA, equal to the occupational exposure limit for nuisance dust.
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. This substance is expected to be readily biodegradable.
B/vB criteria fulfilled?	No. This substance is not expected to be bioaccumulative.
T criteria fulfilled?	Based on QSAR modelling, this substance is not expected to meet the toxicity criteria.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione

Chemical and Physical Properties ^{1,2,3,5}	
CAS number	533-74-4
Molecular formula	C ₅ H ₁₀ N ₂ S ₂
Molecular weight	162.28
Solubility in water	3.5 g/l at 20 °C at pH 5, pH 7 and pH 9
Melting point	103.2 – 105.2 °C
Boiling point	No data available.
Vapour pressure	5.8 x 10 ⁻⁶ Pa at 20 °C (extrapolated)
Henry's law constant	2.66X10 ⁻¹⁰ atm-cu m/mole
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Off-white to yellowish solid of sulphurous odour
Overview	Dazomet (Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione) is a soil fumigant effective for the control of nematodes, insects, germinating weeds and soil fungi. Dazomet is strongly phytotoxic, acting by virtue of the chemical release of methylisothiocyanate (MITC).
Environmental Fate ¹	
Soil/Water/Air	Dazomet's production may result in its release to the environment through various waste streams; its use as a soil sterilant, nematicide, fungicide, slimicide in pulp and paper manufacture, and as a preservative in adhesives and glues will result in its direct release to the environment. If released to air, a vapour pressure of 2.80X10⁻⁶ mm Hg at 20 deg C indicates dazomet will exist in both the vapour and particulate phases in the atmosphere. Vapour-phase dazomet 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 1.4 hours. Particulate-phase dazomet will be removed from the atmosphere by wet or dry deposition; hydrolysis of this compound during rain events or in clouds may occur. It has been suggested that dazomet may also undergo direct photolytic degradation and this process may contribute to atmospheric removal. If released to soil, dazomet is expected to have high mobility based upon an estimated Koc of 52; however it is expected to hydrolyse before extensive leaching occurs. Volatilization from moist soil surfaces is not expected to be an important fate process based upon a Henry's Law constant of 2.66X10⁻¹⁰ atm-cu m/mole. When dazomet is applied to soil, either to the surface or incorporated, it quickly hydrolyzes in the presence of moisture. The major degradate is methyl isothiocyanate, but formaldehyde, monomethylamine, hydrogen sulfide and (in acid soils) carbon disulfide, are also formed. The half-life of dazomet in soil has been reported as less than 1 day (pH >5). The rate of disappearance was found to be the same in both unamended and sterilized soils and in different soil types, indicating that chemical hydrolysis and not biodegradation is the primary removal process. Dazomet is not expected to volatilize from dry soil surfaces based upon its vapour pressure. If released into water, dazomet is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's Henry's Law constant. In water, dazomet is expected to undergo hydrolysis rapidly, forming methyl isothiocyanate and formaldehyde. Half-lives of 3.6, 2.4, 2.8, and 4.0 hours have been reported at pH values of 4.4, 5.7, 7.0, and 8.0, respectively. In salt water (0.15 M), a half-life of 6.1 hours was reported. An estimated BCF of 2.4 suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	In a 78 week study, mice were given dazomet in the diet at 0, 20, 80 and 320 ppm. Compound intakes were estimated as follows: males - 0, 4, 16 and 68 mg/kg/d; females - 0, 6, 22 and 93 mg/kg/d. Survival was not affected and there were no noteworthy clinical signs, or bodyweight or food consumption changes. There was a significant elevation of liver weight at the high dose and an increased number of mid-dose and high dose animals with liver discolouration, liver masses and centrilobular lipid deposition. At the high dose, females showed a slightly increased incidence of hepatocellular adenomas (3, 0, 1 and 7 females, out of 50, in the control, low dose, mid dose and high dose groups, respectively) and a significantly increased incidence of basophilic foci. Increased splenic haemosiderin deposition and extramedullary haematopoiesis were noted at the mid dose (males) and high dose. Three/60 females from each dose group had malignant lymphoma at one or more sites; because of the low incidence, lack of a dose-response, and lack of any effect in males, it was not considered to be directly compound-related. The NOEL was 20 ppm (about 4 mg/kg/d in males, 6 mg/kg/d in females).
Carcinogenicity	Rat studies showed no clear evidence of any carcinogenic effect of dazomet. In mice, there was a slight increase in hepatocellular adenomas (not carcinomas) following 78 weeks of treatment at the high dose (320 ppm). There was also an increase in malignant lymphoma in females, but because of the low incidence, the lack of effect in males and the lack of any dose-response, it was not considered to be directly compound-related. The lack of a carcinogenic effect of dazomet is consistent with the data for MITC.
Mutagenicity/ Genotoxicity	An acceptable package of mutagenicity tests has been conducted covering all three end points. The results are the genotoxicity tests are not clear cut. While the majority of tests gave negative results, there were sufficient positive results to indicate some genotoxic potential of dazomet. In summary, there were positive results in one gene mutation assay (HGPRT locus in Chinese hamster ovary cells), equivocal results in another gene mutation assay (TK locus in mouse lymphoma L5178Y cells), and positive results in two chromosome aberration assays (both in vitro assays in mouse lymphoma L5178Y cells), in one in vitro assay for of unscheduled DNA synthesis in primary rat hepatocytes and in one in vitro assay of sister chromatid exchange. In all cases, the positive findings were relatively weak. There were no positive in vivo studies and there was a trend for results to only be positive (or to be stronger) in the absence of metabolic activation than in its presence. This suggests that unchanged dazomet has greater genotoxic potential than the metabolites of dazomet. The unscheduled DNA synthesis assay was the only assay which gave results suggesting that the metabolites of dazomet may have some genotoxic potential, even if only weak.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Dazomet was fed to rats at 0, 5, 30 and 180 ppm for at least 70 days prior to mating, throughout mating and lactation, during production of F₁a and F₁b litters. Selected F₁a pups were maintained on compound-containing diets post-weaning to produce F₂ litters. Hepatotoxicity was observed in both generations, mainly at the high dose, but to some extent at the mid dose. Liver weights were increased and there was an increased severity of liver fatty change. Some serum enzyme and serum protein changes also indicated effects on the liver. There was no impairment of mating or reproductive performance and no adverse effect on reproductive organs or pup development. The NOEL with respect to reproductive function in rats was 180 ppm (about 18 mg/kg/d), while that for systemic toxicity was 5 ppm (about 0.5 mg/kg/d). An oral (gavage) developmental study was conducted in rats at dazomet doses of 0, 3, 10 and 30 mg/kg/d. Food intake and body weight and also uterine weights were reduced at the high dose and to a lesser extent at the mid dose. There was a higher incidence of runts at 10 mg/kg and above, however, without a clear dose-response relationship. There was no evidence of teratogenic effects. The NOEL for maternal and foetal effects was 3 mg/kg/d.
Acute Toxicity	Dazomet is of moderate acute oral toxicity. The oral LD ₅₀ values for dazomet from two different studies in rats were about 600 - 900 mg/kg for males and 400 - 550 mg/kg for females. The LD ₅₀ of dazomet, given subcutaneously to mice, was 248 mg/kg. The LD ₅₀ of dazomet, given subcutaneously to rats, was 470 and 550 mg/kg in males and females, respectively. The dermal LD ₅₀ of dazomet in rats was greater than 2000 mg/kg. Symptoms associated with acute dazomet toxicity were shaking, salivation, tonic convulsions, trembling, dyspnoea and lassitude.

Irritation	In two studies, the introduction of 39 or 50 mg dazomet into the eye of rabbits caused slight irritation (moderate conjunctival erythema and slight oedema). Results of two acute dermal irritation studies employing 50% aqueous preparations of dazomet in rabbits were reported. No irritation was observed in the study employing a 4 h exposure period. After a 20 h exposure period, moderate erythema and oedema were observed. Application of the EUP, Basamid Granular (2 g coated on a cottonwool carrier), to the rabbit ear for 20 h caused slight inflammation.
Sensitisation	Skin sensitisation was not observed in two studies following the application of dazomet or Basamid Granular to the guinea pig. No justification was given for the doses / concentrations used in one of these studies and positive control compounds were not tested in these studies.
Health Effects Summary	Dazomet has moderate to low acute oral, dermal and inhalational toxicity. It appears that the toxicity of dazomet is somewhat greater by the oral route than by the dermal and inhalational routes. Dazomet is only a slight dermal and ocular irritant.
Key Study/Critical Effect for Screening Criteria	An ADI of 0.005 mg/kg/d is calculated based on a NOEL of 0.5 mg/kg (established in a 1-year dietary dog study and a 2-year dietary rat reproductive study) and a safety factor of 100.
Ecological Toxicity^{1,2,3}	
Aquatic Toxicity	Daphnia magna (Water flea), 48 h, static, EC50 = 0.3 mg/L Salmo gairdneri (Rainbow trout), 96 h, static, LC50 = 0.16 mg/L Ankistrodesmus bribaiianus (Green alga), 72 h, static, EC50 = 1.08 mg/L Colinus virginianus (Bobwhite quail), 21 d, LD50 = 415 mg/kg bw Colinus virginianus (Bobwhite quail), 25 weeks, NOEL = 100 mg/kg food
Determination of PNEC aquatic	An assessment factor of 10 has been applied to the lowest reported LC50 of 0.16 mg/L for Rainbow trout. The PNECaquatic is 0.016 mg/L.
Current Regulatory Controls⁴	
Australian Hazard Classification	Acute toxicity – category 4 Eye irritation – category 2 Hazardous to the aquatic environment (acute) – category 1 Hazardous to the aquatic environment (chronic) – category 1
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^{1,3,5}	
P/vP Criteria fulfilled?	The half-life of dazomet in soil has been reported as less than 1 day (half-life in soil < 6 months). Thus, it is not expected to be persistent.
B/vB criteria fulfilled?	As the Log Pow is 0.63 at 20 °C (Log Pow < 4.5) and estimated BCF is 2.4, it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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Toxicity Summary - Trisodium Nitrilotriacetate

Chemical and Physical Properties ^{1,2,3}	
CAS number	5064-31-3
Molecular formula	C ₆ H ₉ NO ₆ .3Na
Molecular weight	257.0
Solubility in water	640 g/l at 20 °C
Melting point	410 °C with decomposition above 200 °C
Boiling point	No data available
Vapour pressure	No data available
Henrys law constant	No data available
Explosive potential	Non-explosive (100%)
Flammability potential	Non-flammable (100%)
Colour/Form	colourless crystalline powder
Overview	The chemicals in this group are known as nitrilotriacetic acid (NTA) and its trisodium and tripotassium salts, trisodium nitrilotriacetate (trisodium NTA) and tripotassium nitrilotriacetate (tripotassium NTA). The trisodium salt also occurs as its monohydrate form (trisodium nitrilotriacetate monohydrate; CAS No. 18662-53-8). The chemical NTA is an aminocarboxylic acid with three functional carboxylate groups. The chemical forms water-soluble complexes with multivalent metal ions. The chemical NTA and trisodium NTA dissociate to form a common moiety, nitrilotriacetate ion. Thus the systemic toxicity of these chemicals is similar (Health Canada, 2010; SCCS 2010). Tripotassium NTA is considered to be functionally similar to trisodium NTA. The chemicals, NTA and trisodium NTA are used to soften water and to remove traces of heavy metals. These chemicals are commonly used as chelating and sequestering agents, and as builders in detergent and cleaning formulations for domestic and commercial use (EU RAR, 2008; SCCS, 2010).
Environmental Fate ¹	
Soil/Water/Air	Trisodium NTA was tested for ready biodegradability according to OECD 301 E (BASF, 1983b,c), OECD 301 F (in addition to a combined CO₂/DOC test, see Strotmann et al., 1995), and Sturm Test (BASF, 1983d), and in a die away test (Takahashi et al, 1997) as well as for inherent biodegradability according to OECD 302 B (BASF, 1983a). These tests resulted in 75 -100 % degradation after 7 to 28 days with lag phases ranging between 1 and 16 days. According to results from ready biodegradation tests, trisodium NTA can be regarded as readily biodegradable. In accordance with column 2 of REACH Annex IX, trisodium NTA has a log octanol-water partition coefficient of -13.2 at pH 7, is highly water-soluble, and is unlikely, due to its polar nature, to be taken up by fish gills or across other biological membranes. Due to the ionic structure of the substance a relevant adsorption of trisodium NTA onto the organic fraction of soils, sediments or suspended solids is not expected. However, interaction with the mineral phase may be possible. This assumption is in line with available study results (Dunlap et al., 1971; Bolton et al., 1993) which demonstrate that trisodium NTA is neither strongly sorbed by loam, clay-loam and sandy soils or marine surface sediments (K_p sediment-water = 1.6 l/kg).

Human Health Toxicity Summary¹

Chronic Repeated Dose Toxicity

The available data suggest that the chemicals have harmful effects following repeated oral dosing, based on results from animal tests. However, the effects were not sufficient to warrant hazard classification. In a 4-week study, Charles River and Fischer 344 (F344/N) (five or ten animals/group) rats were fed either 0 % or 1.5 % NTA in the diet. Effects observed included reduced growth, increased relative kidney weight, urinary calcium, haematuria and hydronephrosis. A lowest observed adverse effect level (LOAEL) of 1.5 % NTA (equivalent to 750 mg/kg bw/day) was reported (EU RAR, 2008; Health Canada, 2010).

In a 10-week study in male Sprague Dawley (SD) rats, trisodium NTA was administered to the rats in drinking water at 0 %, 0.01 %, 0.1 % or 1 % (equivalent to 0, 10, 100 or 1000 mg/kg bw/day). Increased kidney weights were observed in the rats treated at 0.1 % (100 mg/kg bw/day) and marked vacuolisation of the renal tubules was observed at 1 % trisodium NTA (1000 mg/kg bw/day dose) group. A LOAEL of 100 mg/kg bw/day (0.1 % trisodium NTA) was reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010).

Trisodium NTA was administered to male SD rats by gavage at 0, 0.73 or 7.3 mmol/day (equivalent to 0, 187 or 1876 mg/kg bw/day) for 30 days. Cytoplasmic vacuolisation, focal haemorrhage, necrosis, erosion and hyperplasia of the epithelium of the proximal convoluted tubules were observed in all treated animals. An oral LOAEL of 0.73 mmol/day (187 mg/kg bw/day) was reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb).

In a 90-day study in rats (strain not reported), NTA was administered to male rats at 0, 100, 1000 or 5000 mg/L in drinking water. All treated animals showed reduced serum potassium levels (EU RAR, 2008; Health Canada, 2010).

In two different studies (28-days and 91-days), New Zealand White (NZW) rabbits (six/group) were treated with either 0 or 2.5 % trisodium NTA on intact or abraded skin. No treatment-related effects were observed with or without abrasion (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).

In a 4-week repeated dose inhalation toxicity study, NTA was administered in SD rats, trueblood albino guinea pigs and cynomolgus monkeys at 0, 10, 213 or 343 mg/m³ concentrations for 6 hours/day by whole body exposure. No respiratory irritation or discomfort was observed at the highest tested concentration. The only treatment-related effects included diarrhoea in monkeys and dyspnoea in rats and guinea pigs. The no observed adverse effect concentration (NOAEC) of 213 mg/m³ and the lowest observed adverse effect concentration (LOAEC) of 343 mg/m³ were reported (EU RAR, 2008; Health Canada, 2010; REACHa & b).

In another study, male albino rats were treated with NTA at 0, 2, 20, 200 or 2000 mg/m³ concentrations for 6 hours/day for four consecutive days by inhalation exposure. All animals in the 2000 mg/m³ showed signs of nasal, respiratory and eye irritation, which were fully reversed on day 14 (EU RAR, 2008; Health Canada, 2010).

Carcinogenicity	Trisodium NTA is classified as hazardous with hazard category 'Carcinogenicity – Category 2' and hazard statement 'Suspected of causing cancer' (H351) in the HCIS (Safe Work Australia). The available data support the classification for trisodium NTA. Additionally, the classification for carcinogenicity is considered appropriate for NTA. The International Agency for Research on Cancer (IARC) has classified NTA and its salts as 'Possibly carcinogenic to humans' (Group 2B), based on inadequate evidence for carcinogenicity in humans, but sufficient evidence for carcinogenicity in animal tests (IARC, 1990; IARC, 1995). In two-year carcinogenicity studies in Charles River (CD) rats and B6C3F1 mice, oral administration of Na₃NTA induced benign and malignant tumours of the urinary system in both male and female rats at 80–100 mg/kg bw/day and haematopoietic tumours in male mice at 500–600 mg/kg bw. Trisodium NTA was reported to induce renal tubular adenomas and adenocarcinomas in male rats when administered orally (IARC, 1990; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).
Mutagenicity/ Genotoxicity	Based on the weight of evidence from the available in vitro and in vivo genotoxicity studies, the chemicals are not considered to be genotoxic. Several in vitro and in vivo micronucleus tests for gene mutation and clastogenicity were negative, although several positive results were reported (IARC, 1990; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the available information, the chemicals do not cause specific reproductive or developmental toxicity. In different two-generation reproductive and developmental toxicity studies, oral administration of up to 0.5 % trisodium NTA (equivalent to 450 mg/kg bw/day) in the diet of Charles River rats, up to 250 mg/kg bw/day trisodium NTA by gavage in pregnant NZW rabbits, and up to 0.2 % NTA (equivalent to 570 mg/kg bw/day) in drinking water in Naval Medical Research Institute (NMRI) mice, caused no significant maternal, embryonic or foetal effects. No effect on neonatal development was seen in any of the above studies (NTP, 1977; IARC, 1995; EU RAR, 2008; Health Canada, 2010; SCCS, 2010; HSDB; REACHa & b). In a developmental study, female NZW rabbits (groups of 20) were treated by gavage with trisodium NTA in drinking water at 0, 2.5, 25, 100 or 250 mg/kg bw/day during gestation days 7–16. All animals were sacrificed on day 28 of gestation. No treatment-related effects were observed (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b). A study was conducted in pregnant NMRI albino mice (10 animals/group) treated with 0 or 0.2 % trisodium NTA (equivalent to 0 or 570 mg/kg bw/day) in drinking water on 6–18 days of gestation. No significant differences in maternal weight gains and no developmental effects were observed (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHa & b).

Acute Toxicity	Trisodium NTA is classified as hazardous with hazard category 'Acute Toxicity – category 4' and hazard statement 'Harmful if swallowed' (H302) in the HCIS (Safe Work Australia). The available data (median lethal dose—LD50 of 1470 mg/kg bw in female rats and 750 mg/kg bw in monkeys) support this classification. Reported signs of toxicity include ataxia, tremors, hypopnoea, hypothermia, hypoactivity, prostration, staggering, twitching, opisthotonus, tonic convulsion, apathy, salivation and dyspnoea. Available data for NTA indicate an LD50 >6400 mg/kg in rats. The chemicals have low acute toxicity based on results from an animal test in rabbits following dermal exposure. In an acute dermal toxicity study, a 25 % aqueous solution of trisodium NTA monohydrate was applied occlusively to intact skin of rabbits (one animal/sex/dose) at 1000, 1580, 2510, 3980, 6310 or 10000 mg/kg bw. Mild muscle weakness and reduction in activity and appetite were seen in the higher dose groups. No local symptoms or muscular uncoordination were reported. An LD50 of >10,000 mg/kg bw was reported (EU RAR, 2008; REACHa & b). The chemicals have low acute toxicity based on results from animal tests following inhalation exposure. A median lethal concentration (LC50) in rats of >5.0 mg/L was reported for NTA (EU RAR, 2008; Health Canada, 2010; SCCS, 2010).
Irritation	Trisodium NTA is slightly irritating to the animal skin. The effects were not sufficient to warrant a hazard classification. Trisodium NTA is classified as hazardous with hazard category 'Eye Irritation – category 2A' and hazard statement 'Causes serious eye irritation' (H319) in HCIS (Safe Work Australia). The available data support this classification. In an eye irritation study in rabbits, trisodium NTA was found to be irritating. Conjunctivitis and marked corneal effects were observed at 24, 48 and 72 hours after application (ECHA, 2006). Effects were not reversible within the 7-day period. In a study, albino rabbits had considerable discomfort immediately after application of 100 mg of trisodium NTA monohydrate. Effects observed one hour after application included copious discharge, oedema with partial eversion of the lids, moderate redness and congestion with obscure iris. Discharge and oedema reduced on washing the eyes with saline solution after 24 hours. Complete reversal oedema occurred but mild redness and slight corneal dullness were observed on days 5 to 7 (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb). In another study conducted according to OECD Test Guideline (TG) 405, trisodium NTA (0.1 mL of 38 % solution) applied to the conjunctival sac of three albino rabbits caused slight eye irritation. The average scores for conjunctival redness and chemosis after 24 hours were 2.0 and 0.7, respectively. The conjunctival redness score was 0.1 after 48 hours and no chemosis was present. The conjunctival redness was reversible within 8 days after application. No effects on the cornea and iris were reported (EU RAR, 2008; Health Canada, 2010; SCCS, 2010; REACHb).
Sensitisation	Based on the available data, the chemicals are not considered to be skin sensitisers.
Health Effects Summary	The critical health effects for risk characterisation include systemic long-term effects (carcinogenicity) for all three chemicals, and systemic acute effects (acute toxicity from oral exposure) and local effects (eye irritation) for trisodium NTA and tripotassium NTA only.
Key Study/Critical Effect for Screening Criteria	The Australian Drinking Water Guideline for NTA is 0.2 mg/L.

Ecological Toxicity ⁴	
Aquatic Toxicity	Tests on acute toxicity to fish resulted in 96-hour LC50 values in the range of 98 – 487 mg/l. In a generation-cycle test over 224 days on <i>Pimephales promelas</i> (Arthur et al., 1974), there were no observable differences in survival, spawning activity, and egg hatchability at the highest tested concentration of 54 mg/l trisodium NTA (the active test substance was Ca- or Mg-NTA). Based in this study, the NOEC for fish is determined to 54 mg/L. All tests on acute toxicity to invertebrates showed effects only when the trisodium NTA concentration exceeded the stoichiometric metal levels of the medium. It is expected that effects are caused by the uncomplexed agent. This is supported by the increased effect values in hard water. In long-term tests, the most sensitive organism was the amphipod <i>Gammarus pseudo limnaeus</i>. In a generation-cycle test over 21 weeks exposure, the lowest tested concentration without significant effects was 9.3 mg/l trisodium NTA. Based in this study, the NOEC for invertebrates is determined to 9.3 mg/l. At this concentration, NTA is mainly complexed with Ca and Mg.
Determination of PNEC aquatic	Reliable long-term data was available for a fish, invertebrate and algae. The lowest NOEC of 9.3 mg/L was a result for testing with <i>Gammarus pseudolimnaeus</i> (Arthur et al. 1974). An assessment factor of 10 was used for a resulting PNEC for intermittent releases of 0.93 mg/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	Trisodium NTA is classified as hazardous, with the following risk phrases for human health in the Hazardous Chemicals Information System (HCIS) (Safe Work Australia): Acute toxicity – category 4; H302 (Harmful if swallowed) Eye irritation – category 2; H319 (Causes serious eye irritation) Carcinogenicity – category 2; H351 (Suspected of causing cancer).
Australian Occupational Exposure Standards	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica; Protective Action Criteria (PAC)): Temporary Emergency exposure limits (TEELs) defined by the US Department of Energy (DOE): TEEL-1= 3.7 - 9.2 mg/m³; TEEL-2= 40 - 100 mg/m³; TEEL-3= 220 - 110 mg/m³.
Australian Food Standards	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
Australian Drinking Water Guidelines	The chemical NTA has an Australian drinking water guideline value of 0.2 mg/L (NHMRC, 2011; FSANZ).
Aquatic Toxicity Guidelines	No data available.
PBT Assessment	
P/vP Criteria fulfilled?	NTA is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	Trisodium NTA has a log octanol-water partition coefficient of -13.2 at pH 7, is highly water-soluble. Thus, it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of NTA is > 0.01 mg/L. Hence the substance does not fulfil the screening criteria for toxic (T)

Overall conclusion	Not PBT
Revised	March 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier II Assessment for Nitrilotriacetic acid and salts: Retrieved 2019: <https://www.nicnas.gov.au>
2. ECHA REACH, Trisodium nitrilotriacetate, Retrieved 2019: <https://echa.europa.eu/>
3. HSDB (n.d.). Hazardous Substances Data Bank. Retrieved 2019, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>

Toxicity Summary - Xanthan Gum

Chemical and Physical Properties ^{1,3}	
CAS number	11138-66-2
Molecular formula	Unspecified
Molecular weight	high-molecular weight (of the order of 1000 kDa)
Solubility in water	Water-soluble
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	Xanthan gum is a high molecular weight anionic polysaccharide secreted by the bacteria <i>Xanthomonas campestris</i>. It is used as a stabilizer and thickener for foods, pharmaceuticals, and cosmetics, for rheology control in water-based systems, and in oil and gas drilling. Xanthan gum is used for controlling the viscosity of drilling muds (DoE 2014). 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	Xanthan gum is expected to exhibit similar behaviour to that of guar gum because the two compounds are chemically similar. Thus, it is expected to adsorb strongly to soil and sediment and there is limited potential for it to reach surface waters via dissolved runoff and / or to leach into ground water. Volatilisation from soils and water is not considered to be a likely transport process in the environment (US EPA 2005). Xanthan gum is expected to readily undergo microbial biodegradation in the environment (on the bases that it is polysaccharide and expected to be readily biodegradable), and the potential to bioaccumulate in organisms is considered to be low.

Human Health Toxicity Summary ²	
Chronic Repeated Dose Toxicity	Groups of 30 male and 30 female Charles River CD strain rats were fed diets for 104 weeks supplying 0, 0.25, 0.5, or 1.0 g/kg b.w./day xanthan gum. No abnormalities which could be attributed to ingestion of these experimental diets were found with regard to survival, body-weight gain, food consumption, behaviour, or appearance. Ophthalmic and haematologic examination yielded normal results. Analysis of blood for glucose, SGOT, and prothrombin time showed no abnormalities in test groups. Organ weights were within normal limits and no lesions attributable to xanthan gum were found on gross and histopathological examination (Woodard et al., 1973). Xanthan gum was administered in the diet at levels supplying 0, 0.25, 0.37, or 1.0 g/kg b.w./day to groups of 4 male and 4 female beagle dogs for 107 weeks. No effects attributable to administration of the gum were seen in the treated animals with regard to survival, food intake, body-weight gain, electrocardiograms, blood pressure, heart rate, body temperature, or ophthalmic and neurological examinations. Haemoglobin, total and differential white cell counts, coagulation and prothrombin times, thrombocyte counts, serum alkaline phosphatase, blood urea nitrogen, blood glucose, SGOT, and SPGT were the same in control and treated animals. Urine pH, glucose concentrations, and sediment contents were comparable between test and control groups, but there was a dose-related increase in urine SG and a more frequent appearance of urinary albumin in dogs consuming 1.0 g/kg b.w./day of gum than in the other groups. Stool consistency was normal at the 0.37 g/kg level, but stools were loose at the top-dose level. The weight of the faeces showed a dose-related increase, as would be expected from feeding a non-absorbed hydrophilic gum at high-dose levels. The increased urinary SG is consistent with physiological adjustment for the extra water excreted in the faeces. Examination of the appearance and weights of organs and histopathological examinations failed to detect any adverse effects of treatment with xanthan gum at any dose level (Woodward et al., 1973).
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	No data available.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A three-generation reproduction study was carried out using groups of 10 male and 20 female rats in the first generation and 20 male and 20 female rats in subsequent generations. Dosage levels of 0, 0.25, and 0.5 g/kg/day were administered in the diet. Criteria evaluated were survival, body weight, general appearance, behaviour, the number of litters produced, number of live births and still births, physical condition of the young, weight at birth and weaning, and survival of the young. Females that had fewer than two litters were examined to determine whether there was foetal resorption. Malformations in offspring were recorded and gross and micropathological examinations were made on the offspring of the second and third generations. No adverse effects attributable to xanthan gum were found in this study (Woodard et al., 1973).
Acute Toxicity	A study was carried out on an unspecified number of rats fed diets containing 7.5 or 10% xanthan gum for 99-110 days. No adverse effects were observed in extensive investigations on these animals (Booth et al., 1963). In a 91-day feeding study, a reduced rate of weight gain was found in groups of rats receiving 7.5 or 15% xanthan gum in the diet. Diets containing 3 or 6% gum did not reduce weight gain. No significant alterations in haemoglobin, red or white cell counts, or organ weights were observed in these rats. Histological examination of tissues from rats at the 15% level showed no pathological effects. At the highest-dose level the animals produced abnormally large faecal pellets, but diarrhoea did not occur. A paired-feeding test was used to compare the growth of rats ingesting a diet containing 7.5% xanthan gum and comparable rats restricted to the same intake of control diet. No differences in weight gain were found at the end of 18 days, indicating the absence of a growth-inhibiting factor (Booth et al., 1963). Groups of 3 male and 3 female beagle dogs were fed diets supplying 0, 0.25, or 0.5 g/kg b.w./day xanthan gum for 12 weeks. Animals in the high-dose group had softer stools than normal, but no diarrhoea. Growth was slightly retarded in the males and the serum cholesterol level was lowered in both sexes of the high-dose group. No other adverse effects were seen. The no-adverse-effect-level in this test was considered to be 0.25 g/kg b.w./day (USDA, 1964).

Irritation	Daily application of a 1% solution for 15 days to rat skin produced no signs of irritation. Daily application of a 1% solution for five days to rabbit conjunctiva produced no signs of irritation.
Sensitisation	Intradermal challenge tests in guinea-pigs did not produce evidence of sensitization (Hendrickson & Booth, sine data).
Health Effects Summary	A mild skin and eye irritant
Key Study/Critical Effect for Screening Criteria	The Joint FAO/WHO Expert Committee on Food Additives allocated an Acceptable Daily Intake (ADI) of "not specified".
Ecological Toxicity ^{1,2,3}	
Aquatic Toxicity	Acute Fish (measured) = 420 mg/L
Determination of PNEC aquatic	Based on acute fish toxicity of 420 mg/L, an assessment factor of 1000 was used for a resulting PNEC of 0.42 mg/L.
Current Regulatory Controls	
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 biodegradation information was found on xanthan gum. However, xanthan 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?	Xanthan gum is not expected to meet the criteria for bioaccumulation.
T criteria fulfilled?	Not applicable. Acute toxicity data >1 mg/L in fish, thus xanthan gum does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	March 2019

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. IPCS INCHEM, Xanthan Gum, Retrieved 2019: <http://www.inchem.org/>
3. Food and Agriculture Organization of the United Nations (FAO) 2016, 82nd JECFA - Chemical and Technical Assessment (CTA), XANTHAN GUM

Toxicity Summary - Acrylamide polymers: Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer and Polymer of 2-acrylamido-2-ethylpropanesulfonic acid sodium salt and methyl acrylate

Chemical and Physical Properties ^{2, 3, 4}	
CAS number	38193-60-1 and 136793-29-8
Molecular formula	38193-60-1: (C ₇ H ₁₃ NO ₄ S.C ₃ H ₅ NO.Na) _x 136793-29-8: C ₁₁ H ₁₈ NNaO ₆ S
Molecular weight	Likely >1000 MW
Solubility in water	No data available.
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	No studies are available for the Acrylamide polymers. Information for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt will be referenced in the following sections. 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salts are generally incorporated into polymers. As such, the fate of the monomer is tied to the polymer and no hydrolysis, movement, biodegradation or bioaccumulation of the polymer is expected. A Tier 1 Human Health Assessment for Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer has been conducted by NICNAS which concluded that this chemical was identified as low concern to human health.
Environmental Fate ²	
Soil/Water/Air	The polymers are not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weights and the low water solubilities of the polymers. Due to their high molecular weight, the polymers are not expected to bioaccumulate.
Human Health Toxicity Summary ²	
Chronic Repeated Dose Toxicity	A repeat dose 28 day oral toxicity study carried out in rats with a 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicated no treatment related toxic effects.
Carcinogenicity	No information available.
Mutagenicity/ Genotoxicity	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt did not induce a mutagenic response in bacteria and no clastogenicity was observed when a 50% solution of the notified chemical was tested in albino mice cells in vitro.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.

Acute Toxicity	Aqueous solutions containing 50% of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt exhibited low acute oral and dermal toxicity in rats (LD50 > 5 000 mg/kg, and 2 000 mg/kg respectively).
Irritation	2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt was non-irritant to rabbit skin and a slight eye irritant in rabbits.
Sensitisation	A 50% aqueous solution of 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt showed minimal sensitisation potential when tested in guinea pigs.
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	No data available
Ecological Toxicity ²	
Aquatic Toxicity	Limited information is available. The polymers are expected to be a low concern for toxicity to aquatic organisms. Due to their poor solubility and high molecular weights, they are not expected to be bioavailable. The polymers do not contain any reactive functional groups. Ecotoxicity data for 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt indicate that it is practically non-toxic to fish, water fleas and algae.
Determination of PNEC aquatic	No PNEC values were calculated.
Current Regulatory Controls⁵	
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	Based on health considerations, the concentration of acrylamide in drinking water should not exceed 0.0002 mg/L.
Aquatic Toxicity Guidelines	No data available
PBT Assessment ^{1, 2}	
P/vP Criteria fulfilled?	The polymers are not readily biodegradable, hence they meet the screening criteria for persistence.
B/vB criteria fulfilled?	The polymers are expected to have very high molecular weights and poor water solubility. They are not expected to be bioavailable, hence the polymers do not meet the criteria for bioaccumulation.
T criteria fulfilled?	There are no aquatic toxicity studies on the polymers. They are expected to have low aquatic toxicity because of their very high molecular weights and poor water solubility. As such, the polymers do not meet the criteria for toxicity.
Overall conclusion	Not PBT substances
Revised	December 2018

References

1. Categorization Results from the Canadian Domestic Substance List, CAS# 38193-60-1

2. National Industry Chemicals Notification and Assessment Scheme. 2-Acrylamido-2-methylpropanesulfonic acid, ammonium salt, July 1997.
3. U.S National Library of Medicine, Toxicology Data Network, ChemIDplus, CAS#38193-60-1. Accessed 2017 at <https://chem.nlm.nih.gov/chemidplus/rn/38193-60-1>
4. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2018: <https://www.nicnas.gov.au>
5. National Health and Medical Research Council, Natural Resources Management Ministerial Council, national Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.3 Updated November 2016.

Toxicity Summary - Potassium chloride

Chemical and Physical Properties ^{1,2,3,8,9,10}	
CAS number	7447-40-7
Molecular formula	KCl
Molecular weight	74.55 g/mol
Solubility in water	34.20 at 20 °C
pH	7
Melting point	771.00 °C
Boiling point	1500 °C
Vapour pressure	No data found
Henry's law constant	No data found
Explosive potential	Not explosive
Flammability potential	Not flammable
Colour/Form	White crystals or crystalline powder
Overview	Potassium is an essential element in the body. It is the main intracellular cation with 98% of total body potassium located within the cells. It is mainly used in fertilisers, medicine, lethal injections, scientific applications, feedstock, food processing and as a sodium substitute in table salt. Potassium chloride is an essential element with homeostatic physiological processes regulating levels in the body. In cases of increased exposure to high levels of potassium significant health effects in people with kidney disease or other conditions, such as heart disease may result. Potassium chloride as an inorganic salt is not subjected to further degradation processes in the environment once it dissociates into its respective ions. In water, potassium chloride is highly water soluble, and readily undergoes dissociation. In soil, transport and leaching of potassium and chloride ions is affected by the clay minerals (type and content), pH, and organic matter. 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 ^{1,3,8,9}	
Soil/Water/Air	KCl is a solid inorganic salt that is highly soluble in water (342 g/L at 20° C). Potassium chloride fully dissociates in aqueous solutions to K⁺ and Cl⁻ ions. Cl⁻, either as an inorganic salt or as K⁺ and Cl⁻ ions, is ubiquitous in the environment. There is no potential for bioaccumulation or bioconcentration. Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated.

Human Health Toxicity Summary ^{1,3,8,9}	
Chronic Repeated Dose Toxicity	Fourteen female rats were given KCl in their drinking water (approximately 5,250 mg/kg/day) for 105 days. Ten rats were sacrificed after 105 days of exposure for examination of the heart, kidneys and the adrenals; four rats (recovery group) were kept for an additional month. KCl exposure resulted in decreased heart weight, increased kidney weight, and enlargement of part of the adrenals. All changes were reversible within one month of exposure (Bacchus, 1951). F344/Sic male rats were given 0, 110, 450 or 1,820 mg/kg/day KCl in feed for two years. At the end of the study, survival rates were 48%, 64%, 58% and 84% in the controls, 110, 45 and 1,820 mg/kg/day groups. Nephritis was reported to be predominant in all groups, including the controls. The only treatment-related effect observed was gastritis (inflammation of the stomach lining). The incidence of gastritis and ulcers were 6%, 18%, 18% and 30% in the controls, 110, 450 and 1,820 mg/kg/day groups (Imai <i>et al.</i> , 1968). Male and female Wistar rats were fed diets containing 0 or 3% KCl over a total period of 30 months: Examination after 13 weeks (10 rats/sex/group), after 18 months (15 rats/sex/group) and after 30 months (50 rats/sex /group). Due to the reduction of feed intake the mean test substance intake and mean body weight decreased in time. After 30 months of treatment, there was hypertrophy of the zona glomerulosa in the adrenals (24/50 treated rats versus 4/50 in controls); and cystitis in the urinary bladder (males: 3/59; females 3/50) and single epithelial hyperplasia of the bladder (males 3/50; females 2/50) (Lina <i>et al.</i> , 1994; Lina and Kuijpers, 2004).
Carcinogenicity	Potassium chloride has not been evaluated and is not listed by the IARC as a carcinogen. In a long-term study, male rats (50 per group) were fed potassium chloride in the diet at levels of 110, 450 or 1820 mg/kg bw/day for 2 years. No carcinogenic effects were observed in male rats.
Mutagenicity/ Genotoxicity	No gene mutation ns were reported in bacterial tests, with and without metabolic activation. However, high concentrations of potassium chloride showed positive results in a range of genotoxic screening assays using mammalian cells in culture. The action of potassium chloride in culture seems to be an indirect effect therefore further <i>in vivo</i> studies were not considered necessary.
Reproductive Toxicity Developmental Toxicity/Teratogenicity	A developmental study revealed no foetotoxic or teratogenic effects of potassium chloridel in doses up to 235 mg/kg/day (mice) and 310 mg/kg/day (rats). No fertility study has been located. Further human and ecological assessment was not recommended by the OECD SIDS.
Acute Toxicity	Potassium chloride is an essential element with homeostatic physiological processes regulating levels in the body. In cases of increased exposure to high levels of potassium significant health effects in people with kidney disease or other conditions, such as heart disease may result. Adverse health effects due to consumption of potassium from drinking water are unlikely to occur in healthy individuals. Acute effects are rare in humans although under particular circumstances severe effects may occur. Lethal effects were observed in a 2 month old baby fed 15,000 mg potassium chloride for 2 days and in another case report where an adult woman had ingested slow released potassium chloride tablets (35, 000 mg). The most common form of ingestion is through drinking water. It is not considered necessary to establish a health-based guideline value for potassium in drinking water due to its lack of toxicity.
Irritation	Slight skin and eye irritant. A threshold concentration for skin irritancy of 60% was seen when potassium chloride in aqueous solution was in contact with skin of human volunteers. The threshold concentration when applied to broken skin was 5%.
Sensitisation	No data found.
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	In a two-year rat feeding study, there was an increased incidence of gastritis and ulcers at dose levels of >110 mg/kg/day (Imai <i>et al.</i> , 1968). There was no NOAEL. Thus, the LOAEL for this study is 110 mg/kg/day. Since the gastritis and ulcers are the result of a localized irritation effect of the test substance (site of contact) in the gastrointestinal tract, an uncertainty factor for interspecies variability is deemed unnecessary. For systemic effects, the NOAEL for the two-year rat feeding study is considered to be 1,820 mg/kg/day, the highest dose tested. Uncertainty factors: 10 (intraspecies variability); 10 (interspecies variability); 1 (intraspecies variability) Oral Reference Dose = 1,820/100 = 18.2 mg/kg/day Drinking water guideline: 71 ppm
Ecological Toxicity ^{1,3,8,9,10}	
Aquatic Toxicity	In a guideline study, the 96-hour LC50 in <i>Pimephales promelas</i> was reported to be 880 mg/L (Mount <i>et al.</i> , 1997). The 48-hour LC50 values from two studies on <i>Lepomis macrochirus</i> (Patrick <i>et al.</i> , 1968; Trama, 1954), and one study each on <i>Oncorhynchus mykiss</i> and <i>Ictalurus punctatus</i> (Waller <i>et al.</i> , 1993) ranged from 720 to 2,010 mg/L. In a guideline study, the 48-hour EC50s in <i>Daphnia magna</i> and <i>Ceriodaphnia dubia</i> were 660 and 630 mg/L, respectively (Mount <i>et al.</i> , 1997; ECHA REACH database). The 48-hour EC50 in <i>Daphnia magna</i> in another study was also reported to be 177 mg/L (Biesinger and Christensen, 1972). The toxicity of KCl has been investigated in one algae species (<i>Nitzschia linearis</i>), showing 120 hour-EC50 (growth rate) of 1,337 mg/L (Patrick <i>et al.</i> , 1968). The 72-hour EC50 to <i>Scenedesmus subspicatus</i> is >100 mg/L (growth rate), with a NOEC of >100 mg/L (ECHA REACH database). In a fish early-life-stage test with the fathead minnow (<i>Pimephales promelas</i>), the 7-day NOEC is 500 mg/L (ECHA REACH database). A long term (21-day) study has been performed on <i>Daphnia magna</i> where effects on reproduction were investigated for several metals. A 16% impairment of reproduction (LOEC) was observed at a concentration of 53 mg/L of K ⁺ , equal to KCl concentration of 101 mg/L (Biesinger and Christensen, 1972). The measured NOEC for <i>Daphnia</i> is 373 mg/L
Determination of PNEC aquatic	PNECaquatic: On the basis of the chronic results for <i>Daphnia</i> , an assessment factor of 100 has been applied to the lowest reported effect concentration of 373 mg/L. The PNECaquatic is determined to be 3.73 mg/L.
Current Regulatory Controls	
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 ^{1,8,9,10}	
P/vP Criteria fulfilled?	Potassium chloride is an organic salt that dissociates completely to potassium and chloride ions in aqueous solutions. Biodegradation is not applicable to these inorganic ions; both potassium and chloride ions are also ubiquitous and are present in most water, soil and sediment. For the purposes of this PBT assessment, the persistent criteria is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Potassium and chloride ions are essential to all living organisms and their intracellular and extracellular concentrations are actively regulated. Thus, potassium chloride is not expected to bioaccumulate.

T criteria fulfilled?	The measured chronic toxicity data for potassium chloride was 373 mg/L for Daphnia. Thus, potassium chloride does not meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	April 2018

References

1. WHO (2009). Potassium in drinking-water. Background document for development of Guidelines for Drinking-water Quality. World Health Organization WHO/HSE/WSH/09.01/7.
2. HSDB Hazardous Substance Databank (HSDB) Potassium Chloride. Toxnet <http://toxnet.nlm.nih.gov> U.S. National Library of Medicine.
3. IARC, 2009: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organisation.
4. Material Safety Data Sheet Potassium chloride. ScienceLabs.com Inc. <http://www.sciencelab.com/msds.php?msdsId=9927402>
5. WHO Poisons Information Monograph for Potassium Chloride. Electronic record accessed from www.inchem.org World Health Organization.
6. UNEP Potassium Chloride Screening Information Dataset (SIDS) Initial Assessment Report for 13th SIAM (Bern, 6-9 November 2001. United Nations Environment Programme (UNEP) <http://www.inchem.org/documents/sids/sids/KCHLORIDE.pdf>
7. ECHA REACH database: <http://apps.echa.europa.eu/registered/registered-sub.aspx>
8. IUCLID Data Set for Potassium chloride (CAS No. 7447-40-7), UNEP Publications.
9. OECD (2001b). OECD-Screening Information Assessment Report (SIAR) for Potassium chloride (CAS No. 7447-40-7), UNEP Publications.
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 - 2-Propenoic acid, polymer with sodium phosphinate and 2-Propenoic acid, sodium salt, polymer with 2-propenamide

Chemical and Physical Properties ^{1,2,3}	
CAS number	129898-01-7 25085-02-3
Molecular formula	(C ₃ H ₄ O ₂ .H ₃ O ₂ P.Na) _x .xNa (C ₃ H ₅ NO.C ₃ H ₄ O ₂ .Na) _x
Molecular weight	Likely >1000 MW
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	No data available.
Overview	No studies are available. The polymer is not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weight and the low water solubility of the polymer. Due to its high molecular weight, the polymer is not expected to bioaccumulate. This chemical has been identified by NICNAS to be of low concern to human health and thus required no further assessment.
Environmental Fate ²	
Soil/Water/Air	The polymer is not expected to be readily biodegradable. Biodegradation is limited due to the very high molecular weight and the low water solubility of the polymer. Due to its high molecular weight, the polymer is not expected to bioaccumulate.
Human Health Toxicity Summary	
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	No data available.
Irritation	No data available.
Sensitisation	No data available.
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	No data available.
Ecological Toxicity²	
Aquatic Toxicity	Limited information is available. The polymer is expected to be a low concern for toxicity to aquatic organisms. Due to its poor solubility and high molecular weight, it is not expected to be bioavailable. It does not contain any reactive functional groups.
Determination of PNEC aquatic	No PNEC values were calculated.
Current Regulatory Controls	
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?	The polymer is not readily biodegradable, hence it meets the screening criteria for persistence.
B/vB criteria fulfilled?	The polymer is expected to have a very high molecular weight and poor water solubility. It is not expected to be bioavailable, hence this polymer does not meet the criteria for bioaccumulation.
T criteria fulfilled?	There are no aquatic toxicity studies on the polymer. It is expected to have low concern for aquatic toxicity because of its very high molecular weight and poor water solubility. As such, the polymer does not meet the criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>
2. Categorization Results from the Canadian Domestic Substance List, 2-Propenoic acid, polymer with sodium phosphinate
3. U.S National Library of Medicine, Toxicology Data Network, ChemIDplus, CAS#38193-60-1. Accessed 2017 at <https://chem.nlm.nih.gov/chemidplus/rn/38193-60-1>

Toxicity Summary - Calcium Carbonate

Chemical and Physical Properties ^{1,2}	
CAS number	1317-65-3
Molecular formula	Not applicable
Molecular weight	Not applicable
Solubility in water	No data available
Melting point	Approximately 900°C (Oates 1998).
Boiling point	No data available
Vapour pressure	No data available
Henrys law constant	No data available
Explosive potential	No data available
Flammability potential	No data available
Colour/Form	Solid
Overview	Limestone is the name given to a type of rock mostly composed of calcium carbonate. It also contains minor impurities of iron, magnesium, quartz, clay, pyrite, phosphate, and organic matter (Pohl 2011). It is used widely in agriculture to increase calcium concentrations and the pH of soils (Upjohn et al. 2005). Limestone is used industrially on a very large scale as an ingredient in concrete production and in metallurgy (Oates 1998; Pohl 2011). In the Australian coal seam gas industry, it is used as a bridging agent in drilling fluid formulations. A Tier 1 Human Health Assessment for these chemicals has been conducted by NICNAS which concluded that these chemicals were identified as low concern to human health by application of expert validated rules.
Environmental Fate ²	
Soil/Water/Air	Limestone dissolves slowly in water, releasing calcium and carbonate ions as well as other trace elements, such as iron and magnesium (Deer et al. 1992; Clair and Hindar 2005; Pohl 2011). These trace elements are naturally ubiquitous in the environment and are subject to natural biogeochemical processes. Calcium oxide reacts immediately upon exposure to water, forming calcium hydroxide, which itself reacts with carbon dioxide to form calcium carbonate. The final reaction products of both limestone and calcium oxide in the environment are therefore essentially the same, although calcium oxide typically has lower concentrations of magnesium and other inorganic chemicals than limestone and produces a higher initial concentration of hydroxide ions (Upjohn et al. 2005). Calcium and carbonate ions occur naturally in all environmental compartments, and are important nutrients for various organisms. Calcium is mobile in soil (ANZECC and ARMCANZ 2000) and, if released to the environment, should be expected to experience significant partitioning to the water compartment. However, calcium ions may also form insoluble precipitates with anions present in the environment, such as carbonate ions, and settle out of the aqueous phase. Carbonate is an important component of the global carbon cycle (Wetzel 2001).
Human Health Toxicity Summary ³	
Chronic Repeated Dose Toxicity	No systemic toxicological findings could be detected in rats after repeated administration of uncoated nano calcium carbonate by the oral route for a period of 90 days. The results of this study are read across to bulk calcium carbonate. Several potential adverse effects have been reported following calcium supplementation e.g. effects on kidney function, milk-alkali syndrome, kidney stones and interactions with minerals. However, these effects are more prevalent in those people suffering from renal insufficiency and following the ingestion of high doses of calcium.

	No systemic toxicity was observed in a 90-day inhalation study where rats were exposed to uncoated calcium carbonate at a maximum concentration of 0.399 mg/L, stated as the NOEC. The local effects observed at this level were limited to increased lung weights accompanied by increases in BAL-derived inflammation and cytotoxicity biomarkers, which were reversible in males but were not fully reversible in females within a 4-week recovery period. Hence the NOAEC for local effects was established as 0.212 mg/L and the LOAEC at 0.399 mg/L. The results of this study are read across to bulk calcium carbonate.
Carcinogenicity	Uncoated nano calcium carbonate is not expected to pose a risk of carcinogenicity.
Mutagenicity/ Genotoxicity	Uncoated nano calcium carbonate was negative in the following assays: In vitro gene mutation study in bacteria (OECD TG 471) using Salmonella typhimurium strains TA 98, TA 100, TA 1535 and TA 1537 and Escherichia coli WP2 uvrA with and without metabolic activation (S9). In vitro chromosome aberration study in mammalian cells (OECD TG 473) using human lymphocytes in the presence and absence of metabolic activation. In vitro gene mutation study in mammalian cells (OECD TG 476) using mouse lymphoma L5178Y cells in the presence and absence of metabolic activation. The results of these studies are read across to bulk calcium carbonate.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Under the conditions of the OECD TG 422 study, uncoated nano calcium carbonate administered to male and female rats up to a dose level of 1000 mg/kg bw/day for a period of up to 48 days is not toxic to reproduction and has no effect on fertility or development. No treatment-related effects were observed for reproduction; hence, a NOEL for reproductive toxicity was considered to be 1000 mg/kg bw/day. The results of this study are read across to bulk calcium carbonate. The prenatal developmental toxicity study also demonstrated that calcium carbonate was neither foetotoxic nor teratogenic at the concentrations used. Since no adverse effects were noted at the highest dose level tested (1.25% Ca in diet), the NOAEL for teratogenic and maternal toxic effects in rats is in excess of 1.25% Ca, equivalent to approximately 1963 - 2188 mg/kg bw/day of calcium carbonate.
Acute Toxicity	Bulk calcium carbonate is not considered to be acutely harmful by the oral, dermal or inhalation routes.
Irritation	Bulk calcium carbonate is not considered to be irritating to the skin or eyes.
Sensitisation	Based on the results of an OECD TG 429 study performed using nano calcium carbonate and read across to bulk calcium carbonate, where the Stimulation Index was < 3, bulk calcium carbonate is considered to be a non-sensitiser
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	In the repeated dose toxicity study, NOAEC for local effects was established as 0.212 mg/L and the LOAEC at 0.399 mg/L.
Ecological Toxicity²	
Aquatic Toxicity	Calcium carbonate has low toxicity to aquatic and terrestrial organisms. Ecotoxicological endpoint values for aquatic organisms generally greatly exceed 100 mg/L (LMC 2014), indicating very low toxicity.
Determination of PNEC aquatic	Experimental results are available for three trophic levels. Acute LC50 values are available for fish, invertebrates, and algae. On the basis that the data consists of short term results from three trophic levels, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 310 mg/L for invertebrates. The PNEC aquatic is 0.3 mg/L.
Current Regulatory Controls	
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 chemical, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions.
T criteria fulfilled?	Not applicable. Expected to have low toxicity to aquatic organisms.
Overall conclusion	Not PBT
Revised	October 2019

References

1. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>
2. 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
3. ECHA REACH, Calcium carbonate, Retrieved 2019: <https://echa.europa.eu/>

Toxicity Summary - Cellulose, carboxymethyl ether, sodium salt

Chemical and Physical Properties ^{1,2}	
CAS number	9004-32-4
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	No data available.
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	White odourless hygroscopic granules or powder.
Overview	Sodium carboxycellulose is the sodium salt of carboxymethylcellulose. Carboxymethyl cellulose is a cellulose derivative with carboxymethyl groups (-CH₂COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. Sodium carboxycellulose is listed as GRAS (Generally Regarded as Safe) by the U.S. Food and Drug Administration (FDA GRAS database). It is an approved food additive in the EU (EC, 1995) and may be added to all foodstuffs following quantum satis principle, except in products for the dietary management of metabolic disorders, where the limit of use is 10 g/L or kg (EC, 1999). Sodium carboxycellulose is also listed as an Inert Ingredient Eligible for US Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 25(b) pesticide products and US EPA List 4A. The Joint FAO/WHO Expert Committee on Food Additives has determined an Acceptable Daily Intake (ADI) for sodium carboxymethyl cellulose of "Not Specified" (no upper limit) (JECFA, 1989). A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate ¹	
Soil/Water/Air	Carboxymethyl cellulose (DS 0.7) showed 25% biodegradation after 28 days in a OECD 301A test. Thus, sodium carboxymethyl cellulose is not readily biodegradable. Other studies have also shown partial degradation of carboxymethyl cellulose in ready and inherent biodegradability tests.
Human Health Toxicity Summary	
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	No data available.
Irritation	No data available.
Sensitisation	No data available.
Health Effects Summary	No data available.
Key Study/Critical Effect for Screening Criteria	No data are available for determining the critical effect and the LOAEL/NOAEL for an oral reference dose.
Ecological Toxicity ¹	
Aquatic Toxicity	Carboxymethyl cellulose has been tested in several acute aquatic toxicity tests. The 96-hour LC50 for Brachydanio rerio is >2,500 mg/L; the 48-hour LC50 for Daphnia magna is >5,000 mg/L; and the 96-hour EC50 for Selenastrum capricornutum is 500 mg/L.
Determination of PNEC aquatic	PNECaquatic: Experimental results are available for three trophic levels. Acute E(L)C50 values are available for fish (>2,500 mg/L), Daphnia (>5,000 mg/L), and algae (>500 mg/L). 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 500 mg/L for algae. The PNECaquatic is 0.5 mg/L.
Current Regulatory Controls⁴	
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?	Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is not readily biodegradable. Thus, it meets the screening criteria for persistence.
B/vB criteria fulfilled?	Sodium carboxymethyl cellulose is a water-soluble semisynthetic polymer and is expected to have a molecular weight of >1,000 which limits its bioavailability to aquatic organisms. Thus, it is not expected to bioaccumulate.
T criteria fulfilled?	The acute EC(L)50 of sodium carboxymethylcellulose is >0.1 mg/L in fish, invertebrates and algae. Thus, it does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

1. Van Ginkel, C.G., and Gayton, S. (1996). The biodegradability and nontoxicity of carboxymethyl cellulose (DS 0.7) and intermediates. Environ. Toxicol. Chem. 15: 270-274
2. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>
3. EC (1995). European Parliament and Council Directive No 95/2/EC of 20 February 1995 on food additives other than colours and sweeteners, OJ L 61, 18.3.1995, p. 1-63.

4. EC (1999). Food additives permitted in dietary foods for infants and young children for special medical purposes as defined in Directive 1999/21/EC (Commission Directive 1999/21/EC of 25 March 1999 on dietary foods for special medical purposes, (OJ L 91, 7.4.1999, p. 29).
5. FDA GRAS Database:
<http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/SCOGS/ucm260737.htm>
6. JECFA (1989). <http://apps.who.int/ipsc/database/evaluations/chemical.aspx?chemID=3773>

Toxicity Summary - Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivatives residues

Chemical and Physical Properties ¹	
CAS number	68909-77-3
Molecular formula	C ₃₆ H ₇₈ N ₆ O ₁₄
Molecular weight	UVCB
Solubility in water	100 g/L at 20 °C
Melting point	-20 °C at 101.3 kPa
Boiling point	223 °C at 101.3 kPa
Vapour pressure	0.55 - 20 Pa at 20 - 25 °C
Henry's law constant	No data available
Explosive potential	Non-explosive (100%)
Flammability potential	Not classified (50%), Non-flammable (50%)
Colour/Form	Liquid
Overview	The residuum from the reaction of diethylene glycol and ammonia. It consists predominantly of morpholine-based derivatives such as [(aminoethoxy)ethyl]morpholine, [(hydroxyethoxy)ethyl]morpholine, 3-morpholinone, and 4,4'-(oxydi-2,1-ethanediyl)bis[morpholine].
Environmental Fate ¹	
Soil/Water/Air	The substance is hydrolytically stable at pH 4, 7 and 9 at 25°C. Adsorption to solid soil phase is not to be expected. Based on the assessment of the components, it can be concluded that the mixture will not evaporate into the atmosphere. The substance is not readily biodegradable. Based on the low log K _{ow} , the substance will have a low potential for bioaccumulation. Over time, the mixture will preferentially distribute into the compartment water.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	No adverse effects were observed in male and female rats in a 28 days and a 90 days repeated dose toxicity test conducted according to OECD 407 and OECD 408 respectively (Calvert Laboratories, Inc., 2011 and Envigo Research Limited, 2018) in which animals were exposed orally (gavage) to 0, 100, 500 or 1000 mg/kg bw/d (28 days study) and to 0, 10, 100 or 1000 mg/kg bw/d (90 days study). In both studies, an NOAEL of 1000 mg/kg bw was determined.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	In an in vivo micronucleus test on mouse bone marrow erythrocytes (BioReliance, 2010), performed according to OECD guideline 474, the animals were exposed orally (via gavage) with 500, 1000, 2000 mg/kg. This did not induce a statistically positive increase in micronuclei in the hemopoietic cells of the mouse bone marrow at the time intervals evaluated under the experimental condition of this assay. No toxicity was observed. Vehicle and positive controls were valid.

Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A Reproductive / Development Toxicity Screening Testing in Rats was performed according to OECD guideline 421 (Calvert Laboratories, Inc., 2011, Klimisch 1). In this GLP-compliant study, male and female Sprague-Dawley rats (10 animals/sex/dose) were exposed to 1000 mg/kg bw/day. Control animals received concurrent vehicle (water). The rats were exposed on a daily basis, starting two weeks prior to cohabitation until the day before the scheduled euthanasia (minimum of 4 weeks) for males and starting for a minimum of 15 days prior to cohabitation, during cohabitation and from presumed gestation days 0 through day 19 of gestation for females. One female animal was found dead on lactation day 2. All other females survived until scheduled sacrifice. No treatment-related effects were observed in clinical signs, mortality, body weight (gain), food consumption, gross pathology, organ weights or histopathology in the parental animals. There was no treatment-related effect on reproductive performance or in reproductive parameters like for instance number of gravid animals, corpora lutea per dam, total implantations, litter viability or foetal sex ratios. The incidence of neonates born alive/found dead, stillborn or missing between lactation days 0 -4 was comparable among study groups. No treatment-related malformations were observed for neonates. The body weight of neonates was statistically significantly increased with an unknown biological significance for this finding. A NOAEL of 1000 mg/kg bw/day was established.
Acute Toxicity	The oral LD50 in male and female Sprague-Dawley rats was determined to be 5000 mg/kg bw in a reliable, key study conducted similarly to OECD guideline 420 (Calvert Laboratories, Inc., 2010). Calvert Laboratories Inc (2010) determined acute dermal toxicity in 10 male / female rats following a GLP-compliant study performed equivalent to OECD guideline 402 (key study, Klimisch 1). Only one dose was tested (2000 mg/kg bw). No mortality was observed. Shortly after exposure, local erythema and oedema effects were observed in both males and females. The effects seemed to be reversible in males and 1 female. In the 4 other females, necrosis and slouching appeared.
Irritation	The skin irritation potential of the test substance is investigated in a key, reliable study performed according to OECD guideline 404 (Allen, 1994; Klimisch 1) in 3 rabbits. Semi-occlusive patches were removed from shaved test sites after exposure periods of 3 min, 1h, and 4h to 0.5mL of the test substance. The Draize scoring system was used to evaluate the results. No erythema/eschar formation and no oedema formation is observed after 3 min and 1 hour exposure. After 4 hours of exposure, very slight erythema in all 3 animals and very slight oedema in 2 animals was observed, but this was fully reversible within 24 - 48 hrs. Calvert Laboratories, Inc. (2010) investigated the eye irritation potential of the test substance in a key, reliable study performed according to EU method B.5 (Klimisch 1) in 3 rabbits. The treated eyes (with 0.1mL test substance) will remain unrinsed for at least 24 hours after instillation. The 24-, 48- and 72-hours scores will be added separately for each animal and each total divided by 3 to yield the individual mean scores for each animal. Based on the data and according to the criterion of the CLP regulation, the test substance is classified as irritant to the eyes (category 2).
Sensitisation	Based on a guinea pig maximization study, performed according to the OECD guideline 406 (Allen, 1996; Klimisch 2), the test substance is considered not sensitising to the skin.
Health Effects Summary	This chemical may cause skin and eye irritation.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 1000 mg/kg bw/day from the 90 day repeated oral toxicity study.
Ecological Toxicity ¹	

Aquatic Toxicity	In a static test following the procedures of the German national standard DIN 38412 using <i>Leuciscus idus</i> as test species a LC50 (96 h) of 681.2 mg/L (nominal) was determined [BASF AG, 1988; Study No. 10F0118/885140]. In conclusion, the substance is with high probability not acutely harmful to fish. The EC50 of the test item on daphnids was found to be greater than 122 mg/L (measured value) in a GLP guideline study according to OECD 202 [BASF SE, 2010; Study No. 50E0396/09E012]. Therefore, the test substance is with high probability acutely not harmful to aquatic invertebrates. A study was performed to assess the effect of the test item on the growth of the green alga <i>Pseudokirchneriella subcapitata</i>. The method followed that described in the OECD Guidelines for Testing of Chemicals (2006) No 201, "Freshwater Alga and Cyanobacteria, Growth Inhibition Test" referenced as Method C.3 of Commission Regulation (EC) No 440/2008. The effect of the test item on the growth of <i>Pseudokirchneriella subcapitata</i> has been investigated over a 72-Hour period. the ErC50(72h) of the test item is 45 mg/L for <i>Pseudokirchneriella subcapitata</i>. The toxicity to microorganisms was determined in a GLP short-term respiration test according to OECD guideline 209 using activated sludge from a municipal sewage treatment plant. After 180 minutes no inhibition effect on the respiration rate at the highest test concentration (1000 mg/L) was observed [BASF 2010; Study No. 08G0396/09G004]. Therefore, it can be concluded that inhibition of the degradation activity of activated sludge is not anticipated when introduced in appropriately low concentrations.
Determination of PNEC aquatic	The available short-term aquatic tests covering the three trophic levels (fish, daphnids, algae) showed the lowest L(E)C50 to be 45 mg/L in algae. An assessment factor of 1000 was used for a resulting PNEC for of 0.045 mg/L.
Current Regulatory Controls⁴	
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?	Not readily biodegradable. Thus, it is expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	As the Log Pow is 0.565 at 20 °C (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.1 mg/L. Thus, it is not expected to meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	March 2019

References

1. ECHA REACH, Ethanol, 2,2'-oxybis-, reaction products with ammonia, morpholine derivs. residues,
Retrieved 2019: <https://echa.europa.eu/>

Toxicity Summary - Glyoxal (Ethanedial)

Chemical and Physical Properties ^{1,2,3}	
CAS number	107-22-2
Molecular formula	C ₂ H ₂ O ₂
Molecular weight	58.04
Solubility in water	600 g/L at 25 °C
Melting point	15 °C
Boiling point	50.4 °C
Vapour pressure	29.33 kPa at 20 °C
Henrys law constant	No data available.
Explosive potential	Non explosive
Flammability potential	Not classified
Colour/Form	Light yellow liquid with a mild odour at ambient temperatures; yellow crystals at 15 °C.
Overview	Glyoxal is generally available as an aqueous solution, typically containing 30-50% glyoxal in which hydrated oligomers are present. This chemical is used as a chemical intermediate in the production of pharmaceuticals and dyestuffs, as a cross-linking agent in the production of polymers, as a biocide, and as a disinfecting agent. Due to microbial activity as well as non-enzymatic autooxidation of oil or browning reactions of saccharides, glyoxal is frequently detected in fermented food and beverages. It is found in beer, wine and tea.
Environmental Fate ¹	
Soil/Water/Air	Glyoxal's production and use as a crosslinking agent in permanent-press fabrics, textiles, organic synthesis, glues, and biocides may result in its release to the environment through various waste streams. Glyoxal is also released to the environment from the combustion of wood, automobile exhaust, and the atmospheric degradation of aromatic and olefinic hydrocarbons. It may also be produced as a disinfection byproduct during the treatment of drinking water. Glyoxal is also endogenously produced by a variety of enzyme-independent pathways. If released to air, an extrapolated vapor pressure of 255 mm Hg at 25 deg C indicates glyoxal will exist solely in the vapor-phase. Vapor-phase glyoxal is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 34 hours. Glyoxal also undergoes direct photolysis, with an estimated atmospheric lifetime of 5 hours. If released to soil, glyoxal is expected to have very high mobility based upon an estimated Koc of 1. Volatilization from moist soil surfaces is not expected to be an important fate process based upon a Henry's Law constant of 3.33X10⁻⁹ atm-cu m/mole. The potential for volatilization of glyoxal from dry soil surfaces may exist based upon the extrapolated vapor pressure of this compound. Screening studies using sewage seed have indicated that glyoxal is readily biodegradable. If released into water, glyoxal is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's Henry's Law constant. Photolysis in sunlit surface waters is expected to be an important fate process because glyoxal absorbs light greater than 290 nm and undergoes direct photolysis in the atmosphere. Glyoxal is not expected to undergo hydrolysis in the environment due to the lack of hydrolyzable functional groups. An estimated BCF of 3 suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	From an oral 28 day repeat dose toxicity test conducted in accordance with OECD TG 407 a NOAEL was established at 40 mg/kg bw/day (active substance), based on dose-related changes in body weight gain at higher doses. A single inhalation toxicity study in rats revealed no systemic toxicity even at the highest dose of 0.4 mg/m ³ .
Carcinogenicity	Results from several carcinogenicity studies, tumour initiation/promotion studies and in vitro cell transformation assays show that ethanedial is not carcinogenic.
Mutagenicity/ Genotoxicity	Ethanedial was shown to be mutagenic in both bacterial and mammalian cells in vitro. Unscheduled DNA synthesis was reported in one study in mice in vivo, but only within the pyloric sphincter and liver and not in more remote organs.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Available data on ethanedial and an analogue of ethanedial present in aqueous solutions suggest no effects on fertility or developmental toxicity in the absence of material toxicity.
Acute Toxicity	Ethanedial is moderately toxic via the oral and inhalation routes. In a guideline study in rats, an oral LD50 for a 40% ethanedial aqueous solution was reported at 3300 mg/kg bw. This corresponds to 1320 mg/kg bw/day for the active ingredient. An LC50 for inhalation toxicity was established at 2.44 g/L (active ingredient). Ethanedial is therefore considered to be of low dermal toxicity.
Irritation	Animal studies indicate that ethanedial is a skin and eye irritant
Sensitisation	Based on both animal and human studies, ethanedial is also considered a skin sensitiser.
Health Effects Summary	Ethanedial is moderately toxic via the oral and inhalation routes. In a guideline study in rats, an acute oral median lethal dose (LD50) for a 40% ethanedial aqueous solution was reported at 3 300 mg/kg bw. This corresponds to 1 320 mg/kg bw day for the active ingredient. A median lethal concentration (LC50) for inhalation toxicity was established at 2.44 g/L (active ingredient). Ethanedial is of low dermal toxicity. Animal studies indicate that ethanedial is a skin and eye irritant. From both animal and human studies, ethanedial is also a skin sensitiser.
Key Study/Critical Effect for Screening Criteria	A single repeat dose inhalation toxicity study in rats revealed no systemic toxicity even at the highest dose of 10 mg/m ³ . From an oral 28-day repeat dose toxicity test conducted in accordance with OECD TG 407, a No-Observed-Adverse-Effect Level (NOAEL) was established at 40 mg/kg bw/day (active substance), based on dose related changes in body weight gain at higher doses. An adjustment factor of three is applied for inadequate duration of this study, as the no-effect dose was derived from a 28 day study. Consequently, for the purposes of quantifying the health risk of the chemical, an adjusted NOAEL of 13.3 mg/kg bw/day is used in this risk assessment.
Ecological Toxicity ^{1,2,3}	
Aquatic Toxicity	215 mg/L 96 h-LC50 fish. The result of the key study on freshwater invertebrates (BASF, 1988) indicates no acute toxicity of glyoxal (40% in aqueous solution) to Daphnia magna. The EC50 value is above 100 mg/L even when it is considered that no analytical monitoring was performed since glyoxal was shown to be stable at least for this 48-h period. In a GLP guideline study following OECD 210, the chronic treatment of early-life-stages of fish with the test item (Glyoxal 40%) under flow-through conditions resulted in no substance-related effects. Referring to the nominal concentrations of the active substance glyoxal, the NOEC was 119 mg a.i./L (BASF, 2009).
Determination of PNEC aquatic	An assessment factor of 100 has been applied to the reported LC50 of 215 mg/L for fish. The PNECaquatic is 2.15 mg/L.

Current Regulatory Controls ⁴	
Australian Hazard Classification	Ethanedial is classified as hazardous for human health in the Hazardous Substances Information System (HSIS) with the following risk phrases (Safe Work Australia 2013): • Muta. Cat. 3 (Mutagenic Substances, Category 3) • R68 (Possible risk of irreversible effects) • Xn; R20 (Harmful by inhalation) • Xi; R36/38 (Irritating to eyes and skin) • R43 (May cause sensitisation by skin contact)
Australian Occupational Exposure Standards	No specific exposure standards were available.
International Occupational Exposure Standards	The following exposure standards are identified (Galleria Chemica 2013). Time Weighted Average (TWA): • 0.1 mg/m³ [Belgium, Columbia, Canada (Alberta, British Columbia, Saskatchewan), • Italy, Nicaragua, Portugal, Spain, United States of America] • 0.5 mg/m³ (0.2 ppm) [Denmark]. • Short Term Exposure Limit (STEL): • 0.3 mg/m³ [Canada (Saskatchewan)].
Australian Food Standards	No data available.
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 ^{1,2}	
P/vP Criteria fulfilled?	Expected to be readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	As the Log Pow is 0.85 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

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, Glyoxal, Retrieved 2019: <https://echa.europa.eu/>
3. HSDB (n.d.). Hazardous Substances Data Bank. Retrieved 2019, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>

Toxicity Summary - Guanidine, hydrochloride (1:1)

Chemical and Physical Properties ²	
CAS number	50-01-1
Molecular formula	CH ₅ N ₃ .ClH
Molecular weight	95.53 g/mol
Solubility in water	2,150 g/L at 20 °C
Melting point	188 °C
Boiling point	No data available.
Vapour pressure	For the pure solid guanidinium chloride the vapour pressure is expected to be much lower than 0.000005 Pa.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Solid, powder, odourless
Overview	This substance is used in the following products: laboratory chemicals, extraction agents and pharmaceuticals. This substance has an industrial use resulting in manufacture of another substance (use of intermediates).
Environmental Fate ²	
Soil/Water/Air	The guanidine ion is expected to have such a long hydrolysis half-life at environmentally relevant pH that the measurement is not feasible. Due to the low vapour pressure the substance under investigation will not be present in the gas phase in the atmosphere in appreciable amounts and therefore the elimination path photodegradation in air will be only of minor importance. Guanidine chloride is inherently biodegradable. Guanidine chloride is highly water soluble. For the inorganic solid a negligible vapour pressure is expected. According to the measured log Kow < -1.7, a low potential for adsorption is expected (non-ionic adsorption).
Human Health Toxicity Summary ²	
Chronic Repeated Dose Toxicity	A No Observed Adverse Effect Level (NOAEL) of 100 mg/kg body weight/day for repeated dose toxicity was established from an oral sub chronic toxicity study on Wistar rats according to OECD guideline 408 with Guanidine hydrochloride.
Carcinogenicity	No data available.
Mutagenicity/ Genotoxicity	There is no evidence for genotoxic properties from gene mutation assays in bacteria and mammalian cells, as well as chromosome aberration in mammalian cells.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	A NOAEL of 350 mg/kg body weight/day for developmental toxicity was established from a developmental toxicity study according to OECD guideline 414 with Guanidine hydrochloride.
Acute Toxicity	Acute toxicity data on Guanidine hydrochloride are available for the oral, inhalation and dermal route. The data available from three studies for the oral route all indicate LD50 values for Guanidine hydrochloride in the range between 773.6 and 1120 mg/kg bw. The LC50 from an inhalation study for female rats is 3.181 mg/L air (LC50 for male rats = 7.655 mg/L air). The dermal LD50 is > 2000 mg/kg bw.
Irritation	Based on the available data Guanidine hydrochloride is irritating to the skin and irritating to the eye.

Sensitisation	Not sensitising
Health Effects Summary	After oral exposure signs of systemic toxicity including death were observed in acute toxicity studies, thus absorption of guanidine hydrochloride has occurred. As a consequence, it is likely that the substance will also be absorbed if inhaled. This assumption is supported by data from an acute inhalation toxicity study, where systemic effects and death were observed. The substance is irritating to the skin and eye. The substance is not skin sensitising and there is no evidence of genotoxic toxicity.
Key Study/Critical Effect for Screening Criteria	NOAEL (rat) of 100 mg/kg bw/day from sub-chronic oral toxicity study.
Ecological Toxicity²	
Aquatic Toxicity	Short-term toxicity to aquatic organisms: Fish: LC50 (96 h) = 690 mg/L a.i. for Pimephales promelas (test with read-across substance Guanidine nitrate). Invertebrates: EC50 (48h) = 70.2 mg/L for Daphnia magna (test with read-across substance Guanidine nitrate, similar to OECD 202). Algae and cyanobacteria: ErC50 (72 h) = 33.5 mg/L for Pseudokirchneriella subcapitata (test with read-across substance Guanidine nitrate) Long-term toxicity to aquatic organisms: Fish: NOEC = 181 mg/L for Fathead minnow (test with read-across substance Guanidine nitrate, similar to OECD 210). Invertebrates: NOEC = 2.9 mg/L for Daphnia magna (test with read-across substance Guanidine nitrate, similar to OECD 211).
Determination of PNEC aquatic	PNEC not calculated. Acute and chronic results for species for all three tropic levels are above 1 mg/L.
Current Regulatory Controls	
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. Guanidine chloride is inherently biodegradable.
B/vB criteria fulfilled?	No. Log Kow is -1.7 @ 20 °C and BCF is 3.2 L/kg ww
T criteria fulfilled?	No. Acute and chronic toxicity data >1 mg/L for all three tropic levels.
Overall conclusion	Not PBT
Revised	October 2019

References

1. ECHA REACH, Guanidinium chloride, Retrieved 2019: <https://echa.europa.eu/>

Toxicity Summary - Kaolin

Chemical and Physical Properties ^{1,2,4,5}	
CAS number	1332-58-7
Molecular formula	H ₂ Al ₂ Si ₂ O ₈ H ₂ O
Molecular weight	258 (approx)
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	No data available.
Flammability potential	Not combustible
Colour/Form	White, greyish-white, or slightly coloured
Overview	Kaolin is a mixture of different minerals. Its main component is kaolinite and it frequently contains quartz, mica, feldspar, illite and montmorillonite. Kaolinite composition is tiny sheets of triclinic crystals with pseudohexagonal morphology. It is formed by rock weathering. Kaolin is used in paper production, in paints, rubber, plastic, ceramic, chemical, pharmaceutical and cosmetic industries. It has a high fusion point and is the most refractory of all clays. Kaolin is listed in FIFRA 25(b) and US EPA List 4A. It is also listed as GRAS (Generally Regarded as Safe) by the U.S. Food and Drug Administration (FDA GRAS database). A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate ⁴	
Soil/Water/Air	Kaolin is a natural component of the soil and occurs widely in ambient air. It has a density of 2.1–2.6 g/cm³. The cation exchange capacity of kaolinite is considerably less than that of montmorillonite, in the order of 2–10 meq/100 g, depending on the particle size, but the rate of the exchange reaction is rapid, almost instantaneous (Grim, 1968). Kaolinite adsorbs small molecular substances such as lecithin, quinoline, paraquat, and diquat, but also proteins, polyacrylonitrile, bacteria, and viruses (McLaren et al., 1958; Mortensen, 1961; Weber et al., 1965; Steel & Anderson, 1972; Wallace et al., 1975; Adamis & Timár, 1980; Schiftenbauer & Stotzky, 1982; Lipson & Stotzky, 1983). The adsorbed material can be easily removed from the particles because adsorption is limited to the surface of the particles (planes, edges), unlike the case with montmorillonite, where the adsorbed molecules are also bound between the layers (Weber et al., 1965). Upon heating, kaolinite starts to lose water at approximately 400 °C, and the dehydration approaches completeness at approximately 525 °C (Grim, 1968). The dehydration depends on the particle size and crystallinity.
Human Health Toxicity Summary ^{1,4}	
Chronic Repeated Dose Toxicity	Long-term exposure to kaolin may lead to a relatively benign pneumoconiosis, known as kaolinosis. Deterioration of lung function has been observed only in cases with prominent radiological alterations. Based on data from China clay workers in the United Kingdom, it can be very roughly estimated that kaolin is at least an order of magnitude less potent than quartz.
Carcinogenicity	A4; Not classifiable as a human carcinogen

Mutagenicity/ Genotoxicity	Recently, manufactured nano/microparticles such as fullerenes (C60), carbon black (CB) and ceramic fiber are being widely used because of their desirable properties in industrial, medical and cosmetic fields. However, there are few data on these particles in mammalian mutagenesis and carcinogenesis. To examine genotoxic effects by C60, CB and kaolin, an in vitro micronuclei (MN) test was conducted with human lung cancer cell line, A549 cells. In addition, DNA damage and mutations were analyzed by in vivo assay systems using male C57BL/6J or gpt delta transgenic mice which were intratracheally instilled with single or multiple doses of 0.2 mg per animal of particles. In in vitro genotoxic analysis, increased MN frequencies were observed in A549 cells treated with C60, CB and kaolin in a dose-dependent manner. These three nano/microparticles also induced DNA damage in the lungs of C57BL/6J mice measured by comet assay. Moreover, single or multiple instillations of C60 and kaolin, increased either or both of gpt and Spi- mutant frequencies in the lungs of gpt delta transgenic mice. Mutation spectra analysis showed transversions were predominant, and more than 60% of the base substitutions occurred at G:C base pairs in the gpt genes. The G:C to C:G transversion was commonly increased by these particle instillations. Manufactured nano/microparticles, CB, C60 and kaolin, were shown to be genotoxic in in vitro and in vivo assay systems.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.
Acute Toxicity	Occupationally inhaled kaolin produced chronic pulmonary fibrosis. In an acute oral study in which 120 rats were fed doses of Kaolin ranging from 100 to 210 g/kg. Fourteen rats were controls. Kaolin was inert and nonstatic except for the danger of bowel obstruction resulting in perforation. The clinical signs were listlessness, anorexia, oliguria, hypothermia, and dyspnea. These were a pathological reaction from over distension of the alimentary canal by an inert solid. The number of fatalities and the incidence and advance of bowel obstruction along the small intestine were dose related. The dose that killed 50% of the rats by bowel obstruction was 149 g/kg.
Irritation	Causes moderate eye irritation. May cause irritation of the respiratory system
Sensitisation	No data available.
Health Effects Summary	Kaolin is toxic to a variety of mammalian cells in vitro, and it produces transient inflammation in the lungs of experimental animals after intratracheal instillation.
Key Study/Critical Effect for Screening Criteria	No data available.

Ecological Toxicity ⁴	
Aquatic Toxicity	The 24- and 48-h LC50 values for kaolinite toxicity to the water flea (<i>Daphnia pulex</i>) were >1.1 g/litre (Lee, 1976). Georgia kaolin caused <10% mortality of sea urchin (<i>Strongylocentrotus purpuratus</i>), Japanese clam (<i>Tapes japonica</i>), hermit crab (<i>Pagurus hirsutiusculus</i>), isopod (<i>Sphaeroma pentodon</i>), mud snail (<i>Nassarius obsoletus</i>), blue mussel (<i>Mytilus edulis</i>), and tunicates (<i>Molgula manhattensis</i> and <i>Styela montereyensis</i>) within 5–12 days. The 200-h LC10 values for coast mussel (<i>Mytilus californianus</i>), black-spotted bay shrimp (<i>Crangon nigromaculata</i>), migrant prawn (<i>Palaemon macrodactylus</i>), dungeness crab (<i>Cancer magister</i>), and the polychaete <i>Neanthes succinea</i> were 26, 16, 24, 10, and 9 g/litre, respectively. The 100-h LC10 values for the tunicate <i>Ascidia ceratodes</i>, amphipod <i>Anisogammarus confervicolus</i>, and shiner perch (<i>Cymatogaster aggregata</i>) were 7, 38, and 1 g/litre, respectively (McFarland & Peddicord, 1980). No effect on the hatching success or egg development rate of four marine fish species — red seabream (<i>Pagrus major</i>), black porgy (<i>Acanthopagrus schlegelii</i>), striped knifefish (<i>Oplegnathus fasciatus</i>), and threeline grunt (<i>Parapristipoma trilineatum</i>) — was observed at kaolinite concentrations up to 10 g/litre for 24 h. Larvae were more sensitive to kaolinite: the 12-h LC50 values were 170 and 710 mg/litre for <i>P. trilineatum</i> and <i>O. fasciatus</i>, respectively; mortality was also observed for <i>P. major</i> at concentrations of 1000 mg/litre and above (Isono et al., 1998).
Determination of PNEC aquatic	Kaolin has low toxicity to aquatic species, a large number of which have been tested. As such, PNEC _{aquatic} has not been determined.
Current Regulatory Controls ^{2,3}	
Australian Hazard Classification	No hazard classification according to GHS criteria
Australian Occupational Exposure Standards	TWA: 10 mg/m ³
International Occupational Exposure Standards	TLV: (respirable fraction): 2 mg/m ³ , as TWA
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 salt, ionic species ubiquitous in environment)
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions.
T criteria fulfilled?	Not applicable. Acute toxicity data >1 mg/L in water flea, thus Kaolin does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

1. HSDB (n.d.). Hazardous Substances Data Bank. Retrieved 2019, from Toxnet, Toxicology Data Network, National Library of Medicine: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
2. IPCS Kaolin, Retrieved 2019: <http://www.inchem.org>
3. Safe Work Australia, Hazardous Substances System, Retrieved 2019: <http://hcis.safeworkaustralia.gov.au/>

4. IPCS INCHEM; Environmental Health Criteria (EHC) Monographs. Bentonite, kaolin, and selected clay minerals (EHC 231). Available from, as of June 25, 2007: <http://www.inchem.org/pages/ehc.html>
5. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>

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 sensitizer (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). The constituent ions of potassium hydroxide are naturally present in the body. Chronic systemic health effects such as repeated dose toxicity (apart from alkalosis), carcinogenicity and reproductive toxicity are not expected following exposures at non-irritating concentrations. There are limited available data on systemic health effects of potassium hydroxide in vivo (REACH). The very limited data on potassium chloride (OECD, 2002) concludes that there is no evidence of systemic toxicity of the endogenous potassium ion. In addition, similar results were reported for sodium hydroxide (NICNAS). Potassium salts are generally considered by NICNAS to be of low concern to human health (NICNAS, 2012).
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 (<i>Daphnia magna</i>) and 630 mg/l (<i>Ceriodaphnia dubia</i>), and for NaOH 40 mg/l (<i>Ceriodaphnia dubia</i>). The EC50 algae value (<i>Nitscheria linearis</i>) was 1337 mg/l for KCl.
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	

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
Revised	April 2019

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)
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Toxicity Summary - Smectite

Chemical and Physical Properties ^{1,2,3}	
CAS number	12199-37-0
Molecular formula	No data available.
Molecular weight	No data available.
Solubility in water	No data available.
Melting point	No data available.
Boiling point	No data available.
Vapour pressure	No data available.
Henrys law constant	No data available.
Explosive potential	No data available.
Flammability potential	No data available.
Colour/Form	Off-white to tan fine flakes or powder
Overview	Smectites commonly result from the weathering of basic rocks. Smectite formation is favoured by level to gently sloping terranes that are poorly drained, mildly alkaline (such as in marine environments), and have the high Si and Mg potentials (Borchardt, 1977). Other factors that favour the formation of smectites include the availability of Ca and the paucity of K (Deer and others, 1975). Poor drainage is necessary because otherwise water can leach away ions (e.g. Mg) freed in the alteration reactions. Smectites are used in the industry as fillers, carriers, absorbents and a component in drilling fluids (Grim, 1962). A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate ^{4*}	
Soil/Water/Air	Limited data is available for smectite, read across data has been obtained from bentonite. Bentonite is a rock formed of highly colloidal and plastic clays composed mainly of montmorillonite, a clay mineral of the smectite group, and is produced by in situ devitrification of volcanic ash. Bentonite's production and use in domestic products, cat litter, construction materials, ceramics, pharmaceuticals, beer and wine production and cosmetics may result in its release to the environment through various waste streams. Its use in drilling muds, in agricultural practice as a carrier and an animal feed binder will result in its direct release to the environment. Bentonite is a colloidal native hydrated aluminum silicate (clay) found in midwest of USA and in Canada. Occupational exposure to bentonite may occur through inhalation of dust and dermal contact with this compound at workplaces where bentonite is produced or used. Use data indicate that the general population may be exposed to bentonite via ingestion of and dermal contact with consumer products containing bentonite.
Human Health Toxicity Summary ^{4*}	
Chronic Repeated Dose Toxicity	Mice maintained on diets containing bentonite displayed slightly reduced growth rates. Mice treated with higher doses showed minimal growth and fatty livers and fibrosis of the liver and benign hepatomas. Bentonite increased the susceptibility of mice to pulmonary infection.
Carcinogenicity	No adequate studies are available on the carcinogenicity of bentonite.

Mutagenicity/ Genotoxicity	The genotoxic potential of bentonite particles (diameter < 10 µm) with an a-quartz content of up to 6% and different chemical modifications (alkaline, acidic, organic) was investigated. Human lung fibroblasts (IMR90) were incubated for 36 hr, 48 hr, or 72 hr with bentonite particles in concentrations ranging from 1 to 15 µg/sq cm. Genotoxicity was assessed using the micronucleus (MN) assay and kinetochore analysis. The generation of reactive oxygen species (ROS) caused by bentonite particles via Fenton-like mechanisms was measured acellularly using electron spin resonance (ESR) technique and intracellularly by applying an iron chelator. The results show that bentonite-induced genotoxic effects in human lung fibroblasts are weak. The formation of micronuclei was only slightly increased after exposure of IMR90 cells to an acidic sample of bentonite dust with a quartz content of 4-5% for 36 hr (15 µg/sq cm), 48 hr (5 µg/sq cm), and 72 hr (1 µg/sq cm), to an alkaline sample with a quartz content of 5% for 48 hr and 72 hr (15 µg/sq cm), and to an acidic bentonite sample with 1% quartz for 72 hr (1 µg/sq cm). Native (untreated) and organic activated bentonite particles did not show genotoxic effects in most of the experiments. Also, bentonite particles with a quartz content < 1% were negative in the micronucleus assay. Generation of ROS measured by ESR was dependent on the content of transition metals in the sample but not on the quartz content or the chemical modification. Reduction of MN after addition of the iron chelator 2,2'-dipyridyl showed that ROS formation also occurs intracellularly. It was concluded that the genotoxic potential of bentonite particles is generally low but can be altered by the content of quartz and available transition metals.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Limited studies did not demonstrate developmental toxicity in rats after oral exposure to bentonite.
Acute Toxicity	Single intratracheal injection into rodents of bentonite and montmorillonite with low quartz content caused dose and particle size dependent effects, as well as transient local inflammation, which included oedema and increased lung weight. Single intratracheal exposures of rats to bentonite caused storage foci in the lungs. After intratracheal exposure of rats to this material with high quartz content, fibrosis is noted.
Irritation	The powder may contain large amounts of free silica which can produce pneumoconiosis with chronic inhalation.
Sensitisation	No data available.
Health Effects Summary	The substance can be absorbed into the body by inhalation. The substance is mildly irritating to the eyes and skin. The substance may have effects on the lungs. This may result in fibrosis.
Key Study/Critical Effect for Screening Criteria	No study available.
Ecological Toxicity ^{4*}	
Aquatic Toxicity	The 96-h LC50 for rainbow trout (<i>Oncorhynchus mykiss</i>) of Wyoming bentonite, used as a viscosifier in drilling fluids, was 19 g/litre (Sprague & Logan, 1979).
Determination of PNEC aquatic	PNEC has not been calculated.
Current Regulatory Controls	
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 Assessment⁴	
P/vP Criteria fulfilled?	No data available for Smectite. Information on bentonite reported that Biodegradation of bentonite appears to be minimal.
B/vB criteria fulfilled?	No, bioaccumulation appear minimal for montmorillonite compounds
T criteria fulfilled?	No, read across data from bentonite reported 96h LC50 for fish was > 1 mg/L. Thus, it is not expected to meet the toxicity criteria.
Overall conclusion	Not PBT
Revised	April 2019

* No data available for Smectite. Toxicity data for Bentonite is presented as a surrogate.

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2. HSDB Hazardous Substances Data Bank. U.S. National Library of Medicine, Retrieved 2019: <http://toxnet.nlm.nih.gov/>
3. USGS Coastal and Marine Geology Program, Smectite Group. Retrieved 2019: <https://pubs.usgs.gov/of/2001/of01-041/html/docs/clays/smc.htm>
4. IPCS Bentonite, Kaolin and Selected Clay Minerals, Retrieved 2015: <http://www.inchem.org>

Toxicity Summary - Sodium bicarbonate

Chemical and Physical Properties ^{1,2,4,5,6}	
CAS number	144-55-8
Molecular formula	NaHCO ₃
Molecular weight	84.01
Solubility in water	96 g/L (at 20 °C)
Melting point	Decomposes when heated over 50 °C
Boiling point	Decomposes
Vapour pressure	Negligible, ionizable inorganic compound
Henry's law constant	No data available
Explosive potential	No data available
Flammability potential	No data available
Colour/Form	white, odourless, crystalline powder
Overview	Sodium bicarbonate is classified by the U.S. Food and Drug Administration (FDA) as a 'Generally Recognised as Safe' (GRAS) ingredient in food with no other limitation than current good manufacturing practice (FDA, 1978; FDA, 1983). In the EU it is approved as a food additive (EU, 2000) and a feed ingredient (EU, 1998). In Australia it is recognised by Food Standards Australia New Zealand (FSANZ) as a food additive. Sodium bicarbonate is used as animal feed additive, human food additive and it is used in pharmaceuticals. It is also used for the production of other chemicals and used in cosmetics and detergents and other household cleaning products. A Tier 1 Human Health Assessment for this chemical has been conducted by NICNAS which concluded that it was low concern to human health.
Environmental Fate ³	
Soil/Water/Air	The high water solubility and low vapour pressure indicate that sodium bicarbonate will be found predominantly in the aquatic environment. Sodium bicarbonate is present in the environment as sodium and bicarbonate ions, which implies that it will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.
Human Health Toxicity Summary ^{2,3}	
Chronic Repeated Dose Toxicity	There are no directly relevant studies on repeated dose exposure, however, knowledge of prior use and available literature does not indicate any adverse effects of long-term use of exposure via any route. In humans there is a long history of sodium bicarbonate used as an antacid in doses up to 4 g without adverse effects of long-term use, although it is recommended not to use high doses of pure sodium bicarbonate instead of antacids. In addition, sodium bicarbonate is an important extracellular buffer in vertebrates and is therefore readily regulated in the body.
Carcinogenicity	As with other sodium salts, high doses of sodium bicarbonate promote carcinoma formation in rat urinary bladder after pre-exposure to initiator or BBN. However, when rats were only exposed to sodium bicarbonate no carcinogenic effect on the urinary bladder was found. Based on the available information there are no indications that sodium bicarbonate has carcinogenic effects.
Mutagenicity/ Genotoxicity	<i>In vitro</i> bacterial and mammalian cell tests showed no evidence of genotoxic activity.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Sodium bicarbonate did not induce developmental effects when administered orally at the following doses: 580 mg/kg bw (mice), 340 mg/kg bw (rats) and 330 mg/kg bw (rabbits). Furthermore the substance will usually not reach the foetus when the exposure to sodium bicarbonate is sufficiently low, as it does not become systemically available.

Acute Toxicity	Acute oral ingestion by the patients may result in a ruptured stomach due to excessive gas development. Acute or chronic excessive oral ingestion may cause metabolic alkalosis, cyanosis and hypernatraemia. These conditions are usually reversible, and will not cause adverse effects.
Irritation	Sodium bicarbonate is a minimal or mild ocular and skin irritant
Sensitisation	No data available
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 Australian drinking water screening value for sodium (180 ppm, aesthetic) and pH may apply to sodium bicarbonate.
Ecological Toxicity ³	
Aquatic Toxicity	In a 96-hr acute flow-through test with rainbow trout (<i>Oncorhynchus mykiss</i>) a NOEC of 2,300 mg/l and a LC50 of 7,700 mg/l were determined. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-1. In a 96-hr acute flow-through test with bluegill sunfish (<i>Lepomis macrochirus</i>) a NOEC of 5,200 mg/l and a LC50 of 7,100 mg/l were determined. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-1. In a 48-hr acute flow-through test with <i>Daphnia magna</i> a NOEC of 3,100 mg/l and a LC50 of 4,100 mg/l were determined. The test was conducted under GLP conditions and according to FIFRA Guideline Reference number 72-2. A (chronic) reproduction test with <i>Daphnia magna</i> was carried out. Test solutions were prepared to contain the appropriate concentrations of salts to yield a total hardness of 170 mg/l CaCO ₃ . At the tested concentration NaHCO ₃ of 576 mg/l the survival was 100% and the cumulative number of offspring per female did not significantly differ from the control. This demonstrates that the 21-day <i>Daphnia magna</i> NOEC is higher than 576 mg/l. Standard toxicity tests with algae or aquatic plants have not been found, but test medium for acute algae tests contain 50 mg/l sodium bicarbonate. Glass slides were exposed to a portion of a small stream with an addition of sodium bicarbonate to a concentration of 45 mg/l for a period of 63 days. An increasing algal standing crop compared to the controls was found. Except for a small increase of Cyanophyceae species, no shift in species was determined.
Determination of PNEC aquatic	It is not considered useful to calculate a PNEC for sodium bicarbonate 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 sodium bicarbonate.
Current Regulatory Controls⁴	
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?	Sodium bicarbonate is an inorganic salt that is present in the environment as sodium and bicarbonate ions. Biodegradation is not applicable to these inorganic ions. Thus, the persistent criterion is not considered applicable to this inorganic salt.
B/vB criteria fulfilled?	Sodium and bicarbonate ions are essential to all living organisms and its

	extracellular concentrations are actively regulated. Thus, sodium bicarbonate is not expected to bioaccumulate.
T criteria fulfilled?	The 21 d chronic NOEC is 576 mg/L for Daphnia. Thus, sodium bicarbonate does not meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	March 2019

References

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2. IPCS Sodium Bicarbonate, Retrieved 2015: <http://www.inchem.org>
3. OECD (2008). Screening Information Dataset (SIDS) Initial Assessment Report for Sodium Bicarbonate (CAS No. 144-55-8).
4. FSANZ 2014, Food Standards Australia New Zealand Food Additives – Alphabetical list.
5. National Industrial Chemicals Notification and Assessment Scheme (NICNAS). IMAP, Human Health Tier 1 Assessment. Retrieved 2019: <https://www.nicnas.gov.au>
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 - Sodium carbonate

Chemical and Physical Properties ^{1,2,3,4,6}	
CAS number	497-19-8
Molecular formula	Na ₂ CO ₃
Molecular weight	105.99 g/mol
Solubility in water	215 g/l at 20 °C
Melting point	851 °C
Boiling point	Decomposition
Vapour pressure	No data found
Henry's law constant	No data found
Explosive potential	It reacts violently with acids and reacts with magnesium, phosphorous pentoxide causing explosion hazard
Flammability potential	Reacts with fluorine causing fire hazard
Colour/Form	White powder
Overview	Sodium carbonate has been reviewed in the OECD-SIDS program (OECD, 2002a,b). Sodium carbonate is a strong alkaline compound with a pH of 11.6 for a 0.1M aqueous solution. The pKa of carbonate (CO ₃ ²⁻) is 10.33, which means that at a pH of 10.33 both carbonate and bicarbonate are present in equal amounts. In water, sodium carbonate dissociates into sodium ion (Na ⁺) and carbonate (CO ₃ ²⁻). The carbonate ions will react with water, resulting in the formation of bicarbonate and hydroxide, until equilibrium is established. Sodium carbonate is used in many countries (e.g. U.S. and EU) as a food additive. It is regarded as a 'Generally Recognised as Safe' (GRAS) substance in food with no limitation other than current good manufacturing practice. Sodium carbonate is extensively used across a range of industries and processes such as in the manufacturing of sodium salts, glass, soap/detergents and aluminium
Environmental Fate ^{1,2,3,4}	
Soil/Water/Air	The high water solubility and low vapor pressure indicate that sodium carbonate will be found predominantly in the aquatic environment. In water, sodium carbonate dissociates into sodium (Na ⁺) and carbonate (CO ₃ ²⁻) and both ions will not adsorb on particulate matter or surfaces and will not accumulate in living tissues.
Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	No chronic oral and dermal data are available. Due to the biological importance of the products formed by the stomach acid (bicarbonate and carbon dioxide), systemic toxicity is not expected. In rats, histopathological changes of the respiratory tract and the lungs were seen following repeated inhalation exposure to sodium carbonate (70 mg/m³ aqueous sodium carbonate at pH 11.6 for 3.5 months) and potassium carbonate (0.4 mg/L potassium carbonate at pH 9.9 for 21 days). These effects were considered local responses to the high alkalinity of this group of chemicals (OECD, 2002; REACHa; REACHb).
Carcinogenicity	No data are available. Based on the available data from carcinogenicity studies with related substances (sodium bicarbonate and potassium bicarbonate), the chemicals in this group are not considered carcinogenic (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.

Mutagenicity/ Genotoxicity	Based on the available data, this chemical is not considered to be genotoxic (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Based on the limited information available, this chemical does not show specific reproductive or developmental toxicity (OECD, 2002; REACHa; REACHb). Carbonate ions are neutralised under physiological conditions to form bicarbonate ions and/or carbon dioxide, which are major products of all human metabolic activities; therefore, systemic toxicity is not expected.
Acute Toxicity	In animal tests, this chemical was of low acute toxicity following oral exposure. The median lethal dose (LD50) was >2000 mg/kg bw in rats (OECD, 2002; REACHa; REACHb). The majority of the animals that died following acute oral exposure to sodium carbonate at concentrations up to 2600 mg/kg/bw showed oral or nasal discharge, lesions in the liver, mottled lungs, mottled or pale kidneys and a red or partly gas-filled gastro-intestinal tract. In animal tests, this chemical was of low acute toxicity following dermal exposure. The median lethal dose (LD50) was >2000 mg/kg bw in rats (OECD, 2002; REACHa; REACHb). No systemic effects were observed following dermal exposure to sodium carbonate. Local severe skin irritation (severe erythema and oedema) was seen at the application site (OECD, 2002; REACHa; REACHb). In animal tests, this chemical was of low acute toxicity following inhalation exposure. The median lethal dose (LC50) was >2000 mg/m³ in rats (OECD, 2002; REACH, a & b). Signs of respiratory impairment including dyspnoea, wheezing, excessive salivation and a distended abdomen were observed immediately after inhalation exposure to sodium carbonate of up to 2300 mg/m³. Excessive salivation, repeated swallowing and a lack of appetite were observed 2–5 hours after exposure. Animals that died had lesions in the anterior trachea, posterior pharynx and larynx, along with an accumulation of mucus, vesiculation and mucosal oedema (REACHa).
Irritation	Sodium carbonate is classified as hazardous with the risk phrase 'Irritating to eyes' (Xi; R36) in HSIS (Safe Work Australia). However, in several eye irritation studies in rabbits, sodium carbonate was found to be severely irritating to the eyes, with effects including conjunctivitis, marked corneal opacity and iritis, which persisted for seven days (REACHa; REACHb). The available data support an amendment to the current HSIS eye irritation classification for sodium carbonate.
Sensitisation	Based on the limited data available, sodium carbonate is not considered to be skin sensitisers (OECD, 2002; REACHa; REACHb). No structural flags for sensitisation are present.
Health Effects Summary	The critical health effects for risk characterisation include serious eye damage and respiratory irritation because of the high basicity of the chemicals in this group. Skin irritation and corrosion of eyes and mucous membranes are also of concern where long-term exposure to the solid or concentrated solutions may occur. These effects are particularly relevant to domestic use of the chemicals. Sodium carbonate was not genotoxic or carcinogenic. Reproductive toxicity studies are not available; however, no effects on reproductive organs were noted when rats were exposed to sodium carbonate aerosol for over three months. Developmental studies with rats did not show any toxicity.
Key Study/Critical Effect for Screening Criteria	A No Observed Adverse Effect Level (NOAEL) was not available. Based on the absence of adverse effects observed in a repeat dose inhalation toxicity study, for the purposes of quantifying potential health risk, the highest dose tested in the inhalation exposure study in rats of 70 mg/m ³ (equivalent to 9.67 mg/kg bw/day) is used in the human health risk assessment.
Ecological Toxicity ^{1,2,3,4}	
Aquatic Toxicity	The acute 96-hour LC50 to three sizes of Bluegill sunfish (<i>Lepomis macrochirus</i>) exposed to sodium carbonate is 300 mg/L for all sizes. The acute 96-hour LC50 to mosquitofish (<i>Gambusia affinis</i>) is 740 mg/L. The acute 48-hour EC50 value to the invertebrate <i>Ceriodaphnia</i> cf. <i>dubia</i> is from 200 to 227 mg/L.

Determination of PNEC aquatic	PNECaquatic: Experimental results are available for two trophic levels. Acute E(L)C50 values are available for fish (300 mg/L) and <i>Ceriodaphnia</i> (200 mg/L). On the basis that the data consists of short-term results from two trophic levels, an assessment factor of 1,000 has been applied to the lowest reported effect concentration of 200 mg/L for Daphnia. The PNECaquatic is 0.2 mg/L.
Current Regulatory Controls¹	
Australian Hazard Classification	Sodium carbonate is classified as hazardous, with the following risk phrases for human health in the Hazardous Substances Information System (HSIS) (Safe Work Australia): 'Xi; R36 (Irritating to eyes)'.
Australian Occupational Exposure Standards	Sodium carbonate has an exposure standard of 7.5 mg/m ³ (5 ppm) time weighted average (TWA) and 15 mg/m ³ (10 ppm) short-term exposure limit (STEL) (Safework Australia).
International Occupational Exposure Standards	Occupational exposure standard limits for sodium and potassium carbonate recommended by other countries are provided below (Galleria Chemica, 2013): US Dept of Energy (DOE) Temporary Emergency Exposure Limits (TEELs): Sodium carbonate: TEEL-0 = 10 mg/m ³ , TEEL-1 = 30 mg/m ³ , TEEL-2 = 50 mg/m ³ , TEEL-3 = 500 mg/m ³ No other country has an occupational exposure limit specifically for sodium and potassium carbonate, although many countries have assigned a generic TWA exposure limits of 10 mg/m ³ (inhalable dust), and 3 mg/m ³ (respirable dust) for particles not otherwise classified (PNOC).
Australian Food Standards	No data available.
Australian Drinking Water Guidelines	No data available.
Aquatic Toxicity Guidelines	No data available.
PBT Assessment^{4,6}	
P/vP Criteria fulfilled?	Not applicable, inorganic substance, ubiquitous in environment.
B/vB criteria fulfilled?	Not applicable. Bioaccumulation is not applicable to these inorganic ions.
T criteria fulfilled?	No chronic toxicity data exist; however, the acute EC(L)50s are >0.1 mg/L. Thus, does not meet the screening criteria for toxicity
Overall conclusion	Not PBT
Revised	March 2019

References

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Appendix H

Toxicological Profiles for Chemical Tracers

Toxicity Summary - Water Flow Assurance Tracer (WFT)

Chemical and Physical Properties ^{1,2,3,4}	
CAS number	One chemical (proprietary)
Molecular formula	Proprietary
Molecular weight	534.36
Solubility in water	167.05 g/L at 20 °C and pH 7
Melting point	347.1 °C
Boiling point	909.54 °C at 101.325 kPa
Vapour pressure	7.43 X 10 ⁻²² mm Hg at 25°C (calculated)
Henrys law constant	10-15 atm-m ³ /mol (estimated)
Explosive potential	Non-explosive (100%)
Flammability potential	Non-flammable (100%)
Colour/Form	Bright, odourless, orange-yellow powder
Overview	This chemical is used as a food, drug, and cosmetic colorant. It is used to colour confectionary, bakery goods, animal feeds, aqueous drug solutions, toothpastes, bath salts, hair rinses, and printing inks for use in and on foods, drugs, and cosmetics and on food, drug, and cosmetic packaging materials. This chemical is an azo dye. Azo compounds are formed from arenediazonium ions reacting with highly reactive aromatic compounds, in what is called a diazo coupling reaction. Azo compounds are generally deeply coloured because the azo linkage brings the two aromatic rings into conjugation (Solomon, 1996).
Environmental Fate ²	
Soil/Water/Air	This chemical's production as a dye for wool, silks and as a colorant in food, drugs and cosmetics may result in its release to the environment through various waste streams. If released to air, this chemical will exist solely in the particulate phase in the atmosphere since it is a salt and will be non-volatile. Particulate-phase this chemical will be removed from the atmosphere by wet or dry deposition. This chemical may be susceptible to direct photolysis by sunlight; after exposure to sunlight, This chemical in distilled water exhibited a first order rate constant of 2.31X10⁻³ per day, corresponding to a half-life of 300 days. If released to soil, this chemical is expected to be mobile since this compound is expected to exist almost entirely in anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil surfaces is not expected to be an important fate process because the compound exists as an anion and anions do not volatilize. If released into water, this chemical is not expected to adsorb to suspended solids and sediment based upon this compound's ionic nature in the environment. This chemical passed through pilot scale treatment activated sludge processes relatively unchanged, indicating that biodegradation is not expected to be an important environmental fate process. This chemical will exist almost entirely in the anion form at pH values of 5 to 9 and therefore volatilization from water surfaces is not expected to be an important fate process. Measured BCF values of <0.29 and <3.0 in carp suggests bioconcentration in aquatic organisms is low. Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyse under environmental conditions.

Human Health Toxicity Summary ^{1,2,3,4}	
Chronic Repeated Dose Toxicity	Two separate but concurrent studies in rats given 0%, 0.1%, 1% or 2% in the diet or 0% or 5% in the diet for between 113 and 125 weeks showed decreases in body weight in females at 1% in the diet and in males (12.2% decrease) and females (16.9% decrease) at 5% in the diet, but there were no effects at 2% in the diet. The FAO/WHO Expert Committee on Food Additives concluded that 2% in the diet, equal to 984 mg/kg bw per day, was the NOAEL for this study. During a 2-year study in Fischer 344 rats given This chemical in the drinking water at a concentration of 0%, 1% or 2%, statistically significant increases in mesothelioma in the abdominal cavity in males and endometrial stromal polyps in females in the 1% concentration groups were reported. The incidences of these tumours were not dose dependent, and the authors noted that the incidences were within the historical control range for these tumours in this rat strain.
Carcinogenicity	A 104-week carcinogenicity study in mice given 0%, 0.5%, 1.5% or 5% This chemical in the diet showed no effects other than reductions in body weight at various time points in both sexes at 5% in the diet and slight, but statistically significant, increases in feed consumption in males at 5% in the diet. Although the authors considered the NOAEL to be the highest dose tested, the FAO/WHO Expert Committee on Food Additives concluded that 1.5% in the diet, equal to 2173 mg/kg bw per day, was the NOAEL for this study, on the basis of a body weight reduction concurrent with an increase in feed consumption at the higher dose in males.
Mutagenicity/ Genotoxicity	The FAO/WHO Expert Committee on Food Additives concluded that the overall weight of evidence indicates that this chemical is not genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	Reproductive and developmental parameters were assessed in the rat chronic toxicity studies that included an in utero exposure phase. No significant effects on reproduction or body weights of the offspring were observed. The FAO/WHO Expert Committee on Food Additives concluded that 5% in the diet, equal to 2641 mg/kg bw per day, the highest dose tested, was the NOAEL for reproductive end-points in this study. No reproductive effects were observed in two developmental neurotoxicity studies. Also, no effects on reproductive parameters were observed in several other developmental neurotoxicity studies in rats using a mixture of colours, including This chemical, as the test substance. Two developmental toxicity studies were available in rats, one with dietary administration and one with drinking-water administration of This chemical during gestation days 0–19; these showed no adverse effects at doses up to 1000 mg/kg bw per day.
Acute Toxicity	In reports submitted to the World Health Organization, the acute oral LD50 in mice was reported to be 12,750 mg/kg bw [National Institute of Hygienic Sciences of Japan, 1964]. In rats, the LD50 by intraperitoneal injection was reported to be 2,000 mg/kg bw and the LD50 by intravenous injection was reported to be 1,000 mg/kg bw [Deutsche Forschungsgemeinschaft, 1957].
Irritation	No irritating effects were observed both for skin and for eye.
Sensitisation	The results of the available tests about the evaluation of dermal effects on human showed no sensitizing effects.
Health Effects Summary	A number of case reports have been published showing intolerance or hypersensitivity reactions to This chemical. Although some of these reactions have been shown to be quite severe, their prevalence appears to be very low (0.12% in the general population).
Key Study/Critical Effect for Screening Criteria	An average daily intake (ADI) of 0-10 mg/kg bw per day was assigned by JECFA in 2016.

Ecological Toxicity ¹	
Aquatic Toxicity	Acute short-term administration on fish: LC50 fish (96 h) > 120 mg/L Acute short-term administration on invertebrates: Both of the acute toxicity to Daphnia magna studies does not show any toxic effects. EC50(48h) > 125 mg/L Acute short-term administration on aquatic plants: Both of the acute toxicity to aquatic plants studies does not show any toxic effects. EC50(48h) > 125 mg/L
Determination of PNEC aquatic	On the basis of the three acute toxicity data points, an assessment factor of 1000 has been applied to the lowest reported effect concentration of 120 mg/L. The PNECaquatic is determined to be 0.12 mg/L.
Current Regulatory Controls ^{3,4}	
Australian Hazard Classification	This chemical is a permitted food colour in both Australia and New Zealand.
Australian Occupational Exposure Standards	No data available.
International Occupational Exposure Standards	This chemical is a certified colour additive approved by the FDA in the United States to colour food, drugs and cosmetics.
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 readily biodegradable. Thus, it is expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	As the estimated Log Pow is -10.7 (Log Pow < 4.5), it is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

Redacted

Toxicity Summary - Water Flow Assurance Tracer (WFT)

Chemical and Physical Properties ^{3,4,8,9}	
CAS number	One chemical (proprietary)
Molecular formula	Proprietary
Product name	--
Molecular weight	194.19
Solubility in water	2.16x10 ⁴ mg/L at 25 deg C
pH	6.9
Melting point	236.2 deg C
Boiling point	178 deg C
Vapour pressure	Odourless white crystals or crystalline powder
Henrys law constant	9.0x10 ⁻⁷ mm Hg at 25 deg C
Explosive potential	1.1X10 ⁻¹¹ atm-cu m/mole at 25 deg C
Flammability potential	Combustible. Gives off irritating or toxic fumes in a fire.
Colour/Form	No data found
Overview	This WFT is a naturally occurring substance in various plant species. The use in food is the predominant way of human exposure and of exposure of the environment. It is generally recognised as safe (GRAS) as a food additive by the US FDA.
Environmental Fate ^{4,8,9}	
Soil/Water/Air	If released to air, a vapor pressure of 9.0X10⁻⁷ mm Hg at 25 deg C indicates this chemical will exist in both the vapor and particulate phases in the atmosphere. In vapor-phase the chemical 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 20 hours. The Henry's law constant of 0.00000363 Pa m³/mol indicates that the substance is non-volatile from water surfaces. If released to soil, this chemical is expected to have low to no mobility based upon Koc values of 741 and 7762 determined in silt and sandy loam soils. An approximated Koc of 71 suggests high mobility in sand which contains no clay and very low organic carbon content. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 1.1X10⁻¹¹ atm-cu m/mole. Various biodegradation studies have found this chemical to be readily biodegradable. If released into water, this chemical is expected to adsorb to suspended solids and sediment based upon the Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. An estimated BCF of 3 (log Kow of -0.07) suggests the potential for bioconcentration in aquatic organisms is low. The hydrolysis half-life of this chemical in water is reported to be >1 year. Degradation in natural water can occur through photodegradation and biodegradation.

Human Health Toxicity Summary ^{1,2,3,5,6,7,8,9}	
Chronic Repeated Dose Toxicity	This chemical was tested for carcinogenicity in five studies in rats by oral administration. In two of these studies, no significant difference in the incidence of tumours at any site was found. The other three studies were found to be inadequate for evaluation. Studies on oral and intraperitoneal administration of this chemical to mice were found to be inadequate for evaluation. In one study, decaffeinated coffee to which this chemical was added was tested by oral administration to rats; overall, no increase in tumours at any site was observed as compared to appropriate controls. Administration of this chemical in combination with known carcinogens resulted in decreased incidences of lung tumours in mice treated with urethane, of mammary tumours in rats treated with diethylstilboestrol and of skin tumours in mice treated with either ultra-violet light or cigarette-smoke condensate. This chemical did not influence the incidence of bladder tumours induced in rats by N-nitroso-N-butyl(4-hydroxybutyl)amine in three experiments or of pancreatic tumours induced in rats by 4-hydroxyaminoquinoline-1-oxide in another study. Nawrot et al. (2003) concluded in their review of the effects of this chemical on human health that “for the healthy adult population, moderate daily this chemical intake at a dose level up to 400 mg/day (equivalent to 6 mg/kg body weight/day in a 65-kg person) is not associated with adverse effects such as general toxicity, cardiovascular effects, effects on bone status and calcium balance (with consumption of adequate calcium), changes in adult behaviour, increased incidence of cancer and effects on male fertility.” It was indicated that habitual daily use of this chemical at greater than 500-600 mg/day (8.3 - 10 mg/kg) could be considered a health risk. For women, this chemical intake greater than 400 mg/day (6.7 mg/kg) “may increase the risk of detrusor instability (unstable bladder) development in women”. The EFSA’s panel on dietetic products, nutrition and allergies concluded that single doses of caffeine up to 200 mg (3 mg/kg/bw) from all sources do not raise safety concerns for the general healthy adult population. Intakes up to 400 mg per day (5.7 mg/kg bw) consumed throughout the day do not raise safety concerns for healthy adults in the general population, except pregnant women. A safety level of 3 mg/kg bw per day is also proposed for habitual caffeine consumption by children and adolescents.
Carcinogenicity	IARC evaluates that this chemical is not classifiable as to its carcinogenicity to humans (group 3).
Mutagenicity/ Genotoxicity	The potential for this chemical to induce genotoxicity has been evaluated in both in vitro and in vivo studies, with in vitro studies indicating both genotoxic and non-genotoxic results; in vivo studies have shown that, overall, this chemical is not genotoxic.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	This chemical has been shown to cause adverse reproductive and developmental effects in mice, rats, rabbits and monkeys. Testicular atrophy was observed at high dose levels in rats. Reproductive studies in mice showed no effect on pregnancy but there was a decrease in litter size at birth. Teratogenic effects were usually associated with high, single, daily doses that were also associated with other signs of maternal toxicity. High daily levels given as divided doses were less toxic to the conceptus than when given as a single dose. Reduced fetal body weight was observed in rats. A reversible delay in ossification of the sternum was observed in rats at a relative low dose given by gavage. With administration in drinking-water, similar effects were seen, but at higher doses. One epidemiological study revealed no effect of this chemical on the sex ratio of their children. In lymphocytes of normal, this chemical-exposed people, chromosomal aberrations were not observed. An increased frequency of micronucleated blood cells was observed in otherwise healthy splenectomized people exposed to this chemical. Urine of this chemical-exposed persons was not mutagenic to <i>Salmonella typhimurium</i>.

Acute Toxicity	After oral application the LD50 for rats (10 animals/group/sex) was found to be 261-383 mg/kg bw; as clinical symptoms of toxicity, dyspnoea and staggering were seen after oral intake. In further reports the oral LD50 for rats was reported to be 200-400 mg/kg bw and for mice 185 mg/kg bw. The inhalation of the substance by rats as an aerosol for a period of 4 h resulted in an LC50-value of ca. 4.94 mg/l. Irregular and accelerated respiration were noted in this study. The LD50 for dermal application was >2000 mg/kg bw; no clinical symptoms of toxicity were observed. In animals studies this chemical showed moderate toxicity after oral uptake and inhalation and a low acute toxicity after dermal treatment .
Irritation	The undiluted substance was not irritating to the eyes of rabbits. Mean irritation indices were 0.9 (corneal opacity), 0 (iritis), 1.6 (conjunctival erythema) and 0.6 (conjunctival edema). The strongest signs of irritation were observed in 3/3 animals within the first 24h. By day 8 only one animal showed slight corneal opacity and conjunctival redness. The substance in a 50% aqueous dilution was not irritating to the skin of rabbits (Irritation index was 0) (OECD guideline 404 and 405). This chemical is not irritating to skin and eyes.
Sensitisation	No data available.
Key Study/Critical Effect for Screening Criteria	The American College of Obstetricians and Gynaecologists (2010) concluded that moderate chemical consumption (<200 mg/day) does not appear to be a major contributing factor in miscarriage or preterm birth. The EFSA's panel on dietetic products, nutrition and allergies concluded that single doses of caffeine up to 200 mg (3 mg/kg/bw) from all sources do not raise safety concerns for the general healthy adult population Thus, the acceptable daily intake of this chemical will be set at 200 mg/person/day for the derivation of a drinking water guidance value. Assuming that humans consume 2 litres of water a day, the drinking water guidance value for this chemical is determined to be 100 mg/L.
Ecological Toxicity ^{8,9}	
Aquatic Toxicity	Acute toxicity guideline studies have been conducted in fish, invertebrates and algae (OECD, 2002a,b; ECHA REACH database). A 96-hour LC50 in <i>Leuciscus idus</i> was reported to be 87 mg/L; the 48-hour EC50 in <i>Daphnia magna</i> was reported to be 182 mg/L. and the ErC50 in <i>Scenedesmus subspicatus</i> was reported to be >100 mg/L. .
Determination of PNEC aquatic	Based on the lowest acute toxicity value of 87 mg/L in fish and an assessment factor of 1,000, a PNECaquatic is determined to be 0.087 mg/L
Current Regulatory Controls	
Australian Hazard Classification	No data found
Australian Occupational Exposure Standards	No data found
International Occupational Exposure Standards	No data found
Australian Food Standards	No data found
Australian Drinking Water Guidelines	No data found
Aquatic Toxicity Guidelines	No data found
Australian Hazard Classification	No data found
Australian Occupational Exposure Standards	No data found

PBT Assessment	
P/vP Criteria fulfilled?	This chemical is expected to be readily biodegradable and thus would not be expected to meet the screening criteria for persistence.
B/vB criteria fulfilled?	This chemical is water-soluble and bioaccumulation is not expected according to the log Kow (0.07). Thus, this chemical is not likely to meet the screening criteria for bioaccumulation.
T criteria fulfilled?	Long term data not available (acute data >0.1 mg/L); potentially not toxic.
Overall conclusion	Not a PBT substance (based on screening data).

References

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Toxicity Summary - Water Soluble Tracers (CFTs) - Benzoic acid used as analogue data

Chemical and Physical Properties ¹	
CAS number	20 chemicals (proprietary)
Molecular formula	Proprietary
Molecular weight	140 – 260 (approximate)
Solubility in water	3.5 g/L at 25 °C
Melting point	122.4 °C
Boiling point	249.2 °C
Vapour pressure	0.11 Pa at 20 °C
Henry's law constant	No data available.
Explosive potential	Non-flammable
Flammability potential	Non explosive
Colour/Form	A white crystalline powder with a pleasant odour.
Overview	CFTs are organic compounds. Benzoic acid has been used as analogue data.
Environmental Fate ^{1,2,3}	
Soil/Water/Air	If released to air, a vapor pressure of 7.0×10^{-4} mm Hg at 25 deg C indicates benzoic acid will exist solely as a vapor in the atmosphere. Vapor-phase benzoic acid 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 9 days. Benzoic acid absorbs light at wavelengths >290 nm and, therefore, may be susceptible to direct photolysis by sunlight. If released to soil, benzoic acid is expected to have very high mobility based upon an estimated Koc of 15 (log Kow of 1.87). The pKa of benzoic acid is 4.20, indicating that this compound will exist almost entirely in the anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil is not expected because the compound exists as an anion and anions do not volatilize. Benzoic acid is not expected to volatilize from dry soil surfaces based upon its vapor pressure. If released into water, benzoic acid is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Biodegradation half-lives of 0.85 and 3.6 days using inoculum from a polluted river and a reservoir, respectively, suggest that biodegradation may be an important fate process in water. Measured BCF values of <10, 14, and 21 were reported for Golden ide (<i>Leuciscus idus melanotus</i>)(1), trout(2), and mosquito fish (<i>Gambusia affinis</i>)(3), respectively. This BCF range suggests the potential for bioconcentration in aquatic organisms is low.

Human Health Toxicity Summary ¹	
Chronic Repeated Dose Toxicity	Based on the weight of evidence the chemical is not considered to cause serious damage to health by repeated oral exposure (no observed adverse effect level (NOAEL) of 825 mg/kg bw/d). Effects observed at > 1000 mg/kg bw/d included increased mortality, reduced weight gain, and liver and kidney effects (OECD, 2004). Available animal data suggest that the chemical is not likely to cause serious damage to health via repeated dermal exposure. No treatment-related effects in rabbits at doses of up to 2500 mg/kg bw/d applied 5 d/wk for 3 weeks (OECD, 2004). Available animal data suggest that the chemical is not likely to cause serious damage to health via repeated inhalation exposure. The only available rat study for this chemical reported 2/20 mortalities at 1.2 mg/L 6 h/d (5 d/wk over 4 wk). Local reddish discharge around the nostrils and inflammatory cell infiltrates and interstitial fibrosis of the lung secondary to local irritant effects were also observed at ³ 0.25 mg/L. On the basis of systemic effects, the NOAEC is considered to be > 0.25 mg/L 6 h/d (ECHA, 2011).
Carcinogenicity	Based on the available data, the chemical is not considered carcinogenic. The chemical was not carcinogenic (NOAEL 500 mg/kg bw/d) in a lifetime 3-generation study in rats when given with the diet at doses up to 500 mg/kg bw/d. No increase in the lifetime tumour incidence, clinical abnormalities or histopathological changes were observed (OECD, 2004). A lifelong study using male/female Swiss Albino mice given the chemical (2 %) continuously in drinking water showed no carcinogenic effect (such as effect on survival or incidence of tumours) (CICAD, 2000).
Mutagenicity/ Genotoxicity	Based on the weight of the evidence of the in vitro and in vivo genotoxicity data, the chemical is not considered mutagenic or clastogenic. In vitro data using the reverse mutation assays with various strains of Salmonella typhimurium (with and without metabolic activation) and sister chromatid exchange assays (except one equivocal result) were negative. Weak genotoxic effects or equivocal results were observed in most of the chromosome aberration assays in three mammalian cell lines and two of the recombination assays in Bacillus subtilis (no further information available, only summary given) (REACH). No genotoxicity was observed in the in vivo cytogenetic, micronucleus, or other assays at either somatic or germ cell level (OECD, 2004).
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No evidence of reproductive or developmental toxicity was observed for the chemical.

Acute Toxicity	The chemical is of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in rats and mice is greater than 2000 mg/kg bw/d. LD50 in rats ranged from 1700-3040 mg/kg bw/d and in mouse ranged from 1940-2370 mg/kg bw/d. However, the studies that reported the lower LD50s were all pre-guideline studies and no further information was available to critically assess the data. LD50s reported in two reliable studies were 2250 mg/kg bw/d (mice) and 2565 mg/kg bw/d (rats) (OECD, 2004). The chemical is of low acute toxicity in animal tests following oral exposure. The median lethal dose (LD50) in rats and mice is greater than 2000 mg/kg bw/d. LD50 in rats ranged from 1700-3040 mg/kg bw/d and in mouse ranged from 1940-2370 mg/kg bw/d. However, the studies that reported the lower LD50s were all pre-guideline studies and no further information was available to critically assess the data. LD50s reported in two reliable studies were 2250 mg/kg bw/d (mice) and 2565 mg/kg bw/d (rats) (OECD, 2004). The chemical exhibits low acute toxicity in animal tests as evidenced by reported dermal LD50 (median lethal concentration) in rats of greater than 2000 mg/kg bw (OECD, 2004). The chemical exhibits low acute toxicity in animal tests following inhalation exposure. No mortalities or toxic effects were observed in rats and mice with the reported median lethal concentration (LC50) > 12.2 mg/L/4-h (ECHA, 2011; OECD, 2004).
Irritation	Inhalation toxicity of the chemical was evaluated in one rat study (0, 0.025, 0.25 and 1.2 mg/L, 6 h/d 5 d/wk over 4 weeks) using fine benzoic acid dust (see Repeat dose toxicity - Inhalation). A reddish discharge around the nostrils was seen in the mid and high dose groups. An increased incidence and intensity of interstitial inflammatory cell infiltrate and interstitial fibrosis (indicating upper respiratory tract irritation) was noted at all doses. Observed histopathological changes were most likely due to a persistent irritating effect of the test substance on the lung. No changes in gross pathology were noted (REACH). The chemical was irritating (erythema and swelling of the ear lobe) in the guinea pig ear swelling test at ^a 1%, particularly when dissolved in ethanol, although it was not found irritating in the rabbit (OECD, 2004). The chemical was highly irritating in rabbit eyes, causing irreversible corneal opacity and chemosis in 2/3 animals, and increasing conjunctival redness severity with white/grey discoloration after 2-day observation. A Draize score of 35 was given based on the effects (REACH). In another rabbit study an irritation score of 65.0/110 was noted. No further details were available from this study (OECD, 2004).
Sensitisation	The negative results seen for the chemical from several skin sensitisation animal studies including guinea pig maximisation test (GPMT), Buehler test and local lymph node assay (LLNA) support a conclusion that the chemical is not a skin sensitizer (REACH). The chemical did not induce sensitisation in healthy volunteers although some allergic reactions were noted in 34/537 patients with suspected contact dermatitis (at 2 %) (SCCP, 2005) and 9/121 patients with dermatoses and 10/57 patients with chronic urticaria (at 5 %) (ECHA, 2011).
Health Effects Summary	The critical health effects associated with the chemical (but not the salts) are skin, eye and respiratory tract irritation. However, no systemic effects were seen with benzoic acid. The salts are expected to exist almost entirely as the benzoate ion under normal physiological conditions and will not have the local irritant properties that arise from the acidity of benzoic acid. Therefore, it is unlikely that any systemic effects will be observed with the salts of benzoic acid.
Key Study/Critical Effect for Screening Criteria	The critical lowest No Observed Adverse Effect (NOAEL) level for the purposes of risk assessment is 825 mg/kg bw/day from the repeated chronic oral toxicity study.

Ecological Toxicity ²	
Aquatic Toxicity	Studies on three trophic levels are available with the lowest EC50 found in algae (33.1 mg/L). In this study the concentrations decreased significantly over the exposure period of 72 hours. The LC50 for fish is 44.6 mg/L and for daphnia an EC50 of > 100 mg/L was derived. The EC10 from the algae study is 3.4 mg/L, which is much lower than the NOEC for fish (120 mg/L in a 28 day study) and daphnia (25 mg/L in 21 day reproduction test).
Determination of PNEC aquatic	Long-term data was available for a fish, invertebrate and algae. An assessment factor of 10 was used on the lowest NOEC of 3.4 mg/L for algae for a resulting PNEC of 0.34 mg/L.
Current Regulatory Controls ¹	
Australian Hazard Classification	The chemical is not listed on the Hazardous Substances Information System (HSIS) (Safe Work Australia).
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) of 5–10 mg/m ³ in different countries such as USA (California, Tennessee), Canada and England.
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?	Benzoic acid is readily biodegradable and as such not persistent in the environment.
B/vB criteria fulfilled?	Based on the measured BCF values of <10 to 21 and a log Kow of 1.87 benzoic acid is not expected to be bioaccumulative.
T criteria fulfilled?	The acute aquatic toxicity of this chemical is >0.01 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT
Revised	April 2019

References

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Toxicity Summary - Gas Phase Frac Tracers (GFTs)

Chemical and Physical Properties ^{1,2,3}	
CAS number	15 chemicals (proprietary).
Molecular formula	Proprietary
Molecular weight	~300 – 500
Solubility in water	Insoluble
Melting point	~-37 °C
Boiling point	~76 °C
Vapour pressure	666 @ 25 °C
Henry's law constant	No data available
Explosive potential	Non explosive
Flammability potential	Non-flammable
Colour/Form	Colourless, odourless liquid
Overview	GFTs tracers are compounds that consist of a carbon and fluorine atoms joined by covalent bonds. GFTs are very stable because of the strength of the carbon–fluorine bond. GFTs are chemically inactive, nontoxic, and non-flammable compounds that are found in the atmosphere at very low levels. They are chemical inert, have no biological effects and are very safe. GFTs present no known danger to humans if inhaled or ingested. There are no regulatory restrictions on the use or emission of GFTs. Information for Perfluorocarbons (PFCs) used as analogue data.
Environmental Fate ¹	
Soil/Water/Air	GFTs as a class are extremely stable. They are not susceptible to hydrolysis, and not affected by light (including UV).
Human Health Toxicity Summary ^{1,2,3}	
Chronic Repeated Dose Toxicity	Two-week repeat dose preliminary inhalation toxicity (rat at a target concentration of 10,000 ppm (10%), no treatment-related effects were noted for clinical signs, body weight, food consumption, water consumption, macroscopic pathology or organ weights. 90 day inhalation study in rats: no treatment-related effects were observed in this study in which rats were exposed to 5,000 ppm, 15,000 ppm, and 50,000 ppm of the test material for 6 hours per day, 5 days per week for a total of 13 weeks. These results indicate that the toxicity of the test material following repeated inhalation exposure is very low and suggest that the gas can be treated as a simple asphyxiant. In a short term repeated Dose 28 Day oral toxicity study in rodents conducted in accordance to the OECD Guideline 407, the test subjects showed no toxic effect at a dosage of 1000 mg/kg/day over 28 days. The NOEL was determined to be 1000 mg/kg/day.
Carcinogenicity	Chromosomal aberration test in cultured mammalian cells: non-clastogenic
Mutagenicity/ Genotoxicity	Bacterial mutation assay salmonella typhimurium (strains ta 1535, ta 1537, ta 1538, ta 98 and ta 100): negative.
Reproductive Toxicity / Developmental Toxicity/Teratogenicity	No data available.

Acute Toxicity	Inhalation 4-hour LC50 : > 800,000 ppm in rats Effects observed in animals by inhalation include decreased growth rate, pulmonary changes, irregular respiration, increased urine volume and creatinine, reversible pathological changes in the kidneys, and increased urinary fluoride concentration. One study showed no arrhythmogenic effects in dogs at a concentration of 20 %, while another study did show some arrhythmogenic effects in both guinea pigs and dogs. Long-term inhalation exposures resulted in an initial decrease in growth rate, but no other adverse changes were noted. No animal test reports are available to define carcinogenic, developmental, or reproductive hazards. The compound does not produce genetic damage in bacterial cell cultures but has not been tested in animals. Acute inhalation toxicity study (rat): the 4-hour LC50 is above 110,000 ppm. These results suggest that on an acute inhalation basis the test material can be considered as a simple asphyxiant.
Irritation	Non-irritating
Sensitisation	Not sensitising
Health Effects Summary	The chemicals have been used in various medical applications, both in trials and in routine use, in human subjects, for some forty years, indicating these materials have zero toxicity to humans.
Key Study/Critical Effect for Screening Criteria	The NOEL level for the purposes of risk assessment is 1000 mg/kg bw/day from the repeated short term oral toxicity study.
Ecological Toxicity ¹	
Aquatic Toxicity	Fish 96h LC50 > 100 mg/L Invertebrates 48h EC50 > 0.1 mg/L Microorganism 3h EC50 > 100 mg/L Pimephales promelas (fathead minnow) 96 h NOEC = 1000 mg/L
Determination of PNEC aquatic	PNEC _{aquatic} has not been calculated. The substance exhibits no toxicity.
Current Regulatory Controls	
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?	Yes, GFTs are not biodegradable. However, they are volatile and are quickly removed from the environment.
B/vB criteria fulfilled?	The estimated Log Kow is generally > 4.5 (EPI Suite), thus it is expected to be bioaccumulative.
T criteria fulfilled?	No. Fish 96 h NOEC = 1000 mg/L. Thus, it is not expected to meet the screening criteria for toxicity.
Overall conclusion	Not PBT

Revised	April 2019

References

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Appendix I

Origin Energy
Environmental
Management Plan
Environmental Risk
Assessment

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequent	Likelihood	Risk Rating			
1	Groundwater	Changes in aquifer quality from subsurface (drilling and stimulation) activities impacting a receptor (groundwater user or GDE). (Path 1)	Contamination from drilling fluids. Drilling fluids used to drill through the Cambrian Limestone Aquifer (CLA) are water-based with clay inhibition in the form of KCl. This may result in temporary elevated levels of chlorides in the CLA immediately adjacent to the well bore during the drilling of the top hole section of the well. (Path 1)	Moderate	B.4.10- Drilling fluids B.4.17 Groundwater monitoring	Source: • Drilling fluids used to drill through CLA are low toxic, water-based with addition of salt in the form of potassium chloride for clay inhibition. • Drilling Fluid Safety Data Sheets and used volumes to be provided to DENR/DPIR. Pathway: • Impacted area likely to be localised around the immediate vicinity of well bore Receptor: • No landholder extraction bores within 16km.	1	3	L	Effective	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
2			Cross flow of formation through inappropriate well barrier design. (Path 1)	Serious	B.4.3 Well design and barriers B.4.2 Aquifer Isolation B.4.7 Primary cementing B.4.17 Groundwater monitoring	Source: • Well constructed with multiple casing barriers and specifically-engineered cement in place to protect aquifers. • Well design and Well Barrier Integrity Validation report approved by DPIR as part of Well Operations Management Plan (WOMP). • Well Barrier Integrity Validated (WBIV) during well construction. Pathway: • Any impacted area likely to be localised. Receptor: • No landholder bores within 16km.	3	1	L	Effective	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
3			Crossflow through fracture growth into aquifer from stimulation activities allowing the migration of fluid and gas. (Path 2)	Serious	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	Source: • Geomechanical data collected to understand fracture gradients. • Geomechanical modelling to ensure the appropriate fracture barriers are in place to contain the fracture propagation. • Risk assessment completed prior to stimulation to determine fracture growth. • Real time pressure monitoring to determine if a fracture has propagated outside the design operating envelope. Pathway: • Overlying sequences have a higher fracturing pressure reducing the risk of fracture migration out of the target shale. • Pressure monitoring during stimulation to identify anomalies indicating fluid loss aquifers. • Well designed with multiple well barriers in place to protect aquifers. Receptor: • 1400m separation distance between Kyalla formation and the Gum Ridge Aquifer. • No landholder bores within 16km. • Groundwater monitoring bores installed within 20m down gradient of each stimulated well.	3	1	L	Effective	Origin has extensive experience in drilling conventional and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - Preliminary guidelines: Groundwater monitoring bores for exploration petroleum wells in the Beetaloo Sub-Basin. - 9500km of 2D seismic data used to screen for faults - Wireline logging during drilling to detect major unconformities. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
4			Stimulation activity induces seismic activity that enables cross formational flow between shallow aquifers. (Path 5)	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	Source: • Stimulation is not linked to major seismic events (re injection of wastewater is generally recognised as the main cause). No reinjection of wastewater proposed. • Stimulation stages deployment will be away from geohazards to reduce the loss of fluids into any encountered faults. Pathway: • No significant faults within proximity of activity. • Any faults encountered during drilling will be assessed to determine risk of stimulating. Receptor: • 1400m separation distance between Kyalla formation and the Gum Ridge Aquifer. • No landholder bores within 16km.	2	1	L	Effective	Origin has extensive experience in stimulating unconventional petroleum wells across Australia. - US Geological Survey data. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low

Ref	Environmental Factor	Risk Description	Risk Source	Unmitigated consequence	Risk mitigation Measures		Residual Risk Rating			Effectiveness of Treatment	Scientific uncertainty	Uncertainty Ranking
					Codes of Practice	Site specific risk mitigation measures	Consequent	Likelihood	Risk Rating			
5			Migration via fractures intersecting with offset wells or intersecting an existing geohazard. (Path 2 & 5)	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.3 Well design and barriers B.4.17 Groundwater monitoring	Source: • Fracture modelling undertaken to determine maximum fracture growth. • Fluid injected into a shale formation Pathway: • No significant faults within proximity of activity. • Any faults encountered during drilling will be assessed to determine risk of stimulating. • Closest exploration well 14 km (well is abandoned). Receptor: • No landholder bores within 16km. • Regional groundwater monitoring.	2	1	L	Effective	Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - 9500km of 2D seismic data used to screen for faults. - Wireline logging during drilling to detect major unconformities. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per	Low
6			Leakage of either flowback, produced water, or hydrocarbons (liquid and gaseous) from suspended or abandoned wells. (Path1)	Moderate	B.4.1 Well Integrity Management B.4.2 Aquifer Isolation B.4.3 Well design and barriers B.4.15 Well suspension and decommissioning B.4.17 Groundwater monitoring D.5.5 Leak Remediation and Notification	Source: • Multiple cement and steel casing barriers constructed to protect aquifers. • Well design and construction reports submitted to DPIR. • Integrity of isolation validated and maintained throughout well life. • Well design considers multiple cement and steel casing barriers in place between hydrocarbon-bearing zone and surface. • Well design and Well Barrier Integrity Validation reports submitted to DPIR as part of Well Operations Management Plan (WOMP). • Wells constructed and suspended with barriers in place and verified as per governing code. • Routine well leak detection. • Leaking wells to be remediated as soon as practicable. • Limited gas production time only to extended production test. Pathway: • Impacted area likely to be localised. Receptor: • No landholder bores within 16km. • Groundwater monitoring bores installed.	2	2	L	Effective	Origin has extensive experience in drilling, stimulating, maintaining and abandoning unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
7	Groundwater	Contamination of aquifer from surface activities (chemical and waste storage, handling and spills) impacting a receptor (groundwater user or GDE).	Surface contamination from storage and disposal of drilling fluids, additives, muds and cuttings on-site. (Path 3 & 7)	Serious	A.4.7 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.5.1 Drilling Materials C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan C.8.1 Wastewater Management Plan	Source • Drilling sumps to be lined with an impermeable liner. • Well cellar to be lined to contain drilling fluids with pumps to prevent overflow. • Water levels in drilling sumps to be minimised to reduce hydraulic head. • Inspections of storages to be undertaken weekly to identify potential liner issues. • Spill Management Plan. • Drill cuttings and muds are not expected to contain high NORMS levels- with characterisation of levels undertaken Wastewater tanks and drill sumps to have a 1:1000ARI freeboard. Pathway: • Separation between sump and aquifer over 70m, with interbedded clays present. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination.	3	1	L	Effective	Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - 9500km of 2D seismic data used to screen for faults. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low

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8			Storage, handling and transportation of produced hydrocarbons (condensate). (Path 3)	Serious	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	Source: • Tanks to be compliant with AS 1940 and double-lined • Weekly inspections to identify any potential leaks. • High risk chemical storage areas to have secondary containment (such as mud shakers, pumps and chemical handling areas). Pathway: • Spill Management Plan implemented. • Separation between chemical storages and closest aquifer over 70m, with interbedded clays likely to limit any contaminant migration. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills and leaks to be cleaned up and rectified as soon as possible.	2	2	L	Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
9			Surface spills from storage, handling and transportation of flowback water. (Path 3 & 7)	Serious	A.4.7 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.5.2 Management of produced water from petroleum wells c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan C.8.1 Wastewater Management Plan	Source: • Tanks to be double-lined with leak detection. • High risk chemical storage and handling areas to have secondary containment. • Weekly inspections to identify any potential leaks. • Licenced waste transporters to be used. • Secondary containment utilised for storage of on-site chemicals • Lease bundled with each bund. • Spill Management Plan. • NORMS levels are not anticipated to be significant- with characterisation of levels within drilling wastewater and flowback undertaken to validate. • Site contamination assessments undertaken in accordance with NEPM Pathway: • Separation between chemical storages and closest aquifer over 70m, with interbedded clays likely to limit any contaminant migration. • Spill Management Plan implemented. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills and leaks to be cleaned up and rectified as soon as possible.	3	1	L	Effective	The regulatory regime legislating the storage, handling and transportation of controlled wastes in the NT and Australia is mature. - Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
10			Storage, handling and transportation of chemicals, fuels and wastes. (Path 3)	Serious	A.4.7 Containment of Contaminants C.3.3 Wastewater management legislative requirements C.8.2 Spill Management Plan	Source: • All chemical, fuel and waste storage and high risk spill handling areas are to be bundled. • Weekly inspections to identify any potential leaks. • Licenced waste transporters to be used to transport listed wastes. • Chemicals to be transported in accordance with the Australian Dangerous Goods Code and NT Dangerous Goods Act. • Leases to be engineered and compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Separation between chemical stores and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. • Spill Management Plan implemented. • All transportation of listed wastes and dangerous goods to be undertaken via licenced contractors. Receptor: • Separation between storage areas and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed around exploration wells to detect any potential contamination. • Area is remote with major urban areas to be avoided during the transportation of dangerous goods and wastes in accordance with the NT Dangerous Goods Act.	2	2	L	Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low

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11			Overtopping of drilling sumps and flowback tanks. (Path 7)	Serious	A.4.7 Containment of Contaminants C.6 Monitoring mandatory requirements C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Covered tanks to be used during wet season flowback storage. • Open Tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Separation between lease pad and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills to be cleaned up as soon as possible.	2	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
12			Failure of flowback storage tank. (Path4 & 7)	Major	A.4.1 Site selection and planning c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Separation between lease pad and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. Receptor: • Separation between lease and closest aquifer over 70m. • Nearest landholder extraction bore 16km. • Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. • Spills to be cleaned up as soon as possible.	3	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
13	Surface Water	Contamination of surface water from surface activities.	Failure of flowback storage tank. (Path4 & 7)	Major	A.4.1 Site selection and planning c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Area is flat with the separation between lease pad and closest major watercourse is ~45km away. • Lease pad bunded preventing off-site release of flowback. Receptor: • Separation between lease pad and closest major watercourse is ~45km. • No major wetlands, with closest ~100km away (Lake Woods).	3	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low

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14			Overtopping of drilling sumps and flowback tanks. (Path 4 & 7)	Serious	A.4.7 Containment of Contaminants C.6 Monitoring mandatory requirements c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Covered tanks to be used during wet season flowback storage. • Open tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • Mud sump to be sized to accommodate anticipated material volume with an appropriate margin of safety. Pathway: • Spill Management Plan implemented. • Area is flat with the separation between lease pad and closest major watercourse is ~45km away. • Lease pad bunded preventing off-site release of wastewater. Receptor: • Separation between lease pad and closest major watercourse is ~45km. • No major wetlands, with closest ~100km away (Lake Woods).	2	2	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
15			Transportation accident releasing chemical or wastewater (drilling fluid and flowback).	Serious	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. • All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. Pathway: • Spill Management Plan implemented. Receptor: • Area is remote with major urban centres to be avoided. • Risk to any receptor is identical to that of normal diesel or petroleum tankers.	3	1	L	Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
16			Storage and handling of chemicals and fuel. (Path 4)	Moderate	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • All areas where chemicals and fuels are stored will have secondary containment. • Weekly inspections will be implemented and spills rectified as soon as practicable. Pathway: • Spill Management Plan implemented. • Lease pads compacted and earthen bunded to prevent off-site releases. Receptor: • Area is remote with closest receptor approximately 30km away.	1	3	L	Effective	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. - Origin has extensive experience in transporting, storing and managing chemicals and fuels associated with unconventional petroleum drilling and stimulation activities. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
17			Release of stormwater from activities to surface water.	Minor	A.4.1 Site selection and planning A.4.3 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan. • Lease pad located away from watercourses or regional flow paths. • Contaminated stormwater to be retained on-site, treated and disposed off-site at a licenced disposal facility. • Clean stormwater to be reused or released off-site in a manner that reduces the risk of erosion. • Stockpiled debris to be used to discourage water concentration. Pathway: • Lease pad to be earthen bunded. • Erosion and Sediment Control Plan implemented. Receptor: • Area is remote with closest watercourse approximately 45km away.	1	3	L	Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. -The NT has a range of technical guidance notes covering soil management, erosion and sediment control including the NT Land Clearing Guidelines.	Low

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18			Erosion and sediment releases from lease pads and access tracks.	Moderate	A.4.1 Site selection and planning A.4.3 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan. • Lease pad located away from watercourses or regional flow paths. • Land clearing to be undertaken in accordance with the NT Land Clearing Guidelines. • No clearing of vegetation in watercourses proposed. Pathway: • Lease pad to be earthen bunded. • Erosion and Sediment Control Plan implemented. Receptor: • Lease pad is located away from watercourses. • Area is remote with closest watercourse approximately 45km away.	1	3	L	Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. -The NT has a range of technical guidance notes covering soil management, erosion and sediment control. this includes the NT Land Clearing Guidelines	Low
19			Runoff from sewage treatment irrigation areas.	Minor	A.4.1 Site selection and planning	Source: • Irrigation areas located away from watercourses. • Areas designed in accordance with the DOH irrigation guidelines. • Areas appropriately sized to accommodate irrigation volume. Pathway: • Irrigation areas located away from watercourses. Receptor: • Area is remote with closest watercourse approximately 45km away.	1	3	L	Effective	The management of sewerage and greywater is mature with various NT wastewater management guidelines.	Low
20	Surface Water	Changes in surface water hydrology resulting vegetation dieback from ponding and diversions away from natural surface systems with environmental and cultural value.	Infrastructure located on regional flow path resulting in changes to surface water flow.	Moderate	A.4.1 Site selection and planning A.4.3 Erosion and sediment control and hydrology	Source: • Erosion and Sediment Control Plan. • Lease pad located away from watercourses or regional flow paths. • Land clearing to be undertaken in accordance with the NT Land Clearing Guidelines. • No clearing of vegetation in watercourses proposed. • Lease pads to be designed to divert stormwater around, without impeding natural surface water flows. • Stockpiled debris to be used to discourage water concentration. Pathway: • Lease pads to be designed to reduce impact on overland flows. Receptor: • Area is remote with closest watercourse approximately 45km away. • The lease area is flat, with water to be diverted around the perimeter of the site.	1	2	L	Effective	Well understood risk with management strategies within the NT Land Clearing Guidelines.	Low
21			Changes to terrestrial ground surface levels associated with seismic activity.	Moderate	B.4.13 Hydraulic Stimulation and Flowback Operations	Source: • Exploration wells located away form major structural features. • No wastewater injection to be undertaken. • Monitoring of pressure during stimulation to identify if stimulation fluid is entering a open structural feature. Pathway: • No wastewater injection to be undertaken. • Location of well is away from areas with significant faulting. Receptor: • Area is remote with low pollution density.	2	1	L	Effective	- US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
22	Water usage	Unsustainable groundwater extraction impacts landholders and groundwater dependent ecosystems.	Over extraction of groundwater for civils, drilling and stimulation activities.	Serious	B.4.17 Groundwater monitoring	Source: • Groundwater extraction for activities to be restricted to the minimum water required. • Exploration well located ~17km from closest extraction point. • All water take licenced in accordance with NT Water Act. Pathway: • Drawdown from activity and other users assessed, with impacts to closest receptor determined. Receptor: • Closest receptor is ~16km from extraction point. •Continuous flow meters to monitor take and water balance implemented to ensure compliance with WEL.	3	1	L	Effective	- US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low

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23	Soil	Loss in long-term soil productivity and viability.	Soil compaction from access tracks and leases.	Moderate	A.4.1 Site selection and planning	Source: • Land clearing undertaken in accordance with NT Land Clearing Guidelines; • Land Condition Assessment completed. • Lease pads to be stripped of topsoil. • Areas to be rehabilitated to reduce impacts associated with compaction. Pathway: • Areas to be rehabilitated to reduce impacts associated with compaction. Receptor: • Disturbance area is small (less than 0.005% of total tenure area).	2	1	L	Effective	Well understood risk with management strategies within the NT Land Clearing Guidelines.	Low
24			Soil erosion from cleared areas (access tracks, lease pads and camp pads).	Serious	A.4.3 Erosion and sediment control and hydrology	Source: • Land clearing undertaken in accordance with NT Land Clearing Guidelines. • Land Condition Assessment completed. • Lease pads to be stripped of topsoil. • Areas to be rehabilitated to reduce impacts associated with compaction. • Erosion and Sediment Control Plan implemented. • Stockpiled debris to be used to discourage water concentration. Pathway: • Areas to be rehabilitated to reduce impacts associated with compaction. Receptor: • Disturbance area is small (less than 0.005% of total tenure area).	1	4	M	Effective	The understanding of the risks associated with the release of stormwater from construction sites is mature, with international standards providing guidance to manage the risk. - The NT has a range of technical guidance notes covering soil management, erosion and sediment control including the NT Land Clearing Guidelines.	Low
26	Soil	Soil contamination due to spills and leaks of chemicals, wastes or wastewater.	Spills/leaks from the on-site storing and handling of: - fuels and hydrocarbons - drilling additives - stimulation additives - flowback fluid - solid wastes - storage and transportation of wastes	Serious	A.4.7 Containment of Contaminants c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • All tanks and chemical storage areas to have secondary containment. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Spill Management Plan implemented. • Lease pad compacted and earthen bunded preventing off-site release of wastewater and chemicals. • All wastes stored and handled in accordance with NT Waste Management and Pollution Control Act. Receptor: • Spill Management Plan to be implemented. • Weekly inspections of secondary containment with any spills rectified as soon as practicable. • All wastes stored and handled in accordance with NT Waste Management and Pollution Control Act.	1	3	L	Effective	Origin has extensive experience in transporting, storing and managing drilling and stimulation chemicals (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
27			Drill sump and flowback tank overtopping.	Serious	A.4.7 Containment of Contaminants C.5.1 Drilling Materials C.5.2 Management of produced water from petroleum wells C.6 Monitoring mandatory requirements C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Covered tanks to be used during wet season flowback storage. • Open tank and drilling sump freeboard to be 1:1000 ARI. • Monitoring of tank and sump levels daily when operational. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of wastewater. Receptor: • Lease pad bunded preventing off-site release of wastewater.	2	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report Beetaloo Sub-Basin. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low

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					Codes of Practice	Site specific risk mitigation measures	Consequent	Likelihood	Risk Rating			
28			Chemical and waste transportation accident.	Serious	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. • All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. Pathway: • Spill Management Plan implemented. • Tanker/truck failure are rare events. Receptor: • Area is remote with major urban centres to be avoided.	3	1	L	Effective	The regulatory regime legislating the storage, handling and transportation of controlled wastes in the NT and Australia is mature. - Origin has extensive experience in drilling and stimulating unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report.	Low
29			On-site disposal of drill muds and cuttings.	Serious	B.4.17 Groundwater monitoring C.5.1 Drilling Materials	Source: • Drilling muds are bentonite-based. • Sodium and Chloride levels to be reduced through segregation of drilling fluids from muds. • Drilling muds to be tested and a disposal strategy developed by a suitably qualified third-party in a manner that minimises the risk to the environment. DENR engaged to confirm final disposal strategy. • in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs Pathway: • Depth to groundwater approximately 70m with interbedded clays separating the lease from the aquifer. Receptor: • Closest landholder bore is 16km away.	2	2	L	Effective	Origin has extensive experience in managing drilling wastes associated with and unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - Various US regulatory authorities provide guidance on drilling waste management.	Low
30			Failure of a flowback tank.	Major	A.4.1 Site selection and planning A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure.	3	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
		Soil contamination from the drift of saline wastewater offsite from mechanical evaporation units.	flowback evaporation mist transported offsite during wastewater treatment.	Serious	A.4.1 Site selection and planning	• in the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs	2	2	L	Effective	The use of enhanced evaporators to manage wastewater is a well known technology used through multiple mining and wastewater treatment industries. Evaporators were used successfully on the Amungee Nw 1H well to reduce fluid levels decreasing offsite trucking volumes.	Low
31		Soil contamination from the disposal of greywater and sewerage from camp activities.	Greywater and sewerage disposal (camps).	Minor	C.4.2 Management of flowback water	Source: • All sewerage to be removed off-site in accordance with the NT Waste Management and Pollution Control Act or irrigated as per the NT Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974. Pathway: • Irrigation areas to be sized in accordance with the anticipated irrigation volume and quality. Receptor: • Land Condition Assessment.	1	2	L	Effective	Risks associated with sewerage and greywater disposal are well known, with technical guidance notes for system design are available within the NT.	Low

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33			Activity (vehicle and machinery) noise and lighting on well pads and access tracks.	Minor	A.4.1 Site selection and planning A.4.2 Noise	Source: • Site location avoids areas of high conservation value as a priority. • Field ecology scouting undertaken as a part of a Land Condition Assessment to prevent impacts to high conservation value areas. • Areas are not considered high conservation value, are not threatened/endangered, with impacts unlikely to result in significant disturbance to threatened/endangered species. Pathway: • Land clearing conducted in accordance with NT Land Clearing Guidelines. Receptor: • Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	3	L	Effective	Risks associated with noise on fauna are well understood.	Low
34			Failure of flowback storage tanks.	Major	A.4.1 Site selection and planning A.4.7 Containment of Contaminants c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and spill material to be recovered immediately. - Field ecological survey of areas undertaken to avoid areas of high conservation status so areas are not threatened or endangered. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure. • No high conservation areas or endangered flora and fauna within the vicinity of the proposed lease pad likely to be significantly impacted by a release.	3	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
35			Introduction and spread of weeds in the area.	Major	A.4.5 Weed management	Source: • Weed Management Plan to be approved by DENR and implemented. • All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. • Areas of proposed exploration have been surveyed and are deemed to have low weed abundance. • Activity will be restricted to defined lease pads and camp pads. Pathway: • Equipment to be wash-down and certified. • Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. Receptor: • Area is free of weeds and monitoring will be implemented around infrastructure to detect the spread/ introduction of weed species.	2	3	M	Effective	Risks associated with weeds are well studied within literature and by the NT DENR. - Field weed surveys will be completed prior to and after construction activities.	Low
37			Accidental ignition of fire from exploration activities (drilling, stimulation, flaring and general access).	Serious	A 4.6 Fire management	Source: • Bushfire Management Plan implemented. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Kyalla 117 N2 lease has had recent fire activity, reducing the fuel load.	3	2	M	Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low

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38			Poor rehabilitation.	Serious	A.4.8 Rehabilitation	- A site specific Rehabilitation Plan will be developed prior to rehabilitation. - The final Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. - Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. - Maintenance will be undertaken periodically to fix any defects.	1	2	L	Effective	Risks associated with rehabilitation are well known. Knowledge of rehabilitation within the Beetaloo Basin has been gained, based on previous seismic line rehabilitation programs.	Low
40			Trapping and drowning of fauna in storage tanks and sumps.	Moderate	C.5.1 Drilling Materials	Source: - Tanks walls are raised with minimal risk of animals accessing tanks. - Site manned during operation. Pathway: - Lease pads fenced to prevent stock and wildlife access. Receptor: - Lease pads fenced to prevent stock and wildlife access.	2	2	L	Effective	Risks associated with potentially trapping and drowning fauna in storage tanks and sumps are well understood. Origin has extensive experience in managing sumps, ponds and tanks to prevent fauna ingress.	Low
41			Contaminants in water and soil pass through the food chain and bioaccumulate in fauna.	Minor	A.4.7 Containment of Contaminants C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: - Wastewater Management Plan. - Spill Management Plan. - Chemical risk assessments with no chemicals considered above low concern levels. earthen bunding to prevent off-site release of wastewater and chemicals. Pathway: - Spill Management Plan implemented. - Lease pads fenced. - Lease pad bunded preventing off-site release of chemicals. Receptor: - Bunding to minimise the risk of off-site release of fluid in the event of a tank or storage failure.	1	1	L	Effective	A chemical risk assessment and flowback characterisation program for the Amungee NW 1 well ensures all potential chemicals that are persistent, bioaccumulative and toxic at high concentrations are identified and appropriate management strategies implemented. The risks associated with fauna ingestion of chemicals is well known and measures to prevent ingestion (such as fences and separation distances to activity) are deployed as standard practice. Origin has extensive operational experience in drilling and stimulating 1000s of conventional and unconventional petroleum wells with no evidence of impacts on biota from chemicals.	Low
42			Vehicle collisions with fauna – fauna mortality.	Minor	A.4.4 Biodiversity protection	Source: - Vehicle speed limited to 80km/hr to be reduced around areas of high risk of fauna collision. - Vehicle movements to avoid driving at night. Pathway: - Vehicle speed limits to be reduced around areas of high risk of fauna collision. Receptor: - Vehicle speed limits to be reduced around areas of high risk of fauna collision.	1	3	L	Effective	Risks associated with fauna collisions are well known.	Low
43			Activity noise and lighting on well pads and access tracks disturbs fauna.	Minor	A.4.1 Site selection and planning A.4.2 Noise	Source: - Site location avoids areas of high conservation value as a priority. - Field ecology scouting undertaken as a part of a Land Condition Assessment to prevent impacts to high conservation value areas. - Areas are not considered high conservation value, are not threatened/endangered, with impacts unlikely to result in fragmentation. Pathway: - Land clearing conducted in accordance with NT Land Clearing Guidelines. - Lighting levels minimised to the level required to complete work safely. Receptor: - Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	3	L	Effective	Risks associated with noise and light impacts on flora and fauna are covered extensively in literature.	Low
44			Encouragement of feral animals and other pest species increases leading to competition with native species.	Moderate	A.4.4 Biodiversity protection	Source: - Camp wastes to be stored in a manner to prevent attracting feral animals. - All food scraps to be removed from site and disposed of at a licenced facility. Pathway: - Camps to be fenced. Receptor: - Camps to be fenced	1	3	L	Effective	The risks associated with encouraging feral animals with inadequate waste management are well understood within literature and government policy.	Low

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45			Introduction and spread of weeds in the area.	Major	A.4.5 Weed management	Source: • Weed Management Plan to be approved by DENR and implemented. • All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. • Areas of proposed exploration have been surveyed and are deemed to have low weed abundance. • Activity will be restricted to defined lease pads and camp pads. Pathway: • Equipment to be washed-down and certified. • Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. Receptor: • Area is free of weeds and monitoring will be implemented around infrastructure to detect the spread/introduction of weed species.	2	3	M	Effective	Risks associated with weeds are well studied within literature and by the NT DENR. - Field weed surveys will be completed prior to and after construction activities.	Low
46			Fragmentation of habitat.	Moderate	A.4.1 Site selection and planning A.4.4 Biodiversity protection	Source: • Site location avoids areas of high conservation value as a priority. • Cleared areas to be clearly marked to avoid confusion. • Field ecology scouting undertaken as a part of Land Condition Assessment to prevent impacts to high conservation value areas. • Areas are not considered high conservation value, are not threatened/endangered, are regionally extensive and impacts are unlikely to result in fragmentation. Pathway: • Land clearing conducted in accordance with NT Land Clearing Guidelines. Receptor: • Land Condition Assessment confirms the proposed area is regionally extensive and not of high conservation value. • Land clearing pressures from other industries are not significant in the area.	1	1	L	Effective	The risks associated with habitat fragmentation are well covered in literature. - NT DENR Vegetation Maps - Field ecological surveys completed across the tenure since 2005, including the subject area.	Low
47			Poor rehabilitation reduces habitat quality.	Serious	A.4.8 Rehabilitation	• A site specific Rehabilitation Plan will be developed prior to rehabilitation. • The Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. • Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. • Maintenance will be undertaken periodically to fix any defects.	2	2	L	Effective	The risks associated with habitat fragmentation are well covered in literature. - NT DENR Vegetation Maps. - Field ecological surveys completed across the tenure since 2005, including the subject area.	Low
48			Accidental ignition of fire from exploration activities (civils, drilling, stimulation, flaring and general access).	Serious	A 4.6 Fire management	Source: • Bushfire Management Plan implemented. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Kyalla 117 N2 lease has had recent fire activity, reducing the fuel load.	3	2	M	Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low

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49	Cultural Heritage and Sacred Sites	Disturbance of sacred site or culturally sensitive area	Sites disturbed directly by access track construction or drilling operations.	Serious	A.4.1 Site selection and planning	Source: • All areas of the proposed activity to be cleared by NLC. • AAPA certificates for proposed work program have been granted. • The location of infrastructure has considered proximity to sacred sites. Pathway: • Areas of cultural heritage to be avoided during construction. Receptor: • Areas of cultural significance are not within 14km of the proposed area of activity.	3	1	L	Effective	All sites of the proposed activity must have Traditional Owner clearance via the NLC. - AAPA certificates are required for all activities. - Restricted work areas are identified.	Low
50			Accidental ignition by site activities (civil works, drilling, grinding) or site personnel.	Serious	A.4.6 Fire management	Source: • Bushfire Management Plan implemented. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Kyalla 117 N2 lease has had recent fire activity, reducing the fuel load.	3	2	M	Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
51			Flowback tank structural failure.	Major	A.4.1 Site selection and planning A.4.7 Containment of Contaminants C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	Source: • Wastewater Management Plan. • Spill Management Plan. • Tanks to be engineered to meet the relevant Australian standards including wind loading and bushfires. • Leases to be compacted with earthen bunding and off-site release of contaminants to be minimised. • Field cultural heritage and NLC clearance surveys of areas undertaken to avoid areas of cultural significance. Pathway: • Spill Management Plan implemented. • Lease pad bunded preventing off-site release of flowback. Receptor: • Bunding to minimise the risk of off-site release of fluid in the event of a tank failure. • No sacred sites within the vicinity of proposed activity.	3	1	L	Effective	Origin has extensive experience in managing drilling and stimulation fluids (including flowback) associated with unconventional petroleum wells across Australia. - US EPA Study of Hydraulic Fracturing and its potential impact on drinking water resources (US EPA 2016). - Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. - CSIRO regional baseline monitoring program. - Control and impact monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin.	Low
52			Personnel unauthorised access to restricted work area.	Serious	A.4.1 Site selection and planning	Source: • Restricted work areas are not located in close proximity to explorational activities. • All staff to be inducted covering restricted work areas and cultural heritage. • Access off lease not permitted. Pathway: • Access off lease not permitted. Receptor: • Access off lease not permitted. • No restricted work areas within the vicinity of proposed activity.	2	1	L	Effective	All sites of the proposed activity must have Traditional Owner clearance via the NLC. - AAPA certificates are required for all activities. - Restricted work areas are identified .	Low
53	Community impact	Loss of visual amenity, experience and sense of place for landholder, community members and tourists.	Industrialisation of landscape.	Moderate	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection	• Site is located away from major roads and not visible. • Level of clearing for infrastructure is small.	1	1	L	Effective	Risks associated with aesthetic changes due to infrastructure construction are well known and not restricted to the petroleum industry.	Low

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54			Increased traffic.	Moderate	A.4.1 Site selection and planning	- Traffic impact assessment completed assessing the increased traffic levels as negligible: reflective of limited size and scope of activity. - Traffic impacts are expected to small and temporary. - Access route is away from the main homestead. - Capacity of road and level of service will not be impacted materially. - busses used to limit transportation between airport and remote camps- limited Drive In/Drive Out workers- with most Fly in/fly out of Daly Waters.	2	1	L	Effective	Risks associated with increased traffic are well known throughout literature and policy.	Low
55			Light emissions activities.	Minor	A.4.1 Site selection and planning	Site is located 20km away from the Stuart Highway and the nearest homestead although a visible hue may be present during flaring. This is likely to be consistent with a small town and only visible during the night.	1	1	L	Effective	Risks associated with light emission are well known with various literature and technical guidelines available to mitigate impacts.	Low
			Influx of workers to region	moderate		- The majority of workers will be Fly I Fly Out and based at remote camps away from communities. - Workers restricted to lease areas- with no access to surrounding properties authorised.	2	1	L	Effective	The limited scope and duration of activities reduces the risk and uncertainty associated with risk. Most workers will be located away from communities, meaning there is unlikely to be a major increase in people.	Low
56			Noise emissions from activities.	Minor	A.4.1 Site selection and planning A.4.2 Noise	Site located 20km away from the Stuart Highway and the nearest homestead so activity is not anticipated to be visible.	1	1	L	Effective	Risks associated with noise emission are well known with various literature and NT noise guidelines available to mitigate impacts.	Low
57		Reduction in agriculture productivity.	Introduction and spread of weeds in the area.	Major	A.4.5 Weed management	Source: - Weed Management Plan to be approved by DENR and implemented. - All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. - Areas of proposed exploration have been surveyed and are deemed to have low weed abundance. Pathway: - Equipment to be washed-down and certified. - Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. Receptor: - Area is free of weeds and monitoring will be implemented around infrastructure to detect the spread/introduction of weed species.	2	3	M	Effective	Risks associated with weeds are well studied within literature and by the NT DENR. - Field weed surveys will be completed prior to and after construction activities.	Low
58			Over extraction of groundwater.	Serious	A.4.1.1 Well pad specific site selection requirements B.4.17 Groundwater monitoring	Source: - Groundwater extraction for activities to be restricted to the minimum water required. - Exploration well located ~16km from closest extraction point. - All water take licenced in accordance with the NT Water Act. Pathway: - Drawdown from activity and other users assessed, with impacts to closest receptor determined. Receptor: - Closest receptor ~16km from extraction point.	1	1	L	Effective	The regional understanding of the CLA is sufficient to understand the risks associated with groundwater extraction. The absence of users and small exploration take reduces the uncertainty of the activity.	Low
59			Impact to surface hydrology reduces water capture.	Moderate	A.4.3 Erosion and sediment control and hydrology A.4.1 Site selection and planning	Source: - Lease pads located away form major watercourses or flow paths. - Lease pads designed to not disrupt flow paths, with overland flow diverted around lease. - Infrastructure design in accordance with the NT Land Clearing Guidelines. - Erosion and Sediment Control Plan implemented.	1	1	L	Effective	The risks associated with changes in surface hydrology are well known. Guidance notes are available via the NT Land Clearing Guidelines and BPESC to minimise the impact on surface hydrology.	Low

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60			Bushfire from accidental ignition by site activities (civil works, drilling, grinding) or personnel.	Serious	A 4.6 Fire management	Source: • Bushfire Management Plan implemented. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Kyalla 117 N2 lease has had recent fire activity, reducing the fuel load.	3	2	M	Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
61			Poor rehabilitation of exploration infrastructure.	Serious	A.4.8 Rehabilitation	• A site specific Rehabilitation Plan will be developed prior to rehabilitation. • The Rehabilitation Plan will be developed in consultation with the leaseholder and DENR. • Rehabilitation success criteria will be developed with ongoing monitoring undertaken to measure success. • Maintenance will be undertaken periodically to fix any defects.	2	2	L	Effective	Risks associated with rehabilitation are well known. Knowledge of rehabilitation within the Beetaloo Basin has been gained based on previous seismic line rehabilitation programs.	Low
62			Disruption of agricultural operations.	Moderate	A.4.1 Site selection and planning A.4.2 Noise	• All activities require engagement and consent by leaseholders. • Lease sites are located to avoid disruption to agriculture operations and infrastructure. • Engagement will be undertaken in accordance with NT Petroleum Act. Traffic levels are anticipated to be small- as per Traffic Impact Assessment.	1	1	L	Effective	Origin has extensive experience in co-existing its activities with agricultural users. Consultation with pastoralists is undertaken to ensure impacts on their activities are mitigated.	Low
		Safety hazard to pastoralists, community and tourists from increased traffic levels	Increased risk of vehicle accident	Major	A.4.1 Site selection and Planning	• traffic impact assessment completed • Fatigue management policy implemented • alcohol and drug policy implemented • busses used to transport people from airports to camps- no DIDO from drilling, stimulation and well test workers. • camps located away from major roads with most movements internal between camp lease and drill site • Stuart highway intersection design approved by DIPL with appreciate line of site provided for vehicles to identify turning vehicles.	3	1	L	Effective	The management of traffic related risks are well known throughout industry and the government. The introduction on driver training, fatigue management and alcohol and drug policies is standard across industry	Low
63		Labour competition with local businesses and agricultural procedures.	Exploration activities compete with agricultural industry for resources.	Moderate		• Proposed activity is temporary with no major labour requirements- stakeholders engaged to ensure they know the temporal nature of work. • Local contractors for existing communities will be used where available. • Contracts will be structured to reduce 'boom and bust' cycle (clear understanding of limited scope of work). • All work to be short-term with predominantly skilled workforce sourced regionally/interstate.	1	1	L	Effective	Risks associated with small-scale, limited-duration projects on local economies are well known. The short nature of the projects reduces the risks of 'boom and bust' type cycles.	Low
64	Air Quality	Reduction in air quality associated with exploration emissions (civil, Drilling, Stimulating and Well Testing).	Emissions from the combustion of diesel.	Moderate	A.4.1 Site selection and planning D.5.1 Baseline assessment	Source: • Low emission equipment to be selected. • All equipment to be maintained in accordance with the manufacturer's recommendations. Pathway: • Site is located away from receptors. Receptor: • No sensitive receptors within 20km.	1	1	L	Effective	Risks associated with diesel combustion are well known, both within Australia and Internationally. Methods for estimating emissions are available via the National Pollutant Inventory.	Low

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65			Air emissions from flaring.	Moderate	A.4.1 Site selection and planning D.5.1 Baseline assessment B.4.13 Hydraulic Stimulation and flowback operations D.5.8 Venting and flaring	Source: • Flare with a 98% combustion efficiency. • Emissions of NOx, CO and TVOC are small and not anticipated to reduce ambient air quality. Pathway: • Vertical flare stack used maximising dispersion. • Site located away from receptors. Receptor: • No sensitive receptors within 20km.	1	2	L	Effective	Risks associated with emissions from flares are well known within literature, and Australia and International policy/standards exist (such as NGERS and various US EPA technical guidance notes). Methods for estimating emissions are available via the National Pollutant Inventory.	Low
66			Air emissions from chemical releases during drilling and stimulation activities.	Moderate	A.4.1 Site selection and planning B.4.16 Well site layout and housekeeping b.4.13 Hydraulic Stimulation and flowback operations	Source: • National Occupational Health and Safety Codes: Code of Practice for the Control of Workplace Hazardous Substances. • Chemical Risk Assessment. • Chemical handling and mixing to reduce particulate emissions. Pathway: • Site is located away from receptors. Receptor: • No sensitive receptors within 20km.	1	1	L	Effective	Risks associated with air emissions from petroleum activities are well known, with various risk assessment and emissions estimation technical guidance notes available within Australia and internationally (such as the National Pollutant Inventory and the US EPA).	Low
67			Increased nuisance from dust emissions associated with exploration activities.	Moderate	A.4.1 Site selection and planning	Source: • Water trucks will be used to decrease dust emissions. • Reduced speed limits will be adopted in proximity to homesteads. Pathway: • Site is located away from receptors. Receptor: • No sensitive receptors within 20km.	1	2	L	Effective	Origin has extensive experience in managing nuisance emissions of dust during petroleum and construction activities. Strategies for managing dust emissions are well known throughout Australia and the NT.	Low
68			Bushfire from accidental ignition by site activities (civil works, drilling, grinding) or personnel.	Serious	A.4.6 Fire management	Source: • Bushfire Management Plan implemented. • Bushfire awareness included in site inductions. • Designated smoking areas on-site. • Firefighting equipment to be available to deal with fires. • Fire breaks to be implemented around lease and camp pads. • Appropriate separation distances between flares and surrounding vegetation. • Ignition sources placed outside of the hazardous area. • Intrinsically safe equipment used in hazardous area. • Hazardous area drawing will provide classification of hazardous zones while drilling. Pathway: • Fire breaks to be implemented around lease and camp pads. Receptor: • Activities will comply with landholder and regional bushfire management plans. • Area in the vicinity of Kyalla 117 N2 lease has had recent fire activity, reducing the fuel load.	3	2	M	Effective	Risks associated with bushfire are well known, with numerous literature and NT Government management plans and technical guidance notes.	Low
69	Greenhouse Gas Emissions	Unsustainable Greenhouse Gas emissions from the activity.	Combustion of diesel for exploration activities.	Moderate	A.4.1 Site selection and planning	Source: • Low emission equipment to be selected. • All equipment to be maintained in accordance with the manufacturer's recommendations. Pathway: • Site is located away from receptors. Receptor: • No sensitive receptors within 20km.	1	1	L	Effective	The risks associated with Greenhouse Gas generation through diesel combustion are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC).	Low
70			Flaring of gas during well testing.	Moderate	B.4.13 Hydraulic Stimulation and flowback operations D.5.8 Venting and flaring	• Venting to be minimised with all venting reported under NGERS. • Flare with a 98% combustion efficiency will be used during drilling and well testing. • Emissions from source rock during drilling are negligible.	1	2	L	Effective	The risks associated with Greenhouse Gas generation through the use of flares are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC).	Low

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71			Uncontrolled release of gas encountered during drilling, stimulation, barrier failure and operator error.	Moderate	B.4.1 Well integrity management B.4.3 Well design and barriers B.4.13 Hydraulic Stimulation and flow back operations D.5.8 Venting and flaring	Source: • Flare to be used during drilling to manage gas ingress. • Drilling overpressure to reduce the inflows of hydrocarbons. Pathway: Receptor:	1	2	L	Effective	Impacts associated with Greenhouse Gas emissions are well known. Emissions during petroleum activities are estimated using the National Greenhouse and Energy Reporting Scheme (NGERS) estimation techniques.	Low
72			Uncontrolled release of gas from well due to sabotage.	Moderate	D.5.8 Venting and flaring	• Multiple barriers used during well suspension/operation. • Sites manned during operation. • Security cameras. • Routine inspections. • Sites locked. • Valves locked.	1	1	L	Effective	The risks associated with Greenhouse Gas generation through the use of flares are well documented in literature and domestic/international greenhouse policy (Such as NGERS and IPCC).	Low
73			Leak of gas from wells.	Moderate	B.4.1 Well integrity management B.4.3 Well design and barriers D.5.4 Emission detection and management D.5.5 Leak remediation and notification	• Well design considers multiple specifically-engineered cement and steel casing barriers in place between hydrocarbon-bearing zone and surface. • Well design and Well Barrier Integrity Validation reports submitted to DPIR as part of Well Operations Management Plan (WOMP). • Wells constructed and suspended with barriers in place and verified as per governing code. • Routine well leak detection. • Any leaking wells to be remediated as soon as practicable. • Limited gas production time only to extended production test.	1	3	L	Effective	The risks associated with Greenhouse Gas generation through leaking infrastructure are well documented in literature and domestic/international greenhouse policy (such as NGERS, US EPA and IPCC).	Low
74			Clearing of native vegetation.	Moderate	A.4.1 Site selection and planning A.4.4 Biodiversity Protection	Source: • Clearing requirements are small. • Site location avoids areas where threatened flora and fauna are predicted. • Field ecology scouting undertaken as a part of a Land Condition Assessment to identify protected flora and fauna. • Significant disturbance to threatened/endangered flora and fauna species is not anticipated. • Clearing area reduced to minimum area required to safely undertake activity. • Material stockpiled surrounding lease and not burnt. Pathway: • Land clearing conducted in accordance with NT Land Clearing Guidelines. Receptor: • Land Condition Assessment confirms the proposed area is regionally abundant and not of high conservation value.	1	1	L	Effective	Understanding of Greenhouse Gas emissions from land clearing are well documented within literature. Emission estimates using the Transport Authorities Greenhouse Group Greenhouse Gas Assessment Workbook for Road Projects.	Low
75	Cumulative Risk	Cumulative impacts on groundwater quantify.	Groundwater take from surrounding land users exceeds the natural recharge rate of the Basin.	Serious	Water extraction licences under the NT Water Act	• Groundwater extraction assessments include an estimate of current extraction levels at a regional scale. • No intensive users of groundwater within the region, with stock and domestic being the major usage. • Cumulative impacts considered in the water extraction licence under the NT Water Act.	2	1	L	Effective	The regional understanding of the CLA is sufficient to understand the risks associated with groundwater extraction. The absence of users and small exploration take reduces the uncertainty of the activity.	Low
76		Cumulative impacts on terrestrial ecology.	Impacts from exploration activities and existing agricultural activities results in impacts to vegetation communities, fragmentation and poses a threat to protected flora and fauna.	Moderate	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection A.4.4 Biodiversity Protection	• Area has limited development with no widespread land clearing or other pressures from agriculture or other users. • Activity is limited in scale and will not material decrease availability of habitat across the region.	2	1	L	Effective	The region has low land clearing pressure with no applications for large scale land clearing present. The level of disturbance proposed is small, with field ecological scouting confirming ecological communities present.	Low
77		Cumulative impacts on amenity.	Exploration activities further reduces amenity (visual, noise, traffic and lighting) through additional landscape modification, dust, noise, light and traffic.	Moderate	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection	• Activity is located away from major transportation routes and is not visible from roads. • Flaring may create a visible hue on the horizon consistent with that of a small town. • Traffic volumes are anticipated to be small and well below existing industries. • A Traffic Management Plan covering the intersection upgrade work has been submitted to DPIL for approval . • Low level of development activity within the region, with activity unlikely to cause declines in amenity.	1	1	L	Effective	The region is underdeveloped with the activity located away from major transportation routes, homesteads and communities. The activity is of a small size and unlikely to result in any loss of amenity.	Low

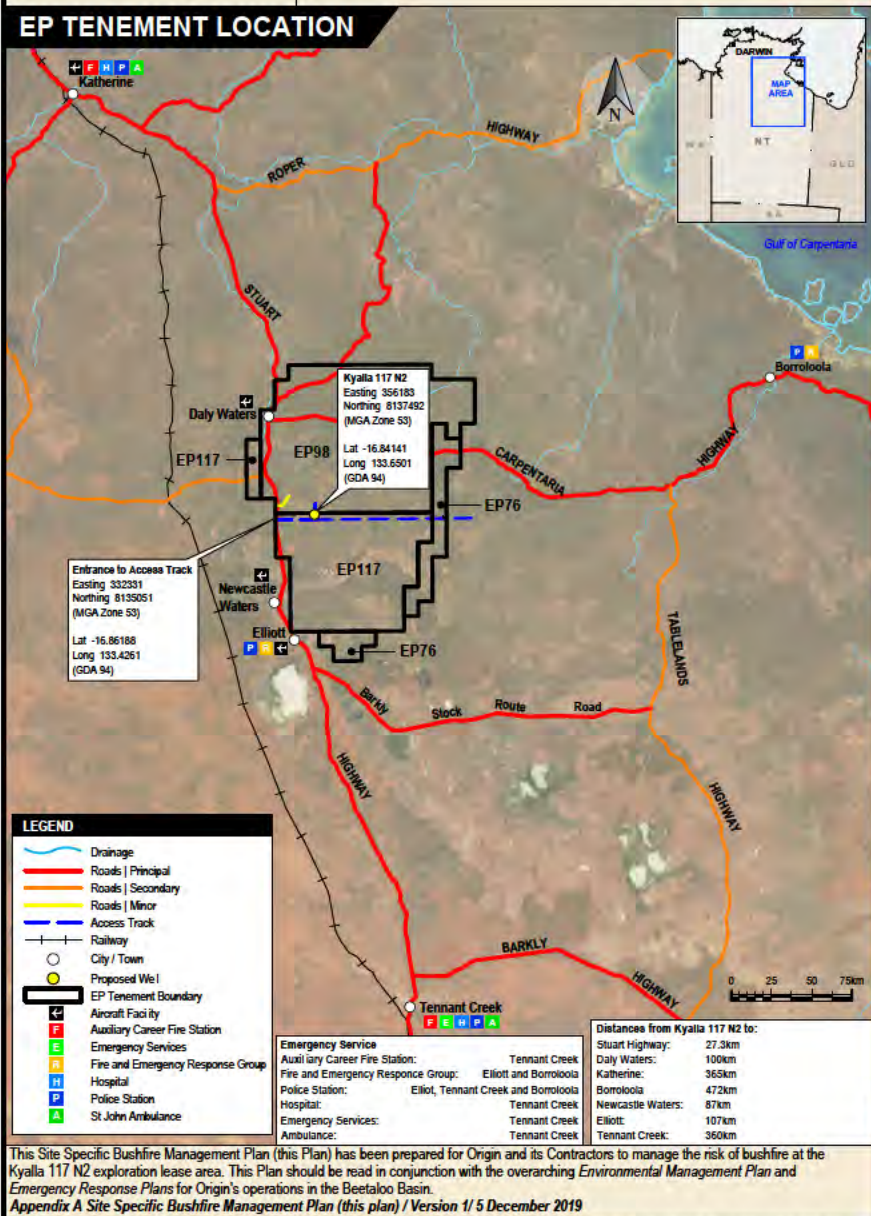
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Appendix D Bushfire Management Plan

Exploration Permit 117
Bushfire Management Plan 2019/2020
Kyalla 117 N2 Lease

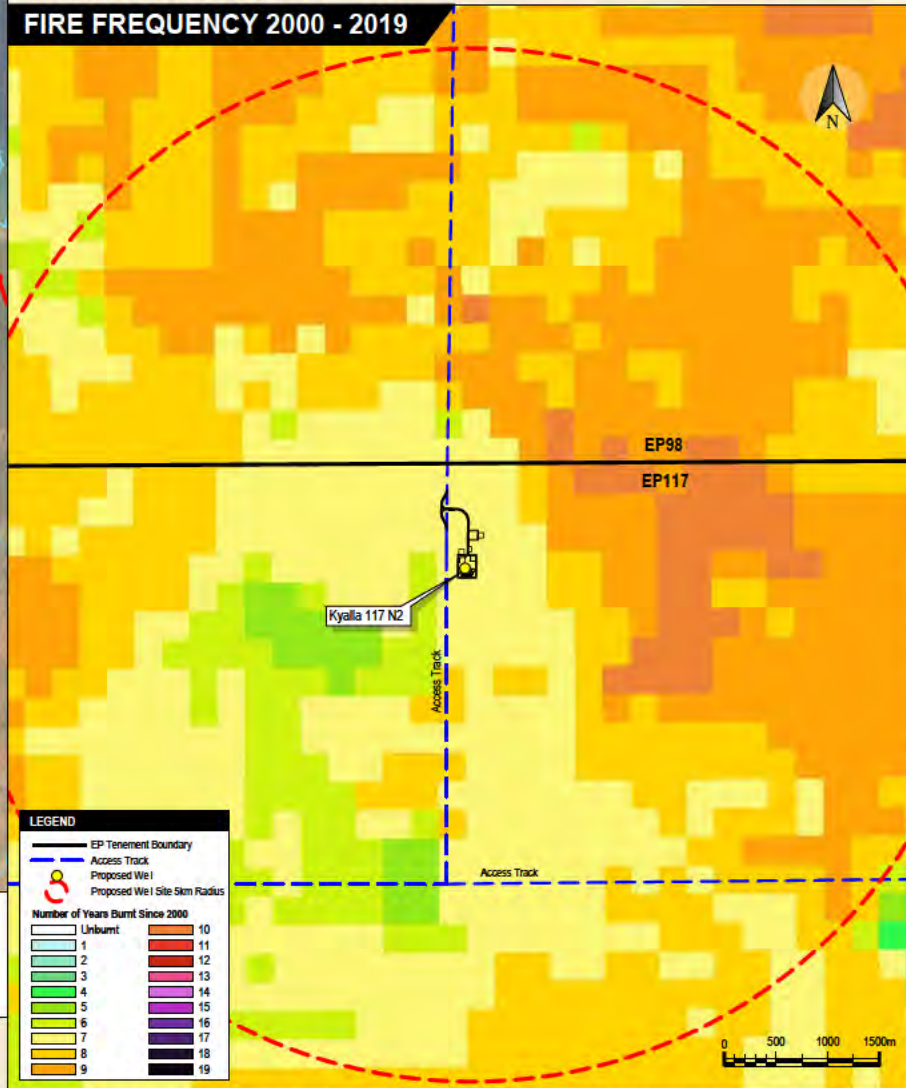


Location of Kyalla 117 N2	
Property land uses	Gas exploration and cattle grazing
Site fire management aim	To reduce the occurrence of, and minimise the impact of bushfires, thereby reducing the threat to life, property, cultural values and the environment.
Site fire management objectives	Mitigate the potential impact of unplanned fires on Origin's people, assets and operations and neighbouring land uses.



Origin Fire Officer	Contact Details	Name
	[REDACTED]	Robert Wear
Properties	Contact Details	Name
Amungee Mungee Station	08 8971 1293 Katherine office	[REDACTED]
Kalala Station	[REDACTED]	[REDACTED]
Hayfield Station	[REDACTED]	[REDACTED]
Beetaloo Station	[REDACTED]	[REDACTED]
Offsite Stakeholders	Contact Details	Name
Bushfire NT Alice Springs Office	(08)8952 3066	
National Response Centre	1800 076 251	24/7 contract line
Emergency	000 or 112 mobile	
Bushfire NT Katherine office	08 8973 8873 08 8973 8871	[REDACTED]
Bushfire NT Head office	08 8922 0840 bushfires.nt@nt.gov.au 08 8922 0844	
NAFI North	https://www.firenorth.org.au/nafi3/	
Secure NT (Fire Bans)	https://securent.nt.gov.au/alerts	
Fire incident map	https://www.pfes.nt.gov.au/incidentmap/	

Fire Frequency 2000-2019
Fire management risks
- Ignitions (humans and lightning) on or off site resulting in harm to workers and loss of equipment. - Fire scar mapping indicates the exploration area burns approximately every 3 years. - Spread of high fuel load grassy weeds could increase fire intensity, eg gamba, grader and buffel grass, adjacent infrastructure areas and access tracks.



Annual Works Calendar					
Month	Bushfire Risk	Action	Month	Bushfire Risk	Action
Jan	Low	• No fire management activity.	July	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Feb	Low	• Manage vegetation onsite including weeds.	Aug	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Mar	Low	• Planning meeting with neighbour. • Manage vegetation onsite including weeds. • Manage fire break and fire access trail.	Sept	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
Apr	Low	• Manage vegetation onsite including weeds.	Oct	High	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
May	Low	• Manage vegetation onsite including weeds.	Nov	Medium	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.
June	Medium	• Monitor NAFI and visual scan horizon for smoke. • Liaise with neighbour regarding bushfires. • IG bushfire preparedness tool to be utilised daily during periods of fire danger of severe or greater.	Dec	Low	• No fire management activity.

Kyalla 117 N2 Fire Management Zones

Bushfire Management Actions

Infrastructure area	- Remove all vegetation. - Treat emerging vegetation with herbicide. - A permit for open flaring and hot works is required during a declared fire danger period. - Open flaring and hot works are not permitted on total fire ban days without written approval from a fire control officer or fire warden.
Fire management break	Maintain a 10 m wide bare earth loop road around the infrastructure area.
Asset Protection Zone (APZ)	- During operations, establish a 40 m wide APZ around the infrastructure area by removing woody understorey vegetation and achieving a grass height of < 100 mm using the methods prescribed in the <i>Origin Generic bushfire asset protection zone guide</i>. - Maintain grass cover to a height < 100 mm. - Remove vegetation from the 10 m wide fire break around the infrastructure area. Monitor for grassy weeds and control where appropriate. - Ensure a 4m wide fire access trail around the perimeter of the asset protection zone is trafficable by fire fighting appliances. Monitor for grassy weeds and control where appropriate.
Fire access trails	Create and maintain a 4m wide access trail around the perimeter of the asset protection zone by grading or spraying.
Neighbouring Property Fire Management Zone	- Annual fire management planning meeting with neighbouring properties. - Neighbour to advise proponent of planned burns.

Bushfire Preparedness - refer to IG Bushfire preparedness tool

Preparedness Planning	Bushfire First Responder Checklist
Mandatory for all Severe, Extreme and Catastrophic FDI days The following must be reviewed daily. If fire alerts are active or presenting with a known risk (fire in the area), personnel must execute their contingency plans which need to encompass the following: - Procedure on identifying and notifying of a bushfire. - Critical equipment to be removed / isolated / shut down. - Safe evacuation routes from site and muster points. - Communication methods: - Team channels and / or phone numbers. - Area channels and / or phone numbers. - Closest 'Safe Havens' (Community or Origin permanent sites).	The following sequence must be followed by the first person responding to a fire: Danger - Remove yourself and others from danger is safe to do so. Alarm - Raise the Alarm either on common radio channel or other agreed process. Gather information Location - Direction from known reference points, eg roads and Origin infrastructure such as well numbers. Impacts (actual and potential) - Life, property and the environment. Fire Characteristics - Grass or woodlands, flame height, fire front and direction of travel. Weather - Wind strength and direction. Response in Progress - What response is underway and by who (Origin, Landowners or Emergency Services). Response required - Origin and / or Emergency Services. Access - Safe access and egress routes. Notify Origin - Fire officer / Supervisor. Notify Pastoralists - Refer to Property Contacts. Notify Emergency Services - Call "000" or "112" (some mobiles) if Origin and Pastoralists unable to manage situation. Respond - if safe to do so in consultation with Pastoralist. Handover - to the Origin On-Scene Commander / Pastoralist of Emergency Services on arrival. Support - provide ongoing support to the response as appropriate.

Monitoring Routine

- Provide timely advice on changes in level of fire risk as available.
- Monitor team and area common channels for bushfire early warning.
- Update changes in work location.

FIRE MANAGEMENT ZONES

LEGEND

- Existing Access Track
- 4m wide Fire Access Trail
- Infrastructure Area
- 10m wide Fire Break
- Asset Protection Zone
- Neighbouring Property Fire Management Zone

Appendix E Water Extraction Licence

NORTHERN TERRITORY OF AUSTRALIA
LICENCE TO TAKE GROUNDWATER
Pursuant to section 60 of the *Water Act 1992*

Licence No: GRF10285

Licence Holder:	Origin Energy B2 Pty Ltd (ABN 42 105 431 525)		
Address:	PO Box 4095 Darwin, NT, 0801		
Commencement Date:	15 May 2020		
Expiry Date:	31 December 2021		
Water Control District:	Daly Roper Beetaloo Water Control District		
Groundwater Resource:	Gum Ridge Formation		
Management Zone:	Not Applicable		
Water Allocation Plan:	Not Applicable		
Bore(s):	RN041132 and RN041134		
Property(s) on which water is used:	NT Portion 7027 (4500 Carpentaria Hwy, Birdum), NT Portion 1079 (8240 Carpentaria Hwy, Arnold), NT Portion 7026 (14981 Stuart Hwy, Birdum), NT Portion 702 (16965 Carpentaria Hwy, Pamayu)		
Beneficial Use(s) of Water Entitlement	Maximum Water Entitlement ML/year	Security Level	Licence Trading Allowed?
Other (Petroleum Activity)	175	Not Specified	No
Total Maximum Water Entitlement:	175 ML/year		

Terms and Conditions:

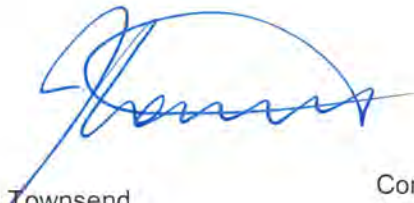
- 1 General Conditions
 - 1.1 The licence holder must comply with the provisions of the Act and all other laws in force in the Territory, including all regulations made under the Act.
 - 1.2 The licence holder can surrender or apply for modification of this licence at any time.
 - 1.3 The Controller may amend, revoke, suspend or modify this licence at any time, as provided for in section 93 of the Act.
 - 1.4 Subject to Conditions 1.2 and 1.3, this licence is in force until the expiry date.
- 2 Water Extraction Conditions
 - 2.1 The licence holder must extract no more than the stated Total Maximum Water Entitlement from the listed groundwater resource.
 - 2.2 Subject to Conditions 2.3 and 2.4, the licence holder must ensure that total extraction from the listed groundwater resource over the Periods specified below does not exceed the following Entitlements:

Period	Entitlement
20 November 2019 to 30 April 2020	80 ML
01 May 2020 to 30 April 2021	175 ML

- 2.3 The licence holder must not extract more than the Monthly Extraction Limit from the listed groundwater resource in any one calendar month.
- 2.4 In at least one Period of every three consecutive Periods, the licence holder must extract from the listed groundwater resource not less than the Minimum Extraction Limit.
- 2.5 If the licence holder contravenes Condition 2.4 and the Controller so requests, the licence holder must provide a written report to the Controller that explains why the Minimum Extraction Limits were not reached and provides a projection of water requirements under this licence for the remaining Term of this licence.
- 2.6 Without limiting the Controller's powers pursuant to s93 of the Act, if the licence holder:
- (a) has contravened Condition 2.4, and
 - (b) the Controller has made a request pursuant to Condition 2.5, and
 - (c) the Controller has considered any report and projection provided by the licence holder,
- the Controller may revoke this licence or reduce the Total Maximum Water Entitlement conferred by this licence.
- 2.7 The Maximum Water Entitlement for each listed beneficial use must be used for no purpose other than that beneficial use.
- 2.8 The licence holder may only extract water under this licence from a bore listed on this licence.
- 2.9 The licence holder must maintain the bores used for extracting water under this licence in accordance with the National Uniform Drillers Licensing Committee 'Minimum Construction Requirement for Water Bores in Australia' as amended.
- 2.10 If the licence holder wishes to extract water under this licence from a bore not listed on this licence, the licence holder may only do so if the Controller has reissued this licence with that bore listed on the licence.
- 2.11 The licence holder may only extract water under this licence for use on a property listed on this licence.
- 2.12 If the licence holder wishes to use water extracted under this licence on a property not listed on this licence, the licence holder may only do so if the Controller has reissued this licence with that property listed on the licence.
- 2.13 This licence does not guarantee that water will be available from the listed groundwater resource at any given time.
- 3 Water Metering and Reporting Conditions
- 3.1 Extraction from the listed groundwater resource must be recorded by a meter or meters supplied, installed and maintained by the licence holder in accordance with the Northern Territory Non-Urban Water Metering Code of Practice for Water Extraction Licences, as amended from time to time.
- 3.2 Within two weeks following the end of each Quarter, the licence holder must supply the Controller with a record of total extraction from each of the listed bore(s) for that Quarter.
- 4 Trading Conditions
- 4.1 The licence holder may only trade the Entitlements under this licence in accordance with a Water Allocation Plan.
- 4.2 The obligations under this licence remain with the licence holder unless and until the Entitlements under this licence are traded in accordance with a Water Allocation Plan.
- 5 Special Conditions
- 5.1 If there is a conflict between the terms and conditions of this licence and the special conditions listed below, the special conditions will prevail to the extent of the inconsistency.
- 5.2 The licence holder may only extract water under this licence for Approved Petroleum Activities.
- 5.3 Before the licence holder commences extracting water from a bore listed on this licence, the licence holder must:
- (a) measure the ground water level in that bore; and
 - (b) undertake a bore test for that bore from which an analysis must indicate a reduction in ground water level is less than one metre at a distance of one kilometre from the relevant bore. The bore test must differentiate bore performance from aquifer performance.
- 5.4 The licence holder must provide a written report to the Controller providing the measurements recorded and the methodology and results of the bore tests conducted in accordance with Special

Condition 5.3. The written report must be provided within 30 days from the date the bore test was complete. The written report must be provided by email to water.regulation@nt.gov.au.

- 5.5 The licence holder must provide a written report to the Controller within forty-eight hours of identifying any contravention of the terms and conditions of this licence, including the special conditions. The written report must set out:
- (a) comprehensive details of the contravention; and
 - (b) how the licence holder proposes to rectify the contravention and prevent the contravention from reoccurring.
- 5.6 The licence holder must have in place an environment management plan to conduct Approved Petroleum Activities, approved by the Minister in accordance with the Petroleum (Environment) Regulations 2016 throughout the Term of this licence. If the environment management plan is revoked, the Controller may, by notice in writing served on the licence holder, revoke this licence or suspend this licence for such period as is specified in the notice.


Joanne Townsend

Controller of Water
Resources

12/5 2020

Definitions

"Act" means the *Water Act 1992* (NT).

"Approved Petroleum Activities" means a petroleum activity or activities which have been approved by the Minister in accordance with the Petroleum Act 1984 and the Petroleum (Environment) Regulations 2016.

"Controller" means the Controller of Water Resources.

"Department" means the Northern Territory Department of Environment and Natural Resources or such other Northern Territory agency which fulfils the same functions from time to time.

"Entitlement" means the amount(s) specified in Condition 2.2.

"Minimum Extraction Limit" means the percentage of the Extraction Limit that is either:

- (a) If a percentage is set out in a relevant Water Allocation Plan, that percentage, or
- (b) Otherwise, 90%.

"Monthly Extraction Limit" means the percentage of the Extraction Limit that is either:

- (a) If a percentage is set out in a relevant Water Allocation Plan, that percentage, or
- (b) Otherwise, 30%.

"Period" means a period of time specified in Condition 2.2.

"Quarter" means each period of 3 months ending on 31 July, 31 October, 31 January and 30 April during the Term (or a part of such a Quarter occurring at the beginning or the end of the Term).

"Registered Bore" means a bore which is identified by a unique registration number and is recorded on the Northern Territory Government Natural Resource Maps at: www.nrmmaps.nt.gov.au.

"Regulations" means the *Water Regulations 1992* (NT).

"Security level" means the order in which announced allocations are applied to licences. E.g. in years when a less than 100% announced allocation is required to ensure that environmental water provisions are satisfied, Low Security licence entitlements are reduced first, then Medium Security entitlements and finally High Security entitlements.

"Term" means the term of this licence commencing on the Commencement Date and expiring on the Expiry Date.

Appendix F Wastewater Management Plan



Beetaloo Exploration WWMP

NT-2050-15-MP-028

THE BEETALOO EXPLORATION PROJECT Wastewater Management Plan

Review record

Rev	Date	Reason for issue	Author	Reviewer	Approver
0	15/06/2019	Released for use	MK	LF	EW
1	26/07/2019	Revised to align with final CoP	Mk	SM	EW
1.1	03/12/2019	Minor update to address DENR comments	MK		MK
1.2	11/02/2020	Minor Updates to include additional wells	RU		MK
1.3	11/02/2021	Minor update to address EPA comments			Mk

Review due: 18/05/2023

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Beetaloo Exploration WWMP

NT-2050-15-MP-028

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Beetaloo Exploration WWMP

NT-2050-15-MP-028

1. Introduction

This Wastewater Management Plan (WWMP) has been prepared to support Origin's Beetaloo exploration program. The WWMP is a mandatory requirement prepared in accordance with the Code of Practice for Petroleum Activities in the northern Territory (referred to herein as "the CoP").

This plan is designed to provide the management strategy for how wastewater will be managed across Origin's Beetaloo exploration project.

The plan will reference the related sections within each various EMP to avoid duplication. The current Environmental Management Plan's (EMP's) covered by this plan are:

- NT-2050-15-MP-025 Origin Energy Beetaloo Kyalla 117 N2 Drilling, Stimulation and Well Testing Environmental Management Plan
- NT-2050-15-MP-032 Origin Energy Beetaloo Velkerri 76 S2 Drilling, stimulation and Well Testing Environmental Management plan
- NT-2050-15-MP-038 Origin Beetaloo Sub-Basin Kyalla 117 N2 Muliwell Drilling, Stimulation and Well Testing EMP

2. Description of activity.

Wastewater, as defined in the CoP, includes the following:

- Drilling fluid, drill cuttings and cement returns
- Flowback fluid: Generated during the well testing phase.
- Completion fluids, kill fluids and well suspension fluids

Wastewater is produced through the following activities:

- **Drilling:** waste drilling fluids are generated as a result of drilling activities. Drilling fluids primary objective is to provide primary well barrier during well construction (unless underbalance drilling is preferred drilling technique) where bottom hole hydrostatic pressure exerted by drilling fluids is used to overbalance formation pore pressure. Drilling fluids are also used to cool the bit and assist in transporting formation cuttings to surface (rock such as shale, mudstone, siltstone etc.). Excess cement when cementing a casing string and waste drill fluids and cuttings are stored in a lined mud sump, tested and either disposed of onsite or disposed of offsite at a licensed waste facility.
- **Stimulation and well testing:** After the completion of hydraulic fracture stimulation, the exploration well is "flowed back" to remove all recoverable injected fluid from the formation. Flowback wastewater is stored in onsite tanks, evaporated and then disposed of offsite at a licenced facility.
- **Completion activities:** Completion fluids, such as kill fluids or well suspension fluids, are used to suppress the formation pressure within the reservoir. The use of these fluids is a form of well control and may need to be removed from the well and disposed of where well interventions are required (i.e. the well may be suspended with fluid post drilling, with the fluid removed prior to completion and stimulation activities

3. Waste Management Framework

Wastewater will be managed with the objective of achieving optimal environmental outcomes and in accordance with the following hierarchy principals:

1. **Avoid:** eliminate the generation of waste through design modification
2. **Reduce:** reduce unnecessary resource use or substitute a less resource intensive product or service.
3. **Re-use:** reuse a waste without further processing
4. **Recycle:** recover resources from a waste
5. **Treatment:** treat the waste to reduce the hazard of the waste prior to disposal
6. **Disposal:** disposal of waste if there is no viable alternative.

It is recognised that the options for avoiding, reducing or re-using wastewater generated during exploration are limited. This is largely restricted to:

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- Maximising the re-use and recycling of drilling fluids during operations; and
- minimising the use of suspension fluids by minimising re-entry activities (i.e. multiple entries into a well requiring fluid to be unloaded).
- Minimise the offsite transportation of flowback through maximisation of evaporation within the designated treatment tanks

The amount of cuttings produced during the drilling activity is dictated by the regional stratigraphy (target zone depth) and lateral length of the horizontal well, whereas the volume of the flowback is a function of stimulation design and number of stages completed during stimulation. There is however an ability to minimise the volume of waste disposed of offsite, through careful waste management and treatment.

4. Wastewater Risk Assessment

The risks associated with wastewater are covered in the risk assessments within each of the Environmental Management Plans.

Detailed assessments of the site-specific risk associated with the disposal of drilling fluids and muds as per condition C.4.1.2 of the Codes of Practice, will be undertaken upon completion of drilling activities.

Geogenic chemical composition of flowback water was sampled as a part of the Amungee Nw-1 H and Shenandoah 1 a hydraulic fracture activity. This data indicates the risk associated with flowback are largely to do with salts- specifically chlorides. The presence of other compounds, such as hydrocarbons and heavy metals are also likely.

The hazards associated with flowback management have been addressed by the Code of Practice and within specific EMP's. Specific controls covered by the Code and EMP's preventing environmental harm include:

- Well operations management plan designed to ensure the risk of the well to surrounding aquifers is mitigated; including the requirement for multiple, verified well barriers containing steel and cement.
- Use of enclosed tanks;
- Use of double lined tanks with leak detection;
- Secondary containment requirements for all pumps and high-risk spill locations;
- Prohibition of wastewater discharges and reinjection;
- Groundwater monitoring bores; and
- Spill management plan.
- Freeboard requirements to accommodate a 1:1000 ARI total wet season

5. Wastewater management overview

A summary of how each wastewater stream is managed to optimise the environmental outcomes is provided in Table 1. An individual description of each wastewater stream is provided in the following section.

5.1 Drilling Fluid and Cuttings

Approximately 750 m³ of solid drilling muds and cuttings and 1ML of drilling fluids will be generated as a result of drilling of each exploration well. Drilling fluids and wastes are saline, polymer/bentonite based material which are stored in line sumps onsite. The primary contaminants associated with drilling fluids and wastes are likely to be from chlorides. All drilling fluids are water-based muds (WBM).

Drilling fluids and muds will be managed in accordance with the following:

- All fluids, muds and cuttings stored in engineered lined Coletanche sumps.
- Sumps will be designed with a 1:1000 ARI freeboard calculated in accordance with the methodology outlined in Appendix C

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- The Maximum Water Level (1.3M wet season and 0.3M dry season freeboard)) will be clearly marked on the side of the sump.
- All lease pads will be fenced to prevent livestock and fauna ingress into open sumps.
- Supernatant liquids will be transferred to lined wastewater storage tanks from the sump upon completion of activity to allow the muds and cuttings contained in lined sump to dry out with liquids evaporated in lined wastewater storage tanks.
- Drilling cuttings and muds may be removed from the sump between wells, or as required to maintain the safe operating level of the sump. Drilling waste material will be stored in pit/sump (in compliance with the Code of Practice) with an impermeable liner with any free water removed to the sump or wastewater tanks. During the wet season, dried drilling muds and cuttings will be covered to prevent rain ingress into the stored area.
- any residual liquids will be transported to a licenced interstate disposal facility (Westrex, Jackson Queensland) with the appropriate interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (NEPM) as implemented under the NT Waste management and Pollution Control Act and Queensland environmental Protection Act 1994..
- Leachability testing of drill cuttings and muds will be undertaken in accordance with Table 10 of the Code of Practice.
- A disposal option assessment will be completed by a suitably qualified person (as outlined in section C.4.1.2), with onsite disposal to land only undertaken where environmental harm will not result from the disposal activities.

5.2 Produced water and Flowback Management

All produce water and flowback fluids will be stored in accordance with the NT Code of Practice for Petroleum Activities.

The volume of flowback generated from the activity is dependent on the number of stages of stimulated, with approximately 20% to 80% fluid recovery expected (based on US ranges). For Origin stage 2 activities, it is anticipated that approximately 9ML of flowback from the stimulation will be generated from each exploration well, with a final offsite disposal figure of approximately 1- 2ML/ E&A well.. Flowback will be highly saline, with a summary of the anticipated quality provided in Appendix A- Table 5 and Table 6

Management controls for flowback implemented during the program include:

- No disposal of flowback wastewater to surface water
- Wastewater stored in above ground tanks
- Tanks to be double lined with built in leak detection.
- All wastewater to be stored in enclosed tanks
- The site will have enough enclosed storage to deal with the total volume of wastewater stored at any time.
- Appropriate venting of enclosed tanks to prevent the build-up of explosive gasses
- Tank design, construction and operation will consider environmental factors, such as wind loading, temperature bushfires and structural integrity.
- All working evaporation tanks will have a minimum freeboard to allow for a 1 in 1000 year average recurrence intensity wet or dry season (depending on which season operations are undertaken in) as calculated in Appendix C;
- Offsite wastewater disposal will be minimised through the treatment of wastewater through evaporation. Evaporation tanks will be used to treat waste water all times; except during periods of significant rainfall.

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- Mechanical evaporators will be used in each tank to increase evaporation to reduce the volume of flowback. Evaporators will be positioned in a manner to avoid offsite drift and have automated wind direction and speed cut-offs.
- When wastewater storage volumes have been reduced onsite and enclosed tank availability permits, enclosed tanks may be converted to open evaporation treatment tanks (noting the requirement to have enough enclosed storage to manage all wastewater onsite at any time)
- The freeboard requirements will be clearly marked on each of the tanks as the Maximum Water Level (MWL).
- All wastewater on location must be able to be transferred into enclosed tanks within 72 hours of becoming aware of a significant rainfall event. This transfer must be completed at least 8 hours prior to the predicted commencement of the significant rainfall event. The determination of a significant rainfall event is provided in section 7.1
- Pumping infrastructure must be available to transfer all wastewater into enclosed storage within 24 hours (noting all wastewater must be transferred 8 hours prior to the onset of the rainfall event). Sufficient pumping redundancy must be available to accommodate pump failures.
- Storage tanks that are connected will be designed to prevent uncontrolled release from multiple tanks.
- Tanks are to be designed and constructed to the relevant Australian Standard (including AS1554.1 and AS3990) with a quality assurance and quality control (QA/QC) plan and installation procedures implemented by the contractor.
- Tanks will be designed to prevent the ingress of stock and fauna, with each exploration site fenced to prevent stock and public access.
- Where drilling sumps are left open with drilling waste and are unattended, fencing will be installed to prevent fauna
- Monitoring of pond levels will be undertaken daily, with management response criteria implemented to prevent tank overtopping. This includes shutting in operations where freeboard requirements cannot be met.
- Residual flowback liquids will be evaporated and transported to a licenced interstate disposal facility (such as, Westrex, Jackson Queensland) with the appropriate interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (NEPM) as implemented under the NT Waste management and Pollution Control Act and Queensland environmental Protection Act 1994.
- When the tanks are decommissioned the associated residual solids, brines and liners are removed and disposed of at an appropriately licensed waste disposal facility by a licenced contractor as per NT Waste Management and Pollution Control Act.
- Daily inspections of all wastewater storages will be implemented during operations.

5.3 Drilling and Completion fluids (suspension and kill fluids)

Drilling and completion fluids (suspension and kill fluids) may be used to maintain bit lubrication and circulation and for well control/ suppress formation pressure. Drilling and completion fluids are likely to have an elevated salinity, with sodium and potassium-based salts being the main compounds.

It is anticipated that up to 0.5-1ML of drilling and completion fluids could be produced per well, with fluids stored in the drill sump or tanks (depending on whether tanks have been installed on site at the stage). The fluids will be evaporated and any residual transported offsite for final disposal at a licenced facility.

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Table 1: Wastewater management summary and implementation plan

Wastewater	Quantity Produced	Properties	Hazards	Implementation Plan					Final Management	Final disposal volume ¹	Alternative Management Options considered
				Storage	Handling	Operational controls	Routine Inspections	Monitoring			
Flowback	7.5 ML per well	Composition influenced by chemical composition of shale formation. Geogenic sourced contaminants include :Salinity (Electrical Conductivity 50,000us/cm-250,000us/cm) with elevated, sodium, chloride, boron, barium and hydrocarbons as per Appendix A.	High salinity wastewater representing a hazard to groundwater, surface water and soils from Chloride dominated salts if released into the environment	•Stored onsite in double lined above ground enclosed tanks and double lined working evaporation Tanks with leak detection. •All tanks have been sized with regards to the 1:1000 average recurrence interval rainfall event as per Appendix C. - maximum water levels (MWL) to be clearly marked on each tank	•Transferred to storage facilities from onsite separators or directly from the well as required under B.4.13.2 (k) of the CoP. •Secondary containment used under all pumps and connections	•Storage volumes of ponds to be monitored daily during operations • Evaporators to be strategically located on or within the boundaries of the pond with drift prevention controls (automated wind direction and speed cut offs) •All wastewater to be transferred into enclosed storage when a significant rainfall event is predicted as per section 7).	•Storage facilities and handling areas inspected Daily during operations •Visual inspections of tanks completed weekly	As per section 6.	Evaporated onsite using fractionating evaporators to reduce final volumes. Trucked offsite to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act waste consignment authority approval.	1-2ML/well	•Due to the saline nature of the material, limited re-use or recycling options exist during exploration. •Treatment using Reverse Osmosis or other mechanical filtration has been considered; salinity and scaling constraint posed by wastewater restricted the use of conventional water treatment •request for proposal (RFP) has been released to identify additional technologies for a potential future trial
Drilling Muds, cuttings and fluids	750m3/well	Saline (KCL and NaCl) polymer/bentonite based drilling fluids with formation cuttings.	KCL and NaCL may represent a hazard in residual drilling muds and cuttings if not segregated prior to disposal. Formation cuttings may contain low level of hydrocarbons, which are likely to be degraded quickly in the open sump.	•Stored onsite in lined drilling sumps with sufficient freeboard to accommodate a 1:1000 average recurrence interval rainfall event as per Appendix C. •Maximum water levels (MWL) to be clearly marked on each tank and sump	•Transferred directly from rig via the shakers into the sump. • Fluid stored in lined tanks as per CoP.	•Storage volumes of sumps to be monitored daily •Material to be dried out after completion of activity, with supernatant fluids evaporated in a separate tank (CoP compliant storage) • Material to be tested prior to determining final disposal requirements	•Sump level to be monitored daily during operations •Sump liner and embankments to be inspected weekly during operations	As per section 6.	•Supernatant fluids will be segregated from muds upon completion of activity and evaporated (in a CoP compliant tank) •Fluids to be transported to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act and related interstate waste consignment authority approval. •Final disposal solution of muds and cuttings to be determine through onsite characterisation and risk assessment by third party. •For onsite disposal, Muds and cuttings to be mixed, buried and covered onsite. •For offsite disposal, material will be transported to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act and related	750m3/well	There are no other viable options currently available in addition to what has currently been considered (offsite and onsite disposal).

¹ Note these values are indicative and the final values are outlined in the respective EMP.

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Wastewater	Quantity Produced	Properties	Hazards	Implementation Plan					Final Management	Final disposal volume ¹	Alternative Management Options considered
				Storage	Handling	Operational controls	Routine Inspections	Monitoring			
									interstate waste consignment authority approval.		
Drilling, completion, suspension and kill fluids	0.5-1ML/well	KCL or NaCl based fluids with a TDS >50,000us/cm	High salinity wastewater representing a hazard to groundwater, surface water and soils from chloride dominated salts if released into the environment	• Stored onsite in the sump and transferred (as required) to the double lined above ground enclosed tanks and Evaporation Tanks with leak detection. • All tanks have been sized with regards to the 1:1000 average recurrence interval rainfall event as per Appendix C. • maximum water levels (MWL) to be clearly marked on each tank and sump	• Transferred to flowback storage facilities directly from well • Secondary containment used under all pumps and connections	• Storage volumes of ponds to be monitored daily during operations • Evaporators to be strategically located on or within the boundaries of the pond with drift prevention controls (automated wind direction and speed cut offs) • All wastewater to be transferred into enclosed storage when a significant rainfall event is predicted as per section 7.1.	• Storage facilities and handling areas inspected Daily during operations • Visual inspections of tanks completed weekly	As per section 6.	Stored in flowback tanks. Evaporated onsite using fractionating evaporators to reduce final volumes. Trucked offsite (if required) to a licenced waste disposal facility (Westrex in QLD) in accordance with NT Waste Management and Pollution Control Act waste consignment authority approval. Currently, it is assumed all drilling wastewater will be evaporated with limited water removed from site.	0-0.5ML	• Due to the saline nature of the material, limited re-use or recycling options exist during exploration. • Treatment using reverse osmosis or other mechanical filtration has been considered; salinity and scaling constrain the use of conventional water treatment • request for proposal (RFP) has been released to identify additional technologies for a potential future trial

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6. Wastewater Monitoring Program

A wastewater sampling program will be implemented to characterise the quality of the wastewater during flowback activities. The monitoring program is summarised in Table 2 below.

Table 2: Minimum Monitoring Requirements

Monitoring Program	Location	Monitoring Requirements	Frequency
Significant rainfall event detection	Each site	Daily review of 8 day total rain forecast as per section 7.1	Daily during wastewater storage
Flowback characterisation	Post separator- prior to entering storage tanks	Electrical Conductivity, pH, temperature and volume of Flowback	Daily for the first 30 days, and weekly thereafter
		Testing samples of Flowback for Analytes listed in Appendix 1	Weekly until the EC level stabilises (<10% change over 4 weeks) and then monthly until practical completion of flowback activities
Stimulation fluid- pre-injection	Post blender, prior to injection	Testing sample of Stimulation Fluid for Analytes listed in Appendix 1	1 sample Pre-injection for each stimulation fluid utilised
Flowback Storage Tanks	Each storage tank	Testing samples of Flowback for Analytes listed in Appendix 1	6 monthly
	Each Storage	Level, estimated evaporation rates	Daily
Drilling Material	Determined by suitably qualified person	Testing samples of drilling cuttings for analytes listed in Table 10 of the Codes of Practice, Naturally Occurring Radiation Material (NORMs) and volume	Prior to disposal
Fauna interactions	Wastewater tanks and surrounding lease area	- Ad hoc Bird and fauna observations and photos to be taken around wastewater tanks - Wastewater tank inspection for bird carcasses - Inspections around area adjacent to lease (within 50m of boundary) - Carcasses present during tank emptying	- Continuous - Daily - Weekly - During final decommissioning

6.1 Sampling Methodology

- Water samples will be collected in accordance with the methodology outlined in Table 3.
- All samples will be collected by appropriately qualified personnel, with all meters calibrated in accordance with the manufacturer's instructions.
- Samples will be collected in laboratory supplied sampling containers and placed in chilled eskies and transported under chain of custody (COC) procedures.
- Analysis will be performed by laboratories with National Association of Testing Authorities (NATA) accredited analysis methodology.

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- Each sample will have a unique identifier that would be cross referenced to the monitoring location and time of sampling. Due to the remote location, samples will be couriered to the laboratory to minimise sample holding time violations.

Table 3 Monitoring program methodologies

Program	Sampling Methodology
Drilling sump characterisation	- National Environment Protection (Assessment of Site Contamination) Measure - AS4482.1- 2005 guide to the investigation and sampling of sites with potentially contaminated soil
Flow back and drilling fluid monitoring	<i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC Guidelines).</i> <i>AS/NZ5667.1: 1998. Water Quality Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples</i>

7. Wastewater storage management response criteria

To minimise the risk of overtopping a tank or sump, the criteria outlined in Table 4 will be implemented when hydraulic fracturing wastewater is stored onsite.

Table 4 Wastewater storage management response criteria

Monitoring program	Criteria Description	Criteria	Criteria Response
Significant rainfall event	Significant rainfall event predicted.	The 4-day total rainfall exceeds 300mm within the 8-day forecast	All flowback fluid must be transferred to enclosed storage at least 8 hours prior to the predicted commencement of the significant rainfall event.
Wastewater tank level monitoring	Enclosed storage level exceedance	The total volume of hydraulic fracturing wastewater stored onsite exceeds the available closed/covered tank storage capacity	Flowback activities to cease, unless authorised by DENR to continue operations. Origin to provide written notification to DENR within 48 hours of exceedance, along with the proposed plan to return back into
Drilling sump level monitoring	Drilling sump storage level exceedance	The total volume of drilling wastewater exceeds the freeboard capacity of the drilling sump, with no additional storage available within other onsite tanks.	Drilling wastewater disposal activities to cease, unless authorised by DENR to continue operations. Origin to provide written notification to DENR within 48 hours of exceedance, along with the proposed plan to return back into compliance

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7.1 Significant rainfall events

The 8-day Bureau of Meteorology 4-day total rain forecast (<http://www.bom.gov.au/jsp/watl/rainfall/pme.jsp>) shall be reviewed daily to identify periods of significant rainfall. Significant rainfall is defined in this WWMP is for an event where greater than 300mm of total rainfall is predicted over a 4-day period. This type of rainfall level is consistent with that from a significant rainfall event; such as a monsoonal trough, tropical low or a cyclone.

Commencement time to transfer the flowback fluid will be selected to ensure that it is completed at least 8 hours prior to the predicted commencement of the significant rainfall event.

8. Waste transportation and disposal

All wastewater transport providers will be licenced under the NT *Waste Management and Pollution Control Act*.

All wastewater will be transported interstate to a licenced waste storage and treatment facility. Westrex at Jackson Queensland is the current default option for wastewater disposal, with other interstate disposal locations available. The transportation of wastewater between states/territories, will require an Interstate waste transport consignment authority as per the National Environmental Protection (Movement of Controlled Waste Between States and Territories) Measure 1998 (NEPM) as implemented under the *NT Waste Management and Pollution Control Act* and relevant accepting state/territory (such as the Queensland *Environmental Protection Act 1994*).

All wastewater storage and treatment facilities will be licenced as per the relevant accepting state/territory (such as the Queensland *Environmental Protection Act 1994*).

9. Waste Tracking and Reporting

The movement of wastewater will be tracked in accordance with the following:

- i. Volumes of wastewater produced from the well;
 - ii. Volumes of wastewater transferred into each tank;
 - iii. Estimates for evaporation rates from each tank updated weekly;
 - iv. Volumes of wastewater reused: and
 - vi. Volumes of water removed from site (whether by vehicle or pipeline).
- Wastewater tracking will be documented and available upon request
 - Offsite wastewater tracking must be in accordance with tracking requirements of listed wastes as per the *Waste Management and Pollution Control Act*, the National Environmental Protection (Movement of Controlled Waste Between States and Territories) Measure 1998 (NEPM) and (where relevant) the *Radiation Protection Act*.
 - Wastewater tracking documentation must be reported to the Minister at least annually in the annual environmental report for the relevant EMP.

10. Fauna interactions

The risk of interactions of fauna, including birds, with wastewater storages is anticipated to be low based on the following:

- All wastewater is saline, reducing the palatability of wastewater. Literature confirms fauna are unwilling to drink high saline water, reducing the potential exposure to wastewater.
- Noise from flaring and equipment likely to deter bird and bat activity during well testing activities (the main period water is stored onsite)
- Wastewater tanks have vertical walls with no clear access points for fauna
- Site is fenced to prevent livestock and fauna access to site- mud sump to have cattle panels with mesh installed when not operational
- Wastewater tanks do not contain tailings beaches or perches, reducing the ability for most birds to land and drink from tanks
- Site will be manned during well testing operations

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In addition to the preventative controls outlined above, additional controls will be implemented to detect and respond to fauna mortality events. These include:

- Detect
 - o Specific monitoring of fauna interactions with wastewater storages will be undertaken in accordance with Table 2. This will include routine inspections of wastewater storages and surrounding areas for fauna mortality, as well as motion triggered cameras to collect fauna presence data.
- Respond
 - o Fauna trapped in wastewater storages will be removed, with individual animals sent to fauna carers for rehabilitation.
 - o Where ongoing fauna mortalities are clearly associated with wastewater storage activities, fauna deterrents shall be utilised to prevent future exposure (such as bird deterrents, netting, increased fencing). This will be implemented in consultation with DENR. Ongoing bird or fauna mortality is defined as >7 carcasses per week for 2 consecutive weeks or >1 endangered fauna species.

11. Measurement Criteria

The following measurement criteria have been developed to demonstrate the risks associated with wastewater storage are reduced as low as reasonably practicable:

- Zero wastewater tank overtopping events
- No offsite releases of wastewater
- No reportable spills of wastewater

12. Incident Reporting

The reporting of incidents shall comply with the *Petroleum (Environment) Regulations* and *Waste Management and Pollution Control Act* and *Waste Management and Pollution Act 1998*.

12.1 Reportable Environmental Incident Reporting

The *Petroleum (Environment) Regulations* define a reportable incident as an incident arising from a regulated activity that has caused, or has the potential to cause, material environmental harm or serious environmental harm as defined under the *Petroleum Act*.

An interest holder must notify (this may be oral or in writing) DENR of a reportable incident as soon as practicable but no later than two-hours after the first occurrence of the incident or after the time the interest holder becomes aware of the incident.

DENR can be notified through the DENR Onshore gas non-compliance hotline on 1800 413 567.

Any verbal report to DPIR must be followed up by a written report from the Project Manager within three days in accordance with the *Petroleum (Environment) Regulations*.

12.2 Recordable incidents

The *Petroleum (Environment) Regulations* define a recordable incident as an incident arising from a regulated activity that:

- I. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or
- II. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or
- III. Is inconsistent with an environmental outcome specified in the current plan for the activity; and

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IV. Is not a reportable incident.

An interest holder must notify (this may be oral or in writing) DPIR of a recordable incident as soon as practicable but no later than 15-days after the reporting period (agreed period or each 90-day period after the day on which the EMP is approved).

12.3 Waste Management and Pollution Control Act incident reporting

In accordance with the WMPC Act, where contaminants or waste is not confined within the land on which the petroleum activities are undertaken (i.e. the approved disturbance areas where the petroleum activity is occurring), Origin will notify the regulator of incidents causing or threatening to cause pollution as soon as practicable, but no later than 24 hours after becoming aware of the incident.

A notifiable incident is defined as an incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm.

A notification must include:

- (a) the incident causing or threatening to cause pollution;
- (b) the place where the incident occurred;
- (c) the date and time of the incident;
- (d) how the pollution has occurred, is occurring or may occur;
- (e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
- (f) the identity of the person notifying

The notification shall be made to the NT EPA Pollution Hotline 1800 064 567.

13. Emergency Response

An Emergency Response Plan (NT-2050-15-MP019) has been developed covering the proposed activities within the EMP. The ERP provides a broad framework for managing potential emergency incidents to minimise the potential risk to human safety and the environment. The ERP should be referenced for any emergency response activities.

Spills must be reported to the Minister in accordance with the requirements of spill management plan (NT-2050-15-MP-027 and Reportable and Recordable incidents of the Petroleum (Environment) Regulations.

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Appendix A Amungee Nw-1 flowback characteristic summary

Table 5 Anticipated flowback quality of the Velkerri formation based on Amungee NW 1 flowback results.

Parameter	Flow back levels
BTEX compounds	BTEX levels are anticipated to be low ranging between 2 and 15 µg/L.
Total nitrogen (as N)	Maximum value of 62.1mg/l observed within flow back.
Salinity (TDS)	Saline with total dissolved solids level exceeding 49,000mg/L
pH	Slightly acidic with a median value of 6.74
Major ions	Predominantly Na and Cl dominated. Bicarbonate present at levels consistent with stimulation fluid.
Dissolved metals	Barium and Boron are the main metal elements anticipated to be present at elevated levels. Maximum levels of 80.1 mg/L for Barium and 54.5mg/l for Boron were recorded during the Amungee NW 1 flowback . Lower level of other metals such as Arsenic and Manganese were observed, with maximum concentration of 0.084mg/l and 3.09 mg/L respectively .
Polycyclic Aromatic Hydrocarbons	Expected to be below detection level
Petroleum Hydrocarbons	All fractions of TPH are anticipated to be elevated.
Phenolic Compounds	Low level of phenolic compounds expected, with only Phenol (max 4µg/L) and 3- & 4- methylphenol (max 11.3ug/L)
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 12.4Bq/L and 18.3Bq/L were recorded in the Flowback of offset wells. The primary component being Radium-226.

Table 6: flowback quality based on Kyalla 117 N2-1 flowback results

Parameter	Flow back levels
BTEX compounds	Total BTEX levels in the flowback ranged between 63 and 190 µg/L
Total nitrogen (as N)	Maximum value of 180mg/l observed within flowback
Salinity (TDS)	Saline with total dissolved solids level from 120,000- 290,000mg/L
pH	Slightly acidic with a median value of 6.54
Major ions	flowback predominantly Na and Cl dominated, with elevated levels of calcium and magnesium
Dissolved metals	All detected dissolved metal concentrations within the flowback were low, with the exception of Barium (1029mg/L), Gallium (290mg/l) and Strontium (279mg/l)

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Parameter	Flow back levels
Polycyclic Aromatic Hydrocarbons	All values in the flowback below laboratory Limit of Reporting (LOR),
Petroleum Hydrocarbons	All fractions of TPH are anticipated to be elevated, with Total Petroleum Hydrocarbon levels likely to range from 25mg/l – 150 mg/l)
Phenolic Compounds	Low level of phenolic compounds detected in flowback with phenol and phenol compounds <3ug/
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 36.2Bq/L and 97Bq/L encountered in the flowback, the anticipated source is likely to be Radium-226

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Appendix B Wastewater monitoring analyte list

Parameter	Reporting Units	Limit of Reporting	Method
Physical Parameters			
Electrical Conductivity (EC)	us/cm	1	Field
Total Dissolved Solids (TDS)	mg/L	10	APHA 2540C
Total Suspended Solids (TSS)	mg/L	5	APHA 2540C
pH		0.1	Field
Sodium Adsorption Ratio	ratio	0.01	APHA 4500 Ca, Mg, Ca, NA
Temperature	°C	0.1	Field
Nutrients			
Nitrate	mg/L	0.01	APHA VC13
Nitrite	mg/L	0.01	APHA 4500 NO2
Total Nitrogen	mg/L	0.1	APHA 4500 NORG
Total Kjeldahl Nitrogen	mg/L	0.1	APHA NORG/TKN
Ammonia	mg/L	0.01	APHA NH4
Reactive Phosphorous	mg/L	0.01	APHA 4500P
Total Phosphorous	mg/L	0.01	APHA 4500P
Anions			
Sulfate	mg/L	1	APHA 4500-SO4-C
Chloride	mg/L	1	APHA 4500-Cl-C
Carbonate	mg/L	1	APHA 2320 B
Bicarbonate (as CaCO3 equivalent)	mg/L	1	APHA 2310 B
Bicarbonate Alkalinity (as CaCO3 equivalent)	mg/L	1	APHA 2320 B
Hydroxide Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Total Alkalinity (as CaCO3 equivalent)	mg/L	0.01	APHA 2320 B
Fluoride	mg/L	0.1	APHA 4500 F-C
Bromide	mg/L	0.01	APHA 4110B
Major Cations			
Sodium	mg/L	1	APHA 4500 Na
Magnesium	mg/L	1	APHA 4500 Mg
Potassium	mg/L	1	APHA 4500 K
Calcium	mg/L	1	APHA 4500 Ca

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Parameter	Reporting Units	Limit of Reporting	Method
Metals and Metalloids (total and dissolved)			
Aluminium	mg/L	0.001	USEPA 6010 ICP/AES
Antimony	mg/L	0.001	USEPA 6010 ICP/AES
Arsenic	mg/L	0.001	USEPA 6010 ICP/AES
Barium	mg/L	0.001	USEPA 6010 ICP/AES
Beryllium	mg/L	0.001	USEPA 6010 ICP/AES
Boron	mg/L	0.001	USEPA 6010 ICP/AES
Bromide	mg/L	0.001	USEPA 6010 ICP/AES
Cadmium	mg/L	0.001	USEPA 6010 ICP/AES
Chromium	mg/L	0.001	USEPA 6010 ICP/AES
copper	mg/L	0.001	USEPA 6010 ICP/AES
iron	mg/L	0.001	USEPA 6010 ICP/AES
Lead	mg/L	0.001	USEPA 6010 ICP/AES
Manganese	mg/L	0.001	USEPA 6010 ICP/AES
Mercury	mg/L	0.001	USEPA 6010 ICP/AES
Molybdenum	mg/L	0.001	USEPA 6010 ICP/AES
nickel	mg/L	0.001	USEPA 6010 ICP/AES
Selenium	mg/L	0.001	USEPA 6010 ICP/AES
Silica	mg/L	0.1	USEPA 6010 ICP/AES
Silver	mg/L	0.001	USEPA 6010 ICP/AES
Strontium	mg/L	0.001	USEPA 6010 ICP/AES
Thorium	mg/L	0.001	USEPA 6010 ICP/AES
Tin	mg/L	0.001	USEPA 6010 ICP/AES
Uranium	mg/L	0.001	USEPA 6010 ICP/AES
Vanadium	mg/L	0.001	USEPA 6010 ICP/AES
Zinc	mg/L	0.001	USEPA 6010 ICP/AES
Naturally Occuring Radioactive Material.			
alpha radiation	Bq/L	0.05	ASTM D7283-06
beta radiation	Bq/L	0.05	ASTM D7283-06
BTEX			
Benzene	µg/L	1	USEPA 5030/8260 HS or P&T/GC/MS
Toluene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Ethylbenzene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
M and P Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS

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Parameter	Reporting Units	Limit of Reporting	Method
O Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Total Xylene	µg/L	2	USEPA 5030/8260 HS or P&T/GC/MS
Hydrocarbons			
TRH C6 - C10	µg/L	20	USEPA 5030/8260 HS or P&T/GC/MS
TRH C6 - C10 less BTEX	µg/L	20	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C10 - C16 less Napthalene	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C16 - C34	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
TRH >C34 - C40	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
Total TRH C6 - C40	µg/L	100	USEPA 5030/8260 HS or P&T/GC/MS
Polycyclic Aromatic Hydrocarbons			
3-Methylcholanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
7, 12-Dimethylbenz(a)anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Acenaphthylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) pyrene	mg/L	0.0005	USEPA 3510/8270 GC/MS
Benzo (b) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (ghi) perylene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (k) fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Benzo (a) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Chrysene	mg/L	0.001	USEPA 3510/8270 GC/MS
Dibenz (ah) anthracene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluoranthene	mg/L	0.001	USEPA 3510/8270 GC/MS
Fluorene	mg/L	0.001	USEPA 3510/8270 GC/MS
Indeno (1,2,3-cd) pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Napthalene	mg/L	0.001	USEPA 3510/8270 GC/MS
Phenanthrene	mg/L	0.001	USEPA 3510/8270 GC/MS
Pyrene	mg/L	0.001	USEPA 3510/8270 GC/MS

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Beetaloo Exploration WWMP

NT-2050-15-MP-028

Parameter	Reporting Units	Limit of Reporting	Method
Carcinogenic PAHs (benzo[a]pyrene equivalents)	mg/L	0.001	USEPA 3510/8270 GC/MS
Total PAH	mg/L	0.0005	USEPA 3510/8270 GC/MS
Volatile Organic Compounds			
2,3,4,6-Tetrachlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4,5-Trichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4,6-Trichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dimethylphenol	µg/L	1	USEPA 3510/8270 GC/MS
2,4-Dinitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
2,6-Dichlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Chlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Methyl-4,6-dinitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
2-Nitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
4-Chloro-3-methylphenol	µg/L	1	USEPA 3510/8270 GC/MS
4-Nitrophenol	µg/L	1	USEPA 3510/8270 GC/MS
Dinoseb	µg/L	1	USEPA 3510/8270 GC/MS
Formaldehyde	µg/L	1	USEPA 3510/8270 GC/MS
Hexachlorophene	µg/L	1	USEPA 3510/8270 GC/MS
m- and p-Cresol	µg/L	1	USEPA 3510/8270 GC/MS
Pentachlorophenol	µg/L	1	USEPA 3510/8270 GC/MS
Phenol	µg/L	1	USEPA 3510/8270 GC/MS
Organic Carbon			
Dissolved Organic Carbon	mg/L	1	APHA 5310 B
Total Organic Carbon	mg/L	1	APHA 5310 B

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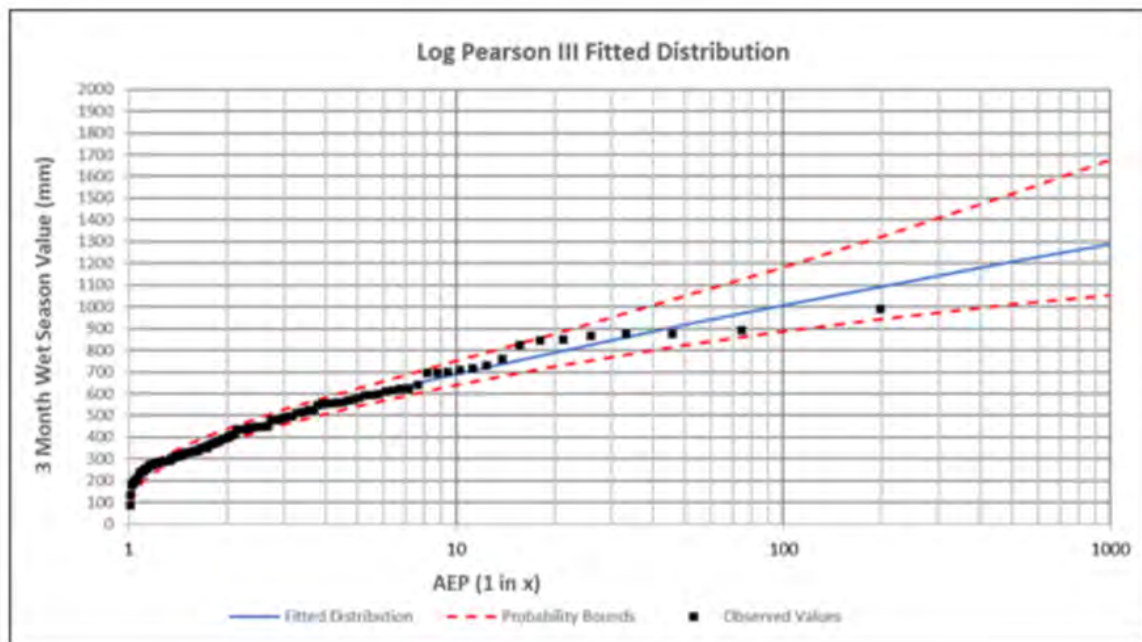
Appendix C 1:1000 ARI Calculation

Monthly rainfall totals were analysed from the Scientific Information for Land Owners (SILO) data for to interpolate rainfall data from 1900 to the present day. Consistent with industry accepted methodology associated with practices (such as dam risk assessments which calculates the wet season based on your geographical location) a 3 month time period was determined applicable.

The highest 3 month rainfall period during the wet and dry seasons was predicted for every year from 1900 till 2018. These values were then used to fit a Log Pearson III distribution to the data to allow us to extrapolate to the 1000 year, 3 month duration wet season (1) and 3 month dry season (figure 2). This method is consistent with the *Australian Rainfall & Runoff* methodologies. The median 1 in 1000 year 3 month wet season is 1289mm and 3 month dry season is 300mm. These figure does not include any evaporation and are therefore considered extremely conservative.

Based on the assessment, a 1300mm wet season and 300mm dry season freeboard will be applied to all open sumps and tanks.

Figure 1 Log Pearson determination of 1:1000 Wet Season ARI.

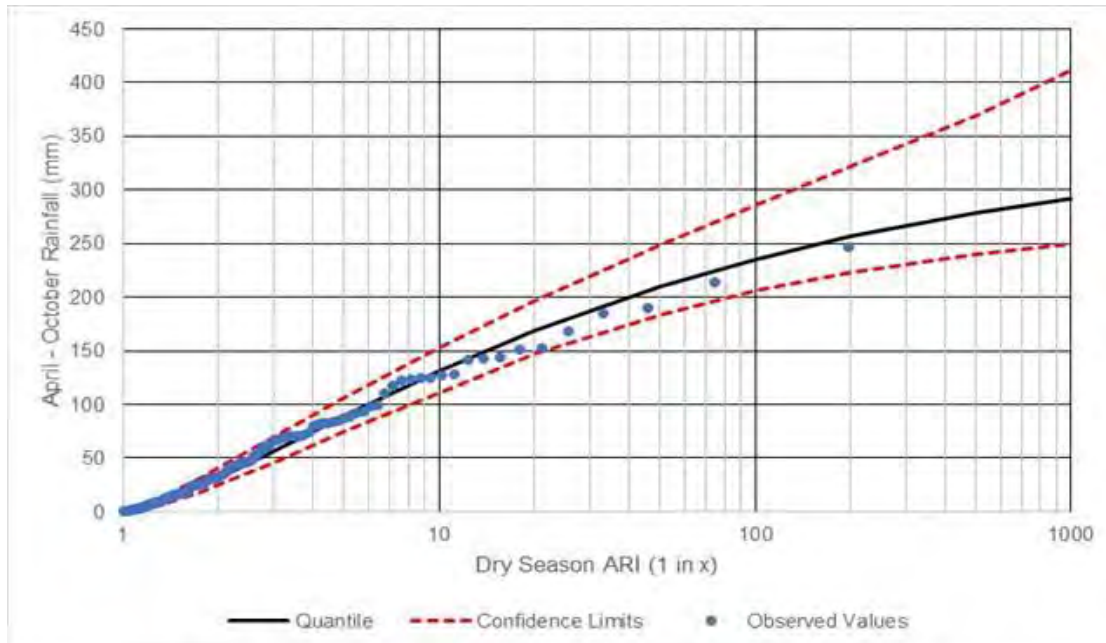


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Figure 2 Log Pearson determination of 1:1000 Dry Season ARI.



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Appendix G Well Operation Management Plan Requirements

B.4.1 Well Integrity Management		
B.4.1.1 Principles		
Monitoring and maintenance is required to preserve the well and its equipment in a suitable condition for their useful life. Well integrity management systems aim to ensure the wells meet operational availability and well integrity goals for the entire well lifecycle, as shown in Figure 1.		
Wells are designed to be operated such that the following are achieved: (a) well integrity is maintained at all times and barriers meet the requirements described in section B.4.3 of this Code; (b) their well integrity is validated through a well integrity testing program; (c) well barrier status is known and technical integrity risks are managed; (d) the well operating envelope is not exceeded; and (e) all materials and equipment installed in a well must maintain well integrity for the lifespan of its intended use.		
B.4.1.2 Mandatory Requirements	Origin Implementation	WOMP Reference
(a) The interest holder must be able to demonstrate that they have a system or process for managing well integrity throughout the whole well life cycle that complies with ISO 16530- 1:2017 Well integrity - Part 1: Life cycle governance. This system or process must include a well integrity management system.	Well to be designed and constructed as per the Origin Well Design and Delivery Process (WDDP) in conjunction with Origin internal design standards. Wells are managed as per Origin Well Integrity Management Plan (WIMP) and in compliance with ISO 16530-1:2017 Well integrity - Part 1: Life cycle governance Life Cycle Phases include: Basis of Design, Design, Construction, Operation, Intervention & Abandonment Elements covered include: Well integrity (management & policies), risk assessment, organisation structure, well barrier, performance standards, well barrier verification, reporting & documentation, MOC, Continuous improvement/Auditing/Learnings	6.1 Well Design Process 6.2 Casing Design 8 Barrier Analysis 9 Risk Management 12 Well Integrity Management System Appendix G
(b) In order to continue operating a well which has, or is believed to have, a compromised well barrier, a risk assessment must be conducted in line with the interest holder's risk assessment process and where required remediation action undertaken.	OE standards require dual barriers. Any deviations require a risk assessment to demonstrate ALARP. Remediations are to be conducted where required and in accordance to OE well failure model.	
(c) A well integrity testing and validation program must be established for all wells, that includes:		

i. subsurface integrity testing (SIT);	All subsurface barriers are validated during well construction and identified in the Well Acceptance Criteria (WAC). WAC are holding points in the program and must be accepted prior to moving onto the next operation.
ii. well integrity and well barrier validation requirements in accordance with this Code	
iii. a minimum testing frequency for wells in the operational phase of their lifecycle that is commensurate with well's well integrity risks as per the accepted WOMP; and	Well monitoring will be conducted in accordance to Origin's WIMP. Routine Operational Inspections: During each operational Visit Mandatory Inspections: 6 Monthly
iv. triggers for well integrity testing based on:	Well integrity barriers are tested when potential failures may be suspected or when known changes to the well barrier/operational envelope have occurred
a. well integrity monitoring; and	
b. substantive changes to well barriers or well operating envelope.	
(d) Casing and tubing wear due to corrosive fluids and erosion should be assessed throughout the well life cycle and its impact on well integrity.	All produced fluids (gas/liquids) are analysed for corrosive attributes to understand the impact on well integrity for the life cycle of the well. Whilst still in exploration, corrosion coupons are implemented to access the rate of corrosion on the material selection of tubulars and wellheads

B.4.2 Aquifer protection		
B.4.2.1 Principles		
Protection of aquifers is an integral consideration in petroleum well design.		
Developing a mechanical reactive barrier for a petroleum well involves the following: (a) definition or specification of a barrier; (b) understanding of causes of failure; (c) asking what signals could be monitored to help predict a failure; and (d) asking what signals could be monitored to help detect a failure.		
The protection of aquifers requires the following to be achieved: (a) well-defined stratigraphic definition to the base of the deepest recognised aquifer in the local area prior to drilling; (b) aquifers must be considered during the well design process and interest holders must include the design of aquifer isolation in their WOMP; (c) all aquifers in the area must be isolated from the surface and each other and any hydrocarbon bearing zones using appropriate barriers, in accordance with section B.4.3.2 of this Code; (d) groundwater quality monitoring conducted in accordance with section B.4.17 of this Code; and (e) drilling fluids must be designed to minimise environmental harm, in accordance with section B.4.10.2 of this Code.		
B.4.2.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Casing setting depth must be selected to protect resources including aquifers in accordance with section B.4.3.2 of this Code.	Each identified aquifer is isolated via a casing string and annular cement to surface. Casing points for the top hole are selected to provide isolation of the different aquifers from each other and from the reservoir. Data collected from offset water monitoring bores are utilised to plan casing points for top hole sections.	6.2 Casing Design 6.5 Cementing Program 10.4 Aquifer Protection 12. Well Integrity Management System
(b) All aquifers, in the area must be isolated from each other and from the surface and any permeable hydrocarbon bearing zones by appropriate well barriers, in accordance with section B.4.3 of this Code.	All identified aquifers are isolated in the top hole sections of the well. Anthony Lagoons (Aquifer) isolated behind conductor casing and cement Gum Ridge (Aquifer) isolated behind surface casing and cement Target hydrocarbon bearing reservoir is isolated behind intermediate and production casing/cement	

(c) Primary cementing design and validation must be carried out in accordance with the interest holder's well operations management plan and in accordance with B.4.7 of this Code.	Cement modelling - lab testing to meet Final cementing program to be prepared Validation metrics outlined in Well Barrier Diagrams	
(d) Monitoring of barriers and casing condition must be carried out in accordance with the interest holder's well operations management plan and in accordance with B.4.1 of this Code.	Barriers are verified during well construction as per the program WACs, this includes mechanical integrity testing of production casing and annular cement verification in the intermediate and production hole sections. On going monitoring of annular pressures conducted as per the OE WIMP.	
(e) If aquifers of environmental value are discovered during drilling that were not identified prior to commencement of drilling notification to the Minister is required under r23 of the PER. This notification should identify whether or not environmental values of the aquifer have been adequately addressed under the EMP and whether or not the EMP requires revision under r17.	Will be complied with if circumstances arise. Control water monitoring bores drilled within 100m of the petroleum bore reduce the likelihood of this occurrence.	

B.4.3 Well design and well barriers		
B.4.3.1 Principles		
Petroleum wells are designed and constructed such that:		
(a) well objectives are met;		
(b) well barriers are designed to prevent unintentional influx, crossflow to other formation layers and outflow to the external environment;		
(c) barrier envelopes are designed such that failure of one barrier should not lead to an uncontrolled release of formation fluids (blowout or cross-flow);		
(d) testing and acceptance requirements specified in the WOMP are satisfied;		
(e) wells can be monitored and maintained to contain and control well fluids, provide structural support and otherwise retain well integrity throughout all reasonably anticipated well construction and production load conditions – which may occur during the life of the well; and		
(f) zonal isolation between different aquifers, and between hydrocarbon bearing zones and aquifers is achieved.		
B.4.3.2 Mandatory requirements	Origin Implementation	WOMP Reference
Wells must be designed such that:		6.2 Casing Design 6.5 Cementing Program 6.12 Well Suspension Program 6.13 Pressure Testing and Well Control 6.15 Well Decommissioning 10.3 Well Control Equipment Appendix B - Well Barriers
(a) casing setting depths and cement isolate aquifers and hydrocarbon bearing zones;	Each identified aquifer is isolated via a casing string and annular cement to surface. Casing points for the top hole are selected to provide isolation of the different aquifers from each other and from the reservoir. Data collected from offset water monitoring bores are utilised to plan casing points for top hole sections. Casing and cement integrity are tested and verified for hole sections that land in the target reservoir formations prior to hydraulic fracturing activity	
(b) unless paragraph (c) applies, they are constructed, maintained and decommissioned in such a manner that it can be demonstrated there are at least two verified well barriers between:		
i. a hydrocarbon bearing zone and aquifers and the surface; and	A 4 string well design is implemented for wells in the Kyalla SRR, which provide a minimum of 2 well barriers between hydrocarbon bearing zone, aquifers and the surface	
ii. deep, saline water bearing formations and aquifers/the surface.		
(c) where one or more of the following circumstances applies, less than two verified barriers may be provided:		

i. during top hole or surface hole drilling where shallow hydrocarbon or water flow risk has been assessed as being negligible;	Regional study and assessment indicate a low risk of shallow hydrocarbon/water flows within the Kyalla fairway
ii. during diverter drilling;	Risk assessed as required
iii. during well decommissioning when two formations need to be isolated from one another and two barriers are not feasible, and a continuous cement plug extending minimum 50m above to 50m below the interface is placed instead; or	A continuous cement plug may be placed across all shallow aquifers inside the production casing during decommissioning.
iv. in other circumstances during well life cycle activities when a risk assessment demonstrates that the same level of risk can be achieved as if two verified barriers were in place.	Risk assessed as required
(d) they are constructed, maintained and decommissioned in such a manner that it can be demonstrated that all aquifers are isolated from each other and the surface by a minimum of one verified well barrier;.	Each operation must meet OE program Well Acceptance Criteria, which prescribe the well barrier elements and validation requirements. The wells are designed in such a manner that annular pressures can be monitored for the life of the well to confirm well integrity
(e) installation of BOP equipment is provided for;	Wellheads designed for allowance of BOP once top hole section is complete
(f) well control is maintained during all well activities;	See Well Barrier Diagrams and Risk Assessment
(g) fit for purpose casing weight and grade are used, having regard to casing corrosion risk and connection suitability;	Mechanical earth models, particularly pore pressure and fracture gradients are utilised in modelling and selecting fit for purpose casing weight and grades for each hole section. Premium connection are implemented for intermediate and production string sections
(h) specific requirements for well construction materials are included in the design;	Corrosion analysis will be undertaken throughout the exploration phase to characterise the gas composition and analyse corrosion rates. Well operating life is assessed annually and decommissioned early if required.
(i) minimum casing centralisation standards in section B.4.7.2 of this Code are met;	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved

(j) engineered cement slurries and appropriate cement placement techniques are part of the design;	Engineered cement slurries designed accommodate the foreseeable load conditions for the life of the well. Laboratory test/modelling will include at a minimum slurry density, rheology, thickening time, free water, fluid loss (if required), and compressive strength development with time. In addition 3D simulation will be conducted for accurate displacement volume, Rotation of casing while cementing to be conducted to enhance uniform cement sheath in the horizontal wellbore	
(k) petroleum fluids produced from the well do not crossflow to aquifers; and	4 string well design and validated barriers prevent cross flow of petroleum fluids to aquifers	
(l) wherever drilling fluid is being used as a primary barrier, sufficient reserves of drilling fluid and supplies of drilling fluid materials shall be available at the well site for immediate use so that the well can be maintained full of drilling fluid.	Sufficient reserves are kept on location 10% contingency in addition to reserves to accommodate a 1 bbl/m dilution factor and sufficient weight agents on location to increase mud weight by 0.5 ppg for the entire active system	

B.4.5 Working with hydrogen sulfide (H2S)		
The scope of this section B.4.5 covers any well location where H2S is expected to exceed 10 ppm (by volume) in the breathing zone.		
B.4.5.1 Principles		
Hydrogen sulfide (H2S) is classed as a hazardous substance and a dangerous good that is sometimes found in fluids encountered in oil and gas producing and gas processing operations. The interest holder is responsible for ensuring that suitable operational practices are in place to manage the risks associated with H2S.		
H2S management practices include:		
(a) characterisation of the probability and concentration levels of H2S that may be encountered; and		
(b) the safe handling of any H2S encountered during well operations.		
B.4.5.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) On detection in exploration wells or appraisal wells, or where there has been regional evidence of H2S, a review of reservoir and offset well data must be carried out for a well, or campaign of wells in the same reservoir, to determine the probability and concentration levels of H2S.	N/A - H2S not expected	N/A
(b) As hydrogen sulfide is classed as a hazardous substance a risk assessment must be conducted and recorded for all work activities where personnel may be exposed to the substance.		
(c) Prior to operations in an H2S environment, an H2S management plan must be developed that is consistent with API RP49, Recommended Practices For Safe Drilling Of Wells Containing H2S.		
(d) All drilling contractors and service companies involved in well site operations must be notified of predicted H2S levels and temperatures.		
(e) A flare system must be provided to safely collect and burn H2S gas during well control or well test operations. Flare lines must be located as far away from the well as reasonably practicable.		

(f) For operations where H₂S is predicted, continuous H₂S monitoring equipment shall be installed, which is capable of continuously measuring and displaying the concentration of H₂S in ambient air. H₂S gas detectors must be available for personnel working in a known high risk zone when H₂S is present or predicted in any quantity. A H₂S alarm setting of 5 ppm must be used for personal, portable and fixed detectors.		
(g) Personnel are to be provided with personal protective equipment to prevent exposure to H₂S if the work area concentration of H₂S are expected to exceed or are found to exceed 10 ppm (by volume) 8-hour time weighted average or 15 ppm (by volume) as a short term exposure level . Personnel safety provisions do not apply when the atmospheric concentration of H₂S could not exceed 10 ppm (by volume) in the breathing zone.		
(h) For H₂S operations, equipment and materials shall be selected on the basis of resistance to sulfide stress cracking and corrosion where the partial pressure of H₂S gas exceeds 350 Pa (0.05 psi), or 70 kPa (10 psia) in sour crude systems.		
i. If it is proposed to use a material which is intended for 'non H₂S service', a risk assessment and supporting data must be conducted to demonstrate the integrity of equipment or materials over the following timeframes:		
a. during a single temporary exposure to sour reservoir fluids (e.g. circulating out a kick, or if there is a leak in the test string while production testing) or,		
b. in the time between exposure to sour reservoir fluids and completion of evacuation of the well site in the event of uncontrolled total displacement of the well contents by such fluids.		
ii. If operations on a well are suspended then the effects of H₂S over the suspension period must be considered.		
(i) Elastomers, packing and other non-ferrous parts exposed to H₂S must be resistant at the maximum anticipated temperature of exposure.		
(j) A drilling fluid program must include the use of an H₂S scavenger to remove any H₂S from the drilling fluid.		

(k) When coring operations are conducted in possible H2S bearing zones, the wearing of breathing equipment and testing for H2S using hand held sensors must be used for the final 10 stands, and must continue while retrieving the inner core barrels, opening the core barrels and examining the cores. Prior to transportation, cores must be sealed and marked to indicate the presence of H2S.		
(l) If H2S in the gas phase is predicted during well test operations, H2S concentration must be monitored at first hydrocarbons to surface and at regular intervals throughout the test.		
(m) If H2S levels exceed original design assumptions or cannot be controlled by the resources available on the rig, then the well must be shut-in. The well must remain shut in until such a time as the level of H2S readiness is increased such that operations can continue safely.		

B.4.6 Casing and tubing		
B.4.6.1 Principles		
The casing program should be configured to accommodate all identified sub-surface hazards and to minimise risk either from cross-flow between formations or the uncontrolled release of well fluids to surface, throughout the life of the well.		
Casing setting depths should be selected to provide an adequate safety margin between the formation fracture pressure and anticipated pressures during well control and casing cementation operations.		
Well casing must be:		
(a) designed, installed, tested and maintained in a way that is consistent with the well integrity management system for the well;		
(b) designed, installed, tested and maintained in a way that is consistent with the well design and barrier requirements set out in section B.4.3 of this Code; and		
(c) designed to consider the required strength, metallurgy (to resist corrosion and erosion), sealing capacity, and circulation capacity.		
B.4.6.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Casing and tubing stress analysis must be carried out on all reasonably foreseeable load scenarios that may be imposed on the well. Working stress design must consider both uniaxial and triaxial analysis.	Casing and tubing stress analysis is conducted on all hole sections incorporating axial and triaxial analysis on all foreseeable load scenarios and in accordance to the OE Casing and Tubing Standard.	6.2 Casing Design 6.8 Wellhead Design 6.13 Pressure

(b) Casing, casing connections, wellheads, and valves used in petroleum wells must be designed to withstand the loads, pressures and temperatures that may act on them throughout the entire well life cycle. This includes casing running and cementing, any treatment pressures (e.g. hydraulic stimulation), production or injection pressures, potential well control situations, any potential corrosive conditions (H₂S, CO₂, etc.), and other factors pertinent to local experience and operational conditions.	Wellhead and tubulars are designed to withstand the anticipated loads experienced for the life cycle of the well. Load cases may include: • casing running • cementing • pressure testing • hydraulic fracturing • production Whilst in exploration, produced fluids are monitored and analysed for potential corrosion. Corrosion coupons will be available to determine the corrosion rate. The well will be abandoned or workover should CO₂ be present and causing higher than expected wall loss.	testing and Well Control
(c) Sections B.4.6.2 (a) and (b) do not apply to a conductor pipe.		
(d) Methods of preventing external corrosion that impact well integrity must be applied.	Wells a planned and designed to have cement returned to surface in all annuli. Where reservoirs are discovered to have corrosive fluids CO₂ tolerate cement designs can be implemented	
(e) All casing and tubing must be manufactured to the latest edition of API 5CT. The rated capacity of the pipe body and connections must be obtained from the latest edition of API 5CT or the manufacturer's technical specifications.	All OCTG are to meet API 5CT standards	
(f) Welded joints are permitted in construction of petroleum wells provided they are manufactured in compliance with API 5CT, sections 6, 7, 8, 10, and 13, and Tables C.3/E.3.	N/A - Welded joints not permitted under Origin's Casing and Tubing Standard	
(g) The yield stress of Oil Country Tubing Goods must be de-rated for temperature.	Standard temperature deration has been applied to the design (0.054% per degree)	

(h) When designing casing strings and casing connections for petroleum wells, interest holders must design each well, or similar wells, and the casing string using appropriate design safety factors. Design safety factors used must be specified in the WOMP. A generic worst case design and stress analysis may be adopted to cover multiple wells in a field development targeting the same or a similar reservoir.	All wells are design and constructed to comply with the minimum Safety Design Factors set out in the OE Casing and Tubing Standards • 1.1 for burst • 1.0 for collapse • 1.3 for static tension • 1.6 for dynamic tension • 1.25 for triaxial loads • 1.10 for axial compression	
(i) To verify casing integrity during the well construction process, casing must be pressure tested prior to drilling out for the next hole section (in the case of surface casing or intermediate casing), and prior to stimulation, diagnostic fracture injection test (DFIT), or completion operations commencing (in the case of production casing).	Casing integrity for top hole/intermediate hole sections are verified with a pressure test on plug bump. The production casing is tested to maximum allowable operating pressures. These pressure tests formulate part of the well acceptance criteria's must be met before proceed with the next programd operation.	
(j) Interest holders must provide DITT evidence of successful testing of the mechanical integrity of the well through pressure testing prior to hydraulic stimulation or DFIT operations.	Well integrity verification to be submitted to DITT prior to stimulation/DFIT operations	

B.4.7 Primary cementing			
	B.4.7.1 Principles		
	Well cementing is designed, installed, tested and maintained in a way that is consistent with:		
	(a) the well integrity management system (see section B.4.1) for the well, and;		
	(b) well design and barrier requirements set out in section B.4.3 of this Code.		
	Primary cementing of casings and/or liner strings is designed to:		
	(a) provide axial support for the casing string to permit further drilling and to provide an anchor for BOP equipment;		
	(b) reduce possibilities of casing buckling and/or collapse, particularly in situations where abnormal formation stresses occur;		
	(c) provide a seal across permeable and impermeable formations to prevent undesired flow of formation fluids and crossflow behind casing/liner;		
	(d) provide a seal to protect aquifers from contamination;		
	(e) seal off the bottom of the casing in order to control pressure; and		
	(f) provide corrosion protection, in particular such that corrosion rates of steel with an adequate cement coating are sufficiently low that cement encapsulation of steel is accepted as a permanent barrier.		
	B.4.7.2 Mandatory requirements	Origin Implementation	WOMP Reference
	(a) The constituents and properties of materials used in primary cementing must be suitable for the intended conditions of use and used in compliance with the relevant safety data sheet requirements.	Proposed slurries will be lab tested to ensure intended conditions are met and used in compliance with the relevant SDS	6.5 Cementing Program 6.15 Well Decommissioning Appendix B - Well Barriers
	(b) The cement slurry density must be designed to maintain well control, prevent gas channelling and achieve the required compressive strength while avoiding losses during cement placement.	Planned cement density will be overbalanced. A lighter cement slurry will be utilised across known loss zones. Slurry displacement modelling will be conducted and spacer train utilised to ensure optimal conditions for cement placement and strength development.	

(c) Cement laboratory testing procedures must be carried out (as per ISO 10426-2, API RP 10B-2 - Recommended Practice for Testing Well Cements) on representative samples of the mix water, cement and additives to confirm the resulting slurry used for primary cementing meets the requirements of the well design.	Laboratory testing on cement will be carried out in accordance to ISP 10426-2 and API RP 10B-2	
i. In the case where a number of similar wells are drilled in an area with similar well properties (depths, temperatures, and well design) and well integrity risks, constant cement materials and mix water properties, then a representative lab test is acceptable.		
ii. The testing, as a minimum, must include slurry density, rheology, thickening time, free water, fluid loss (if required), and compressive strength development with time.		
(d) The top of cement must be designed in accordance with Table 2.	Cement is planned to be brought to surface in all strings	
Table 2: Primary cementing criteria		
Property		
Planned Top of Cement		
Primary cementing criteria		
Top of cement (TOC) to comply with barrier requirements set out in section B.4.3 of this part of this Code and the following minimum requirements:		
· Conductor casing string (other than those placed by jetting or driving) TOC must be designed to surface.		
· TOC for surface casing must be designed to surface.		
· The TOC for any intermediate and production casing strings must overlap with the shoe of the previous casing string by a minimum of 200 m (656 ft).		
· The designed TOC, if not to surface, for any intermediate or production casing strings must be determined such that it has been demonstrated that the length of the cement column will not undermine the primary cementing Principles.		

· Where interest holders choose not to bring cement to surface, they should consider that after decommissioning , two adjacent cement barriers across all aquifers will be required as per B.4.15.2 d) of this Code .		
· The required compressive strength slurry for fracture stimulation must be placed up to at least 150 m (500 ft) measured depth above any zone to be hydraulically fractured.		
· On high temperature wells the TOC must be designed to mitigate against wellhead growth due to temperature during flow back and production		
(e) In cases where an approved WOMP specifies that production casing will not be cemented across the production zones, production casing cement must be designed so that the base of the cement is no more than 30 m TVD above the predicted depth of the shallowest production zone.	N/A	
(f) Unless conducting a green cement pressure test on bump, a minimum 3.5 MPa (500 psi) compressive strength on the tail cement shall be achieved prior to:	Green cement test are planned for the surface/intermediate and production hole section	
i. pressure testing of casing; or	For the production casing pressure test in advance of hydraulic fracturing, a minimum of 500 psi CS will be achieved prior to conducting the test	
ii. drilling out the shoe track for a subsequent hole section.		
(g) Casing centralisation must be designed to achieve a minimum of 70% standoff across the entire cementing interval.	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved	
(h) Centraliser selection must suit application (refer to API Technical Report 10TR4 Selection of Centralizers for Primary Cementing Operations).	Centralisers are selected in accordance to API Tech Report 10TR4	
(i) Casing centralisation simulation must be undertaken for the proposed casing centralisation plan. Simulation for a vertical well must include:	Once hole section is TD, a well centralisation model is conducted to ensure a minimum of 70% standoff is achieved	
i. actual deviation at casing depth; or		
ii. where the actual deviation is not known, a deviation of three degrees from vertical at casing depth.		

	(j) Wiper plugs or cementing darts shall be used for production casing to prevent contamination of cement, and to enable plug bump and pressure test of the casing before cement cures.	Wiper plugs are planned as part of the cementing programme
	(k) There must have be a validation procedure for primary cement jobs which must utilise at least one of the validation methods described in Table 4. If it cannot be verified that zonal isolation is achieved through primary cementing, the interest holder must submit that information,	Cement validation achieved as per below
Job Type	Table 4: Validation and evaluation recommendations for primary cement jobs	
Casing cementation	Validation Criteria	
	• Slurry mixed and placed in accordance with approved cementation procedures. • Shoe track volume not over displaced when displacing cement slurry. • Downhole losses not greater than the excess pumped within the cement procedure, and calculated TOC using final circulating pressure (FCP) and measured fluid returns achieves the objective(s) identified within the cementation program. • No significant losses or slumping post-placement of cement. • Casing successfully pressure tested. • If drilling out casing, a Formation Integrity Test (FIT) satisfactory after drilling out shoe track.	Primary verification for top hold sections
	Contingency	
	• Where the validation is inconclusive or not completed, the extension of good quality cement above the shoe, above hydrocarbons or aquifers should be verified by	CBL run planned as primary verification intermediate and production hole sections. Contingent CBL on surface hole.

	appropriate cement evaluation tools, interpreted by a competent person .	
	• Remedial cementing/top-up job cementing as required.	
Liner cementation	Validation Criteria	
	• Slurry mixed and placed in accordance with approved cementation procedures. • Shoe track volume not over displaced when displacing cement slurry. • Downhole losses not greater than the excess pumped within the cement procedure, and calculated TOC using final circulating pressure (FCP) and measured fluid returns achieves the objective(s) identified within the cementation program. • No significant losses or slumping post-placement of cement. • Casing successfully pressure tested. • Pressure test of liner top packer should be performed and recorded to verify zonal isolation. Testing pressures should be no less than 3.5 MPa (500 psi) over the previous casing leak-off test at the shoe or inflow tested where practicably possible • If drilling out casing, Formation Integrity Test (FIT) satisfactory after drilling out shoe track.	NA
	Contingency	

	- Where the validation is inconclusive or not completed, the extension of good quality cement above the shoe, above hydrocarbons or above aquifers should be verified by appropriate cement evaluation tools, interpreted by a competent person. - If failed pressure test on bump, set liner top packer, circulate out excess cement and WOC prior to conducting pressure test again. - If failure again, may opt to run a liner tie back packer on top of the liner top and re-test. Remedial cementing if necessary.	NA	
	(l) Wait on cement time prior to slacking off or removing BOPs shall be based on the cement achieving a minimum of 700 kPa (100 psi) compressive strength at the temperature of any potential flow zone in the annulus just cemented. Alternatively, interest holders may use an annulus pack-off or mechanical barrier that is compliant with API Standard 65-2 and tested to verify a pressure seal prior to removing BOPs.	Annulus pack off installed in the annulus and will wait for 100 psi CS on the shoe track before removing BOP	
	(m) when a hydrocarbon bearing zone is intersected during drilling and subsequently cemented, a Cement Bond Log should be performed as a verification of hydraulic isolation from aquifers, the surface and other formations where cross flow is prohibited.	CBL to be conducted on all casing cement jobs for hole sections that penetrate the SRR (intermediate and production casing strings)	
	(n) Calcium chloride or other chloride-based accelerants must not be added to the cement mix unless the free water content of the cement is specified as <2%.	If implemented, will be on top up jobs for surface strings. Free water requirement will be adhered to.	
	(o) A minimum required ultimate compressive strength must be determined for cement slurries to be used across zones which may be hydraulically fracture stimulated.	HFS wells require a minimum 2000 psi unconfined UCS cement slurry	
	(p) For wells that are to be fracture stimulated, including DFIT in a cased section of a well; zonal isolation of the production casing cementation must be validated by a cement bond log which confirms at least 150 m vertical depth of good cement is in place above the any zone to be hydraulically fractured	Planning on cementing to surface, CBL to be conducted from 60deg inclination to surface	

B.4.8 Wellheads		
B.4.8.1 Principles		
The wellhead performs the general functions of:		
(a) supporting casing and completion tubing strings;		
(b) supporting the installation of surface barriers, which include the BOP during the drilling phase, and the Christmas tree during the production phase; and		
(c) providing the arrangement for sealing, testing, monitoring, injecting into, and bleeding off between annuli.		
B.4.8.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Wellhead equipment and running tools must be specified in accordance with API Spec 6A/ISO 10423 and NACE MR0175/ISO 15156.	Wellhead equipment and running tools compliant with API spec 6A, ISO 10423 and NACE MR0175/ISO 15156 for the design life of the well. During exploration, reservoir parameters will be monitored, well design life will be de-rated where required.	6.8 Wellhead Design 6.13 Pressure Testing and Well Control 10.3 Well Control Equipment
(b) Wellhead and Christmas 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.	• Temperature Class – U 0°F to 250°F • Material Class – AA General Service, Non-sour, Non-corrosive • (A-C Section) Product Specification Level (PSL) – 3 Rated WP 10,000 psi • (D- Section) Product Specification Level (PSL) – 1 Rated WP 5,000 psi • Performance Requirements (PR) – 2 Minimum API cycle testing The wellhead (A & B) sections are isolated from all reservoir fluid contact from a downhole production packer and tubing. Should well conditions change over time, the production tree can be isolated and changed out	

(c) Side outlet valves must be rated to the same pressure as the wellhead they are attached to. Moreover, all components on the hanger and Christmas tree and valves must be rated to the well pressure envelope.	All SOV are rated to the same pressures as the wellhead section they are attached to
(d) Wellheads must have adequate valve outlets accessible and operational for all annuli to allow for monitoring of annuli in accordance with paragraph B.4.1.2 (c).	Wellhead design with annuli access for the following: • production tubing x production casing annulus • production x intermediate annulus • intermediate x surface annulus • surface x conductor annulus
(e) Wellheads for high temperature wells must include design for lock down of hangers, rated for the well conditions.	N/A
(f) Casing to wellhead pressure tests ('P' seal area or equivalent) must not exceed 80% of the collapse rating of the casing.	Casing to wellhead pressure tests are not programed to exceed 80% of the casing collapse rating.
(g) Any change of usage of a wellhead (i.e. to incorporate gas lift or re-injection) must be fully risk assessed ensure the compatibility of the existing equipment with the proposed usage.	N/A

B.4.9 Well Control		
B.4.9.1 Principles		
Well control aims to reduce hazards when conducting petroleum well construction and production operations. The primary purpose of well control is to provide barriers to prevent uncontrolled release of formation fluids to surface or other formations. Well control can be categorised at two levels:		
(a) Primary well control - the maintenance of a hydrostatic pressure of fluid in the well, sufficient to balance the fluid pressure (pore pressure) in the formations drilled. In practice a defined excess hydrostatic pressure is maintained to provide a safe level of 'overbalance' to formation pressure using weighted drilling or kill fluids in most cases. Where a weighted fluid is not used, primary well control is provided by a combination of pressure and flow control equipment.		
(b) Secondary well control - used when the primary well control fails - should there be a loss of hydrostatic pressure or a situation develops where the formation pressure exceeds the hydrostatic pressure, there is the potential for influx of formation fluids into the well. If the well begins to flow, well control equipment will be in place to contain any influx of formation fluid and allow it to be safely circulated out of the well.		
The guiding principle is to maintain at least two well control barriers in place during all well operations as per section B.4.3 of this Code.		
B.4.9.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) There must be a well control manual for all phases of a well's lifecycle available for inspection at well sites (as part of or along with safety management system information), detailing requirements for equipment level, kick detection and well control techniques.	Well control documentation to be made available: • OE Well Control standard • Contractor SOPs • Well Control Bridging Document • Beetaloo Safety Management Plan	6.3 Kick Tolerance 6.13 Pressure Testing and Well Control 10.3 Well Control Equipment 14.6 Contractual Provisions / Bridging Document 14.12 Well Control Procedures / Multiple
(b) During well construction, well control equipment (e.g. BOP stack and wellhead) must be installed for all operations prior to drilling below the surface casing string. Well control equipment can be terminated once the well is decommissioned or cased and suspended after all hydrocarbon zones and aquifers are isolated and barriers established and verified.	Well control equipment will be utilised for all operations subsequent to drilling the conductor section	
(c) A gas detection system must be used on the well site to identify hydrocarbon bearing formations and potential gas influx.	The rig contractor uses a Pason system for gas detection and mud-level monitoring at relevant points around the rig and cellar. Gas detection sensors will also be replicated as part of the mudlogging service.	

(d) Well control equipment must be used and operated compliant with API Specifications 16A, 16C and 16D.	All contracting services/well control equipment must meet the minimum requirements of Origin's Well Control Standard. Relevant section - Section 11.1 Well control equipment specification which are compliant with API Spec 16,A, 16C & 16D.	Contractors Appendix B - Well Barrier Diagrams
(e) If undertaking underbalanced drilling or managed pressure drilling activities, well control measures must be in place to counter the absence of weighted drilling fluid as the primary well control method.	N/A	
(f) If undertaking underbalanced drilling or managed pressure drilling activities, Rotary Control Devices must use and operated compliant with API Specification 16RCD and non- return valves must use and operated compliant with API Specification 7NRV.	N/A	
(g) The level of well control equipment required on any operation, and the configuration employed, shall be suitable for the well.	Well control equipment requirements comply with OE Well Control Standard. Drilling, and completion/workover activities - 5Ksi Stimulation activities - 10 Ksi	
(h) Working temperature rating for well control equipment must meet the maximum anticipated continuous exposure temperature for rubber/elastomer components.	Maximum expected temperature is considered 'normal range' and well below the rating of the elastomer components.	
(i) Other than annular BOPs, all well control equipment must be rated to exceed maximum anticipated shut-in surface pressure.	See Well Barrier diagrams, high test pressures are greater than reservoir pressure	
(j) Well control equipment must be function tested and pressure tested in accordance with API Standard 53 at least every 3 weeks.	All contracted well control equipment to be compliant with OE Well Control Standard / API Standard 53	
(k) The surface gas handling system for drilling operations must be fit for purpose and used within operating limitations, that the potential risks of fire and explosion from free gas are identified and managed, and volumes of gas vented or flared are recorded in accordance with Part D of this Code.	Rig surface fluid system rated to 5,000 psi. Poorboy and vacuum degassers installed. Two-phase separator provided through third-party for formation evaluation.	
(l) Methods must be established for early identification of fluid influx (well kick).	Incorporated in Drilling Program in accordance to: Contractor SOPs Well Control Standard Well Control Bridging Document	

(m) Regular and realistic drills pertaining to on-going or up-coming operations should be conducted to train involved personnel in detection, prevention and recovery of a lost barrier.	All contracted services and well control equipment to be compliant with OE Well Control Standard including regular well control drill requirements	
(n) Prior to drilling below the conductor casing string in exploration wells, or in development wells or appraisal wells in those areas having known shallow gas accumulations, a system shall be installed to safely divert hydrocarbons and other fluids in the event of pressurised fluids occurring below the shoe of the conductor string.	N/A	
(o) Methods must be established that prevent blowouts up the drill pipe in case unexpected subsurface pressures are encountered.	Float Valves / Stab-in Valves, etc to be used in the drill string. FOSV with appropriate X/Os positioned on the floor for use in emergency	
(p) The kick tolerance of the formation being drilled must be known. This may be demonstrated through a Formation Integrity Test or data from offset wells.	Kick tolerance analysis will be conducted for each well. LOT will be conducted on surface, intermediate and production casing and Kick Tolerance calculations updated	

B.4.10 Drilling fluids		
B.4.10.1 Principles		
The primary objectives for drilling and completion fluids are to:		
(a) maintain well integrity and meet well barrier requirements (set out in sections B.4.1 and B.4.3 of this Code respectively);		
(b) optimise hole conditions for the retrieval of quality geological and reservoir data;		
(c) minimise reservoir damage and therefore optimise well productivity; and		
(d) improve drilling performance.		
Containment of drilling fluids and additives must be considered in the well site layout (see section B.4.16) and as part of a spill management plan (section C.7.2).		
B.4.10.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Drilling fluids must be selected and managed to ensure all products used during well operations on petroleum wells are used in accordance with the manufacturer's recommendations and relevant safety data sheets. The name, type and quantity of each chemical used on each well throughout the well construction process must be recorded.	All fluid additives are managed and used in accordance with the manufactures recommendations/SDS. All chemical usage are tracked and documented	6.4 Drilling Fluids Program 10.4 Aquifer Protection
(b) Drilling fluids shall not contain benzene, toluene, ethylbenzene, or xylene (BTEX) above the levels prescribed in section B.5 of this Code.	Drilling and stimulation fluids/additives are screened for BTEX by an independent NATA certified lab to ensure BTEX levels are below the prescribed levels in Table 8 of section B.5 of the CoP	
(c) Testing of the active drilling fluid must be carried out in accordance with API RP 13B a minimum of twice per day.	Drilling fluids program to specify testing frequency of active drilling fluids and compliant with API RP 13B	
(d) The interest holder must implement a system for accurately monitoring drilling fluids during all drilling operations that:	PVT systems in place measure active fluid levels. Standard operating procedures in place (trip sheets) to monitor trip volumes.)	
i. allows the determination of drilling fluid volume gains and losses;	Mud logging engineers on location to measure and record mud densities	
ii. allows the determination of drilling fluid volumes required to fill the hole on trips;		
iii. allows the determination of density in/out of the well to ensure the correct weight is being maintained to control the well; and		

iv. allows the monitoring and recording of gas readings in the return fluid flow once gas bearing strata are intersected.	Redundant gas monitors on location to monitor gas shows in return line	
(e) The drilling fluid handling system and surface gas handling system for drilling operations must allow for the removal of gas from the drilling fluid in accordance with section B.4.9.2. (j).	Poor boy degasser and vacuum degasser system setup with the drilling rig package	
(f) The source of water used for all well operations (drilling, workover and hydraulic fracture stimulation) must be recorded.	Source water used for all regulated well activities will be recorded. Fluid sourced from on-site water bore are equipped with flow meters to actively monitor volumes	
(g) Where use of a non-aqueous drilling fluid is planned, a risk assessment must be carried out to identify all risks associated with the use of non-aqueous drilling fluid and controls put in place. Confirmation must be demonstrated that the rig is suitable for non-aqueous drilling fluid use, including:	N/A	
i. suitable seals and valves and loading/unloading hoses; and		
ii. inclusion in the spill management plan to ensure spills are contained.		
(h) At the end of every well where non-aqueous drilling fluid has been used, a summary must be prepared, reconciling whole quantities of non-aqueous drilling fluid left in the well, returned for storage/refurbishment. This information is to be included in the well completion report.	N/A	
(i) When drilling through local aquifers and until these aquifers are isolated by a minimum of two verified barriers, then:	A non toxic KCL polymer WBM is planned for all top hole section drilling operations	
i. only air, water or water-based drilling fluids are permitted to be used; and		
ii. chemicals or other substances that could leave a residual toxic effect in the aquifer shall not be added to the drilling fluid.		
(j) Where H2S is deemed likely, then:	N/A	
i. the pH of the fluid must be monitored on a regular basis (a decrease in pH may indicate H2S contamination), high pH can be used to hold the sulphides in the mud		
ii. sufficient Zinc Carbonate (ZnCO3), Zinc Oxide or Ironite Sponge must be available to treat a fluid system containing up to 500 ppm (by volume) H2S.		

B.4.11 Air and Gas Drilling Fluids		
B.4.11.1 Principles		
When planning to use air or gas as a drilling fluid, or as a component of a drilling fluid (such as mist, foam, or aerated fluids), the following are required:		
(a) well integrity must be maintained and well barrier requirements met as set out in sections B.4.1 and B.4.3 of this Code, respectively; and		
(b) hazards and risks associated with potentially flammable and/or explosive mixtures of gasses in the well or at the well site must be mitigated to acceptable levels.		
B.4.11.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Compressors and boosters must be located to prevent the ingestion of flammable gasses from drilling activities and fuel stores.	N/A - Not currently in the well construction work scope for Kyalla SRR Wells	N/A
(b) All pressure lines and manifolds must be:		
i. identified with appropriate signage		
ii. positioned so that it does not interfere with vehicular access to the drilling location or cross areas on the drilling location frequented by vehicles and persons		
iii. constructed using hoses, pipes, fittings and connections that have a rating sufficient to withstand the maximum supply pressure		
iv. properly restrained to prevent dangerous movement in the event of coupling or hose failure		
(c) A check valve shall be installed on the delivery line at or near the standpipe.		
(d) The main air or gas supply line shall have at least two valves:		
i. one on the standpipe and accessible from the rig floor		
ii. one located at the compressors and boosters.		
iii. each valve shall be rapid acting, clearly labelled and readily accessible.		
(e) In relation to blooey, diverter or bleed-off lines:		
i. they must only be used during underbalanced drilling.		

ii. where used, they must be run to a pit or tank capable of catching any drill cuttings produced		
iii. they must extend at least 45 metres from the wellhead and shall, where practicable, be laid downwind of the well, or at right angles to the direction of the prevailing wind		
iv. they must include adequate dust suppression to reduce risks to human health and the environment to a level that is as low as reasonably practical and acceptable		
v. reservoir liquids must not be produced to the pit or tank;		
vi. any geological sample catcher installed on a blowby line shall be designed to avoid flashback and to protect persons from dust; and		
vii. a continuous purge of any blowby, diverter or bleed-off diverter line should be conducted using a primary jet during circulation, start-up and shut-down, and when making connections.		
(f) For well control during air drilling operations, all equipment shall be lined-up for a soft shut-in at all times. It is safety critical to avoid a rapid pressure build-up within the well when the well is known to contain hydrocarbons and air.		
(g) Drilling crew from the Assistant Driller and above must be well-control certified and must be trained on soft shutting techniques applicable for underbalanced drilling operations.		
(h) Explosive limits or mist injection shall be established for circulating media that can introduce O ₂ into the circulating system. If explosive limits are not clearly defined, systems which could introduce O ₂ should not be used.		
(i) Explosive limits shall be documented and posted next to the O ₂ monitoring system for all circulating systems that contain O ₂ . Monitoring stations should include the rig floor, inside the substructure next to the BOP stack, and near separation vessels / storage / circulating tanks.		
(j) All gas influxes shall be checked for H ₂ S. If any H ₂ S is detected, the well must be circulated to a kill fluid immediately. The impact of H ₂ S to the flammability limits (e.g., LEL) is unpredictable during reservoir inflow flush production events, therefore, with any detection of H ₂ S air drilling operations shall be terminated.		

(k) Sufficient firefighting equipment and systems must be available at the drilling rig to extinguish an ignition at the wellhead or on the rig floor.		
(l) Enough kill fluid of sufficient density to be able to kill the well in an emergency must be available on site.		
(m) At least one portable gas detector, of a kind acceptable to an Inspector as appointed under the <i>Petroleum Act 1984</i> , must be available for use where air or gas drilling is in progress.		
(n) A downhole float valve must be fitted in the drilling string. Top and bottom kelly cocks must also be installed.		
(o) The rig substructure must be kept adequately ventilated (either by natural ventilation or by fans).		

B.4.12 Well evaluation, logging, testing and coring		
B.4.12.1 Principles		
In petroleum exploration and development, formation evaluation (FE) is used to characterise formation fluids and determine the ability of a well to produce petroleum. Formation evaluation seeks:		
(a) to characterize reservoir properties, including the following:		
i. petrophysical properties;		
ii. formation fluid properties;		
iii. geomechanical properties; and		
(b) to evaluate reservoir productivity.		
Cuttings samples, core samples, fluid samples and other samples from the petroleum well drilling process must be collected, stored and/or distributed according to legislative and regulatory requirements.		
B.4.12.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Equipment must be available to attempt recovery of survey or logging equipment lost down hole.	Fishing equipment has been contracted and will be available on-site	5.5 Evaluation Plan 6.9.1 DFIT Program 6.11 Well Test Program
(b) If a radiation source cannot be retrieved from down hole, all relevant information must be submitted in writing and an approval must be sought in relation to disposal of a radiation source under the <i>Radiation Protection Act 2004</i> (NT).	Will comply if contingency operations are required	
(c) When coring operations are conducted, the testing for gas using hand-held sensors at the rig floor must be conducted while retrieving the inner core barrels as well as when opening the core barrel and examining the cores.	Gas detectors are available on the rig floor during coring operations	
(d) Well testing requirements for subsurface open hole tests are as follows:		
i. Well & tool schematic must be prepared and included in the well test program.	Production testing program will comply and address this CoP requirement	
ii. All well test equipment must be located in appropriate hazardous classification areas.	Well testing equipment will be spotted on location in appropriate hazardous classification areas	

iii. Clear and accurate definitions of temperature and pressure ratings must be provided for all surface equipment. Any pressure de-rating due to elevated temperatures must be addressed in the emergency shutdown and monitoring systems.	All surface testing equipment to be appropriately rated to the operating condition (pressure and temperature)
iv. The line to the testing choke manifold must be rated and pressure tested to the maximum expected surface pressure as calculated from reservoir pressure less the hydrostatic of a gas column to surface plus any kill or surface treatment pressure.	All surface well testing equipment will be designed to have a rated working pressure in excess of the anticipated working pressures
v. Pressure monitoring capability must be available at the wellhead. During the well test, actual flowing conditions must be recorded and compared to predicted values.	Pressure will be monitored at the wellhead for well testing activities
vi. The well test surface equipment must be designed, prepared and operated in accordance with API Specification 6A, NACE MR-01-075, ASME B31.3 (Spools & X-Over).	Surface equipment to be designed, prepared and operated in accordance with API Spec 6A, NACE MR-01-75, ASME B31.3
(e) Extended production testing (EPT) requirements:	Production testing program will comply and address this CoP requirement
i. A production testing program must include (but is not limited to):	
a. proposed timing and duration;	
b. the equipment proposed to be used for the test including accurate flow measurement device(s);	
c. the well schematic; and	
d. the proposed method of disposal of the petroleum, produced water, flowback fluid or gas produced (see Part C of this Code).	
ii. All well test equipment must be located in appropriate hazardous classification areas.	Well testing equipment will be spotted on location in appropriate hazardous classification areas
iii. For cased hole testing a pressure test that exceeds the maximum anticipated pressures must be completed to demonstrate mechanical integrity and define a maximum allowable operating pressure (MAOP).	All equipment will be pressure tested to establish a MAOP. The Maximum Allowable Pumping Pressure (M APP) will be set below this value
iv. For open hole testing a pressure test to the MAOP of the pressure-exposed elements of the system must be completed.	

v. All flowlines, valves and equipment used in a production test must have a rated working pressure in excess of all anticipated pressures and must be tested and operated in accordance with relevant standards.;	All surface well testing equipment will be designed to have a rated working pressure in excess of the anticipated working pressures	
vi. Pressure monitoring capability must be available at the wellhead. During the well test, actual flowing conditions must be recorded and compared to predicted values.	Pressure will be monitored at the wellhead for well testing activities	
vii. The well test surface equipment must be designed, prepared and operated in accordance with API Specification 6A, NACE MR-01-075, ASME B31.3 (Spools & X-Over).	Surface equipment to be designed, prepared and operated in accordance with API Spec 6A, NACE MR-01-75, ASME B31.3	
(f) Diagnostic Fracture Injectivity Testing (DFIT) requirements:		
i. Pressures, rates, and volumes shall be recorded during the DFIT.	Pressure, rates and volumes are to be recorded for a DFIT	
ii. For cased hole DFITs a pressure test that exceeds the maximum anticipated pressures must be completed to demonstrate mechanical integrity and define a MAOP. Refer to B.4.6.3 (c).	All equipment will be pressure tested to establish a MAOP. The Maximum Allowable Pumping Pressure (MAPP) will be set below this value	
iii. For open hole DFITs a pressure test to the MAOP of the pressure-exposed elements of the system must be completed. Refer to B.4.6.3 (c).		

B.4.13 Hydraulic stimulation and flowback operations		
B.4.13.1 Principles		
Hydraulic fracture stimulation and flowback operations are conducted to improve or enable the recovery of hydrocarbons. Hydraulic fracture stimulation and flowback operations must seek the following:		
(a) to maximize the potential for enhanced petroleum recovery from the resource;		
(b) to ensure protection of aquifers is maintained during all operations phases for hydraulic stimulation and flowback;		
(c) to not exceed the well operating envelope and to maintain well barriers;		
(d) to flowback fluids in such a manner as to ensure all recovered flowback fluid is isolated and does not come into contact with aquifers or pollute soil or soil substrate; and		
e) to manage any gas contained within flowback fluids.		
Containment of hydraulic fracturing fluids and additives must be considered in the well site layout (see section B.4.16) and as part of wastewater management and spill management plan (see section C.7).		
B.4.13.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Hydraulic fracture stimulation activities must be designed to not impact aquifers.	Prior to HFS activities the mechanical casing integrity if verified, a cement evaluation log is conducted to verify that a minimum of 150m of good cement is in place above the target reservoir. Geological barriers must be in place to constrain the height growth of the hydraulic fracture. Geohazards are assessed and sufficient standoff is implemented where required. For surface operations, chemical storage is banded to prevent seepage from surface into the aquifer	6.9 Hydraulic Fracture Stimulation Appendix B - Well Barriers Appendix G - Well Acceptance Criteria
(b) Hydraulic fracturing fluid additives must be selected and managed to ensure all products used during well procedures on petroleum wells are used in accordance with the manufacturer's recommendations and relevant safety data sheets.	All fluid additives are managed and used in accordance with the manufactures recommendations/SDS	

(c) In accordance with Schedule 1, Part 2, Clause 6 and Part 3, Clause 11 of the PER, the Implementation Strategy of an EMP for petroleum activities that include hydraulic fracture stimulation must include details of monitoring and reporting of the as-pumped composition of any hydraulic fracturing fluid used. As a minimum, the following must be recorded and reported for each stage (where a stage in this context means all fluids pumped at a particular depth interval):	Pre and post stimulation volumes and additives will be disclosed, containing details of fluid volumes, additives/concentrations and water quality. In addition fluid samples at various stages of the stimulation operations will be sampled and tested for analytes at a NATA certified lab
a. total volume of hydraulic fracturing fluid pumped,	
b. quality of water used (tested for analytes in section C.8 of this Code. Analyses do not need to be repeated if the same water source is used for multiple stages) and	
c. typical and maximum concentrations of chemicals or other substances used.	
(d) Hydraulic fracturing fluids must not contain benzene, toluene, ethylbenzene, or xylene (BTEX) above the levels prescribed in section.B.5 of this Code.	No fluid additives contain BTEX above the levels prescribed in Section B5 of this Code.
(e) A WOMP that includes hydraulic fracture stimulation must take into account location and characteristics of known geohazards and any other wells near the well to be hydraulically stimulated.	Geohazard assessments are conducted pre and post well construction. Where potential geohazards are identified risk assessments are conducted and suitable standoffs are implemented to mitigate HFS challenges
(f) WOMPs must demonstrate that fractures are contained within the proposed stimulation area, containing the target zone(s) and that the stimulated area and target zone(s) are sufficiently separated from aquifers.	Geomechanical models are developed to demonstrate geological stress barriers to contain fracture height growth
(g) Well integrity must be validated before and after hydraulic fracturing operations.	All HFS wells must meet the pre/post frac WACs to demonstrate well integrity. In addition the well barrier integrity validation reports are submitted to DITT as to the Well Barrier Integrity Validation Reporting Guideline
(h) A pressure test that exceeds the maximum anticipated hydraulic fracture stimulation pressures at screen out conditions must be completed to demonstrate mechanical integrity and define a MAOP.	Pressure test Wellhead and production casing to 10ksi.(MAOP) Max allowable pump pressure (MAPP) during HFS will be 9.2ksi
(i) Pressure communication between casing annuli must be monitored and controlled while conducting hydraulic fracture stimulation.	Wellhead designs allow for monitoring of annuli. Stimulation programs include real time monitoring provisions
(j) The pressure kickout on the pump units and in-line pressure relief valves (where utilised) must be set below the MAOP.	Pump trips and in line relief valves will be set below 10,000 psi

(k) All flowback activities must be managed to minimise the release of gas to atmosphere, in accordance with the following requirements:	
i. For exploration wells and appraisal wells and low pressure wells (including those with a low gas to oil ratio), all flowback fluid must be either:	Flowback activities are to be routed through a well completion vessel and/or a separator where gas is separated and sent to be disposed of via a flare.
a. routed directly to a completion combustion device with a continuous ignition device (e.g. a pilot flame) or,	
b. routed to a well completion vessel and with flowback fluid sent to a separator as soon as the separator will function and then directing the separated gas to a completion combustion device with a continuous ignition device.	
ii. For all development wells undergoing hydraulic fracture stimulation, unless it is not technically feasible to do so, the operator must:	N/A - for Exploration
a. route all saleable quality gas from the separator to a gas flow line or collection system; or-inject the gas into the well or another well;	
b. use the gas as an on-site fuel source; or use the gas for another useful purpose that a purchased fuel or raw material would serve; or	
c. where technically infeasible, direct the gas to a combustion device with a continuous ignition device	
iii. Despite condition 1 and 2 of this section, venting is only permitted during flowback activities when:	Where gas flows are insufficient to function the separator, venting may be conducted in minor volumes
a. the gas flow is insufficient to allow the separator to function properly; or	
b. the use of a combustion device creates a fire or safety hazard or where heat emissions may negatively impact the environment	
iv. Where venting is the only technically feasible option for managing produced gas, the technical considerations preventing the use of the recovered gas must be recorded and included in the operator's annual report.	Volumes of gas produced will be measured, monitored and reported
v. Volumes of gas emitted during the separation flowback stage must be measured using direct measurement as governed under the Commonwealth National Greenhouse and Energy Reporting (Measurement) Determination (2008), and reported in accordance with Part D of this Code.	

(1) Hydraulic fracture stimulation operations should not be conducted in a formation that does not have more than 600 m vertical separation to the nearest aquifer unless it can be demonstrated that the risks of connectivity with the nearest aquifer is as low as reasonably practicable and acceptable.

Kyalla SRR is prognosed to have >600m vertical separation from the nearest aquifers

B.4.14 Workover and Intervention		
B.4.14.1 Principles		
Any re-completion or well modification needs to be designed to ensure the well is operated within the maximum expected pressures and load conditions until final decommissioning. Well integrity must be maintained, as set out in section B.4.1 of this Code.		
B.4.14.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) Well barrier elements must be in place to intervene on the well during workover and intervention activities. as specified in section B.4.3 of this Code.	Well and wellhead designs allow for well barrier elements to be in place prior to re-entering a well for workover or well intervention activities.	6.14 Well Intervention 12.2 Well Barriers Appendix B - Well Barriers Appendix G - Well Acceptance Criteria
(b) Fit for purpose well design and construction materials must be used workover and intervention activities as specified in this Code (sections B.4.6, B.4.7, and B.4.8).	Material selection, cement and wellhead designs will be fit for purpose for the well and comply with the NT CoP and OE well construction standards. Reservoir fluids, temperature, pressures, anticipated load conditions are assessed and factor into the design life of the well/well completion	
(c) All new barriers or new well operating envelopes must be verified and clearly documented and reported by submission of an updated well barrier integrity validation (WBIV) report to DITT.	All new barriers will be validated and a WBIV will be submitted to DITT as per the Well Barrier Integrity Validating Reporting Guideline	
(d) The potential for accumulation of naturally occurring radioactive materials (NORM) in well equipment must be assessed and appropriate measures put in place to reduce risks to the health and safety of people and the environment are put in place.	During exploration NORM will be monitored. Future well interventions will be designed with appropriate measures in place to reduce HSE risk if applicable.	

B.4.15 Well suspension and decommissioning			
B.4.15.1 Principles			
The goal of well decommissioning is to permanently seal the well to prevent the flow of fluids into, out of and along the well at the end of its useful life.			
The decommissioning objectives are to ensure:			
(a) well integrity is maintained at all times, as set out in section B.4.1 of this Code;			
(b) all aquifers are isolated from the surface, each other and from permeable hydrocarbon zones;			
(c) permeable formations containing fluids at different pressure gradients and/or significantly different salinities are isolated from each other to prevent crossflow;			
(d) discrete, permeable hydrocarbon zones are isolated from each other (unless co-mingling of discrete zones is permitted), or a minimum of one well barrier is set above the shallowest co-mingled zone (if co-mingling is permitted);			
(e) all permeable hydrocarbon zones are isolated from the surface; and			
(f) the site is rehabilitated and left safe and free from contaminants as per section A.3.9 of this Code.			
Decommissioning and monitoring of decommissioned wells is conducted through a two stage process as summarized in Table 5.			
The primary considerations for suspension of a petroleum well are to ensure that:			
(a) well integrity is maintained at all times as set out in section B.4.1 of this Code;			
(b) monitoring requirements can be met and that production can readily be resumed; and			
(c) all safety requirements are met.			
B.4.15.2 Mandatory requirements for decommissioning wells		Origin Implementation	WOMP Reference
(a) Decommissioning and monitoring of decommissioned wells must be conducted through a two stage process, as shown in Table 5		A 2 stage process is planned for all OE Beetaloo wells.	6.12 Well Suspension Program 6.15 Well Decommissioning
Table 5: Two Stage Decommissioning Process		Stage One: Establish downhole barriers across hydrocarbon zones and aquifers Kyalla SRR to be isolated as per NT CoP Table 5: Cement	
	<table><tr><th>Stage</th><th>Description</th></tr></table>		
Stage	Description		

One	- Interest holder places downhole barriers across all identified hydrocarbon bearing formations and aquifers to be zonally isolated as per section B.4.15.2. - This includes placing of casing shoe cement plug and any cased hole plugs for permanent zonal isolation in accordance with section B.4.15.3: <i>Cement plug requirements and validation methods..</i> - A surface cement plug is not placed in the well and the wellhead is not removed at this stage. - The well is left in a state that casing annuli and casing can be monitored for pressure (i.e. verify well integrity) with all downhole barriers in place. - Monitoring of pressures at an agreed frequency for duration of 1-6 months, depending on well risk and classification as per approved WOMP. - Concurrently to the well integrity monitoring, the well pad may be rehabilitated as much as practicable.	plug requirements and validation methods for well decommissioning - (G) Perforated casing. - Other potential permeable zones/different pressure regimes to be isolated as per NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning - (B) Cased hole section (unperforated) - Annular pressures will be monitored on surface for a minimum of 6 months to validate downhole decommissioning barriers Stage Two: Surface decommissioning - Aquifers to be isolated as per NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning - Surface cement plug (50m below deepest aquifer/15m below ground level - Wellhead removal - cut casing 1.5m below ground level and covered with a minimum 30 cm of cement - Site rehabilitation	Appendix B - Well Barriers Appendix G - Well Acceptance Criteria
Two	- On successful validation of no well integrity issues, the interest holder completes wellhead removal and surface cement plug placement as per section B.4.15.2. - These may be rigless activities as required. - Well status is officially changed to fully decommissioned once requirements of section B.4.15.2 are satisfied. - Site rehabilitation may be completed.		
(b) Cement must be used as the primary sealing material. Cement testing must be carried out as per requirements set out in section B.4.7.2 of this Code.		Cement slurries are tested in accordance to ISO 10426-2 and API RP 10B-2	

(c) Biocide, oxygen scavenger and/or corrosion inhibitor must be used in water-based fluid used for the decommissioning process.	As a minimum biocide, oxygen scavenger / corrosion inhibitors are utilised as suspension fluids during decommissioning	
(d) All aquifers must be isolated:	4 string Kyalla SRR well design enables aquifers to be isolated by a minimum one well barrier (primary cement) and isolate aquifers from hydrocarbon bearing zones by a minimum of two barriers (primary cement + casing strings)	
i. from each other and the surface by a minimum of one well barrier; and		
ii. from any permeable hydrocarbon bearing zones by a minimum of two well barriers.		
(e) Cement plugs must conform to the requirements as detailed in section B.4.15.3: Cement plug requirements and validation methods.	The following cement plugs are to be implemented for decommissioning from NT CoP Table 5: Cement plug requirements and validation methods for well decommissioning • (B) Cased hole section (unperforated) • (G) Perforated casing. • (-) Surface Cement Plug Cement plugs to be verified as per B.4.15.2 (G) of the NT CoP	
(f) BOPs and/or the wellhead must not be removed until the cement plug across the surface casing shoe or the plug across the uppermost perforations has been verified.	Wellheads are not planned to be removed until cement barriers above upper most perforations have been verified	
(g) Cement plugs for decommissioning or suspension must be verified as follows:		
i. Off bottom open hole cement plugs are to be verified by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	To be applied in suspension/decommissioning of vertical pilot hole section	
ii. For consecutive stacked cement plugs with the first plug set on bottom or solid base (e.g. mechanical packer, other verified cement plug) validation of the top of good quality cement to be carried out by tagging the top plug with a minimum 2270 kg (5000 lb) drill string weight. If using a sacrificial stinger to set open hole plugs, no tag is necessary where no losses are observed during cement placement.	If stacked plugs are implemented with a solid base, verification will be completed via tagging the top plug with a minimum 5000 lb.	

iii. For a cased hole cement plug with the bottom of the plug exposed to open hole validation is to be done by tagging the top plug with a minimum 2270 kg (5000 lb) drill string weight and by pressure testing to 3.5 MPa (500 psi) above the estimated (or previously recorded) leak-off pressure (within the limits of the casing and wellhead pressure ratings).	N/A	
iv. For a cased hole cement plug supported by a pressure tested bridge plug, validation may be by post cement job report and calculations, or by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	Where pressure tested mechanical plugs are implemented to support a cement plug, validation will be achieved via successful cement displacement	
v. For an unsupported cased hole cement plug barrier not exposed to open hole below, validation is to be done by tagging the plug with a minimum 2270 kg (5000 lb) drill string weight.	Where cased hole cement plug barriers are placed, validation will be achieved via tagging plug with 5000 lb string weight	
vi. For a final surface cement plug extending from ground level no validation is required. A shallow set plug is not considered a permanent barrier given the very low formation pressures at ground level. Well barriers are to be established with the plugs below the surface cement plug.	Surface cement plugs are not considered a barrier in the Kyalla decommissioning design	
vii. When a sacrificial string is used to place a cement plug, validation may be via a combination of:	A plugged off packer and tail pipe assembly may be utilised as a base mechanical barrier to support a cement plug. Where this is conducted the sacrificial string must be successfully pressure tested prior to spotting cement	
a. pressure testing to confirm isolation; and		
b. validation of the conduct of the cement job.		
(h) Prior to wellhead removal, zero pressure on any casing or annulus must be confirmed. Wellheads must be removed, and casing must be cut as per Case: Surface cement plug detailed in B.4.15.3: Cement plug requirements and validation methods.	Prior to wellhead removal, a minimum of 6 months of annuli pressure monitoring is conducted to verify zero pressure is present at surface	
(i) A steel marker plate cut from corrosion resistant alloy or similar grade steel for corrosive environments must be installed after the wellhead has been cut off detailing the following:	After the wellhead has been cut and capped, steel marker plate will be installed as per the requirements of B.4.15.2 (i)	
i. the identifying name of the well or bore;		
ii. the total depth in metres of the well or bore;		
iii. the date the well or bore was decommissioned; and		
iv. the marker plate shall be covered with soil to ground level.		

(j) Complete and accurate records of the entire decommissioning procedure must be kept, with these records submitted as part of the legislative reporting requirements for the decommissioning of petroleum wells.	Daily drilling/completion reports and well pressure monitoring records are maintained and to be submitted as part of the well completion report in accordance to Section 314 of the Schedule of onshore petroleum exploration and production requirements and Section 76 of the Act	
(k) The potential for accumulation of NORM in well equipment must be assessed and appropriate measures put in place to reduce risks to the health and safety of people and the environment.	On going NORMs monitoring will be conducted. If required, control measures will be implemented to reduced risk to the health and safety of people and the environment	

B.4.16 Site Material and Fluids Management		
B.4.16.1 Principles		
The well site should be laid out to minimise the potential for harm to others and the environment.		
B.4.16.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) The well site must be selected and designed in accordance with Part A of this Code.	Well sites are selected and designed in accordance to Part A of the CoP	6.4 Drilling Fluids Program 6.9 Hydraulic Fracture Stimulation 6.11 Well Test Program
(b) The well site must be designed and operated to minimise the risk of causing a fire on the well site or in the surrounding environment.	Well sites are designed and operated to minimise the risks of fire. Fire mitigation plans may include • robust monitoring of seasonal conditions and fuel loads; • maintenance of fire access trails; • maintenance of fire breaks around infrastructure; • appropriate fire control measures on location; • planned well/equipment spacing and stand off to mitigate risk of ignition	
(c) The well site must be clearly identified in a permanent manner with the well name, well number, major hazards and details of the interest holder.	Each well site will be appropriately signed with the following: • Well name • Details of interest holder • Description Hazards where applicable • Details of PIC where applicable	
(d) The name of the person-in-charge of any active well operations must be displayed in writing at all approaches to the well site.		
(e) The well must be adequately secured to prevent access by wildlife.	The well site will be equipped with stock proof fencing and constructed with earthen berm around the perimeter of the lease to prevent access by wild life. Drilling sumps when not in use will be fenced to prevent fauna access. Wastewater tank height is >2m preventing fauna access.	
(f) The well site must be designed and operated to minimise the potential for releases of contaminants to the environment and the impacts of such a release.	Chemicals and produced fluids are stored in accordance with B.4.16.2(i) The well pad is compacted with an earthen berm around the	

	perimeter to minimise the potential release of contaminants to the environment
(g) An assessment must be carried out as to whether any materials (solid or liquid) used on, or produced at, a well site could be considered to be, or to contain, hazardous chemicals or those that may cause environmental harm. The outcomes of this assessment must be described in the spill management plan, as outlined in Part C of this Code.	A chemical risk assessment has been conducted on all proposed drilling/stimulation additives and on anticipated flowback composition by an independent third party. Controls measures are documented in the associated spill management plan
(h) Use, storage and handling of materials on site must be conducted in accordance with section A.3.8 and Part C of this Code, and:	
i. secondary containment must be instituted on areas of the well site where any hazardous chemicals or those that may cause environmental harm are to be stored or handled during all well operations.	Hazardous Chemicals: • Stored on location with secondary containment compliant to the section A.3.8 of the CoP Flowback/Produced fluids management: • Stored in dual lined enclosed above ground tanks. • Open top tanks with sufficient freeboard will be implemented where flowback fluids are being treated via evaporation. • Freeboard requirements are based on 1:1000 ARI rainfall for the duration the open tank is in operation. Freeboard requirements will be assessed for each well pad location. • Sufficient fluid transfer ability will be on location to transfer fluids out of the open top pond into enclosed storage at least 8 hours prior to any significant storm event • Sufficient covered storage volume available on location at all times to transfer fluid from open tanks to enclosed tanks Hydrocarbon management: • Stored in double lined tanks • Disposed of on location via flare
ii. areas where any hazardous chemicals or those that may cause environmental harm are to be stored or handled must be lined to be sufficiently impervious and able to contain spilled material or waste until it can be removed or treated. This lining may be a geomembrane or a suitably constructed clay liner.	Well sites are designed and constructed with a sufficient quantity of clay to enable spill containment until it can be removed or treated

B.4.16 Ground Water Monitoring		
B.4.17.1 Principles		
Groundwater is a key environmental receptor in onshore petroleum exploration and development in the Northern Territory. Groundwater monitoring serves as a signal to differentiate natural and human-induced perturbations in the well pad area. Where an impact is detected, further investigation is required and any necessary remediation is undertaken to ensure water quality guidelines are met.		
B.4.17.2 Mandatory requirements	Origin Implementation	WOMP Reference
(a) An accurate understanding must be gained of what aquifers exist at the well site and their depth from surface, and their relationships to each other and other hydro-stratigraphic units during the well design phase.	Desktop studies and assessments regional water bores are conducted, in addition to data collected from water impact monitoring bores drilled within 100m downstream of the petroleum bore are used to identify aquifers	5.6 Ground Water Monitoring
(b) Where there is an intention to hydraulically fracture the well(s) at a well site:		
i. At least six months of local baseline data for water quality indicators of the key aquifers that may be affected by the activity must be acquired:	Control water monitoring bores are planned to be drilled 6 months prior to drilling the petroleum bore. Where this is not achievable (due to circumstances outside the control of the interest holder), bores will be drilled 6 months prior to HFS as approved upon by the regulator. Water quality indicators are monitored as per Table 6 of CoP: Minimum suite of analytes for groundwater monitoring	
a) prior to drilling the well(s); or		
b) prior to hydraulic fracturing where six months monitoring data from the control bore is not achievable before drilling due to circumstances that lie outside of the control of the interest holder;		
c) the minimum suite of water quality indicators to be monitored are listed in Table 7, however monitoring of additional water quality indicators may be necessary based on the interest holder’s risk assessment conducted for an EMP.		
ii. Electrical conductivity data from the monitoring bore(s) must be measured as soon as practicable after the completion of construction of the monitoring bore (s) until decommissioning of all wells on the well site. Results submitted to the regulator:	Electrical conductivity data will be collected and reported quarterly, a minimum of 6 months prior to stimulation, 3 month post stimulation and annually for the remaining life of the wells on the lease pad	
a) by electronic means from the well site as soon as they are available; or		

b) if the requirement in a) is unachievable to implement in the first stages of exploration, an alternative plan and timetable may be proposed before hydraulic fracturing commences, detailing how electrical conductivity information will be regularly submitted.		
(c) Any guidelines published by the Northern Territory Government from time to time relating to groundwater monitoring parameters, methodologies and frequencies for petroleum operations must be followed. This includes the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin.	OE to comply with all guidelines published by the Northern Territory Government	
(d) Any guidelines published by the Northern Territory Government from time to time relating to reporting and data submission, and groundwater monitoring data standards must be followed.		
(e) In karstic groundwater terrain, which is common in the Northern Territory, a precautionary stratigraphic bore hole (which potentially can be used as a water production bore) to the base of the deepest recognised aquifer may be required at the well pad for an accurate understanding of what aquifers and potential geohazards, if any, exist at the site and their depth from surface.	In regions of karstic groundwater terrain, data collected from control water monitoring bores are utilised to assess aquifers and geohazards around the wellpad region	
(f) Records must be maintained for each well, or group of similar wells, if grouping the wells is appropriate given their similarity.	OE to maintain records for well or group of wells	

B.5 BTEX Limits			
Benzene, toluene, ethylbenzene, or xylene (BTEX) are only permissible in drilling or fracturing fluids, at or below the levels prescribed and when it is either,			
• Naturally occurring in water used to make up the drilling or fracturing fluid • Present as a contaminant in chemicals or other substances used in drilling or stimulation fluids and has no beneficial use			
• Present as a contaminant in chemicals or other substances used in drilling or stimulation fluids and has no beneficial use			
B.5.1.1 Drilling and stimulation fluid chemical additives	Origin Implementation	WOMP Reference	
(a) The combined chemicals or other substances used at their maximum possible concentrations for a particular drilling or stimulation fluid cannot increase BTEX levels of the overall fluid above the BTEX content of the base water of the fluid by more than those levels prescribed in Table 8.	Drilling and stimulation fluids/additives are screened for BTEX by an independent NATA certified lab to ensure BTEX levels are below the prescribed levels in Table 8	6.4 Drilling Fluids Program 6.9 Hydraulic Fracture Stimulation	
Table 8:BTEX Levels in drilling fluids when drilling through local aquifers.			
Compound			Maximum Level (ppb or µg/L)
benzene			1*
toluene			180#
ethylbenzene			80#
xylene	200#		
*From Version 3.5 of the Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra as updated in August 2011. # Australian and New Zealand Environment Conservation Council Environmental Protection Guidelines (ANZECC 2000) 99% protection level.			
B.5.1.2 Recycled produced water and flowback fluid	Origin Implementation	WOMP Reference	

(a) Produced water or flowback fluid used in drilling fluids or stimulation fluids must not contain BTEX at levels greater than those expected in water produced (including flowback) from the well being drilled.		N/A For the initial exploration drilling/stimulation operations, it is not anticipated that flowback/produced fluids are re-used for drilling/stimulation fluid make up.	N/A
(b) In the event BTEX levels expected in produced water or flowback fluid from the well being drilled are not known, then the BTEX levels in water used for drilling fluids or stimulation fluid cannot exceed the levels prescribed in Table 9			
Table 9: BTEX Levels in water used for stimulation and drilling fluids.			
Compound	Maximum Level (ppb or µg/L)		
benzene	600#		
toluene	180#		
ethylbenzene	80#		
xylene	200#		
# Australian and New Zealand Environment Conservation Council Environmental Protection Guidelines (ANZECC 2000) 99% protection level.			
B.5.1.3 BTEX levels in drilling fluids when drilling through local aquifers		Origin Implementation	WOMP Reference
(a) Despite sections B.5.1.1 and B.5.1.2 and pursuant to section B.4.10.2 (i) of this Code, drilling fluids used to drill through aquifers and until these aquifers are isolated by a minimum of one verified well barriers cannot contain BTEX levels at the greater of,		Drilling fluids planned for the top hole section are verified to be compliant with the prescribed BTEX level in the CoP	6.4 Drilling Fluids Program
i. minimum BTEX levels in the local aquifers; or			
ii. The levels listed in Table 8			

Appendix H Methane Emission Management Plan



MEMP

NT-2050-MP-15- 030

BEETALOO EXPLORATION PROGRAM

Methane Emission Management Plan

Review record

Rev	Date	Reason for issue	Reviewer/s	Consolidator	Approver
0	15/04/2019	Released for use	MK	LF	MH

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1. Purpose

This Methane Emissions Management Plan (MEMP) is designed to outline the measures as to how the risks of methane emissions associated with Origin Energy's Beetaloo Basin exploration activities will be managed. This Plan has been developed in accordance with the Code of Practice for Petroleum Activities in the Northern Territory.

2. Key Legislation

Key legislation and documents consulted in the development of this plan are provided below. A full list of applicable legislation is provided in the corresponding management plans.

- **Code of Practice for Petroleum activities in the Northern Territory:** Mandatory code of practice legislating the management of chemicals and wastewater onsite, including the use of secondary containment, lined tanks and spill management plan,
- **National Greenhouse and Energy Reporting Act 2007:** Regulates the reporting of greenhouse gas emissions, energy production and energy consumption associated with company activities. Data to be supplied annually to the regulator in accordance with emission/energy use guidance manuals.

3. Activity description

The activities undertaken as a part of this MEMP are summarised in Table 1. These activities are restricted to the drilling, stimulation, well testing and ongoing operation of exploration wells. They do not cover any production, compression or pipeline activities as these are currently not proposed.

Table 1 Activity and emission description summary

Activity	Emission Description	Controls	Emission monitoring
Drilling	Methane emissions are small (<1 tonne) and restricted to outgassing of hydrocarbon within intersected shales brought to surface.	•Drilling is overbalanced, preventing gas influx into well bore •Shale formations have negligible permeability with limited influx of gas from target formations	•Due to low emission level, gas is qualitatively monitored in mud stream as a concentration (not flow rate). •Gas desorption data is collected from target reservoir allowing emission estimates.
Stimulation	During stimulation, the well will be overbalanced restricting the flow of hydrocarbons to surface.	•Well is kept overbalanced to prevent gas influx during and after stimulation. •Flowback kept within the formation after each stage.	N/A
Well Testing	Well is unloaded to allow hydrocarbons and fluid to flow to surface. All fluids and hydrocarbons diverted to a separator and then a flare onsite Small emissions (<1 tonne) of methane may be released prior to the onsite of flaring, as the hydrocarbon production rate may not be enough to sustain a flare initially. Small volumes (kg's/day) of methane is entrained within liquid hydrocarbons and flowback fluid and will be released to atmosphere	Well heads are designed in accordance with the NT Code of Practice and API standards to minimise loss of methane containment. A reduced emission completion will be utilised- where all gas is sent to a separator and then flared. Personal Gas Detector during all operational visits	•Personal Gas Detector during well testing activities •All flared gas measured using flow meters
Ongoing Well Operations/ suspension	Methane emissions restricted to unplanned leaks from well heads, including surface casing vents.	•Operation staff to carry personal calibrated gas detectors during every routine operational visit to well sites.	•Personal Gas Detector during well testing activities •6 monthly leak detection

Activity	Emission Description	Controls	Emission monitoring
		•Routine wellhead maintenance as per well Integrity Management System •Each well and equipment on a well pad to be inspected every 6 months for leaks using a US EPA Method 21 compliance technique	

4. Equipment Selection and Activity Design

The uncontrolled emissions of natural gas during drilling, stimulation and well testing activities represents a potential hazard to workers and the environment. All equipment will be selected to minimise the emissions during production activities.

- Exploration wells and associated surface infrastructure shall be designed to mitigate leaks in accordance with the relevant standards. These Standards include:
 - o ISO 16530-1-2017 Petroleum and natural gas industries- Well Integrity - Life cycle governance
 - o API SPEC 5CT 2016 Casing and Tubing
 - o API SPEC 16D 2013 Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment
 - o API RP 59 2012 Well control operations
 - o API SPEC 6A 2016 Wellhead and Christmas Tree equipment
 - o NORSOK Standard D-010, Well integrity in drilling and well operations
- Leak detection implemented consistent with Codes of Practice.
- Ongoing well maintenance as per the Well Operations Management Plan.

5. Flowback Activities

5.1 Reduced emission Completion

- A Reduced Emission completions (REC) shall be used to minimise the amount of venting
- A REC for the purpose of the Beetaloo Exploration Project is a separator equipped with a flare.
- Venting shall only be used where the capture or flaring is not possible.
- The recovery of gas and hydrocarbons for sale will be prioritised (where practicable) to minimise flaring.

6. Leak Detection Inspections.

The leak inspection programs will be implemented in accordance with Table 2.

Table 2 Leak detection program

Monitoring Program	Monitoring methodology	Frequency
Routine operational Inspections	Calibrated personal gas detector	During each operational visit
Mandatory inspection	US EPA Method 21	6-monthly

7. Monitoring Methodology

- Mandatory inspections will be completed on all surface infrastructure (vents, flanges, valves, connections, drains, pressure relief vents, etc.) of the exploration well in accordance with the USEPA Method 21 requirements or a vehicle mounted cavity ring-down spectrometer (CRDS).

7.1 Instrument Selection

- A Method 21 detector must be able to detect methane at the minimum detection range of 10 Parts Per Million (PPM), with an +/- accuracy of 50PPM.

- A vehicle mounted CRDS detectors shall have a 10 Parts Per Billion (PPB) minimum detection accuracy with an accuracy of +/- 10PPB
- The instrument shall be intrinsically safe (where used within hazardous areas) and equipped with an electrically driven pump, to ensure that a sample is provided to the detector at a constant flow rate.

7.2 Qualifications

- Inspections must be carried out by a suitably qualified person
- A suitably qualified person is defined as a person that has been specifically trained in leak detection or has at least 3 years industry experience in conducting leak detection activities.

7.3 Calibrations

- Gas detectors must be maintained and calibrated in accordance with the manufacturers instructions. Records of instrument calibration shall be retained.
- A two stage calibration shall be used, with a Air calibration and a 10PPM by volume CH₄ calibration gas used.
- The instrument response time shall be less than 30 seconds.

7.4 Testing procedure

7.4.1 Method 21

Method 21 inspections are used to survey individual pieces of equipment. These types of inspections require access to the surface of the equipment and are extremely effective at pinpointing leaks. The following procedure is to be followed when conducting method 21 inspections:

1. Ensure gas detector is calibrated and functioning properly
2. Ensure the appropriate permitting is obtained before entry into a hazardous area
3. Place the probe inlet at the surface of the component interface where leakage could occur.
4. Move the probe along the interface periphery while observing the instrument readout. If an increased meter reading is observed, slowly sample the interface where leakage is indicated until the maximum meter reading is obtained.
5. Leave the probe inlet at this maximum reading location for approximately two times the instrument response time (i.e. at least a minute).
6. If the maximum observed meter reading is greater than 500PPM at the surface of a piece of infrastructure, the leak is to be measured again at 150mm immediately above (and downwind) of the leak in an open-air environment
7. The leak shall be classified in accordance with section 7
8. The location of the leak shall be clearly documented and photographs taken (if safe to do so)
9. Any liquid petroleum leaks should also be identified, along with estimates of leak rate and volume released.

7.4.2 Vehicle mounted CRDS

Vehicle mounted CSRDS uses highly sensitive, PPB level detectors to screen clumps of infrastructure for leaks. They are extremely effective at providing a rapid assessment and are used in combination of method 21 assessment to pin point leaks. The following procedure shall be followed when conducting vehicle mounted CRDS inspections:

1. The vehicle shall be driven within 20m up and downwind of the infrastructure at a speed below 20km/hour: it is advisable to drive around a piece of infrastructure in a circular motion to obtain up and down wind in the same pass.
2. Where a survey cannot be made within 20m downwind of a piece of infrastructure, a method 21 inspection shall be undertaken.
3. Downwind methane concentrations shall be compared to upwind (background) concentration.
4. Where an emission is identified at 5PPM above background, a method 21 inspection shall be undertaken
5. Where enrichment is recorded below 5PPM, the infrastructure has no material leaks present.

7.5 Leak Classification, Repair and Notification

Each leak shall be classified, repaired and reported in accordance with Table 3. It should be noted, that classification of leaks is only undertaken using a method 21 approach outlined in 7.4.1.

Table 3 Leak classification and remediation summary

Classification	Threshold	Response	Notification	Comments
Minor Leak	>500ppm measured at the surface of the component in accordance with section 6.4.1	All minor leaks must be documented and repaired as soon as practicable, but within 30 days. Where 30 days is unachievable, the reason for the delay and target date for completion must be submitted.	All minor leaks must be documented	A minor leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning
Significant Leak	>5000ppm (or 10% of the Lower Explosive Limit) when measured at 150mm above the leak source. Or A Liquid Petroleum (condensate/oil) loss of containment that exceeds 200L. Or The leak is too large or not safe to measure.	1. The activities safety management plan, risk assessment and emergency response requirements must be followed. 2. Remediation work must only commence after a suitable risk assessment has been undertaken (at a level appropriate to the nature of the leak) and the relevant safety procedures are followed including the consideration of all the required Personal Protective Equipment and emergency response material. 3. If safe to do so, the leak source should be isolated and repaired immediately. The response priority must be to make the site safe above all other actions. 4. The leak shall be repaired or made safe as soon as practicable, as follows: i) the leak must be isolated, repaired if possible, contained or otherwise made safe within 72 hours. ii) Where isolation and repair is not possible, an exclusion zone must be established around the leak and appropriate restrictions to on access to the exclusion zone imposed. iii) in the event the 72 hour deadline is unachievable, the reason for the delay and the target date for repair shall be submitted to DPIR before the deadline has passed.	In the case of an emergency situation, DPIR must be notified within 24 hours via the emergency response hotline number 1300 935 250. Notification must include the date of identification, nature and level of the leak, infrastructure name, number and location as well as the initial actions to minimise the risk. The land owner or occupier of the property in which these leaks are occurring must be notified in the following circumstances: i) if the leak cannot be repaired immediately; and ii) if the leak is likely to affect any of the land owner's or occupiers facilities or activities. A written close-out report must be submitted within 5 business days of the remediation of the leak, specifying the date of identification, nature and level of leak, location and name of the operating plant, and the rectification actions taken.	A significant leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning

Classification	Threshold	Response	Notification	Comments
		5. If it is contended that the risk of immediately repairing the leak exceeds the risk posed by the leak, an extension of the 72-hour deadline may be sought provided that other measures to mitigate the risk are undertaken (eg. ensuring an appropriate exclusion zone has been implemented) 6. For leaks identified on well equipment, higher order controls such as containment by repair must be implemented wherever possible. 7. For leaks identified on well casings or adjacent to the well casing (where a work over rig is necessary to effect repair) it must be determined whether the leak requires immediate repair, or whether the risk can be adequately managed via other control measures until a work over of the well is scheduled for normal operational reasons. The risk assessment to determine the above shall consider the location of the well, likely access to the well from landholders or the general public, and landholder/community concerns in relation to the leak.	If finalising the remediation is delayed more than 7 business days from the identification of the leak an update must be submitted on that day. The final close out report shall be provided when all work is completed.	

8. Reporting

8.1 Flaring and Venting Emissions

- Where natural gas is vented or flared during exploration activities, these emissions shall be measured or estimated using methods consistent with those outline under the National Greenhouse and Energy Reporting (Measurement) Determination 2008. This include:
 - o Leaks, venting and flaring during flowback activities
 - o Equipment blowdowns, system upsets and accidental releases

8.2 Annual reporting

An annual report will be provided to the Northern Territory Government summarising the following:

1. The records of the stages of flowback activities including:
 - i. the date and time of the onset of flowback;
 - ii. the date and time of each attempt to route flowback fluid to the separator;
 - iii. the date and time of each occurrence in which the operator reverted to the initial flowback stage;
 - iv. the date and time of well shut in or connected into adjacent gathering lines;
 - v. the date and time that temporary flowback equipment is disconnected.
 - vi. the total duration of venting, combustion and flaring over the flowback period.
2. The results of leak detection surveys (in the annual report under the Act) outlining:
 - i. the extent of compliance with the leak management plan;
 - ii. a summary of monitoring undertaken during the period;
 - iii. a summary of minor and significant leaks identified during the reporting period, including the date of identification and repair for each leak and those leaks that could not be repaired; and
 - iv. an explanation of why any component could not be repaired and what actions will be taken to either decommission the component or otherwise remedy the problem.

Appendix I Spill Management Plan



BEETALOO EXPLORATION PROGRAM

Spill Management Plan

Review record

Rev	Date	Reason for issue	Authors	Consolidator	Approver
0	18/04/2019	Issued for review	MK	LF	EW
1	26/07/2019	Updated to meet final CoP	Mk	SM	EW
1.1	14/11/2019	Minor update to incident notification	MK		LF
1.2	03/12/2019	Minor update to address DENR comments	MK		LF
1.3	02/11/2020	Minor Update to include additional wells	RU		MK

Review due: 18/05/2023

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issued under a transmittal.

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Appendix A - Chemical volumes per well and storage areas

1. Purpose

This spill Management Plan (SPMP) is designed to outline the measures as to how the risks of spills associated with Origin Energy's Beetaloo Basin exploration activities will be managed. The exploration activities covered under this SPMP include:

- The Kyalla 117 N2- 1,2 and 3H exploration wells
- The Velkerri 76 S2 exploration well.

This Plan has been developed in accordance with the Code of Practice: Onshore Petroleum Activities in the Northern Territory (referred to herein as the Code of Practice).

2. Key Legislation

Key legislation and documents consulted in the development of this plan are provided below. A full list of applicable legislation is provided in the corresponding management plans.

- **Code of Practice: Onshore Petroleum Activities in the Northern Territory:** Mandatory code of practice legislating the management of chemicals and wastewater onsite, including the use of secondary containment, lined tanks and spill management plan,
- **Transport of Dangerous Goods by road and Rail (National Uniform Legislation) Act 2010:** covers the transportation of goods by road in the NT. This also covers licences for vehicles and drivers carrying dangerous goods.
- **Workplace Health and safety (National Uniform Legislation) Act 2011;** covers the storage and handling of chemicals on site.
- **Waste Management and Pollution Control Act 1998:** Covers the requirements for the transportation and disposal of waste within the NT. This includes the requirements for contractors, vehicles and facilities managing listed wastes to be licenced.

3. Chemicals and Wastewater Description

Chemicals and Wastewater stored onsite includes:

- Chemicals used for drilling
- Waste drilling fluids
- Chemicals used for stimulation
- Flowback Wastewater
- Completions and well suspension fluids
- Condensate and oil
- Diesel and fuels
- General equipment maintenance chemicals (hydraulic oils, degreasers etc.)

The full list of chemicals and wastewater stored onsite, including their volume and location are provided in appendix A.

4. Spill Failure Scenarios

Potential spill scenarios associated with exploration activities are summarised in Table 3.

These scenarios include:

- Spills from chemical and wastewater handling and storage activities onsite
- Spills from chemical and wastewater during transportation (offsite)
- Tank, drilling sump and containment vessel overflows and structural failures

The loss of containment due to the failure of well barriers is covered under the Well Operations Management Plan (WOMP).

Table 1 Spill Scenario summary table

Spill Scenario	Activity duration	Mechanisms	Location	Quality	Quantity	Key management controls	Monitoring	Receptors
Spills from chemical and wastewater handling and storage activities onsite	•Drilling – 45 days •Stimulation- 30 days •Well testing- 12 months	•Containment rupture •Spill during chemical handling and mixing	•Chemicals storage area • Drilling rig •Stimulation spread •Drilling sumps •Flowback storage tanks •well testing equipment	•Saline drilling fluids •Saline flowback •Chemicals listed in appendix A	<1000L <1000L <100L	•Designated storage areas with appropriate segregation of incompatible chemicals •Secondary containment to be deployed under high risk spill/ leak storage and handling areas •Spill kits available •Routine inspection of chemical stores •Sites are manned during operations •wastewater management plan	- Routine inspection of chemical stores, sumps and tanks during operations - Tank leak detection	Retained onsite.
Loss of containment during transfer onsite (leakage from pipes, hoses, fittings etc)	•Drilling 45 days •Stimulation 30 days •Well testing 12 months	Coupling, valve, hosing and equipment failure,	Chemical mixing and transfer areas on the drill rig, mixing hoppers and wastewater storages.	•Saline drilling fluids and wastewater r. •Chemicals listed in Appendix A.	<5000L	•Secondary containment to be deployed under high risk spill/ leak storage and handling areas •Spill kits available •Routine inspection of chemical stores •Sites are manned during operations •Wastewater management plan	Routine inspection of all chemical handling areas, including wastewater transfer points and chemical mixing areas.	Retained onsite.
Spills from chemical and wastewater during transportation (offsite)	•Drilling chemical transfer- 1-5 days of bulk chemical transfer generally pre-drilling. •Stimulation chemical transfer 2-3 truckloads of chemicals per week for ~6 weeks •Wastewater disposal over 3 weeks- up to 100 truck movements total over the duration.	•Transport spill •Traffic accident (total or partial release)	Offsite along highway	•Various chemicals as listed in Appendix A •Saline wastewater r.	<1000L for transport spill <50,000L for total loss of B- triple carrying flowback.	•All transport companies to be appropriately licenced to transport chemicals and waste (Dangerous goods and Waste Management and Pollution control Act) including the requirement to detect and respond to spills. •Wastewater management plan	Performance of contractors to be monitored as a part of transportation contractors.	•Chemical transport between Darwin/ south Australia and Queensland/ and Daly Waters. •Wastewater transportation between Daly Waters and Queensland Via Tennant Creek.
Tank, drilling sump and containment vessel overflows and structural failures	•Duration of all activities plus ongoing wastewater storage which may be extended beyond 12 months to allow for ongoing evaporation of fluids.	- Overfilling of a sump and Flowback tank - Structural failure of embankment or tank wall	Sumps and Tanks on lease	Saline wastewater with TDS >50,000mg/l	>10,000 L	•Lease pads bunded during the storage of flowback •Enclosed tanks used during wet seasons operations - Open tanks with 1:1000ARI freeboard •Tanks constructed to Australian Standards Routine tank and sump inspections	Routine tank and sump level and structural integrity (visual) inspections.	Retained on lease pad within bund.

5. Potential Receptors

A description of the environment, including environmental and cultural sensitivities, with the potential to be impacted by a spill is provided in each of the EMP's. The location of activities is remote Figure 1 illustrates the separation distance from sensitive receptors such as:

- Watercourses
- Communities
- Homesteads
- Heritage places
- Vegetation communities; and
- Protected areas

Maps regarding sacred sites and restricted work areas are also applicable and will be provided to work crews to ensure awareness of these features.

6. Risk Assessment

The risk of spills associated with all drilling, stimulation and well testing activities is covered under following EMP's

- Kyalla 117 N2 Drilling, Stimulation and Well Testing EMP NT-2050-MP-15- 023
- Kyalla 117 N2 Multiwell Drilling, Stimulation and Testing EMP NT-2050-MP-15- 038
- Velkerri 76 S2 Drilling Stimulation and Well Testing EMP NT-2050-MP-15-032

7. Control Measures

Controls measures to manage spills associated with exploration activities are provided in the Environmental Management Plans and summarised in Table 3. The key management controls include:

- Contractors are required to develop spill management procedures to comply with the requirements of this plan.
- All flowback, completion fluids, chemicals, oil and fuel storage will be equipped with secondary containment (or dual liners), as per the codes of practice
- Drilling will be lined, with enough freeboard to manage a 1:1000ARI wet season (~1300mm)
- Flare pits will be designed to manage a 1:1000ARI 24-hour storm event (377mm)
- Tanks will be designed, installed and operated as per the manufacturers specifications and COP
- Where flowback is being stored on a lease pad, the lease pad shall be earthen bunded to prevent release to surrounding areas in the case of a catastrophic failure.
- The earthen bund shall be designed to hold 110% of the volume of the largest wastewater tank onsite
- The earthen bund shall be constructed to withstand a failure event, with the bund appropriately compacted and stabilised
- Well sites are designed and constructed to prevent spills of hazardous chemicals; this includes
 - compacting the lease pad surface to 100kpa prevent infiltration
 - provision of bunded (lined) chemical segregation areas
- Monitoring to detect spills will be undertaken in accordance with section 9
- Procedures will be developed by contractors designed to detect, remediate and report any spills. This includes:
 - Chemical handling procedures
 - Chemical storage and handling Inspection procedures
 - Spill prevention, detection and response procedures
- the transport of hydraulic fracturing chemicals and wastewater during the wet season will be avoided, unless a site specific risk assessment indicates the risk is equal to or below a moderate.
- effective spill clean-up material readily available at each work site and on all mobile service trucks or vehicles, where hydrocarbons and chemicals are stored and / or used
- Inspection reports and maintenance records of secondary containment shall be kept and available for review upon request.
- Spill response mock up drills to be completed as a part of routine emergency response

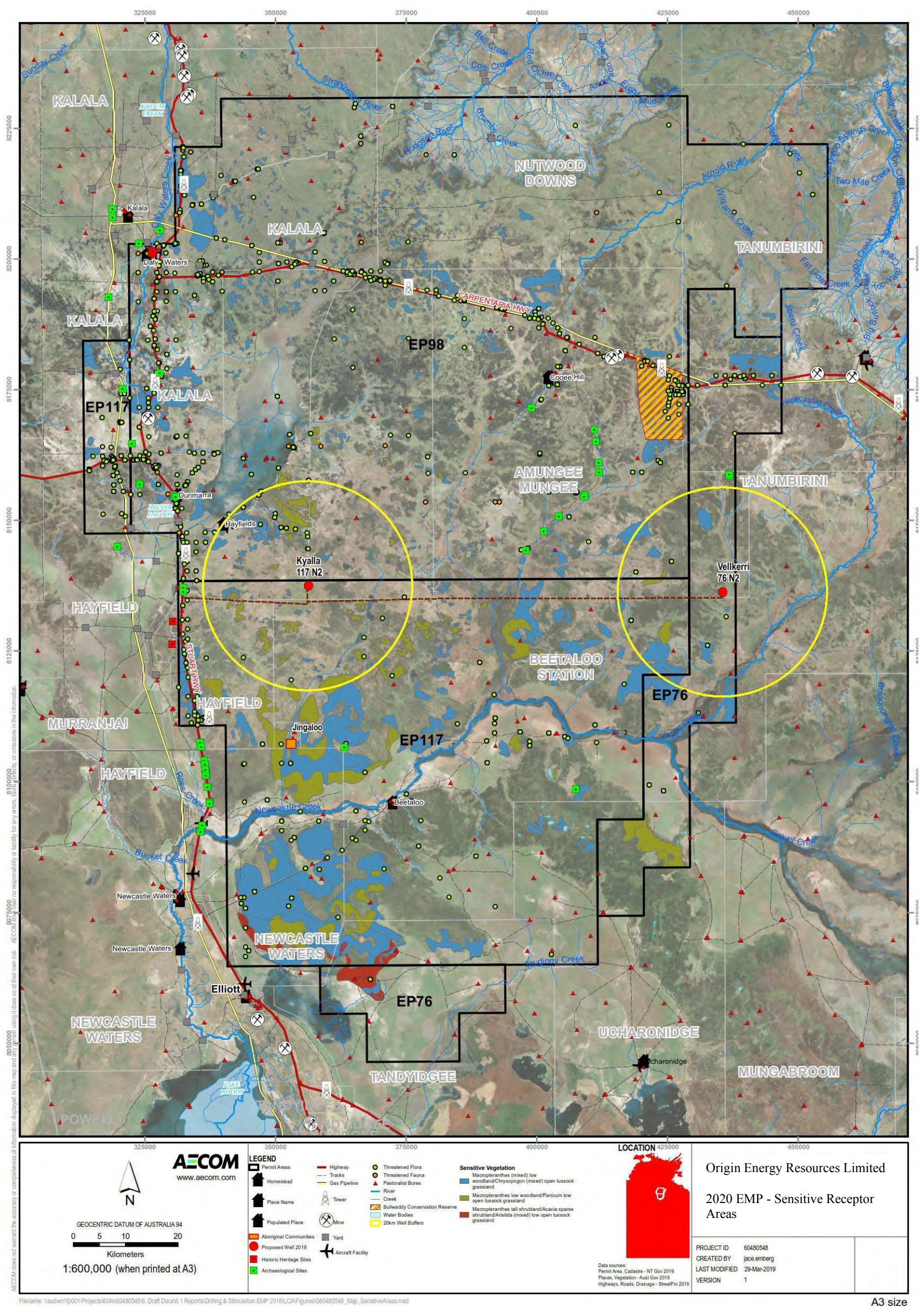


Figure 1 Location of activities and potential receptors

8. Spill Response and management

The following section provides an overview of the response to spills during drilling, stimulation and well testing activities. Where the spill is the result of an emergency situation that is still active, the Beetaloo Exploration Emergency Response Plan (NT-2050-15-MP-024) will take precedence over this plan

8.1 Rapid spill Assessment

When a spill occurs, the on-site Supervisor will carry out a rapid assessment to determine the potential hazards and the type and location of emergency assistance required. This assessment shall include the following:

- Determine the physical (volume and state) and location of the spill
- Determine the appropriate spill category and type of response as per section 12.1.
- Assess the hazard of the material spilled, including any potential hazards associated with chemical mixing (such as oxidising and reducing agents);
- Determine the safety hazard to immediate response personnel and whether additional resources (such as emergency services or specialised equipment or advice) are required to managed the spill safely;
- Determine spill movement, factors affecting the movement (i.e. impending weather, topography, drainage lines etc.) and spill response priorities as per Table 2 (people, communities, environmental and cultural heritage).

Table 2 Spill response priorities

Spill Priority	RESPONSE CONSIDERATIONS
People and communities	• Evacuate and muster (if deemed necessary). • Account for all people and determine missing persons. • Stop unauthorised access. • Provide a technical resource to the Emergency Services (if required). • Protect community and pastoralists
Environment and sacred sites	• For emergencies that are safe to manage, onsite personnel will respond with available resources to limit the extent of the impact to the environment or a protected site. • For larger incidents, or where it is unsafe for onsite personnel to respond, trained people will be mobilised to control and contain the emergency to minimise the impact to the environment or protected site.
Regulators	• Notify Regulators as per incident reporting requirements
Assets	• Monitor automatic shutdown of the equipment or part thereof, or initiate manual shutdowns where it is safe to do so. • Mobilise Emergency Services to intervene.
Reputation	• Notify neighbours (if required).

8.2 Spill containment and clean up procedures

Generic spill containment clean-up procedures must be developed and implemented by each drilling, stimulation and well testing contractor aligning with the requirements of this plan. These procedures shall be adapted (where appropriate) to consider the site and chemical specific hazards associated with each spill event.

The procedures shall consider the following generic spill containment and response procedure:

- Move all people out of harm's way.
- Alert others near-by
- Assess the situation – determine what substances are involved, the potential receptors (people and the environment) and if additional support is required. The substance must be known prior to taking any action (refer to MSDS).

- If applicable; remove any possible risk escalating factors (e.g. ignition hazards in case of flammable/combustible spills); approach from up-wind to reduce fume risks, isolate the spill source (close containment valve, similar). Ensure appropriate controls requirements are met – e.g. PPE, first aid support, etc. - prior to conducting spill clean-up.
- If it is safe to do so; stop the source of the leak (if possible) and contain the spill using onsite equipment to prevent from leaving site or entering a waterway or sensitive feature
- Recover free liquid and contaminated material as soon as practicable (i.e. immediately) to mitigate infiltration. Material recovery should consider the benefit of recovery versus the additional impact that recovery of all contaminated material could cause as per the National Environment Protection (Assessment of Site Contamination) Measure
- Prevent people, livestock and wildlife access to hazardous material through fencing or other barriers.
- Store contaminated material in a manner to minimise the risk of additional contamination.
- For level 2 spills and higher, the Project Manager shall be notified as soon as it is safe to do so, but within 2 hours.
- Project Manager to ensure appropriate external (DPIR/DENR) incident reporting requirements are actioned in accordance with the impact of the spill.
- For level 2 spills and higher, Origin Project Manager to seek expertise as to whether additional testing and remediation is required upon completion of the initial containment and clean up. This consideration will be undertaken in accordance with the National Environment Protection (Assessment of Site Contamination) Measure
- Upon rectification of a reportable spill, an incident investigation shall be completed as per the Petroleum (Environment) Regulations. This shall include the root cause of the incident, actions taken to mitigate the impact and ongoing monitoring and maintenance required to ensure the site is stable and non-polluting.

8.3 Contaminated Material Disposal

Contaminated material disposal will be undertaken in consideration of the following:

- During a spill clean-up, the storage of contaminated material must be undertaken in a manner that minimises additional contamination
- Offsite disposal must be undertaken in accordance with the NT Waste Management and Pollution Control Act 1998.
- All listed waste transportation shall be undertaken by licenced contractors, be tracked and disposed of at approved waste management facilities.

9. Monitoring and inspections

The monitoring and inspection programs to identify spills is summarised in Table 3.

Table 3 Spill monitoring and inspections

Monitoring Program	Frequency	Methodology	Purpose	Minimum volume of leak
Tank and sump level monitoring (when wastewater is stored onsite)	During operations: Daily All other times: Weekly during Dry season Daily during the wet season	Level dip/ visual assessment	Prevent the overtopping of tanks	10's of litres.
Tank leak detection (when wastewater is stored onsite)	Continuous	Instrument	Detect the migration of fluid through primary containment	10's of Litres
Chemical storage areas (when chemical stored onsite)	Daily during operations Weekly all other times	Visual	Detection of leaks	Litres
Tank structural integrity (when wastewater is stored onsite)	Weekly	Visual inspection	Detect potential structural weakness	N/A

10. Roles and Responsibilities

The critical roles and responsibilities set out in Table 4 are for the main members of the Spill Response Group. This team represents the core group of resources that will lead a spill response with the support of the broader Origin Energy Team.

Table 4 Roles and responsibilities

Position	Role & Responsibility
Project Manager	Ultimately accountable for the implementation of the spill management Plan. Role, or delegate, will liaise with Origin Environment Specialists to determine remediation requirements and external reporting obligations.
On-Site Supervisor	Responsible for the initial response to a spill. This role will be delegated to the well site representative or nominated contractor in charge of a work program. Role will undertake the initial spill assessment, engage emergency services (if required) and co-ordinate immediate spill clean-up operations associations to minimise the potential impacts to people, places and the environment.
Environment/ HSE Lead	Report Spill to Regulatory Authorities. Provide expertise on clean up requirements and ongoing monitoring and management requirements. Interface with government and regulatory bodies for communication and consents
Emergency Response Lead	Provide specialist technical advice (Emergency Response) to support spill management activities

11. Implementation

All contractors engaged to perform drilling, stimulation and well testing will be required to comply with this plan. A bridging SPMP will be developed by each contractor summarising the activities to be undertaken to comply with this plan and the NT Code of Practice.

12. Spill Reporting

12.1 Spill Rating

Table 5 provides a summary of the spill classification based upon the volume and location of spill. The hazards of the potential spill to people and the environment should be assessed independently, to ensure incident specific hazards are considered in the spill response. This table provides guidance as to the likely spill scenarios that may trigger the different incident reporting requirements.

When classifying spills and determining the reporting requirements, Ministerial conditions and environmental performance objectives and criteria should also be considered when determining the whether the event is a recordable or reportable event.

The spill tiers include:

- **Level 1:** Spills that can be contained within the well site and can be cleaned up by the operator without involvement of external organisations. Most Tier 1 spills are likely to be less than 2,500 L and would include diesel spills during fuel transfer, oil spillage during routine maintenance or small wastewater spills during well testing. Clean up time is generally less than 1 day. These spills will most likely be classified as recordable incidents as per Section 12 Spill Reporting.

- **Level 2:** Spills that have not been completely contained within the site boundary and/or may require additional resources to clean-up. Clean up time is generally less than a week. Level 2 spills are typically reportable incidents as defined in section 12 and may also require notification under the WMPCA.
- **Level 3:** Severe spills that cannot be contained by the operator and requires substantial additional resources to manage the spill. Clean up time is generally greater than a week. Level 3 spills are reportable incidents.

• **Table 5 Spill Tier Levels**

		Spill (L)		
		20-200L	200-2,500 L	>2,500 L
Receiving environment	Bund or contained impervious area	Not reportable*	Level 1	Level 1
	Onsite (lease pad, camp pad, hardstand, road or work area) compacted or sealed surface**	Not reportable*	Level 1	Level 2
	Offsite permeable surfaces- areas adjacent to lease pads, camp pads, roads where spills have moved beyond the approved activity area. **	Level 1	Level 2	Level 3
	Sensitive environmental or cultural feature (such as a waterway, drainage lines, wetland, high valued habitat and sacred site) or where the spill has, or has the potential to, cause material or serious environmental harm **	Level 2	Level 2	Level 3

Notes:

* Non-reportable spills must be recorded in Origin's OCIS (and made available for review by Contractor), with monthly reviews.

** spills of Dangerous goods or wastes offsite may need to be reported under NT Dangerous Goods Act or Waste Management and Pollution control Act 1998.

12.2 Incident Reporting

Incidents may require reporting under the Petroleum (Environment) Regulations and Waste Management Pollution Control act

12.2.1 Petroleum (Environment) Act Incident Reporting

12.2.1.1 Reportable Environmental Incident Reporting

The Petroleum (Environment) Regulations define a reportable incident as an incident arising from a regulated activity that has caused, or has the potential to cause, material environmental harm or serious environmental harm as defined under the Petroleum Act.

An interest holder must notify (this may be oral or in writing) DENR of a reportable incident as soon as practicable but no later than two-hours after the first occurrence of the incident or after the time the interest holder becomes aware of the incident.

DENR can be notified through the DENR Onshore gas non-compliance hotline on 1800 413 567.

Any verbal report to DPIR must be followed up by a written report from the Project Manager within three days in accordance with the Petroleum (Environment) Regulations.

12.2.1.2 Recordable incidents

The Petroleum (Environment) Regulations define a recordable incident as an incident arising from a regulated activity that:

- I. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or
- II. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or
- III. Is inconsistent with an environmental outcome specified in the current plan for the activity; and
- IV. Is not a reportable incident.

These types of spills are typically a level 1 type spill as defined in Table 5.

An interest holder must notify (this may be oral or in writing) DPIR of a recordable incident as soon as practicable but no later than 15-days after the reporting period (agreed period or each 90-day period after the day on which the EMP is approved).

12.2.2 Waste Management and Pollution Control Act incident reporting

In accordance with the WMPC Act, where contaminants or waste is not confined within the land on which the petroleum activities are undertaken (i.e. the approved disturbance areas where the petroleum activity is occurring), Origin will notify the EPA any incident causing or threatening to cause pollution as soon as practicable, but no less than 24 hours after becoming aware of the incident.

A notifiable incident is defined as an incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm.

A notification must include:

- (a) the incident causing or threatening to cause pollution;
- (b) the place where the incident occurred;
- (c) the date and time of the incident;
- (d) how the pollution has occurred, is occurring or may occur;
- (e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
- (f) the identity of the person notifying

The notification shall be made to the NT EPA Pollution Hotline 1800 064 567.

Appendix A Chemical volumes per well and storage areas

Material Name	Typical volume	Maximum Volume	Unit	Storage Area
Acetic Acid - 60%	3,000	6,000L	L	Stimulation chemical storage area
BE-9 Biocide	17,000	34,000	L	Stimulation chemical storage area
Caustic Soda Liquid	15,000	30,000	L	Stimulation chemical storage area
DCA-11001 Breaker Activator	5,000	10,000	L	Stimulation chemical storage area
DCA-13002 Breaker	300	600	kg	Stimulation chemical storage area
DCA-13003 Breaker	10,000	20,000	L	Stimulation chemical storage area
DCA-16001 Clay Stabiliser	42,000	84,000	L	Stimulation chemical storage area
DCA-17001 Corrosion Inhibitor	1000	2000	L	Stimulation chemical storage area
DCA-19001 Crosslinker	600	1200	kg	Stimulation chemical storage area
DCA-19002 Crosslinker	10,000	20000	L	Stimulation chemical storage area
DCA-23001 Friction Reducer	5,000	10,000	kg	Stimulation chemical storage area
DCA-23003 Friction Reducer	18,000	36,000	L	Stimulation chemical storage area
DCA-25005 Gelling Agent	35,000	70,000	kg	Stimulation chemical storage area
DCA-30001 Scale Inhibitor	15,000	30,000	L	Stimulation chemical storage area
DCA-32002 Surfactant	15,000	30,000	L	Stimulation chemical storage area
DCA-32014 Surfactant	200	400	L	Stimulation chemical storage area
FE-2 Buffer	200	400	kg	Stimulation chemical storage area
Hydrochloric Acid - 32%	50,000	150,000	L	Stimulation chemical storage area
100 Mesh Sand	91,000	182,000	kg	Stimulation chemical storage area
40/70 Sand	1,650,000	3,300,000	kg	Stimulation chemical storage area
30/50 Sand	610,000	1220,000	kg	Stimulation chemical storage area
Sodium Chloride	15,000	3000	kg	Completion chemical storage area

Material Name	Typical volume	Maximum Volume	Unit	Storage Area
ALDACIDE G	500	1000	L	Completion chemical storage area
OXYGON	100	200	kg	Completion chemical storage area
BARACOR 100	2,000	4,000	L	Completion chemical storage area
CON-DET	50	100	kg	Drilling chemical Storage
SAPP	50	100	kg	Drilling chemical Storage
Bentonite	3,000	6,000	kg	Drilling chemical Storage
Caustic Soda	1,400	2,800	kg	Drilling chemical Storage
EZ MUD DP or EZ MUD Liquid	2000	4,000	kg	Drilling chemical Storage
ALDACIDE G	336	672	kg	Drilling chemical Storage
STOPPIT	1,000	2,000	kg	Drilling chemical Storage
Soda Ash	350	700	kg	Drilling chemical Storage
BARACOR 100	250	500	kg	Drilling chemical Storage
Sodium Chloride (Flossy Salt)	96,000	192,000	kg	Drilling chemical Storage
Barite	500	1000	kg	Drilling chemical Storage
BARACARB	500	1000	kg	Drilling chemical Storage
Citric Acid	500	1000	kg	Drilling chemical Storage
BARADEFOAM HP	500	1000	kg	Drilling chemical Storage
Sodium Bicarbonate	500	1000	kg	Drilling chemical Storage
PERFORMATROL	500	1000	kg	Drilling chemical Storage
SOURSCAV	500	1000	kg	Drilling chemical Storage
DRIL-N-SLIDE	500	1000	kg	Drilling chemical Storage
STEELSEAL	500	1000	kg	Drilling chemical Storage
BARAZAN D or BARAZAN D PLUS	4,150	8,300	kg	Drilling chemical Storage
PAC L	2,300	4,600	kg	Drilling chemical Storage
Potassium Chloride	22,500	45,000	kg	Drilling chemical Storage
GEM CP/GP	500	1000	kg	Drilling chemical Storage
QUIK-FREE	500	1000	kg	Drilling chemical Storage
BAROFIBRE, BAROFIBRE Superfine and BAROFIBRE COARSE	500	1000	kg	Drilling chemical Storage
BaraBlend-657	500	1000	kg	Drilling chemical Storage
N-DRIL HT PLUS	500	1000	kg	Drilling chemical Storage
DEXTRID LTE	4,600	9,200	kg	Drilling chemical Storage
BARABUF	500	1000	kg	Drilling chemical Storage
BORE-HIB	500	1000	kg	Drilling chemical Storage
BDF 933 or BaraLube W-933	864	1728	kg	Drilling chemical Storage
BAROLIFT	500	1000	kg	Drilling chemical Storage

Material Name	Typical volume	Maximum Volume	Unit	Storage Area
OXYGON	500	1000	kg	Drilling chemical Storage
ENVIRO-THIN	500	1000	kg	Drilling chemical Storage
Lime	500	1000	kg	Drilling chemical Storage
BDF 677	4,770	9540	kg	Drilling chemical Storage
BDF 988	3,390	6,780	kg	Drilling chemical Storage
Waste Drilling Fluids	2,500	2,500	m3	Drilling mud sump
Completion fluids	1.4	1.4	ML	Drilling sump/ onsite tank
Condensate	160	320	KL	Condensate storage area
Diesel	250	500	KL	Diesel storage tanks
Hydraulic oil	1000	3000	L	Workshop
Engine oil	1000	3000	L	Workshop
Degreasers	100	300	L	Workshop
Flowback	0.5-1	6.8	ML	Flowback tanks

Appendix J Weed Management Plan



Weed Management Plan

NT-2050-15-MP-0016

BEETALOO BASIN EXPLORATION PROJECT Weed Management Plan

Review record

Rev	Date	Reason for issue	Author	Reviewer	Approver
0	05/10/2018	Issue for release	A Court	M Kernke	M Hanson
1	29/03/2019	Issue for release	A Court	M Kernke	M Hanson
2	20/05/2019	Minor Update	A Court	M Kernke	M Hanson
2.1	10/09/2019	Minor update	M.Kernke		M.Hanson

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1. Introduction

1.1 Objectives of the WMP

This WMP has been developed to ensure that the risk of weed introduction and spread, resulting from activities associated with Origin Exploration activities are mitigated to protect the economic, community, industry and environmental interests of the Territory.

The plan provides an overview of:

- The project context (Section 2)
- Legal requirements in relation to weed management (Section 3)
- The appointment of a Dedicated Weed Officer (Section 4)
- Identified risks and proposed mitigation measures and management objectives (Section 5 and 6)
- The weed species that are considered likely or known to occur within the Permit Area (Section 6 and 7)
- The Annual Action Plan for those species that are known to occur with the Permit Area (Section 8)
- Control options for species known to occur within the Permit Area (Section 8).
- The monitoring, notification, recording and reporting requirements for the WMP (Sections 9 – 12).

This plan is supported by Appendices that provide guidance on how to identify weed species in the field and collect the necessary data to support the monitoring and reporting requirements of this WMP.

The location of the proposed exploration activities are shown on Figure 1.

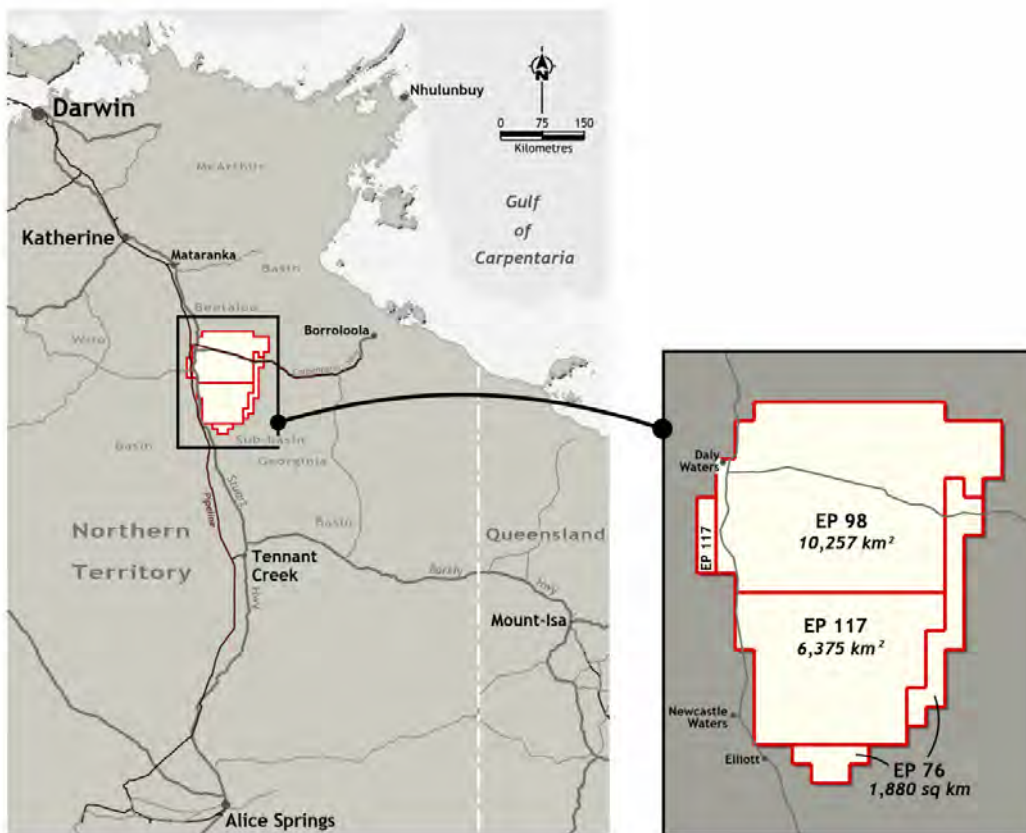


Figure 1 Location of Origin Permit Area

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1.2 Intent of the WMP

Weed control is considered to be a significant land management issue in the Northern Territory. This Weed Management Plan (WMP) forms a core component of Origin's overarching environmental management strategy and supports the various project Environmental Management Plan (EMP's).

The movement of rigs, vehicles, machinery and other materials to, from and within the exploration permit area may result in weeds being moved around the pastoral lease, into the lease from surrounding areas or interstate, depending on where the vehicles and materials are sourced from or returned to.

The focus of this WMP is therefore to ensure that infestations are eradicated, or at the very least that existing weed infestations are controlled such that no further weed species colonise the permit area as a result of Origin's activities.

This document is based upon the Weed Management Planning Guide - Onshore Shale Gas Development Projects produced by the Department of Environment and Natural Resources (2018).

2. Project Context

This plan covers all civil, drilling, stimulating, rehabilitation and routine maintenance/monitoring activities undertaken by Origin within permit EP76, EP98 and EP117 as detailed in Table 1. The proposed activities for the 2019/2020 program are highlighted within the table.

Table 1 Coordinates of centroid of proposed exploration lease areas

Exploration Permit	Lease Name	Zone*	Easting	Northing
EP98	Velkerri 98 E1-	53	415515	8180683
EP98	Velkerri 98 N1	53	392292	8189891
EP98	Kyalla 98 W1	53	364955	8177458
EP76	Velkerri 76 S1	53	424362	8113273
EP76	Velkerri 76 S2	53	435488	8136321
EP117	Kyalla 117 N2	53	356175	8137500
EP117	Stuart Highway Intersection	53	332371	8135170
EP117	Velkerri 117 E1	53	428861	8120782
EP117	Kyalla 117 W1	53	368079	8106696

Grey shading are planned sites for 2019/200

** Universal Transverse Mercator (UTM) geographic coordinate system is Geocentric Datum of Australia (GDA) 94.*

The primary activities subject to this WMP are:

- Access track construction, use and maintenance
- Exploration lease pad construction, use and maintenance
- Gravel pit construction and maintenance
- Drilling, stimulating, completing and maintaining petroleum exploration wells
- Routine access, maintenance and monitoring of all exploration areas subject to this plan.

3. Legal Requirements

The following presents the relevant legislation and statutory obligations for the project.

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3.1 Northern Territory Petroleum (Environment) Regulations

Petroleum Act 2016, Petroleum (Environment) Regulations 2016 and Code of Practice for Petroleum Activities with in the Northern Territory

The *Petroleum Act 2016* provides legal framework within which persons are encouraged to undertake effective exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the Territory. It regulates the exploration for, and production of petroleum, including environmental protection measures which should be employed during exploration and production activities, including protection of parks and reserves and rehabilitation.

In addition, the Act is supported by the *Petroleum (Environment) Regulations 2016*.

The *Petroleum (Environment) Regulations 2016* requires that regulated activities are carried out in a manner consistent with the principles of ecologically sustainable development, and by which the environmental impacts and environmental risks of the activities are identified and reduced to an acceptable level.

The *Code of Practice for Petroleum Activities in the Northern Territory* is a mandatory code of practice for the petroleum industry to ensure that petroleum activities in the Northern Territory are managed according to minimum acceptable standards to ensure that risks to the environment can be managed to a level that is as low as reasonably practical (ALARP) and acceptable.

Under these regulations Origin is required to submit an EMP prior to any petroleum exploration or production activity.

EMP's must include:

- potential environmental risks or impacts (in this instance relating to the introduction and spread of weeds);
- appropriate environmental outcomes, environmental performance standards and measurement criteria;
- appropriate implementation strategy and monitoring, recording and reporting arrangements; and
- demonstrate that there has been an appropriate level of engagement with directly affected stakeholders in developing the plan.

This WMP is designed to support and implement the requirements of Origins Project Specific Environmental Management Plans.

3.2 Northern Territory Weeds Management Act

The aim of the *Weeds Management Act (2013)* is 'to protect the Territory's economy, community, industry and environment from the adverse impact of weeds'.

The purpose of the Act, as defined in section 3, is:

- To prevent the spread of weeds in, into and out of the Territory and to ensure that the management of weeds is an integral component of land management in accordance with the Northern Territory Weeds Management Strategy 1996 – 2005 or any other strategy adopted to control weeds in the Territory.
- To ensure there is community consultation in the creation of weed management plans.
- To ensure that there is community responsibility in implementing weed management plans.

The Act identifies declared weeds (those which must be controlled) and provides a framework for weed management. It includes the following weed declaration classes:

Class A – to be eradicated

Class B – growth and spread to be controlled

Class C* – Not to be introduced into the Northern Territory

* All Class A and B weeds are also Class C.

The Act enables the relevant Minister to approve statutory weed management plans. Management obligations in these plans must be adhered to.

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Currently there are statutory management plans for 10 high priority weed species in the Northern Territory.

The WMP must address weeds in accordance with their declaration status and the statutory requirements of any relevant weed management plans.

3.3 Regional Weed Management Plans

Regional Weed Management Plans (RWMP) have been developed for areas of the NT, with the Barkly and the Katherine RWMP overlapping Origin's Beetaloo exploration tenure. The aim of these regional plans is to assist in prioritising weed management by:

- identifying the region's priority weeds and associated pathways of spread to inform management priorities
- identifying landscapes that may need prioritised protection from weed impacts like river corridors or sacred Aboriginal sites
- containing information on alert weeds that are not yet found in the region, but could become major issues if they establish

3.4 Commonwealth Environment Protection Biodiversity Conservation Act

The objectives of the *Environment Protection and Biodiversity Conservation (EPBC) Act* (1999) are, among other things:

- provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance; and
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources; and
- promote the conservation of biodiversity; and
- promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples; and
- assist in the co-operative implementation of Australia's international environmental responsibilities.

The *EPBC Act* provides for the identification and listing of key threatening processes. A threatening process is defined as a key threatening process if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community. Key threatening processes include invasive species, such as weeds, which have a major impact on Australia's environment, threatening our unique biodiversity and reducing overall species abundance and diversity (DOTEE 2018).

4. Dedicated Weed Officer

As per recommendation 8.3 of the Scientific Inquiry into Hydraulic Fracturing Stimulation there must be a dedicated Weed Officer for each gas field.

The Weed Officer must have relevant skills and experience and availability to successfully manage weed related issues for the project, including:

- Knowledge of the biology/ecology of local weeds.
- Knowledge of relevant weed management frameworks including Northern Territory legislation and plans, the *EPBC Act*.
- Understanding of existing weed management arrangements being undertaken by landholders.

The Weed Officer is responsible and accountable for delivery of all weed related requirements of the project in accordance with the WMP and the overarching Environmental Management Plan, including:

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Weed Management Plan

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- Planning and execution of weed monitoring requirements, including baseline weed assessments and ongoing monitoring both during periods of gas related activities as well as during the target identification period of February to May.
- Facilitate training all workers (including contractors) in weed management requirements, with support from the Northern Territory Government Regional Weed Officer - Onshore Shale Gas Development.
- Oversight of implementation of weed control mechanisms including but not limited to wash-downs and proactive weed control programs.
- Ensuring all reporting requirements are met.
- Act as the designated point of contact for and rapidly responding to any weed related complaints and incidents in accordance with the pre-determined strategies in this WMP and additional strategies as required developed in consultation with the Regional Weed Officer - Onshore Shale Gas Development and affected landholders.
- Review and update of WMP's to remain effective in communication with relevant landholders and Regional Weed Officer - Onshore Shale Gas Development in consideration of monitoring results and emerging weed issues for both gas and pastoral operations.

Origin has appointed **Robert Wear, Construction Superintendent** as the dedicated Weed Officer of the Beetaloo Exploration Activities.

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5. Weed Species Information

Weed surveys completed in August 2018 indicate the abundance of weeds within the proposed project area is low. *Hyptis suaveolens* (Hyptis), was identified along the access track to the proposed Velkerri 98-E1-1 site, whilst Gamba Grass (*Andropogon gayanus*) is also known to be in the broader region and is used by some Pastoralists in the region for wet season pasture. The pastoral properties using Gamba would be required to control the growth and spread to neighbouring areas (NTG, 2000).

Previous surveys within the permit area completed in 2014, 2015 and 2016 also confirmed the presence of Hyptis in the vicinity of the Carpentaria Highway near Velkerri 98 N1-2 (previously known as Amungee NW-1) site. *Parkinsonia aculeata* (Parkinsonia) and *Calotropis procera* (Rubber Bush) have been previously identified along/in close proximity to the Beetaloo access track. Parkinsonia is considered a Weed of National Significance (WoNS), which are weed species that are the focus of national management programs for the purpose of restricting their spread and/or eradicating them from parts of Australia. These species are specifically presented in Table 2 and Section 9.

Figure 2 illustrates the weeds species confirmed in the region during field surveys, along with other weed species that are known to occur or likely to occur within the wider exploration Permit Areas. This information is based on:

- Origin exploration program weed survey data (2014-2018 results)
- Mapping data provided by the Weed Management Branch, DENR.
- Guidelines for the *Management of the Weeds of Beetaloo 2018* (DLRM et al 2018).
- Barkly and Katherine Regional Weed Management Plans (RWMP)
- Department of the Environment and Energy (DEE) EPBC Act Protected Matters Report database.

Table 3 has been separated into priority weeds, RWMP alert species and other species previously identified in the area. Priority weed species are considered higher risk of being introduced or spread through the following criteria:

- Weed species that has been confirmed in the area within the relevant RWMP or through field surveys.
- Weed species listed in a RWMP that is in close proximity to Origin tenure.
- Weed species that are at risk of introduction through the use of machinery sourced from other regions in the NT or from other states.

Alert weed species are identified under the Katherine and Barkly RWMP. These species are not yet naturalised in the region, but have the potential to have a high level of impact to the region should it become established. The likelihood of the species naturalising and spreading in the region is perceived to be high (Department of Land Resource Management 2015).

It is noted that *Parthenium hysterophorus* is a major problem in rangelands and cropping areas of Queensland and is estimated to cost farmers and graziers more than \$22 million a year in reduced production and increased management costs. Vehicle, machinery and material movements from Queensland into the project area present a risk of spread of *Parthenium* if not managed correctly (Department of Primary Industry and Resources 2016).

Additional mapped locations of weeds within the Barkly and Katherine RWMP are provided in Figure 3 and Figure 4.

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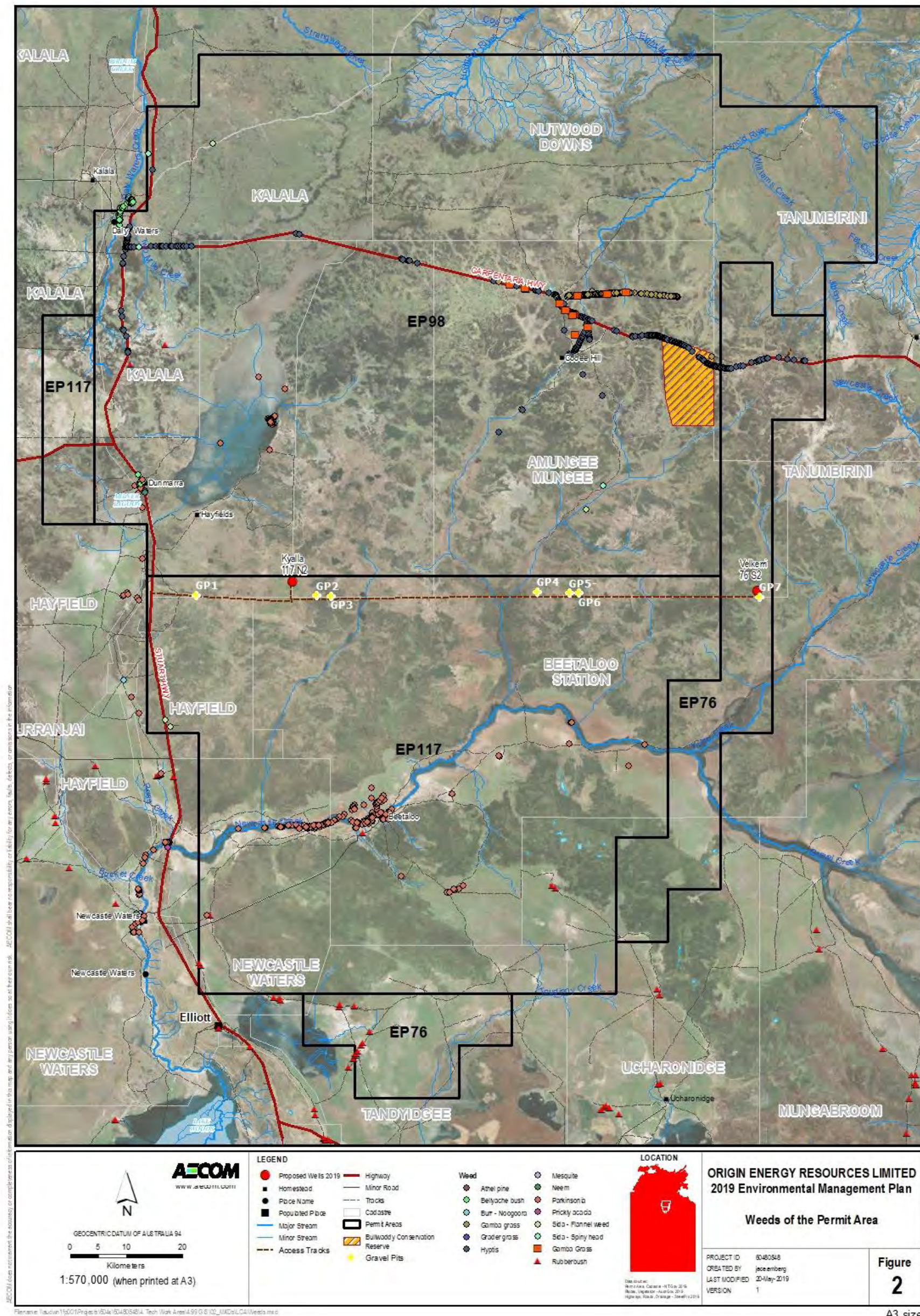


Figure 2 Location of Weeds Species in Permit Areas

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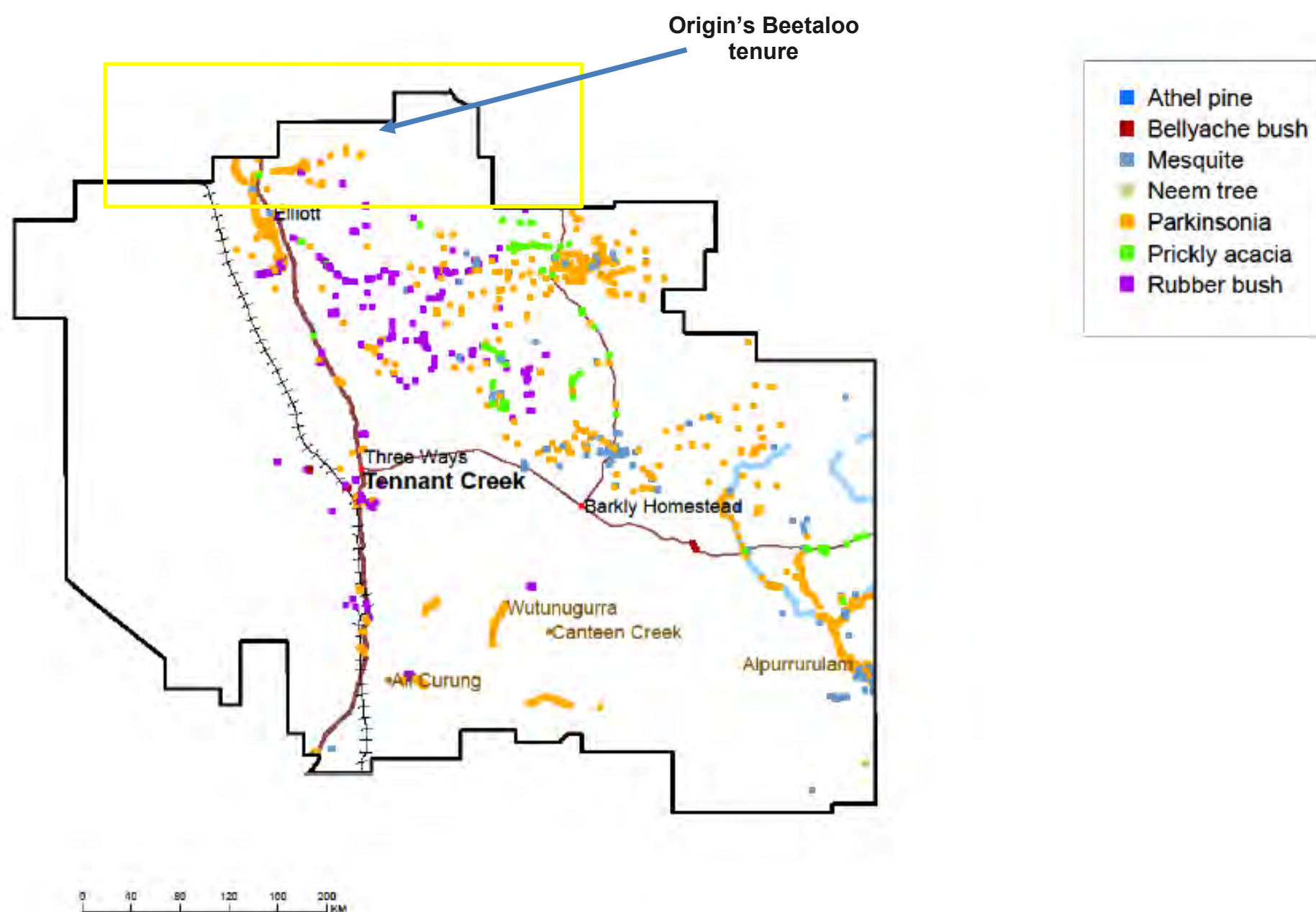


Figure 3 Barkly RWMP mapped priority weed locations

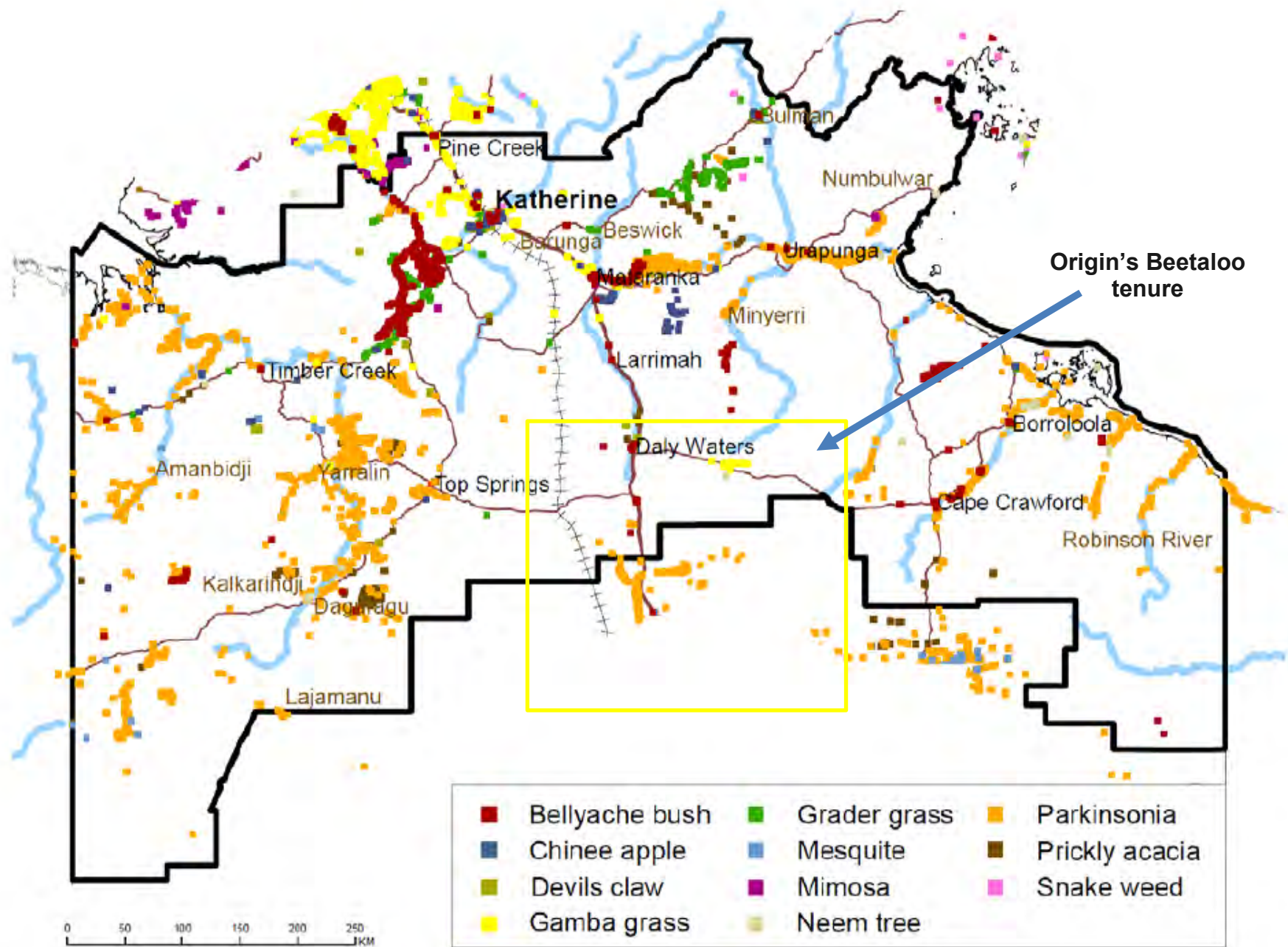


Figure 4 Katherine RWMP mapped priority weeds

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Table 2 NT listed weeds known of likely to occur within the Permit Area

Scientific Name	Common Name	Status	Data Source
Priority Weed Species			
<i>Acacia nilotica</i>	Prickly Acacia	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP
<i>Andropogon gayanus</i>	Gamba Grass	Class A WoNS	Confirmed within exploration lease. High potential introduction through sourcing of equipment from Katherine and Darwin area.
<i>Calotropis procera</i>	Rubber Bush	Class B and C	Mapped in the exploration lease within the Barkly RWMP
<i>Hyptis suaveolens</i>	Hyptis	Class B and C	Confirmed within exploration lease during previous weed Origin surveys
<i>Jatropha gossypifolia</i>	Bellyache Bush	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP. Potential introduction through sourcing of equipment from Katherine area.
<i>Parkinsonia aculeata</i>	Parkinsonia	Class B and C, WONS	Confirmed within exploration lease during previous weed Origin surveys and Mapped in the exploration lease within the Katherine RWMP. Potential introduction through sourcing of equipment from Katherine area.
<i>Prosopis pallida</i>	Mesquite	Class A and C, WONS	Mapped in the area surrounding exploration lease within the Katherine and Barkly RWMP
<i>Themeda quadrivalvis</i>	Grader Grass	Class B and C, WoNs	Confirmed within the exploration lease and mapped in the area within the Katherine RWMP. High potential introduction through sourcing of equipment from Katherine area.
<i>Parthenium hysterophorus</i>	Parthenium	Class A and Class C, WoNS	Confirmed by DENR to occur within the exploration lease. Potential introduction through equipment sourced from QLD.
Alert Species under RWMP			
<i>Cenchrus setaceum</i>	Fountain grass	Class B and C	Alert Species within the Barkly Region
<i>Cryptostegia grandiflora</i>	Rubber vine	Class A and C, WONS	Alert Species within the Barkly and Katherine RWMP
<i>Chromolaena odorata</i>	Siam Weed	Class C	Alert Species Katherine RWMP

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Scientific Name	Common Name	Status	Data Source
Other species potentially found in region			
<i>Alternanthera pungens</i>	Khaki Weed	Class B and C	DLRM databases (DLRM <i>et al</i> 2018)
<i>Azadirachta indica</i>	Neem	Class B and C	Weed Management Branch – Mapping data
<i>Cenchrus ciliaris</i>	Buffel Grass	Not declared in NT	DOTEE Protected Matters Report
<i>Cenchrus echinatus</i>	Mossman River Grass	Class B and C	DLRM databases (DLRM <i>et al</i> 2018)
<i>Datura ferox</i>	Fierce Thornapple	Class A and C	DLRM databases (DLRM <i>et al</i> 2018)
<i>Sida acuta</i>	Spinyhead sida	Class B and C	Weed Management Branch – Mapping data
<i>Sida cordifolia</i>	Flannel Weed	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM <i>et al</i> 2018)
<i>Sida rhombifolia</i>	Paddy's Lucerne	Class B and C	DLRM databases (DLRM <i>et al</i> 2018)
<i>Xanthium occidentale</i>	Noogoora Burr	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM <i>et al</i> 2018)

Note: Declarations under the Northern Territory Weeds Management Act 2013:

6. Weed Management Mandatory Requirements

6.1 Weed hygiene declarations for vehicles and equipment

1. All vehicles, equipment and loads are to be clean (free of plant matter, seeds, dirt and mud) and have a valid weed hygiene declaration form prior to accessing any pastoralist property
2. Weed hygiene certificates are only to be issued by an authorised inspector that is satisfied that the vehicle is free of plant matter, seeds, dirt, mud animal wastes and any other time that could potentially represent a biosecurity or weeds risk.
3. An authorised inspector is someone who has successfully completed the nationally recognised "AHC BIO201- Inspect and clean machinery for plant, animal and soil material" training course
4. Weed hygiene declarations shall contain:
 - a) The identification details of the vehicle or thing inspected.
 - b) Odometer reading (where applicable)
 - c) Date and location inspected
 - d) Name and signature of the authorised inspector issuing the declaration
 - e) The organisation with which the inspector issuing the declaration is affiliated
 - f) Name and signature of the driver (where applicable)
5. A biosecurity hygiene declaration for a vehicle/equipment remains valid when the vehicle/equipment:
 - a) does not travel off sealed/formed roads, or
 - b) clean (i.e. free of biosecurity matter including weeds, pests and diseases, and biosecurity carriers) or

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- c) is located on the same or adjacent property and has not come in contact with any areas with weeds. Areas where it is reasonably expected to come in contact with weeds include the unsealed shoulders of road corridors and known infestation areas as provided in Figure 2.
- 6. A biosecurity declaration becomes invalid when:
 - a) The vehicle or equipment has come into contact with known areas of weed infestations.
 - b) The vehicle or equipment has come from a property that is not adjacent to the property to be accessed
 - c) It is not known where the vehicle/ equipment has been previously used.

6.2 Weed hygiene declarations for loads and materials.

- 1. Weed hygiene declarations are to be utilised to satisfy that a load of materials (including hay, seed, sand, gravel, topsoil) is free of or containing a biosecurity matter and carriers. Anyone who is either the seller, supplier or the driver may issue a Weed Hygiene Declaration for a load just as long as they have direct knowledge of the product and the status as weed free or containing a biosecurity matter.
- 2. Weed declarations are not required for loads moved within areas within the same or adjacent properties that have been determined through baseline weed studies as being weed free.

6.3 Weed washdown facility requirements

- 1. Cleaning activities should be undertaken at facilities with effective environmental controls to prevent the spread of biosecurity matter.
- 2. Wash water, mud/ silt, weed material and other contaminants must be bagged and disposed of at a licenced landfill.
- 3. Where possible, high pressure water spray should be used. This is the preferred method. If this is impractical, (such as at a site location) the minimum requirement is to use a suitable bar or shovel, brooms/ brushes and compressed air to remove contaminants (dry cleaning).

6.4 Equipment sourcing and selection

- 1. Equipment shall be sourced based on the following prioritisation:
 - a) Local equipment, particularly civil construction equipment, shall be sourced as a priority.
 - b) Regional equipment (NT) shall be sourced where no local equipment supplier exists
 - c) Interstate equipment should be sourced only where local/regional equipment is not available (due to availability or cost constraints). In such cases, additional inspections may be required to ensure vehicles/ equipment are free of weed containing material prior to accessing site.

6.5 Interstate Transportation

All vehicles, equipment and loads moved interstate/territory shall be free of weeds and weed containing material (vegetation, seed, grass, soil, mud etc.) prior to entry into the NT.

All vehicles, equipment and loads travelling from interstate shall have a further inspection prior to access to any pastoral property. If required, additional cleaning shall be undertaken to remove any weeds or weed carrying material.

Where a load/equipment/ vehicle is unclean and is suspected of not being washed prior to entry into the NT, a load must be refused entry into a pastoralist property. The vehicle will require a washdown at an appropriate facility within the state/territory the equipment/vehicle/load originated from.

6.6 Weed management awareness

All staff and contractors shall be made aware of their weed management obligations. This shall be undertaken through:

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- Building weed prevention and management requirements into contracts and assessed as a part of work readiness reviews and ongoing assurance activities.
- Inclusion of weed management requirements within site inductions and toolbox talks

7. Weed Introduction and Spread Risks Assessment

As part of the development of the EMP for this project, Origin has undertaken an assessment of the risk of introducing or spreading weeds in the project area. This assessment and the corresponding proposed mitigation measures and management objectives are presented in Table 3 below. Due to the low abundance of weeds within the proposed project area, management controls will primarily focus on preventing the introduction of weed species through appropriate equipment sourcing cleaning and inspection.

Table 3 Risk of weed introduction and spread and corresponding mitigation measures

Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	Potential Risks		Management Controls
	Introduction of new weeds	Spread of existing weeds	
Vehicle and equipment movements	Vehicles and equipment sourced from other locations infested with weed species not found in or around Project Area	Traversing of weed infested areas with machinery	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. Wash-down would occur at Contractors depot or a commercial wash facility prior to mobilisation in a manner that prevents pollution of the surrounding environment. - Machinery to be preferentially sourced locally, with machinery sourced from surrounding areas or Queensland being the 2nd and 3rd preferred option respectively. - Weeds will be actively controlled in cleared/hardstand areas. - Major equipment moves will be planned from weed-free areas to infested areas and not the other way around. - Ensuring all material imported to or between sites is free of weeds.
Construction of access tracks	Importing materials from areas where weeds are present	Traversing of weed infested areas and creating	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities.

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Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	Potential Risks		Management Controls
	Introduction of new weeds	Spread of existing weeds	
and monitoring bore pads	and creating opportunities for weed species to colonise disturbed areas	opportunities for weed species to colonise disturbed areas	- Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification. - Machinery to be preferentially sourced locally, with machinery sourced from surrounding areas or Queensland being the 2nd and 3rd preferred option respectively. - Weeds will be actively controlled in cleared/hardstand areas. - Stabilise disturbed areas.
Drilling, stimulation and well testing	Introduction of weed species not found in or around EP area.	Traversing of weed infested areas with machinery	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Activities will adhere to the guidelines within the NT Weed Management Handbook. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - All equipment will have certified equipment wash-down completed prior to entry to the field. Wash-down would occur at Contractors depot or a commercial wash facility prior to mobilisation in a manner that prevents pollution of the surrounding environment. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification. - Weeds will be actively controlled in cleared/hardstand areas. - Major equipment moves will be planned from weed-free areas to infested areas and not the other way around. - Drilling and stimulation equipment will be restricted to cleared lease areas.

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Environmental Values	Maintain the integrity of significant ecosystems and agricultural productivity		
Management Objectives	Avoid the introduction of weeds Avoid the spread of existing weeds		
Measures Criteria	No introduction or spread of declared weeds resulting from Origins activities.		
Activity	Potential Risks		Management Controls
	Introduction of new weeds	Spread of existing weeds	
			- Ensuring all material imported to or between sites is free of weeds.
Operational/ site management	Personnel unable to identify weeds or unaware of weed species present in areas where machinery and equipment is sourced from	Existing weed distribution not known due to: insufficient survey effort, surveys conducted at wrong time of year, surveyors not familiar with / unable to identify declared weed species	- Code of Practice for Petroleum Activities in the Northern Territory Part A- Surface Activities. - Staff members responsible for preventing, identifying and managing weeds to be appropriately trained. - Weed desktop and field-based surveys to be provided to identify existing weed areas. - Pre-and post wet (February to May) inspections and periodic audits will be conducted to identify and report weed outbreaks.
	Insufficient management control to prevent the introduction of weeds	Insufficient management control to prevent the spread of weeds	- Staff members responsible for preventing, identifying and managing weeds to be appropriately trained. - Ensure field staff, contractors and machinery operators are familiar with hygiene protocols and weed identification (Weed identification posters and the NTG Weed Deck will be made available) - Weeds will be actively controlled in cleared/ hardstand areas. - Weed management and control measures to be implemented in alignment with existing landholder biosecurity requirements. - New activities will be planned to address prevention of weed or non-indigenous plant spread.

8. Statutory Weed Management Plans

No statutory weeds have been identified during surveys of the Project Area, however the following plans apply to species that have been found/ could be potential found in the broader region.:

- Weed Management Plan for Athel pine (*Tamarix aphylla*)
- Weed Management Plan for Mesquite (*Prosopis* spp.)
- Weed Management Plan for Prickly Acacia (*Acacia nilotica*)
- Weed Management Plan for Bellyache Bush (*Jatropha gossypifolia*)

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- Weed Management Plan for Neem (*Azadirachta indica*)
- Weed Management Plan for Gamba Grass (*Andropogon gayanus*)
- Weed Management Plan for Grader Grass (*Themeda quadrivalvis*).

The weed management plans detail the legislated obligations of all land owners, land managers and land users in the Northern Territory to eradicate or manage and avoid further spread of the weed species. Conducting land management practices in accordance with the weed management plans will secure compliance with the requirements of the Act (Department of Land Resource Management 2015).

9. Annual Action Plan

An action plan for each of the weed species identified in the Project Area is presented in Table 4. Treatment options as contained in the Northern Territory Weed Management Handbook are presented in Section 9.1 to Section 9.3.

This section will be undated if new weed species are discovered over the life of the program to ensure that statutory requirements with relation to declaration status and relevant weed management plans are addressed (refer to Section 8)

As part of the 2019 Annual Weed Management Action Plan, Origin also commits to undertaking finer detailed weed mapping of all permit area, lease pads, access tracks and gravel pits, as well as any other areas disturbed as part activity.

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Table 4 Annual Weed Management Action Plan

Management objective	- Avoid the introduction of weeds - Avoid the spread of existing weeds			
Weed species	Survey time/s	Treatment time/s	Control options	Where located
Hyptis <i>Hyptis suaveolens</i>	6 monthly- pre-and post wet season	- Preferred Dec – Mar - Also Nov and April	Refer to section 7.1.	Beetaloo access track Access track to Velkerri 98-E1-1 site
Parkinsonia <i>Parkinsonia aculeata</i>	6 monthly- pre-and post wet season	- Preferred Mar – May - Also all year round	Refer to section 7.2.	Beetaloo access track
Rubber Bush <i>Calotropis procera</i>	6 monthly- pre-and post wet season	- Preferred October – March - April - July	Refer to section 7.3.	Close proximity to the Beetaloo access track

9.1 Hyptis (*Hyptis suaveolens*) treatment options

Table 5 includes herbicide and non-chemical treatment options for Hyptis (*Hyptis suaveolens*) (Northern Territory Government 2015).

Table 5 Hyptis (*Hyptis suaveolens*) treatment options

Weed Species	Hyptis (<i>Hyptis suaveolens</i>)		
Control Methods	Chemical and concentration	Rates	Weed growth stage, method and comments
Herbicides	2, 4-D amine 625 g/L Various trade names	320 mL / 100 L	Seedling or adult (individuals or infestation): Foliar spray - apply when actively growing.
	Glyphosate 360 g/L Various trade names and formulations	15 mL / 1 L	Seedling or adult (individuals or infestation): Foliar spray - apply when actively growing.
Non-chemical applications	- Manually remove all plant material; slash to encourage competition from desirable species.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

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9.2 Parkinsonia (*Parkinsonia aculeata*) treatment options

Table 6 includes herbicide and non-chemical treatment options for Parkinsonia (*Parkinsonia aculeata*) (Northern Territory Government 2015).

Table 6 Parkinsonia (*Parkinsonia aculeata*) treatment options

Weed Species	Parkinsonia (<i>Parkinsonia aculeata</i>)		
Control Methods	Chemical and concentration	Rate	Weed growth stage, method and comments
Herbicides	Aminopyralid 8 g/L + Triclopyr 300 g/L + Picloram 100 g/L Grazon™ Extra	350 mL / 100 L or 3 L / ha	Seedling (individuals and infestation) Foliar spray – avoid spraying if plants are stressed or bearing pods – Uptake Spraying Oil required Foliar spray – plants up to 2 m or 2 years old - Uptake Spraying Oil required.
	Triclopyr 240 g/L + Picloram 120 g/L Access™	1 L / 60 L (diesel) 1 L / 60 L (diesel)	Seedling or adult (individuals or infestation) Basal bark < 5 cm stem diameter Cut stump > 5 cm stem diameter
	Tebuthiuron 200 g/kg	1.5 g / m2	Seedling or adult (individuals or infestation) Granulated herbicide - ground applied Do not use within 30 m of desirable trees or apply to continuous area > 0.5 ha. Do not use if fire is eminent. Apply when there is soil moisture or prior to rain.
Non-chemical applications	- Blade-ploughing, stick-raking, bulldozing and chaining can be effective if the root layer is removed from the soil. - Cultivation of pasture or native vegetation after mechanical control will help to prevent re-sprouting and seedling establishment. - Fire destroys seed in the soil surface and can be used as a follow-up to remove seedlings after other control efforts. - Fire may also be used to manage mature trees. Hand grubbing for single plants or small outbreaks, ensure removal of the root system. - Biocontrol options are available with Uu establishing slowly in some areas.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

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9.3 Rubber bush (*Calotropis procera*) treatment options

Table 7 includes herbicide and non-chemical treatment options for Rubber bush (*Calotropis procera*) (Northern Territory Government 2015).

Table 7 Rubber bush (*Calotropis procera*) treatment options

Weed Species	Rubber bush (<i>Calotropis procera</i>)		
Control Methods	Chemical and concentration	Rate	Weed growth stage, method and comments
Herbicides	Triclopyr 300 g/L + Picloram 100 g/L Conqueror®	750 mL / 100 L (water)	Seedling (individuals or infestation): Foliar spray. Check label for recommended adjuvant product. More effective on plants <2m as thorough coverage on all leaves is required
	+ Aminopyralid 8 g/L Grazon™ Extra	500-750mL / 100 L (water)	
	Triclopyr 240 g/L + Picloram 120 g/L Access™	1 L / 60 L (diesel) 1 L / 10 L (diesel) 1 L / 60 L (diesel)	Adult (individuals and infestation): Basal bark < 5cm stem diameter. Spray all stems. Spray to point of runoff. Thin Line up to 5cm stem diameter. Cut stump > 5cm stem diameter.
	Tebuthiuron (200g/kg) Graslan Pending registration. Please check with Weed Management Branch for status confirmation.	1.5-2g/m2	
	Fluroxypyr (333g/L) Starane™ Advanced	3 L / 100 L (diesel)	Adult: Cut stump method for plants up to 10cm diameter and 3m high.
Non-chemical applications	- This plant is difficult to eradicate as the deep roots survive almost any treatment. - Maintenance of a dense pasture sward will assist in preventing invasion.		

Source: Northern Territory Weed Management Handbook (Northern Territory Government 2015).

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10. Notification Procedure

The Regional Weed Officer – Onshore Shale Oil Gas Development at the Weed Management Branch of the DENR should be notified within 48 hours of the discovery of a new weed species in the Project Area.

Initial notification may be verbal, with follow-up written notification provided within seven working days. The notification should include a preliminary species identification and location information. The Regional Weed Officer will advise what further action is required.

It is noted that some species spread rapidly so immediate action may be required to control spread. For example, as stated above *Parthenium* (*Parthenium hysterophorus*) is a Class A (to be eradicated) and Class C (not to be introduced) weed in the Northern Territory as well as being classified as a Weed of National Significance. Early detection is crucial in not allowing this species to spread in the Northern Territory (Department of Primary Industry and Resources 2016).

In addition, it is noted that under the *Weeds Management Act* that:

'The owner and occupier of land must... within 14 days after becoming aware of a declared weed that has not previously been, or known to have been, present on the land, notify an officer of the presence of the declared weed'.

All weed outbreak incidents will be reported in Origin's OCIS and corrective action initiated.

11. Recording

Records of weed inspections will be maintained by Origin.

Data on weed distribution will be maintained within Origin's GIS and provided to the Weeds Officer at DENR as part of the annual report on performance against the Weed Management Plan, or as requested.

Data will be collected as per the requirements of the Northern Territory Weed Data Collection Manual - Section One Technical Data Description (Weed Management Branch, 2015).

Data will be recorded using the guidelines provided in Appendix A using the data sheet provided in Appendix B (Weed Management Branch, 2015).

The Northern Territory Weed ID Deck (Northern Territory Government 2017) will be referenced to assist with identification of species that have been identified as likely or known to occur in the Permit Area.

Field data will be submitted directly to the Weed Management Branch in a shapefile format or as an Excel spreadsheet, including incidental identification of weeds and following completion of field surveys.

12. Reporting

All weed outbreak incidents will be reported in Origin's OCIS and corrective action initiated.

A report on the performance against this Weed Management Plan will be submitted to DENR on an annual basis.

At a minimum, this should include:

- a) Details of activities implemented to address weed spread and introduction risks (e.g. vehicle wash down/ blow down locations, examples of track construction from working from weed free areas into weed infested areas to reduce spread).
- b) Details of survey and monitoring events, including dates, personnel, maps and track data.
- c) Submission of all weed data collected.
- d) Overview of weed control events and success rates (weed control should be captured in detail through the data collection process and submitted as a component of (a)).

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13. References

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- Northern Territory Government. 2000. *Information Sheet Gamba Grass*. http://www.drytropics.org.au/weeds_gamba_control.htm accessed 29 March 2019.
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- Northern Territory Government. 2018. *A – Z List of Weeds in the Northern Territory*. <https://nt.gov.au/environment/weeds/weeds-in-the-nt/A-Z-list-of-weeds-in-the-NT> accessed 13 September 2018.
- Scientific Inquiry into Hydraulic Fracturing in the Northern Territory. 2018. *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory – Final Report*.
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Appendix A Weed Data Collection Methodology

Field data collection for weed infestations

The following is a guide to efficiently evaluating and recording a weed site in the field.

Each record must identify the person or organisation taking the record, as well as the details explained below.

How to record weed area as a point record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as "Unknown weed" and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the size of the weed patch.

Look across the area of weeds to the furthest weed plant and decide the diameter. Decide if the area is best fits in a circle of either 20, 50 or 100 metres. If it is a single plant or small patch you would choose 20 metres. The size 100 metres extends about as far as you can see on the ground, if the weeds extend out of sight you will need to make another point further on. You may place overlapping circle areas to reflect different densities.

3. Assess the density of weeds within the circle.

Decide how much of the area is covered by weeds. Assign a score from 2 to 5 based on the percentage table below. It will be useful (if possible) to move into the centre of the weed circle. Consider the whole circle size chosen in step 2 deciding on the density score. Area covered should be determined by a 'projected canopy' method.

Density categories

- 1 = Absent, no weeds of this species in this area.
- 2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.
- 3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.
- 4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.
- 5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Take the GPS location (ideally) from the centre of the circle. If weed seeds may be spread or it is difficult to access the centre it is acceptable to take the reading from the location as close to the centre as practical.

5. Record the treatment.

Record the method you apply a treatment to the weeds, or record 'No Treatment'.

Choose from the list of treatment methods

i.e: No treatment, Unknown, Treated, Foliar spray etc.

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How to record weed area as a line (polyline) record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as "Unknown weed" and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the 'best fit' width in metres of the linear weed area.

Look along the area of weeds to the furthest weed plant and decide a width that best sums up the width of the infestation from values of 5, 20, 50 or 100 metres. If the width is too variable you may need to make more than one line or consider recording as points or as a polygon.

3. Assess the density of weeds within the line.

For the area of the line, being from start to finish at the designated width, decide the area covered by weeds. Assign a score from 2 to 5 based on the percentage table below. Consider the whole line area when deciding on the density score. Area covered should be determined by a 'projected canopy' method.

Density categories

- 1 = Absent, no weeds of this species in this area.
- 2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.
- 3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.
- 4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.
- 5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Start the GPS track, or line sketch from one end of the linear weed area. Walk or sketch a line as best fit through the middle of the linear weed area and finish at the end point.

5. Record the treatment.

Record the method you apply a treatment to the weeds, or record 'No Treatment'.

Choose from the list of treatment methods

ie: No treatment, Unknown, Treated, Foliar spray etc.

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How to record weed area as a polygon record

1. Record the species.

When a weed is sighted, move to the area and confirm identification of the weed. If you cannot positively identify the weed record it as “Unknown weed” and take a sample or photograph, do not try to guess. If more than one weed species is present then repeat the process with separate records for each species.

2. Assess the extent of the weed area and ensure it can be practically enclosed.

Polygons are good for clearly delineated areas of weeds, you should be able to walk around the edge of the weed area with confidence. Ensure the defined area of weed at a similar density can be delineated before attempting to create the area, you may need more than one polygon. If the area is poorly defined then the point method may be a more useful.

3. Assess the density of weeds within the polygon.

Assess the area covered by weeds for density, you may need to move to several vantage points to get a clear picture. Assign a score from 2 to 5 based on the percentage table below. Consider the whole area within the polygon when deciding on the density score. Area covered should be determined by a ‘projected canopy’ method.

Density categories

1 = Absent, no weeds of this species in this area.

2 = < 1%, Very few, not many weeds eg: single plant, perhaps with seedlings.

3 = 1 -10%, More than one or two isolated plants but not a lot eg: a few small plants.

4 = 11-50%, A lot, up to half the area covered eg: a tree, dense patches of weeds.

5 = > 50%, Dominant cover is weed, more than half covered eg: thickets, monocultures.

4. Record the location.

Start the GPS track, or polygon sketch from one point of the polygon weed area. It is useful to start from a landmark or flagging tape. Create the polygon edge line by walk a path or sketching along the outer edge of the weed area until you return to the start point. If using a GPS track to create the polygon ensure that you cross your start point so as to close the polygon.

5. Record the treatment.

Record the method you apply a treatment to the weeds in the area, or record ‘No Treatment’. Choose from the list of treatment methods

ie: No treatment, Unknown, Treated, Foliar spray etc.

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Weed Management Plan

NT-2050-15-MP-0016

Appendix B Example Weed Data Collection Sheet

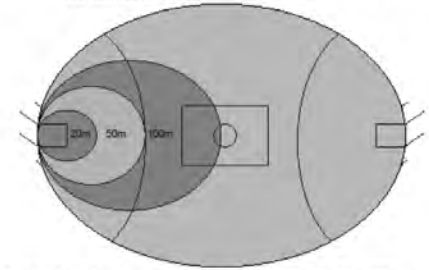
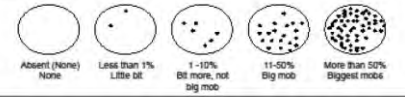
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RECORDER:					PROJECT:					LOCALITY:				
ORG_NAME:					GPS NAME/MODEL:					RECORDING METHOD :				
SITE_ID	DATE_REC	LAT_G94	LONG_G94	WEED_NAME	SIZE_DIA_M	DENS_CAT	SEEDLINGS	JUVENILES	ADULTS	SEED PRES	PAST_TREAT	TREATMENT	HERBICIDE	COMMENTS

Notes:

Treatment method Control method applied today as per below. If none, record 'No treatment' - Foliar spray - Residual application - Basal bark - Cut stump - Stem injection - Aerial spray - Slashed or cut - Hand pull Herbicide The active ingredient(s) of the herbicide applied today (if any) GPS waypt Waypoint ID as entered in the GPS Weed name Common name or scientific name for the weed recorded S (y/n) Seedlings: Are seedlings visible? J (y/n) Juveniles: Are juvenile plants visible? A (y/n) Adults: Are there adult plants, or seeds, or evidence of past seeding present? Seed (y/n) Seeds: Are seeds visible today? Or plants with seeds or pods? Treat (y/n) Treatment: Did you apply treatment to this site? Comment Record any notes for yourself here.	Size dia m Size/diameter of the area you are recording information about (in metres). Use 20m, 50m or 100m.  Example of size/diameter compared to a football oval. (Sizes 20m, 50m, 100m)	Dens cat Density of weeds in the assessed area using categories described below <table border="1"> <tr> <td>1 = No weeds (absent)</td> <td>2 = Single plant or very few (<1%)</td> <td>3 = A few plants (1-10%)</td> </tr> <tr> <td>4 = Many weeds, up to half (11 - 50%)</td> <td>5 = Mostly weeds, more than 50%</td> <td>6 = Density not assessed</td> </tr> </table> Density category (Dens cat) examples 	1 = No weeds (absent)	2 = Single plant or very few (<1%)	3 = A few plants (1-10%)	4 = Many weeds, up to half (11 - 50%)	5 = Mostly weeds, more than 50%	6 = Density not assessed
1 = No weeds (absent)	2 = Single plant or very few (<1%)	3 = A few plants (1-10%)						
4 = Many weeds, up to half (11 - 50%)	5 = Mostly weeds, more than 50%	6 = Density not assessed						

(extracted from *Northern Territory Weed Data Collection Manual - Section One Technical Data Description*.)

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Appendix K Drilling, Stimulation, Completion and Testing Program Risk Assessment

Risk Matrix

Risk Matrix								LIKELIHOOD							
								1 REMOTE	2 HIGHLY UNLIKELY	3 UNLIKELY	4 POSSIBLE	5 LIKELY	6 HIGHLY LIKELY		
								<1% chance of occurring within the next year. Only occurs as a '100 year event' or less frequent.	<10% chance of occurring within the next year. Could occur within decades.	<30% chance of occurring within the next year. Could occur within the next few years.	<60% chance of occurring within the next year. Could occur within months to years.	<90% chance of occurring within the next year. Could occur within weeks to months.	Likely to happen multiple times a year		
IMPACT ON ORIGIN OPERATIONS						EXTERNAL RESPONSE									
Conduct Business with Due Care			Create Value			Decisions are Subject to Scrutiny									
People		Environment and Community	EBIT	Cash flow	NPV	Stakeholder Perceptions	Laws, regulation and civil actions								
CONSEQUENCE	6 CATASTROPHIC	Multiple fatalities ≥4 or life threatening illness or total permanent disability to a large exposed group (10 or more people)	Extensive permanent damage to endangered species, habitats, ecosystems or area/s of cultural significance Extensive irreversible loss of community livelihood. Long-term social unrest and outrage	>\$200m	>\$1b	>\$1.5b	Multiple stakeholder groups confirming coordinated action, as reflected in media channels with significant reach and influence (eg. scheduled blockade or boycott covered in media for more than 1 week).	Criminal charges against any director or senior executive involving jail or loss of right to manage the company. Public inquiry – requiring considerable resources and Executive Management time. Loss of licence to operate an asset	6 CATASTROPHIC	HIGH	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
	5 CRITICAL	1 – 3 fatalities or life threatening illness or total permanent disability to a small exposed group (<10 people)	Extensive long term partially reversible damage to vulnerable species, unique habitats, ecosystems or area/s of cultural significance Extensive reversible loss of community livelihood. Prolonged community outrage.	>\$50m - \$200m	>\$250m - \$1b	>\$375m - \$1.5b	Multiple stakeholder groups mobilising and encouraging others to take action, as reflected in media channels with significant reach and influence (eg. social media campaign calling for protest, escalating over several days).	Criminal charges against any director, senior executive or senior manager not involving jail or loss of right to manage the company. Prolonged major litigation – exposure to significant damages / fines / costs. Suspension / restriction to operate an asset.	5 CRITICAL	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH	VERY HIGH
	4 MAJOR	Injury or illness to one or more persons, resulting in permanent partial disability	Long term reversible impacts to listed species, habitats, ecosystems or area of cultural significance Significant impacts to community cost of living, business viability or social wellbeing. High levels of community tension.	>\$20m - \$50m	>\$100m - \$250m	>\$150m - \$375m	More than one stakeholder group's opinion or view influencing other stakeholders, reported through media channels with some reach and influence (eg. government comments in national media or in Parliament).	Criminal charges against any employee (not described above) Major litigation – exposure to damages / fines / costs.	4 MAJOR	MEDIUM	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH
		3 SERIOUS	Injury or illness to one or more persons resulting in hospitalisation, 5 or more days lost time or alternative / restricted duties for 1 month or more	Serious medium term reversible impacts to low risk species, habitats, ecosystems or area/s of cultural significance Moderate impacts to community cost of living, business viability or social wellbeing. Moderate levels of community tension.	>\$5m - \$20m	>\$25m - \$100m	>\$37.5m - \$150m	More than one stakeholder group offering an opinion or view, reported through media channels with some reach and influence (eg. state based commentary lasting one 24 hour media cycle across internet, print, television, radio).	Non-compliance with conditions of licence to operate an asset or to conduct an activity. Litigation – exposure to damages / fines / costs.	3 SERIOUS	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH
	2 MODERATE	Injury or illness to 1 or more persons resulting in medical treatment, up to 5 days lost time or alternative / restricted duties for up to 1 month	Moderate short term impacts to common regional species, habitats, ecosystems or area of cultural significance Small scale impacts to cost of living, business viability or social wellbeing. Isolated examples of community tension.	>\$1m - \$5m	>\$500k - \$25m	>\$750k - \$37.5m	A single stakeholder group drawing attention to an incident, issue or approach, conveyed though media channels with potential reach and influence (eg. some social media complaints or local media reports).	Moderate non-compliance with external mandatory obligations or breach of contractual or other legal obligations (not described above). Litigation possible.	2 MODERATE	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
	1 MINOR	Injury or illness requiring first aid to 1 or more persons, or no treatment (record only)	Minor environmental or community impact - readily dealt with	>\$100k - \$1m	<\$500k	<\$750k	A person or organisation within stakeholder group signaling an interest in an incident, event or approach, using channels with limited reach or influence (eg. letter of complaint/commendation).	Minor non-compliance with external mandatory obligations or breach of contractual or other legal obligations.	1 MINOR	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
1	Groundwater	Changes in aquifer quality from subsurface (drilling and stimulation) activities impacting a receptor (groundwater user or Groundwater Dependent Ecosystem).	Contamination from drilling fluids Drilling fluids used to drill through the Cambrian Limestone Aquifer (CLA) are water-based with clay inhibition in the form of KCl. This may result in temporary elevated levels of chlorides in the CLA immediately adjacent to the well bore during the drilling of the top hole section of the well. (Path 1)	B.4.10- Drilling fluids B.4.17 Groundwater monitoring	1	5	M	•Drilling fluids used to drill through CLA are low toxic, water-based with addition of bentonite and salt in the form of potassium chloride for clay inhibition. (Engineering) •Drilling Fluids included in chemical risk assessment and determined to be of low concern through adoption of standard chemical management practices (Administration) •Results of Kyalla 117 N2-1 exploration well will be used to optimise the drilling of all proposed new wells, with fluid systems modified where fluid loss zones are anticipated (Elimination) •Impacted area likely to be localised around the immediate vicinity of each well bore (Elimination) •Karst system likely to result in rapid dilution (Elimination) •Site selection: No pastoralist extraction bores within 1km. (Elimination) •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range	•Monitoring of drilling fluid returns to identify fluid losses and modify fluid systems (Engineering) •Impact groundwater monitoring bores constructed within 20m of exploration well, with any changes detected rapidly (Engineering)	•Use of loss of circulation material (such as fibres or dissolvable marbles) to mitigate drilling fluid losses when drilling within aquifers (Engineering) •Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	1	3	L	Yes	This risk consequence is managed through the COP requirements that only water based drilling fluids are to be used which will not result in a residual toxic effect to the aquifer. The consequence is anticipated to be "minor", with a locally restricted, rapidly reversible impact. The likelihood is reduced by the type of drilling fluids used, rapid dilution of karst formations and the 16km separation distance from the closest pastoral user. The likelihood of contamination at any receptor is considered remote- with a probability lower than 1%.	Yes	Low
2			Cross flow of formation through inappropriate well barrier design and construction. (Path 1)	B.4.3 Well design and barriers B.4.2 Aquifer isolation B.4.7 Primary cementing B.4.17 Groundwater monitoring	3	1	L	•Each well designed and constructed with multiple (4) casing barriers and specifically-engineered cement in place to protect aquifers- this includes the 18.625" Conductor casing, 13.75" surface casing, 9.625" intermediate casing and 5.5" production casing. •Casing shoe for the conductor and surface casing section to be located in the base of each aquifer unit, with cement returned to surface •Any impacted area likely to be localised, around the immediate vicinity of the E&A wells. •No driving head between saline formations (below Gum Ridge) and surface aquifers- cross flow potential is limited •No landholder bores within 1km. •No major GDE linked to CLA within 100km of extraction point	•Well Barrier Integrity Validated (WBIV) through casing pressure tests and Casing shoe integrity leak of test during the construction of each casing string •Monitoring of cement returns to surface, with cement volume sand density as per programme •Cement bond logs (CBL) completed on each well prior to stimulation to confirm integrity •Each well designed, with a Well Barrier Integrity Validation report approved by DITT as part of Well Operations Management Plan (WOMP). •Groundwater monitoring bores installed to detect and trigger response in the case of contamination.	•2 stage cement job completed where fluid losses. 1st stage places cement from the casing shoe to the base of the loss zone. 2nd stage places cement 30m above the zone of losses, using an inflatable casing packer coupled with a stage tool assembly. •Cement repair jobs (such as squeeze jobs) to be performed to mitigate poor cement coverage. •Plug and abandonment and re-drilling of new vertical/ horizontal well sections where required.	3	1	L	Yes	The risk of cross formation flow is managed through the COP which provides specific well barrier design and validation requirements to mitigate the risk of aquifer interconnectivity. The well barrier design is submitted to DITT as a part of the WOMP and must be approved prior to the commencement of drilling. The integrity of each well is validated prior to the commencement of hydraulic fracture. the consequence of an interconnectivity event is likely to be "serious", with spatially restricted (to the vicinity of the well), medium term reversible impacts. The Likelihood of multiple casing and cement failures from occurring is considered remote, with a probability lower than 1%. this is confirmed by the NT inquiry that estimated the likely well failure rate (total failure of all barriers) to be less than 0.1%.	Yes	Low
3			Crossflow through fracture growth into aquifer from stimulation activities allowing the migration of fluid and gas. (Path 2)	B.4.3 Well design and barriers B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	3	1	L	•Each well designed and constructed with multiple (4) casing barriers and specifically-engineered cement in place to protect aquifers- this includes the 18.625" Conductor casing, 13.75" surface casing, 9.625" intermediate casing and 5.5" production casing. •Casing shoe for the conductor and surface casing section to be located in the base (Aquitard) of each aquifer unit, with cement returned to surface •Geomechanical data collected during Kyalla 117 N2-1 used to understand fracture gradients. •Geomechanical modelling validated from Kyalla 117 N2-1 stimulation results and ensure to appropriate fracture barriers are sufficient to contain the fracture propagation. •Modelling to factor in results of Kyalla 117 N2-1 to optimise stimulation design. •Hydraulic fracture stimulation risk assessment completed prior to stimulation to determine fracture growth. •Minimum 1400m vertical separation distance between target formation and closest aquifer. •Each horizontal well to be at least 2-400m separated, with the separation distance determined through the Mechanical earth model and results from Kyalla 117 N2-1 stimulation. •Overlying sequences have a higher fracturing pressure reducing the risk of fracture migration out of the target shale.. •Any impacted area likely to be localised, around the immediate vicinity of the E&A wells. •No driving head between saline formations (below Gum Ridge) and surface aquifers- cross flow potential is limited •No landholder bores within 1km. •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range	•Well Barrier Integrity Validated (WBIV) through casing pressure tests and Casing shoe integrity leak of test during the construction of each casing string •Monitoring of cement returns to surface, with cement volume sand density as per programme •Cement bond logs (CBL) completed on each well prior to stimulation to confirm integrity •A Well Barrier Integrity Validation report approved by DITT as part of Well Operations Management Plan (WOMP). •Real time pressure monitoring of stimulation pressure to determine if a fracture has propagated outside the design operating envelope. •Groundwater monitoring bores installed to detect and trigger response in the case of contamination.	•Stimulation activities to cease and be reviewed where fracture propagation extends beyond the target formation (noting a 1400m separation between the closest regional aquifer). Where fracture growth is suspected to reach an aquifer, Stimulation activity on pad suspended until a go forward plan submitted by Origin and approved by DITT.	3	1	L	Yes	The risk is managed through the COP requirements for well integrity, validation and stimulation modelling. The consequences of aquifer interconnectivity is further reduced through pressure monitoring during stimulation. Any uncontrolled fracture growth is likely to be detected rapidly using pressure monitoring and managed to prevent growth into aquifers. Management of any pressure indicating interconnection would be investigated and could result in a potential repair and/ or abandonment of the well. Contamination is likely to be serious, with impacts locally restricted to the vicinity of the well and reversible over the moderate term (months to years). The likelihood of a fracture growth into an aquifer is controlled by the stress regime of the overburden and the 600m separation distance between the target formation and overlying aquifers. The likelihood is considered "remote", with a probability of <1%.	Yes	Low
4			Stimulation activity induces seismic activity that enables cross formational flow between shallow aquifers. (Path 5)	B.4.13 Hydraulic Stimulation and Flowback Operations B.4.17 Groundwater monitoring	2	1	L	•Wells are located away from known geohazards, with no significant faults within proximity of activity (Elimination) •Kyalla 117 N2-1 stimulation completed without inducing seismic activity (Elimination) •Stimulation is not linked to major seismic events (reinjection of wastewater is generally recognised as the main cause). No reinjection of wastewater proposed (Elimination) •Stimulation stages deployment will be away from geohazards to reduce the loss of fluids into any encountered faults (Elimination) • The Beetaloo is not prone to seismic activity and there is no evidence of recent earthquake activity as most faults and the major subsurface structure are confined to Cambrian or older strata. This is supported by the National seismic Hazard Assessments completed by Allen 2018 (Figure 33), which highlight the Beetaloo is located within a low hazard area (Elimination) •Any faults encountered during drilling will be assessed to determine risk of stimulating with appropriate separation distances applied (Elimination). •1400m separation distance between target Kyalla formation and the Gum Ridge Aquifer. (Elimination) •No landholder bores within 1km (Elimination) •Depth of aquifers generally below known stygofauna distribution range (elimination)	•Monitoring of stimulation pressure to detect and respond to anomalies which may indicate fluid being pumped to an open geological structure (Engineering) •Geoscience Australia's Waramungu seismic array located approximately 300km of the proposed Kyalla 117 N2 well pad. It is likely that any material seismic events above a 2 MI. will be detected via this array if they occur (Administration) •An induced seismicity traffic light system has been adopted and outlined in the WOMP (Administration)	•Where seismic activity is recorded in Origin's tenure during hydraulic stimulation activities, the actions in the WOMP Traffic Light System will be enacted as summarised below: Green: Local Magnitude (MI) <2.0- no action required Orange: ML 2.0- <3.5MI- Report event to DITT and continue operations Red: ML> 3.5- Stimulation activity on pad suspended until a go forward plan submitted by Origin and approved by DITT.	2	1	L	Yes	The consequence of a induced seismicity, based upon evidence from the UK and US, indicates that the consequence is likely to be "moderate", with most events restricted to discrete areas at a size that generally cannot be detected at the surface (below 2 order of magnitude). Larger events are rare and generally a factor of the existing built up stress regime of the area- rather than a factor of the intensity of hydraulic fracturing or wastewater injection. The likelihood of a seismic event is reduced through the geological setting of the Beetaloo Basin itself and the safeguards implemented in the COP requiring geohazard assessment and avoidance. In the Beetaloo, there have been no earthquakes over magnitude 3 measured since records began. The area is not prone to seismic activity and there is no evidence of recent earthquake activity as most faults and the major subsurface structure are confined to Cambrian or older strata. This is supported by the National seismic Hazard Assessments completed by Allen 2018 (Figure 33), which highlight the Beetaloo is located within a low hazard area. The COP requires any geohazard (such as fault) identified prior to drilling (from existing seismic or interpreted data) or encountered during drilling to have a risk assessment to the determine the potential for reactivation. Any faults identified would not be stimulated, with a risk-based buffer applied. Given the number of wells stimulated in the US without issue and geological setting of the Beetaloo basin, the likelihood is considered remote, with a probability less than 0.1%.	Yes	Low

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5			Migration via fractures intersecting with offset wells (including the adjacent horizontal wells) or intersecting an existing geohazard. (Path 2 & 5)	B.4.13 Hydraulic Stimulation and Flowback Operations	2	1	L	•Kyalla 117 N2 site screened for geohazards using seismic before drilling • Wells are located away from known geohazards, with no significant faults within proximity of activity (Elimination) •Results from Kyalla 117 N2-1 confirm the lack of significant faulting or other geohazards •Kyalla 117 N2-1 stimulation completed without any uncontrolled fracture growth (Elimination) •Fracture modelling undertaken to determine maximum fracture growth prior to the commencement of stimulation activities. • Any faults encountered during drilling will be assessed to determine risk of stimulating with appropriate separation distances applied (Elimination). •Stimulation stages deployment will be away from geohazards to reduce the loss of fluids into any encountered faults (Elimination) •Separation of at least 200m between each horizontal well, with final separation distance determined through modelling. •Each adjacent well designed and constructed with multiple (4) casing barriers and specifically-engineered cement in place to protect aquifers- this includes the 18.625" Conductor casing, 13.75" surface casing, 9.625" intermediate casing and 5.5" production casing. •1400m separation distance between target Kyalla formation and the Gum Ridge Aquifer. (Elimination) •No landholder bores within 1km (Elimination) • Closest legacy exploration well 10 km (well is abandoned). •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range (elimination)	•Monitoring of stimulation pressure to detect and respond to anomalies which may indicate fluid being pumped to an open geological structure or migrating away from target zone (Engineering) • Pressure monitoring undertaken on adjacent wells •Groundwater monitoring bores adjacent to exploration wells (Administration)	•Stimulation activates to cease where fracture propagation is suspected to have interacted with an adjacent well. Stimulation activity on pad suspended until a go forward plan submitted by Origin and approved by DITT.	2	1	L	Yes	If an integrity issue was to occur, leakage of gas and flowback would be contained within the inner casing strings of the adjacent well (in this case the existing Kyalla 117 N2-1 or other newly installed well), significantly reducing the consequence and likelihood of an event. The likelihood risk is mitigated through the 1) design of adjacent E&A wells which are constructed in accordance with the COP using multiple, verified barriers (Cement and steel casing) 2) the location of the closest historic exploration well is located approximately 10km from the well pad and 3) Geohazards have not been identified during the drilling of the Kyalla 117 N2-1 exploration well. The likelihood is considered Remote", with a probability lower than 1%.	Yes	Low
6			Crossflow/well integrity caused by the deviation of an E&A well into the adjacent well during drilling	B.4.1 Well Integrity Management B.4.3 Well design and barriers	3	1	L	•Separation distance between adjacent wells: Vertical separation of >10m and horizontal separation of >200m used to ensure appropriate well separation. (Engineering) •Each adjacent well designed and constructed with multiple (4) casing barriers and specifically-engineered cement in place to protect aquifers- this includes the 18.625" Conductor casing, 13.75" surface casing, 9.625" intermediate casing and 5.5" production casing.(Engineering) • 1400m separation distance between target Kyalla formation and the Gum Ridge Aquifer. (Elimination) •Subsurface collision of a well during drilling is unlikely to result in formation cross flow, with collision likely at depth (below Aquifers) and flow restricted to the well being drilled. Well being drilled will have multiple barriers (at least the conductor casing and surface casing) and blow out prevention in place during drilling (Engineering/Elimination) • Origin has conducted multiwell drilling operations across Australia, including the Cooper, Bowen and Surat Basins. Origin and their contractors experience is mature. (Engineering) •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range (elimination)	•Continuous GPS tracking of the drill bit to detect and respond to vertical and horizontal well deviations during drilling (Engineering) •Pressure monitoring undertaken on adjacent wells (Engineering)	•Well orientation to be actively controlled to prevent deviations into adjacent wells (Engineering) • Wells remediated in accordance with the code of practice (engineering) •Well suspension and abandonment may be required where wells interact during drilling (Engineering)	3	1	L	Yes	The consequence of the vertical or horizontal section of the well deviating into the adjacent well during drilling is primarily a destruction in asset value (potential plug and abandonment of both wells). Any cross flow is likely to be contained within both of the well bores- with casing and cement isolating the relevant aquifers. Given the continuous logging of GPS location of the bit, the likelihood is considered remote, with a probability less than 1%.	Yes	Low
7			Leakage of either flowback, produced water, or hydrocarbons (liquid and gaseous) from suspended or abandoned wells. (Path1)	B.4.1 Well Integrity Management B.4.2 Aquifer Isolation B.4.3 Well design and barriers B.4.15 Well suspension and decommissioning B.4.17 Groundwater monitoring B.4.15.2 D.5.5 Leak Remediation and Notification	3	1	L	•Each well designed and constructed with multiple (4) casing barriers and specifically-engineered cement in place to protect aquifers- this includes the 18.625" Conductor casing, 13.75" surface casing, 9.625" intermediate casing and 5.5" production casing (Engineering) •Casing shoe for the conductor and surface casing section to be located in the base of each aquifer unit, with cement returned to surface (Engineering) •Well design and Well Barrier Integrity Validation reports submitted to DITT as part of Well Operations Management Plan (WOMP). (Administration) •Cement plugs used to isolate hydrocarbon zones from aquifers •Cement plugs to be tagged to test plug integrity •Casing annuli pressure to be monitored to determine successful formation isolation. •Any impacted area likely to be localised, around the immediate vicinity of the E&A wells. (Elimination) •No landholder bores within 1km. (Elimination) •No major GDE linked to CLA within 100km of extraction point	•Integrity of isolation validated before and after stimulation and maintained throughout well life (Engineering) •Monitoring of cement returns to surface, with cement volume sand density as per programme (Engineering) •Cement bond logs (CBL) completed on each well prior to stimulation to confirm integrity (Engineering) •A Well Barrier Integrity Validation report approved by DITT as part of Well Operations Management Plan (WOMP) (Administration) •Routine (6 monthly) monitoring of well integrity in accordance with code of Practice (Engineering) •Routine (6 monthly) well leak detection on all wells.	•Any contamination event to be characterised and have remediation plans developed and executed immediately in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	3	1	L	Yes	The risk is primarily reduced through the stringent well barrier design, construction and verification requirements outlined in the COP. If an integrity issue was to occur, leakage of gas and flowback would be contained within the inner casing strings significantly reducing the consequence and likelihood of an event. A contamination event is likely to result in "serious", reversible moderate impacts (months to years) restricted to the vicinity of the lease pad. The likelihood is reduced by the presence of multiple casing strings, likely low leakage rate and rapid dilution of any contamination. The NT inquiry concluding the likelihood of this scenario being very low, typically less than 0.1%. This likelihood of this risk is therefore considered to be "remote".	Yes	Low
8	Groundwater	Contamination of aquifer from surface activities (chemical and waste storage, handling and spills) impacting a receptor (groundwater user or GDE).	Surface contamination from storage and disposal of drilling fluids, additives, muds and cuttings on-site. (Path 3 & 7)	A.4.7 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.5.1 Drilling Materials C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan C.8.1 Wastewater Management Plan	2	2	L	•Each well cellar to be concrete lined to contain drilling fluids with pumps to prevent overflow. •Drill cuttings and muds are not expected to contain high NORMs levels- with validation testing undertaken in accordance with the COP •Open wastewater evaporation tanks and drill sumps to have a 1:1000ARI wet season freeboard (wet season freeboard 1.3m). •Drilling sumps to be lined with an impermeable coletanche liner with a permeability of less than 6 x10-14 m/s. •Drilling sump to be designed and operated to handle the drilling of multiple wells •Sump solid levels to be periodically removed from the sump between wells to maintain sump capacity •Any removed drilling muds and cuttings from the sump will be stored on an impermeable liner with a permeability of less than 6 x10-14 m/s- any fluid captured and directed to the wastewater tank •Drill cuttings and muds to be tested and either disposed of onsite in accordance with the Code of Practice or disposed of at a licenced waste management facility.. •Storage areas to be lined with an impermeable liner (with a permeability of less than 6 x10-14 m/s to prevent contamination •Separation between sump and aquifer over 70m, with interbedded clays present. •Nearest landholder extraction bore 1km. •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range (elimination)	•Inspections of storages to be undertaken daily during the wet season and weekly at other times to identify potential liner issues. •Impact and control groundwater monitoring bores installed on the Kyalla 117 N2 lease pad to detect any potential contamination. •Groundwater monitoring completed quarterly to detect changes in groundwater quality.	•Any damage to sump liner to be repaired as soon as practicable. •Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering) • Any spills of drilling fluid and muds to be cleaned up as soon as practicable	2	2	L	Yes	In accordance with the COP, the onsite storage and disposal of drilling fluids and cuttings can only occur if the activity does not represent an unacceptable environmental hazard. All drilling fluids, muds and cutting will be stored in a lined sump, with testing undertaken prior to final disposal. Sump liner failure is considered to be a low consequence event, with contamination likely to be restricted to the immediate vicinity of the sump due to a lack of hydrological head. Onsite disposal will only occur if determined to be safe by an independent third party. The consequences are therefore likely to be restricted to a Moderate- short term reversible impacts. The likelihood of contamination through drilling fluid, mud and cuttings storage and failure is considered highly unlikely, with the probability below 10%. this is largely due to the separation distance between the underlying aquifer, use of lined sumps and third party disposal suitability assessments.	Yes	Low

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9			Storage, handling and transportation of produced hydrocarbons (condensate). (Path 3)	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	2	1	L	- Tanks to be compliant with AS 1692 and double-lined - Spill Management Plan implemented to prevent, detect and respond to spills. - Separation between condensate storages and closest aquifer over 70m, with interbedded clays likely to limit any contaminant migration. - Any condensate transportation to be undertaken by licenced transporters (for Dangerous goods or wastes) - Flare pit to be lined and freeboard maintained to prevent contaminant releases or overflows. - Nearest landholder extraction bore 1km. - Impact and control groundwater monitoring bores installed to of to detect any potential contamination. - Spills and leaks to be cleaned up immediately. - No major GDE linked to CLA within 100km of extraction point	- Weekly inspections to identify any potential leaks or spills from storage and handling areas. - Daily level monitoring during production - Quarterly groundwater monitoring	- Spill management plan implemented outlining leak classification, response and reporting requirements - All leaks to be cleaned up as soon as practicable - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	1	L	Yes	The regulatory regime legislating the storage, handling and transportation of dangerous goods and combustible liquids within Australia is mature. Double lined tanks will be used which will reduce the potential for spills/ leaks. Any spillage is likely to be locally restricted, small and rapidly detected. Consequences are considered moderate, with impacts spatially restricted to the lease pad, primarily located on the surface (condensate has low mobility) an likely to be of a short term (days to weeks). The likelihood of contamination is influenced by the lack of mobility of condensate, separation distance between aquifer and the surface and likely rapid detection of any spills. The likelihood of a groundwater event from condensate management is considered remote with a <1% probability	Yes	Low
10			Surface spills from storage, handling and transportation of flowback water. (Path 3 & 7)	A.4.7 Containment of Contaminants B.4.13 Hydraulic Stimulation and Flowback Operations C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan C.8.1 Wastewater Management Plan	2	1	L	- Tanks to be double-lined with impermeable liners with impermeable membrane with coefficient of permeability of less than 10-9 m/s - Leak detection to be located within the interstitial space between the primary and secondary liner to detect any potential leaks. - Chemical storage and handling areas to have secondary containment, with an impermeable membrane with coefficient of permeability of less than 10-9 m/s - The leases is compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. - The earthen bund is constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. - The site earthen bund has a bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. - Licenced waste transporters to be used for all listed waste transportation - Based on the N2-1H well, NORM levels are not anticipated to be significant- with characterisation of levels within drilling wastewater and flowback undertaken to validate. - Separation between chemical storages and closest aquifer over 70m, with interbedded clays likely to limit any contaminant migration. - Nearest landholder extraction bore 1km. - No major GDE linked to CLA within 100km of extraction point - Depth of aquifers generally below known stygofauna distribution range (elimination)	- Leak detection to be located within the interstitial space between the primary and secondary liner to detect any potential leaks. • Leak detection alarms to identify when a leak is potentially identified - Daily inspections during wet season and weekly inspections during the dry season to identify any potential leaks. - Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination - Quarterly groundwater monitoring - Sampling for NORMs to characterise and assess levels within drilling wastewater and flowback undertaken.	- Liner leaks to be investigated and liners repaired as soon as practicable - Spills and leaks to be cleaned up and rectified immediately - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	1	L	Yes	The consequence and likelihood of groundwater contamination are reduced by the duration of the activity, separation of underlying aquifer units for the surface, mandated use of double lined tanks with continuous leak detection and secondary containment for all chemical storage areas. Any spill onsite is therefore likely to be small, restricted to the chemical storage areas and rapidly detected. The potential consequence of ground water contamination event is likely to be "moderate", with potential spill consequences likely to be locally restricted, moderate-short term and reversible. The likelihood is reduced down to remote with a probability of less than 1%. This is primarily influenced by the lack of spill sources, separation distance between aquifers and the surface and spill management plan that will rapidly detect any spills.	Yes	Low
11			Storage, handling and transportation of chemicals, fuels and wastes. (Path 3)	A.4.7 Containment of Contaminants C.3.3 Wastewater management legislative requirements C.8.2 Spill Management Plan	2	2	L	- All chemical, fuel and waste storage and high risk spill handling areas are to have secondary containment, with an impermeable liner with coefficient of permeability of less than 10-9 m/s - Licenced waste transporters to be used to transport listed wastes. - Chemicals to be transported in accordance with the Australian Dangerous Goods Code and NT Dangerous Goods Act. - No chemical or wastewater transportation during wet season, unless a risk assessment determined the activity is safe and low risk - Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. - Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. - The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. - All transportation of listed wastes and dangerous goods to be undertaken via licenced contractors. - Area is remote with major urban areas to be avoided during the transportation of dangerous goods and wastes in accordance with the NT Dangerous Goods Act. - Separation between chemical stores and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. - Nearest landholder extraction bore 1km. - Origin has completed 100,000's of chemical and wastewater trucking movements in QLD without significant incident causing material environmental harm - Depth of aquifers generally below known stygofauna distribution range (elimination)	- Daily inspections during wet season and weekly thereafter to identify and respond to any potential leaks. - Impact and control groundwater monitoring bores installed around exploration wells to detect any potential contamination. - Groundwater monitoring of control and impact monitoring bores on a quarterly basis,	- Liner leaks to be investigated and liners repaired as soon as practicable - Spills and leaks to be cleaned up and rectified immediately - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	2	L	Yes	The storage, handling and management of chemicals is a standard activity that is managed through a mature nationally uniform regulatory setting. The COP further reduces the likelihood/consequence of chemical spills and contamination, through the mandated use of secondary containment, a spill management plan and groundwater monitoring. Any spills are likely to be locally restricted and rapidly detected (hours to days). The consequence of a spill/ leak is therefore considered to be "moderate", with moderate short term (days). Given the requirement for a spill management plan, secondary containment requirements and 70m separation distance to aquifers, the likelihood of a spill/leak reaching an aquifer is considered remote with a probability of less than 1%.	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
12			Overtopping of drilling sumps and flowback tanks (including during wet season) (Path 7)	A.4.7 Containment of Contaminants C.6 Monitoring mandatory requirements C.8.2 Spill Management Plan	2	1	L	•Drilling sump to be designed and operated to handle the drilling of multiple wells •Sump solid levels to be periodically removed from the sump between wells (or as required) to maintain sump capacity •Covered tanks to be used to manage flowback storage, with enough enclosed storage onsite to manage all stored flowback. •Results from Kyalla 117 N2-1 well testing have been used to optimise available tank capacity to allow for multiple wells •Additional tank capacity to be installed as required, with new tank capacity taking less than 14 days •Open wastewater evaporation tanks and drill sumps to have a 1:1000ARI wet season freeboard (wet season freeboard 1.3m). •All flowback wastewater to be transferred to enclosed tanks prior to the onsite of a "significant rainfall event (>300mm of forecasted rain over a 4 day periodic) •Sufficient pumps available onsite to meet volume transfer requirements, with available pump redundancy in case of mechanical issues. •Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. •Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. •Site is manned at all times or have telemetered level logging during wastewater storage, with helicopters to be used to fly in staff when road access is prevented. •Separation between lease pad and closest aquifer over 70m, with interbedded	•Daily monitoring of tank and sump levels (along with available storage space) during the wet season and weekly at all other times •Daily significant rainfall monitoring during the wet season. •Spill Management Plan implemented to prevent, detect and respond to spills. •Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination, with monitoring completed quarterly	•Drilling fluids to be transferred to wastewater tanks or removed from site where maximum freeboard is exceeded •New wastewater tanks to be constructed onsite if wastewater storage is insufficient •Flowback to be transferred to enclosed tanks 8 hours before the onset of a significant rainfall event (defined as >30mm of rain over a 4 day period) •Operations (flowback and drilling) to cease if insufficient wastewater (sump or flowback storage) is available to meet freeboard and enclosed tank availability requirement. •Spill Management Plan implemented to prevent, detect and respond to spills. implemented- this includes regular inspections of containment facilities. •In the event of a major spill, a site assessment in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure, including the assessment of NORMs will be undertaken	2	1	L	Yes	The COP provides onerous regulatory requirements that essentially eliminate the risk of wastewater storage overtopping events. The consequences of an overtopping event are limited through the construction of earthen bunds and compaction of the lease pad. A wastewater management plan, spill management plan and emergency response plan is implemented to further ensure any overtopping events are prevented, detected and responded to. In the event of an overtopping incident, such spill is likely to be contained onsite and rapidly responded to. The consequence of an overtopping event is therefore considered to be "moderate", with moderate short term (weeks-months) contamination. Given the requirements for enclosed tanks and a 1"1000 wet season freeboard, the potential for overtopping are considered remote, with a probability less than 1%.	Yes	Low
13			Failure of flowback storage tank. (Path4 & 7)	A.4.1 Site selection and planning c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	3	1	L	•Wastewater Management Plan implemented in accordance with the Codes of Practice to mitigate the risk associated with wastewater generation and management. •Spill Management Plan implemented to prevent, detect and respond to spills- including requirements for daily wastewater tank inspections during the wet season and weekly at all other times. •Tanks designed and engineered to AS3990 Mechanical Equipment- Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating) •Wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10-9 m/s permeability, 120N picture resistance and 49N tear resistance •Covered wastewater tanks and condensate tanks to have vents to prevent pressure build up. •Sufficient pump capacity available to recover any spilled wastewater. •Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. •Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. •Separation between lease pad and closest aquifer over 70m, with interbedded clays likely to limit any potential contaminant migration. •Nearest landholder extraction bore 1km. •No major GDE linked to CLA within 100km of extraction point •Depth of aquifers generally below known stygofauna distribution range (elimination)	•Weekly wastewater tank integrity inspections during wastewater storage to detect •Impact and control groundwater monitoring bores installed within 20m of exploration wells to detect any potential contamination. •Quarterly groundwater monitoring completed to detect potential contamination.	•Wastewater tank structural defects to be rectified as soon as practicable. •Wastewater to be transferred from defective tanks to alternative tanks onsite until repairs completed. •Pumps located onsite to recover fluid and transfer into existing tanks, with spills and leaks to be cleaned up and rectified immediately •Earth moving equipment available regionally to clean up spills •Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering	3	1	L	Yes	The consequences of a tank failure are negated through the use of double lined, engineered above ground tank which have continuous leak detection and alarms. Tanks and their liners are designed with sufficient structural integrity to withstand cyclonic winds, extreme temperatures and loading stress forces under a range of conditions. A spill management pan is in force to detect, prevent and respond to potential spills of wastewater. If a storage failure was to occur, the wastewater would be restricted to the lease pad. Flowback would be pumped into available enclosed and open tank storage, with contaminated soil removed from site. the consequences are likely to be "serious", being locally restricted, moderate duration (weeks) and reversible. The likelihood is reduced by the COP requirements , tank design separation distances to the underlying aquifer. The likelihood is considered Remote, with a probability less than 1%	Yes	Low
14	Surface Water	Contamination of surface water from surface activities.	Failure of flowback storage tank. (Path4 & 7)	A.4.1 Site selection and planning c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	3	1	L	•Wastewater Management Plan implemented in accordance with the Codes of Practice to mitigate the risk associated with wastewater generation and management. •Spill Management Plan implemented to prevent, detect and respond to spills- including requirements for daily wastewater tank inspections during the wet season and weekly at all other times. •Tanks designed and engineered to AS3990 Mechanical Equipment- Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating) •Wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10-9 m/s permeability, 120N picture resistance and 49N tear resistance •Covered wastewater tanks and condensate tanks to have vents to prevent pressure build up. •Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. • Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. • Separation between lease pad and closest stream order 1 located 12km away and major watercourse is ~45km. • No major wetlands, with closest ~100km away (Lake Woods).	•Weekly wastewater tank integrity inspections during wastewater storage to detect •Routine level monitoring and alarms	•Wastewater tank structural defects to be rectified as soon as practicable. •Wastewater to be transferred from defective tanks to alternative tanks onsite until repairs completed. •Pumps located onsite to recover fluid and transfer into existing tanks, with spills and leaks to be cleaned up and rectified immediately •Earth moving equipment available regionally to clean up spills •Emergency response plan implemented. • Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	3	1	L	Yes	The consequence and likelihood of a containment failure are negated through onerous wastewater management requirements stipulated in the COP. The lease pad is bunded, preventing the offsite release of wastewater in the event of a failure. A spill management plan is required to be implemented to prevent, detect and respond to spills to prevent offsite releases. The spill is therefore likely to be smaller, with any spillage restricted to the lease pad. The consequence of a spill is therefore considered to be "serious", with moderate short term (weeks-months) contamination. The area is not in close proximity to major watercourse with a 45km separation distance. Given the separation distance and bunding, the likelihood is considered remote, with the probability of occurring less than 1% .	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
15			Overtopping of drilling sumps and flowback tanks (including wet season operations) (Path 4 & 7)	A.4.7 Containment of Contaminants C.6 Monitoring mandatory requirements c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	3	1	L	•Drilling sump has been designed to accommodate the anticipated drilling waste volumes of multiple wells. •Sump solids (cuttings and muds) to be periodically removed from the sump between the drilling of wells (or as required) to maintain sump capacity to prevent overflows • Spill Management Plan implemented to prevent, detect and respond to spills- this includes daily inspections during wet season and weekly inspections during dry season. •Covered wastewater tanks to be used to manage flowback storage- with enough capacity onsite to deal with •Open wastewater evaporation tanks and drill sumps to have a 1:1000ARl wet season freeboard (wet season freeboard 1.3m). • Monitoring of tank and sump levels daily when operational. •Results from Kyalla 117 N2-1 well testing have been used to optimise available tank capacity to allow for multiple wells •Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. •Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. •Site is manned at all times or have telemetered level logging during wastewater storage, with helicopters to be used to fly in staff when road access is prevented. • Area is flat with the separation between lease pad and closest stream order 1 located 12km away and major watercourse is ~45km away.	•Daily monitoring of tank and sump levels (along with available storage space) during the wet season and weekly at all other times •Daily significant rainfall monitoring during the wet season	•Drilling fluids to be transferred to wastewater tanks or removed from site where maximum freeboard is exceeded •New wastewater tanks to be constructed onsite if wastewater storage is insufficient - flowback to be transferred to enclosed tanks 8 hours before the onset of a significant rainfall event (defined as >30mm of rain over a 4 day period) •Operations (flowback and drilling) to cease if insufficient wastewater (sump or flowback storage) is available to meet freeboard and enclosed tank availability requirement. • Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	1	L	Yes	The consequence and likelihood of a wastewater storage overflowing are minimised through the onerous wastewater management requirements stipulated in the COP. This includes lease pad bunding, tank level alarms, tank freeboard requirements and use of a wastewater management plan. Any overflow is likely to be restricted to the lease pad, rapidly detected and promptly cleaned up. The use of enclosed tanks, freeboard and lease pad bunding essentially eliminates the likelihood potential for a wastewater storage tank to overflow. Given the onerous regulatory requirements, the likelihood of an overtopping event is considered Remote, with a <1% probability of occurring.	Yes	Low
16			Transportation accident releasing chemical or wastewater (drilling fluid and flowback).	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	3	1	L	•Risk assessment completed for all wet season transportation of chemicals and wastes •All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. •All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. •Transportation route to avoid major urban areas •All drivers to be appropriately licenced •Fatigue management plan implemented, requiring journey management plans and drivers to rest every 2 hours •Strict drug and alcohol policy implemented, with routine testing and 0 zero tolerance policy to alcohol (0.00% limit) and drugs •Area is remote with major urban centres to be avoided. •Risk to any receptor is identical to that of normal diesel or petroleum tankers. •Training of Origin supervisors regarding chain of responsibility requirements to minimise the risk of driver fatigue •Origin has completed 100,000's of chemical and wastewater trucking movements in QLD without significant incident causing material environmental harm •The transportation of waste and chemicals across Australia is a standard practice with mature codes and legislation in place, the transportation of fuels, chemicals and wastes occurs every year in the NT to support existing industry's during the wet season.	•Transport incident statistics collected and monitored. •Onsite assurances and fit for work assessments completed periodically on transport companies.	•Spill Management Plan and Emergency Response Plan implemented to prevent, detect and respond to spills. •Contractor performance reviews completed where breaches in requirements are escalated and actions implemented to rectify defects.	3	1	L	Yes	The transportation of wastes and chemicals is a tightly controlled industry with mature practices designed to prevent, detect and respond to transportation spills. Any accident is likely to be restricted to road corridors and result in "serious", short term (days-weeks) reversible impacts. All contractors must be appropriately licenced, with National uniform legislation in place to offer a high level of regulatory protection. This risk is considered identical to that of bulk diesel and other dangerous goods transportation- a common activity throughout Australia. Fuel and chemical transport accidents are rare given the number of transportation movements in Australia. The likelihood of an event occurring is therefore considered "remote", what a probability of less than 1%.	Yes	Low
17			Storage and handling of chemicals and fuel. (Path 4)	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	2	2	L	•All areas where chemicals and fuels are stored will have secondary containment with a coefficient of permeability of less than 10-9 m/s • Secondary containment to be maintained in a good working order •Spill Management Plan implemented to prevent, detect and respond to spills. implemented. •Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s •The site is earthen bunded to prevent offsite release of contaminants, with all stormwater directed to an onsite retention pond for testing prior to offsite release •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. •Area is remote with closest receptor approximately 30km away.	•Daily inspections will be implemented during the wet season and spills rectified immediately	•All spills to be cleaned up as soon as practicable (within the shift that spill was observed) •Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	1	L	Yes	The storage, handling and management of chemicals is a standard activity that is managed through a mature regulatory setting. The COP further reduces the likelihood and consequence of chemical spills and contamination, through the mandated use of secondary containment, a spill management plan and groundwater monitoring. A spill event is likely to result in moderate, short term reversible impacts restricted to the existing lease pad. The likelihood is further reduced down to remote (<1% probability of occurring) based on the 45km separation distance to the closest watercourse.	Yes	Low
18			Release of stormwater from activities to surface water.	A.4.1 Site selection and planning A.4.3 Erosion and sediment control and hydrology	1	3	L	•Erosion and Sediment Controls implemented around the site to minimise erosion and sediment releases (Engineering) •Stockpiled debris to be used to discourage water concentration. (Engineering) •Lease pad to be earthen bunded to prevent offsite release of stormwater from exposed surfaces (Engineering) •Sites to be maintained, with vegetation cover on exposed bunds/ stockpiles established and erosion and sediment controls kept in working order (Elimination) •Contaminated stormwater to be retained on-site, treated and disposed off-site at a licenced disposal facility (Administration/ Engineering) •A sediment sock to be used to reduce sediment levels within stormwater releases. (Engineering) •Clean stormwater to be reused or released off-site in a manner that reduces the risk of erosion (Elimination) •Lease pad located away from watercourses or regional flow paths. (Elimination) •Area is remote with closest stream order 1 located 12km away and major watercourse approximately 45km away.(Elimination)	•Pre-wet season site assessment completed to identify any maintenance requirements (Administration) •Stormwater captured in sediment basin to be tested and released offsite in a controlled manner (Engineering)	•Maintenance to be undertaken on erosion and sediment controls to ensure ongoing functionality (Engineering)	1	1	L	Yes	All stormwater retained onsite during well testing will be collected in a purpose built sediment basin and tested prior to release. Releases must comply with the stipulated criteria to ensure contaminants are not released from site. The release of stormwater will also be via a "Sediment sock", with a reasonable consequence of minor, localised reversible impacts. The likelihood is reduced down to remote (<1% probability of occurring) based on the 45km separation distance to the closest watercourse and routine testing requirements..	Yes	Low
19			Runoff from sewage treatment irrigation areas.	A.4.1 Site selection and planning	1	2	L	•Irrigation areas located away from watercourses (Elimination) •A wastewater suitability acceptance assessment has been completed and a design approval for wastewater disposal received in accordance with the NT Department of Health code of Practice for On-site Wastewater Management (July 2014) (Engineering) •Wastewater irrigation to comply with DOH requirement (Engineering) •Areas appropriately sized to accommodate irrigation volume (Engineering) •Area is remote with closest stream order 1 located 12km away and watercourse approximately 45km away (Elimination)	•Wastewater system performance to be monitored in accordance with the manufacturers requirements (Administration)	•Where wastewater specifications are exceeded, corrective actions will be implemented to ensure wastewater is returned back into specification (Engineering)	1	1	L	Yes	The management of sewerage and greywater is mature with various NT wastewater management guidelines. Due to the temporary nature of the activity, the maximum contamination resulting from sewerage and grey water irrigation is likely to be minor, with any impacts locally restricted and temporary in nature. The closest watercourse is approximately 45km, with the potential contamination of these features considered remote (probability <1%).	Yes	Low

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					Consequence	Likelihood	Risk Rating				Consequence	Likelihood	Risk Rating				
20	Surface Water	Changes in surface water hydrology resulting vegetation dieback from ponding and diversions away from natural surface systems with environmental and cultural value.	Infrastructure located on regional flow path resulting in changes to surface water flow.	A.4.1 Site selection and planning A.4.3 Erosion and sediment control and hydrology	1	2	L	•No clearing of vegetation proposed (Elimination) •Lease pad located away from watercourses and regional flow paths. (Elimination) •Lease pads designed to divert stormwater around, without impeding natural surface water flows (Engineering) •Stockpiled debris to be used to discourage water concentration, with vegetation establish on stockpiles to reduce exposed surfaces •Area is remote with closest stream order 1 located 12km away and major watercourse approximately 45km away. (Elimination) •The lease area is flat, with water to be diverted around the perimeter of the site. (Elimination)	•Erosion and Sediment Control Plan in place with routine pre and post wet season inspection and maintenance (administration)	•Maintenance to be undertaken on erosion and sediment controls to ensure ongoing functionality (Engineering)	1	2	L	Yes	No clearing is proposed under this EMP, with any potential impact associated with an existing lease pad or access track. Due to the lack of major water courses, and impact is likely to "minor", locally restricted and reversible. The likelihood is reduced down to highish unlikely (probability <10%) due to the absent of watercourses and controls implemented in accordance with NT Land Clearing Guidelines to avoid changes in the hydrological setting.	Yes	Low
21			Changes to terrestrial ground surface levels associated with seismic activity.	B.4.13 Hydraulic Stimulation and Flowback Operations	1	1	L	•Wells are located away from known geohazards, with no significant faults within proximity of activity (Elimination) • Kyalla 117 N2-1 stimulation completed without inducing seismic activity (Elimination) •Stimulation is not linked to major seismic events (re injection of wastewater is generally recognised as the main cause). No reinjection of wastewater proposed (Elimination) •Stimulation stages deployment will be away from geohazards to reduce the loss of fluids into any encountered faults (Elimination) •The Beetaloo is not prone to seismic activity and there is no evidence of recent earthquake activity as most faults and the major subsurface structure are confined to Cambrian or older strata. This is supported by the National seismic Hazard Assessments completed by Allen 2018 (Figure 33), which highlight the Beetaloo is located within a low hazard area (Elimination) •Any faults encountered during drilling will be assessed to determine risk of stimulating with appropriate separation distances applied (Elimination). •Any induced seismicity likely to be minor(<3 MI) and not at a level capable of altering earths surface.	•Monitoring of stimulation pressure to detect and respond to anomalies which may indicate fluid being pumped to an open geological structure (Engineering) •Geoscience Australia's Waramungu seismic array located approximately 300km of the proposed Kyalla 117 N2 well pad. It is likely that any material seismic events above a 2 MI will be detected via this array if they occur (Administration) •An induced seismicity traffic light system has been adopted and outlined in the WOMP (Administration)	•Where seismic activity is recorded in Origin's tenure during hydraulic stimulation activities, the actions in the WOMP Traffic Light System will be enacted as summarised below: Green: Local Magnitude (MI) <2.0- no action required Orange: MI 2.0- <3.5MI- Report event to DITT and continue operations Red: MI> 3.5- Stimulation activity on pad suspended until a go forward plan submitted by Origin and approved by DITT.	1	1	L	Yes	The consequence of a induced seismicity, based upon evidence from the UK and US, indicates that the consequence is likely to be "minor", with most events restricted to discrete areas at a size that generally cannot be detected at the surface (below 2 order of magnitude). This limits the potential for changes in terrestrial surface level. Larger events are rare and generally a factor of the existing built up stress regime of the area- rather than a factor of the intensity of hydraulic fracturing or wastewater injection. The likelihood of a seismic event is reduced through the geological setting of the Beetaloo Basin itself and the safeguards implemented in the COP requiring geohazard assessment and avoidance. In the Beetaloo, there have been no earthquakes over magnitude 3 measured since records began. The area is not prone to seismic activity and there is no evidence of recent earthquake activity as most faults and the major subsurface structure are confined to Cambrian or older strata. This is supported by the National seismic Hazard Assessments completed by Allen 2018 (Figure 33), which highlight the Beetaloo is located within a low hazard area. The COP requires any geohazard (such as fault) identified prior to drilling (from existing seismic or interpreted data) or encountered during drilling to have a risk assessment to the determine the potential for reactivation. Any faults identified would not be stimulated, with a risk-based buffer applied. Given the number of wells stimulated in the US without issue and geological setting of the Beetaloo basin, the likelihood is considered remote, with a probability less than 0.1%.	Yes	Low
22	Water usage	Unsustainable groundwater extraction impacts landholders and groundwater dependent ecosystems.	Over extraction of groundwater for civils, drilling and stimulation activities.	B.4.17 Groundwater monitoring	3	1	L	•Groundwater extraction for activities to be restricted to the minimum water required. (Elimination) •All water take licenced in accordance with NT Water Act under Water Extraction Licence (WEL) GRF 10285 (Administration) •Drawdown from activity and other users assessed by DEPWS as a part of WEL; impacts to closest receptor not anticipated (Administration/ Elimination) - Karst system is under allocated, with sufficient available capacity to support proposed water extraction requirements. (Elimination) •Closest receptor is ~16km from extraction point (Elimination)	•Continuous flow meters to monitor take and water balance implemented to ensure compliance with WEL (Administration) •Groundwater monitoring completed to identify impacts associated with water extraction (Engineering)	•Groundwater extraction to cease where sustained drawdown post pumping exceeds 1 m (Administration)	3	1	L	Yes	The extraction of groundwater for hydraulic fracturing activities requires all take to be licenced. The proposed take is assessed as a part of the licence application, with the assessment considering current and future water take levels. Based on this assessment, it was determined that the extraction rate would not impact upon adjacent users. The risk consequence is determined to be "serious"- given any impact is likely to cause pastoralist and broader community concern. The likelihood of such a consequence from occurring is considered remote (probability <1%) due to the quality of the Cambrian limestone aquifer, separation distance from surrounding users and under utilisation of the targeting aquifer.	Yes	Low
23	Soil	Loss in long-term soil productivity and viability.	Soil compaction from access tracks and leases.	A.4.1 Site selection and planning	1	3	L	•No Land Clearing proposed (Elimination) •Lease pads to be stripped of topsoil (Elimination) •Areas to be rehabilitated to reduce impacts associated with compaction (Engineering) •Disturbance area is small (less than 0.005% of total tenure area) (Elimination)	•Rehabilitation monitoring to assess soil productivity impacts (Administration)	•Areas with poor rehabilitation will be maintained to reduce impact (Engineering)	1	3	L	Yes	During the operation of lease pads, access tracks , camp pads etc., these sites will be compacted. Long term impacts of this compaction will be addressed during the rehabilitation of the sites. A loss of productivity is anticipated in the earlier stages of rehabilitation, returning back to pre-disturbed state within ~10 years. This will be accelerated through removal of hard stand areas, ripping and scarifying compacted surface. the consequences is likely to be "moderate", being locally restricted, with a moderate- long (years) recovery time. The likelihood of long term productivity impairment is considered "unlikely" (probability <30%), given the observed rehabilitation from previous disturbance activities.	Yes	Low
24			Soil erosion from cleared areas (access tracks, lease pads and camp pads).	A.4.3 Erosion and sediment control and hydrology	1	5	M	•No Land Clearing proposed (Elimination) •Erosion and Sediment Control Plan in place and maintained in functioning condition (Engineering) •Sites to be maintained, with erosion and sediment controls kept in working order (Engineering) •Stockpiled debris to be used to discourage water concentration. (Engineering) •Areas to be rehabilitated to reduce impacts associated with compaction (Engineering)	•Pre and post wet season erosion and sediment control inspections. •Rehabilitation monitoring to assess soil productivity impacts (Administration)	•Maintenance completed on areas where erosion is occurring or where the controls are defective (Engineering) •Areas with poor rehabilitation will be maintained to reduce impact (Engineering)	2	3	M	Yes	The erosion and sediment release from cleared area is a well document impact. The consequences of sediment releases are likely to be minor, a function of the low risk nature of the site soils types, design of lease pads and ongoing inspection and maintenance programs. The likelihood of these minor locally restricted releases of sediment is considered likely (Probability 90%) .	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
25	Soil	Soil contamination due to spills and leaks of chemicals, wastes or wastewater.	Spills/leaks from the on-site storing and handling of fuels. Condensate, hydrocarbons, drilling additives, stimulation additives, flowback fluid, solid wastes, storage and transportation of wastes	A.4.7 Containment of Contaminants C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	2	2	L	- All chemical, fuel and waste storage and high risk spill handling areas are to have secondary containment, with an impermeable liner with coefficient of permeability of less than 10-9 m/s - Licensed waste transporters to be used to transport listed wastes. - Chemicals to be transported in accordance with the Australian Dangerous Goods Code and NT Dangerous Goods Act. - No chemical or wastewater transportation during wet season, unless a risk assessment determined the activity is safe and low risk - Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. - Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. - The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. - All transportation of listed wastes and dangerous goods to be undertaken via licenced contractors. - Area is remote with major urban areas to be avoided during the transportation of dangerous goods and wastes in accordance with the NT Dangerous Goods Act. - Origin has completed 100,000's of chemical and wastewater trucking movements in QLD without significant incident causing material environmental harm	Daily inspections during wet season and weekly thereafter to identify and respond to any potential leaks.	- Liner leaks to be investigated and liners repaired as soon as practicable - Spills and leaks to be cleaned up and rectified immediately - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	2	L	Yes	The storage, handling and management of chemicals is a standard activity that is managed through a mature regulatory setting. The COP further reduces the likelihood and consequence of chemical spills and contamination, through the mandated use of secondary containment, a spill management plan and groundwater monitoring. A spill event is likely to result in moderate, short term reversible impacts restricted to the existing lease pad. The likelihood is further reduced down to highly unlikely(<10% probability of occurring) based on the use of secondary containment, rapid spill detection and rehabilitation requirements..	Yes	Low
26			Drill sump and flowback tank overtopping.	A.4.7 Containment of Contaminants C.5.1 Drilling Materials C.5.2 Management of produced water from petroleum wells C.6 Monitoring mandatory requirements C.8.2 Spill Management Plan	2	1	L	- Drilling sump has been designed to accommodate the anticipated drilling waste volumes of multiple wells. (Engineering) - Sump solids (cuttings and muds) to be periodically removed from the sump between the drilling of wells (or as required) to maintain sump capacity to prevent overflows (Engineering) - Covered wastewater tanks to be used to manage flowback storage- with enough capacity onsite to deal with (Engineering) - Open evaporation tank and drilling sump freeboard to accommodate a 1:1000 ARI total wet season (Engineering) - Monitoring of tank and sump levels daily when operational. (Administration) - Results from Kyalla 117 N2-1 well testing to be used to optimise available tank capacity to allow for multiple wells (Engineering) - Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s (Engineering) - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. (Engineering) - Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume (Engineering) - The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied (Engineering) - Sufficient transfer pump capacity onsite to transfer fluids prior to the onset of a significant rainfall event or major wastewater release - Site is manned at all times or have telemetered level logging during wastewater storage, with helicopters to be used to fly in staff when road access is prevented. (Administration)	- Daily monitoring of tank and sump levels (along with available storage space) during the wet season and weekly at all other times (Administration/ Engineering) - Daily significant rainfall monitoring during the wet season (Administration/ Engineering)	- Drilling fluids to be transferred to wastewater tanks or removed from site where maximum freeboard is exceeded (Engineering) - New wastewater tanks to be constructed onsite if wastewater storage is insufficient (engineering) - flowback to be transferred to enclosed tanks 8 hours before the onset of a significant rainfall event (defined as >30mm of rain over a 4 day period) (Engineering) - Operations (flowback and drilling) to cease if insufficient wastewater (sump or flowback storage) is available to meet freeboard and enclosed tank availability requirement (Elimination) - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	2	1	L	Yes	The consequence and likelihood of a wastewater storage overflowing are minimised through the onerous wastewater management requirements stipulated in the COP. This includes lease pad bunding, tank level alarms, tank freeboard requirements and use of a wastewater management plan. Any overflow is likely to be restricted to the lease pad, rapidly detected and promptly cleaned up. The use of enclosed tanks, freeboard and lease pad bunding essentially eliminates the likelihood potential for a wastewater storage tank to overflow. Given the onerous regulatory requirements, the likelihood of an overtopping event is considered Remote, with a <1% probability of occurring..	Yes	Low
27			Chemical and waste transportation accident.	A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	3	1	L	- Risk assessment completed for all wet season transportation of chemicals and wastes (Administration) - All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. (Administration) - All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code.(Administration) - Transportation route to avoid major urban areas - All drivers to be approximately licenced (Administration) - Fatigue management plan implemented, requiring journey management plans and drivers to rest every 2 hours (Administration) - Access track maintained to allow periodic wet weather access - Strict drug and alcohol policy implemented, with routine testing and 0 zero tolerance policy to alcohol (0.00% limit) and drugs (Administration) - Area is remote with major urban centres to be avoided. (Elimination) - Risk to any receptor is identical to that of normal diesel or petroleum tankers. - Training of Origin supervisors regarding chain of responsibility requirements to minimise the risk of driver fatigue (Administration) - Origin has completed 100,000's of chemical and wastewater trucking movements in QLD without significant incident causing material environmental harm (elimination) - The transportation of waste and chemicals across Australia is a standard practice with mature codes and legislation in place. the transportation of fuels, chemicals and wastes occurs every year in the NT to support existing industry's during the wet season. (Engineering)	- Transport incident statistics collected and monitored. (Administration) - Onsite assurances and fit for work assessments completed periodically on transport companies (Administration)	- All transport spills to be cleaned up immediately (engineering) - Contractor performance reviews completed where breaches in requirements are escalated and actions implemented to rectify defects. (administration)	3	1	L	Yes	The transportation of wastes and chemicals is a tightly controlled industry with mature practices designed to prevent, detect and respond to transportation spills. Any accident is likely to be restricted to road corridors and result in "serious", short term (days-weeks) reversible impacts. All contractors must be appropriately licenced, with National uniform legislation in place to offer a high level of regulatory protection. This risk is considered identical to that of bulk diesel and other dangerous goods transportation- a common activity throughout Australia. Fuel and chemical transport accidents are rare given the number of transportation movements in Australia. Origin has completed 100,000's of chemical and wastewater trucking movements in QLD without significant incident causing material environmental harm The likelihood of an event occurring is therefore considered ""highly unlikely", what a probability of less than 10%.	Yes	Low
28			On-site disposal of drill muds and cuttings.	C.5.1 Drilling Materials	2	2	L	- Drilling muds are bentonite-based, saline with low residual toxicity (Elimination) - Sodium and Chloride levels to be reduced through segregation of drilling fluids from muds and mixing with clean material onsite - Drilling muds and cuttings from the sump maybe transferred and stored in a pit/sump on site that is compliant with C.4.1.2 for the storage of drilling muds and cuttings to dry the cuttings and reduce waste volumes. - Drilling muds to be tested and a disposal strategy developed by a suitably qualified third-party in a manner that minimises the risk to the environment. - Drilling muds removed from site where onsite disposal is unsafe. - DEPWS engaged to confirm final disposal strategy. - Rehabilitation monitoring to monitor ongoing site rehabilitation	Drilling muds to be tested and a disposal strategy developed by a suitably qualified third-party in a manner that minimises the risk to the environment. Rehabilitation monitoring completed on all disposal areas	Additional rehabilitation actions implemented where rehabilitation objectives are not being met.	2	2	L	Yes	In accordance with the COP, the onsite storage and disposal of drilling fluids and cuttings can only occur if the activity does not represent an unacceptable environmental hazard. All drilling fluids, muds and cutting will be stored in a lined sump, with testing undertaken prior to final disposal. Onsite disposal will only occur if determined to be safe by an independent third party. The consequences are therefore likely to be restricted to a Moderate- short term reversible impacts. The likelihood of contamination through drilling fluid, mud and cuttings storage and failure is considered highly unlikely, with the probability below 10%. this is largely due to the separation distance between the underlying aquifer, use of lined sumps and third party disposal suitability assessments.	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
29			Failure of a flowback tank.	A.4.1 Site selection and planning A.4.7 Containment of Contaminants C.8.2 Spill Management Plan	3	1	L	- Tanks designed and engineered to AS3990 Mechanical Equipment- Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating) - Wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10-9 m/s permeability, 120N picture resistance and 49N tear resistance - Covered wastewater tanks and condensate tanks to have vents to prevent pressure build up. - Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. - Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. - The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied.	- Weekly wastewater tank integrity inspections during wastewater storage to detect - Routine level monitoring and alarms	- Wastewater tank structural defects to be rectified as soon as practicable. - Wastewater to be transferred from defective tanks to alternative tanks onsite until repairs completed. - Pumps located onsite to recover fluid and transfer into existing tanks, with spills and leaks to be cleaned up and rectified immediately - Earth moving equipment available regionally to clean up spills - Emergency response plan implemented. - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	3	1	L	Yes	The consequences of a tank failure are negated through the use of double lined, engineered above ground tank which have continuous leak detection and alarms. Tanks and their liners are designed with sufficient structural integrity to withstand cyclonic winds, extreme temperatures and loading stress forces under a range of conditions. A spill management pan is in force to detect, prevent and respond to potential spills of wastewater. If a storage failure was to occur, the wastewater would be restricted to the lease pad. Flowback would be pumped into available enclosed and open tank storage, with contaminated soil removed from site. the consequences are likely to be "serious", being locally restricted, moderate duration (weeks) and reversible. The likelihood is reduced by the COP requirements , tank design separation distances to the underlying aquifer. The likelihood is considered Remote, with a probability less than 1%.	Yes	Low
30		Soil contamination from the drift of saline wastewater offsite from mechanical evaporation units.	Wastewater evaporation mist transported offsite during wastewater treatment.	A.4.1 Site selection and planning	2	2	L	- Automated wind speed and direction cut offs to be implemented to prevent drift (Engineering) - Evaporators located within the wastewater tank considering the predominant wind direction (from the SE) to avoid offsite drift (Engineering) - Drift likely to be restricted to within the lease pad (elimination) - No homesteads, sacred sites or sensitive environmental areas in the vicinity of the proposed lease pad (Elimination)	Daily monitoring to detect drift (Engineering)	- Evaporation units to cease operation where drift identified (Engineering) - Evaporators to be modified/ repositioned to control drift (Engineering)	2	2	L	Yes	The use of enhanced evaporators to manage wastewater is a well-known technology used through multiple mining and wastewater treatment industries. Evaporators were used successfully on the Amungee NW 1H well to reduce fluid levels decreasing offsite trucking volumes. Offsite release of wastewater drift is restricted through wind speed and direction cut offs and the location of the evaporator within the wastewater storage. The sites are continuously manned during well testing, thus the risk of drift and associated impacts is anticipated to be moderate, with short term, reversible impacts. Given the aforementioned controls, the likelihood of moderate impacts is reduced to Highly unlikely, with a potential of lower than 10%	Yes	Low
31		Soil contamination from the disposal of greywater and sewerage from camp activities.	Greywater and sewerage disposal (camps).	C.4.2 Management of flowback water	1	2	L	- Sewerage wastewater irrigated as per Department of Health code of Practice for On-site Wastewater Management (July 2014) (Engineering)(Elimination) - A wastewater suitability acceptance assessment has been completed and a design approval for wastewater disposal received in accordance with the NT Department of Health code of Practice for On-site Wastewater Management (July 2014) (Engineering) - Wastewater irrigation to comply with DOH requirement (Engineering) - Areas appropriately sized to accommodate irrigation volume (Engineering) - Area is remote with closest watercourse approximately 45km away (Elimination)	Wastewater system performance to be monitored in accordance with the manufacturers requirements (Administration)	Where wastewater specifications are exceeded, corrective actions will be implemented to ensure wastewater is returned back into specification (Engineering)	1	2	L	Yes	The management of sewerage and greywater is mature with various NT wastewater management guidelines. Due to the temporary nature of the activity, the maximum contamination resulting from sewerage and grey water irrigation is likely to be minor, with any impacts locally restricted and temporary in nature. The closest watercourse is approximately 45km, with the potential contamination of these features considered remote (probability <1%).	Yes	Low
32	Flora and fauna	Impact to listed threatened habitats and listed threatened flora and fauna through exploration activities.	Activity (vehicle and machinery) noise and lighting on well pads and access tracks.	A.4.1 Site selection and planning A.4.2 Noise	1	3	L	- Site location avoids areas of high conservation value as a priority (Elimination) - Areas are not considered high conservation value, are not threatened/endangered and not fragmented, with impacts unlikely to result in significant disturbance to threatened/endangered species. (Elimination) - Impacts likely to be temporal, with fauna able to move to adjacent areas to escape impacts. (Elimination) - Fauna monitoring at the Kyalla 117 N2 site has not identified any impacts, with fauna identified in areas around operations. (Engineering)	- Anecdotal evidence form pastoralists and Traditional Owners (Administration) - Impacts are likely to be temporal, with detection extremely difficult.	Where impacts are identified, practices will be reviewed and modified to reduce impact on fauna (Administration/ engineering)	1	3	L	Yes	Fauna may be disturbed through transport movements along access tracks and drilling, stimulation and well testing activities around the lease pad. The consequence of activity nuisance is anticipated to be minor, with localised, short term impacts to areas immediately adjacent to access tracks. The likelihood of the risk is reduced through the isolated location (lack of sensitive receptors), regionally extensive vegetation communities (good outside refuge away from access tracks and limited transport movements during the evenings). The impact to fauna is considered highly unlikely given the ability of fauna to move to other areas of refuge away from E&A activities	Yes	Low
33			Failure of flowback storage tanks.	A.4.1 Site selection and planning A.4.7 Containment of Contaminants c.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	3	1	L	- Tanks designed and engineered to AS3990 Mechanical Equipment- Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating) (Engineering) - Wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10-9 m/s permeability, 120N picture resistance and 49N tear resistance (Engineering) - Covered wastewater tanks and condensate tanks to have vents to prevent pressure build up. (Engineering) - Leases to be compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s (Engineering) - The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. (Engineering) - Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. (Engineering) - The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. (Engineering)	- Weekly wastewater tank integrity inspections during wastewater storage to detect (administration) - Routine level monitoring and alarms (Engineering)	- Wastewater tank structural defects to be rectified as soon as practicable. (Engineering) - Wastewater to be transferred from defective tanks to alternative tanks onsite until repairs completed. (Engineering) - Pumps located onsite to recover fluid and transfer into existing tanks, with spills and leaks to be cleaned up and rectified immediately (Engineering) - Earth moving equipment available regionally to clean up spills (Engineering) - Emergency response plan implemented (Administration) - Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	3	1	L	Yes	The consequences of a tank failure are negated through the use of double lined, engineered above ground tank which have continuous leak detection and alarms. Tanks and their liners are designed with sufficient structural integrity to withstand cyclonic winds, extreme temperatures and loading stress forces under a range of conditions. A spill management pan is in force to detect, prevent and respond to potential spills of wastewater. If a storage failure was to occur, the wastewater would be restricted to the lease pad. The consequences are likely to be "serious", being locally restricted, moderate duration (weeks) and reversible. The likelihood is reduced by the COP requirements , tank design, separation distances to sensitive places and the lease pad bunding. The likelihood is considered Remote, with a probability less than 1%.	Yes	Low
34			Introduction and spread of weeds in the area.	A.4.5 Weed management	2	3	M	- All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site (Elimination) - Areas of proposed exploration have been surveyed and are deemed to have low weed abundance (elimination) - Activity will be restricted to defined lease pads and camp pads (Elimination)	6 monthly monitoring implemented around infrastructure to detect the spread/ introduction of weed species (administration) - Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. (Administration)	- Where weed outbreaks are identified associated with Origin's activities, infestations will be treated in accordance with the Weed Management Plan. (elimination) - Corrective actions implemented where ongoing biosecurity breaches are identified.	2	3	M	Yes	The area in the vicinity of the Kyalla 117 N2 site is free of weeds. Weeds are present across the broader property. Any introduction of weeds is likely to result in localised impact, with weed management requirements likely to reduce the consequence down to "moderate, short term. Due to the inherent nature of weed prevention the risk likelihood is considered unlikely, with a probability less than <30%	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
35			Accidental ignition of fire from exploration activities (drilling, stimulation, flaring and general access).	A 4.6 Fire management	3	2	M	•Bushfire management plan implemented to prevent and respond to bushfires- including establishment of communication and fire response protocols with pastoralists (Administration) •Bushfire awareness included in site inductions. (Administration) •Designated smoking areas on-site (Elimination) •Firefighting equipment to be available to deal with fires (Engineering). •Fire breaks have been constructed around the Kyalla 117 N2 lease and camp pads (Engineering) •Minimum of 45m separation distances between flares and surrounding vegetation (Engineering) •Ignition sources placed outside of the hazardous area. (Elimination) •Intrinsically safe equipment used in hazardous area. (Elimination) •Hazardous area drawing will provide classification of hazardous zones while drilling. (Elimination) •No flaring during periods of total fire ban (Elimination) •Activities will comply with landholder and regional bushfire management plans. (Elimination) •Area in the vicinity of Kyalla 117 N2 lease has had recent (within 1-2 years) fire activity reducing the fuel load (Elimination)	•Annual fire preparedness assurance activities completed where activities are proposed during high fire risk periods (administration) •Daily monitoring of bushfires in the region during periods of high fire danger (administration) •Annual fire frequency mapping using the Northern Australia Fire Information fire history database (administration)	•Fire hazard reduction strategies (such as back burning) to be implemented to reduce the risk of fire ignition/ impact as required (Elimination) •Where a bushfire is started and cannot be controlled, Origin to engage with pastoralist to coordinate response activities	3	2	M	Yes	Fire is a common occurrence within the Barkly Region. A fire is likely to have a serious impact, with moderate term reversible impacts (years). With the appropriate controls, such as separation distances, firebreaks, and adherence to total fire bans, the likelihood of causing a fire from drilling, stimulation and well testing is anticipated to be highly unlikely, with a predicted occurrence of <10%	Yes	Low
36			Poor rehabilitation of the site reduces regional habitat and promotes weed invasions	A.4.8 Rehabilitation	1	3	L	•A site specific Rehabilitation Plan has been developed and will be implemented progressively Engineering) •Areas will have infrastructure and wastes removed, sumps and pits backfilled, topsoil respread and vegetation re-introduced. (Engineering) •Rehabilitation timing will consider seasonal constraints, with rehab completed prior to the wet season to maximise revegetation chance (Engineering)	•Rehabilitation monitoring to be undertaken to track rehabilitation progress (Administration)	•Maintenance will be undertaken periodically to fix any defects (Engineering)	1	3	L	Yes	Risks associated with rehabilitation are well known. Knowledge of rehabilitation within the Beetaloo Basin has been gained, based on previous seismic line rehabilitation programs.	Yes	Low
37			Trapping and drowning of fauna in storage tanks and sumps.	C.5.1 Drilling Materials	2	2	L	•Wastewater tank walls are 2m high with minimal risk of animals accessing tanks (elimination) •Lease pads fenced to prevent stock access (engineering) •Sump coletanche liner is rough, with fauna able to climb out of sump (Engineering) •Sump fenced when not in use in a manner to reduce fauna access to sump (Engineering) •Limited habitat for threatened fauna in area surrounding site (Elimination) •Wastewater saline, with freshwater tanks to be preferred by birds • Fauna cameras installed around lease pad have not detected significant wildlife presence in and around operating sites. (Elimination)	•Weekly inspections during wastewater storage. •Monitoring of fauna interaction with wastewater	•Where ongoing fauna interactions with wastewater are identified through monitoring, additional controls shall be implemented as appropriate (such as additional fencing, deterrents etc.) (Engineering)	2	2	L	Yes	Risks associated with potentially trapping and drowning fauna in storage tanks and sumps are well understood. Origin has extensive experience in managing sumps, ponds and tanks to prevent fauna ingress.	Yes	Low
38			Contaminants in water and soil pass through the food chain and bioaccumulate in fauna causing detrimental impacts to local species and communities	A.4.7 Containment of Contaminants C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	1	2	L	•All chemicals stored in designated areas with secondary containment (Engineering) •Chemical risk assessments with no chemicals considered above low concern levels when used in accordance with standard procedures and controls (Elimination) •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. (Engineering) •Site earthen bunding will have a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. (Engineering) •The earthen bund will be constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied. (Engineering) •Wastewater evaporation to have drift controls to prevent offsite release (engineering) •No offsite wastewater discharge (elimination) •Chemical mixing units and operating procedures designed to mitigated the formation of chemical airborne particulate matter (Engineering/ Administration) •Onsite burial of drilling waste can only occur where no material impacts to flora and fauna are anticipated (engineering) •Salt is the main hazard and does not bioaccumulate- UV and oxidation of organic compounds and metals in wastewater likely to degrade chemicals rapidly (within days) (Elimination) •Lease pads fenced to prevent livestock accesses (engineering) •Sump fenced to prevent fauna access. (engineering)	•Routine weekly inspections to identify poor chemical handling or wastewater storage practices (engineering) •Monitoring of fauna interaction with wastewater tanks and area surrounding the site (Administration)	•Where ongoing fauna interactions with wastewater or chemicals are identified through monitoring, additional controls shall be implemented as appropriate to reduce the potential for exposure (such as additional fencing, deterrents etc.) (Engineering)	1	1	L	Yes	A chemical risk assessment and flowback characterisation program for the Amungee NW 1 well ensures all potential chemicals that are persistent, bio accumulative and toxic at high concentrations are identified and appropriate management strategies implemented The risks associated with fauna ingestion of chemicals is well known and measures to prevent ingestion (such as fences and separation distances to activity) are deployed as standard practice. Origin has extensive operational experience in drilling and stimulating 1000s of conventional and unconventional petroleum wells with no evidence of impacts on biota from chemicals.	Yes	Low
39			Vehicle collisions with fauna – fauna mortality results in a localised impact to listed threatened species	A.4.4 Biodiversity protection	1	5	M	•Vehicle speed limited to 60km/hr to be reduced around areas of high risk of fauna collision (Administration) •Vehicle movements to avoid driving at night (Elimination) •Fauna collisions observed during Kyalla 117 N2-1 activities have been minimal, with collision restricted to several wallabies along access track (elimination) • Absence of listed threatend species identified in the vicinity of the Lease apd and access tracks.	•Fauna mortality data is collected as part of Origin's incident and observation management procedures (Administration)	•Where ongoing fauna collisions are reported, additional controls shall be investigated, such as reduced speed limits in high risk areas will be implemented.(Administration)	1	3	L	Yes	Fauna collisions with vehicles are a commonly associated with roads. It is anticipated that a small number of fauna collisions will be experienced during the activity (1-2 animals per month), with minor, short term, reversible impacts to local fauna species. The likelihood of causing a localised decline in species abundance is considered remote.	Yes	Low
40			Encouragement of feral animals and other pest species increases leading to competition with native species. This includes the introduction of cane toads.	A.4.4 Biodiversity protection	1	3	L	•Camp wastes to be storage to be animal proof (Engineering) •All food scraps to be removed from site and disposed of at a licenced facility (Elimination) •Food scraps to be frozen and stored within freezer during wet season (Elimination) •Experience from Kyalla 117 N2-1 activities has not detected increased feral animal prevalence, with only 1 feral dog identified in 6 months of camp operations. (Elimination)	•Feral fauna observation data is collected as part of Origin's incident and observation management procedures (Administration)	•Where ongoing feral animal presence is detected, additional controls will be investigated in consultation with the pastoralist (such as fencing, removal of water sources etc.) (Engineering)	1	3	L	Yes	Feral animals may be increased through the provision of access to water, food (camps) and hunting habitat (such as road corridors). The use of the existing site and access tracks limits the additional risk associated with provision of additional hunting habitat. Food scraps and waste will be frozen and disposed of offsite which will reduce the food availability for pests. Wastewater is too saline for cane toads to survive, with the design of the tanks likely to restrict load habitat. The anticipated consequence is minor, with the potential pest species increase anticipated to be small. The likelihood is determined to be unlikely, with a probability of less than 30%.	Yes	Low

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					Consequence	Likelihood	Risk Rating	Prevent	Detect	Recover	Consequence	Likelihood	Risk Rating				
41	Cultural Heritage and Sacred Sites	Disturbance of sacred site or culturally sensitive area and decline in environmental value of area used for hunting, foraging and enjoyment.	Sites disturbed directly by exploration activities	A.4.1 Site selection and planning	3	1	L	•Exploration Agreements with Determined Traditional owners covering all proposed exploration activities. •All areas of the proposed activity to be cleared by NLC. (Elimination) •AAPA certificates for proposed work program have been granted (Elimination) •The location of infrastructure has considered proximity to sacred sites (Elimination) •Areas of cultural heritage to be avoided during construction (Elimination) •Areas of cultural significance are not within 14km of the proposed area of activity (Elimination) •Implementation of the unexpected finds protocol (Administration).	•Origin completes 6 monthly assurance programs to confirm access to sacred sites has not occurred.	•N/A- no access to sacred sites anticipated. (Elimination)	3	1	L	Yes	All sites of the proposed activity must have Traditional Owner clearance via the NLC. AAPA certificates are required for all activities to ensure sacred sites are not impacted by activities. The remote location of the activity, lack of sacred sites in the vicinity of the Kyalla 117 N2 lease pad and access tracks and contractual requirements prohibiting access reduce the likelihood down to "highly unlikely", with a probability lower than 10%.	Yes	Low
42			Accidental ignition by site activities (civil works, drilling, grinding) or site personnel.	A.4.6 Fire management	3	2	M	•Bushfire management plan implemented to prevent and respond to bushfires- including establishment of communication and fire response protocols with pastoralists (Administration) •Bushfire awareness included in site inductions. (Administration) •Designated smoking areas on-site (Elimination) •Firefighting equipment to be available to deal with fires (Engineering). •Fire breaks have been constructed around the Kyalla 117 N2 lease and camp pads (Engineering) •Minimum of 45m separation distances between flares and surrounding vegetation (Engineering) •Ignition sources placed outside of the hazardous area. (Elimination) •Intrinsically safe equipment used in hazardous area. (Elimination) •Hazardous area drawing will provide classification of hazardous zones while drilling. (Elimination) •No flaring during periods of total fire ban (Elimination) •Activities will comply with landholder and regional bushfire management plans. (Elimination) •Area in the vicinity of Kyalla 117 N2 lease has had recent (within 1-2 years) fire activity, reducing the fuel load (Elimination)	•Annual fire preparedness assurance activities completed where activities are proposed during high fire risk periods (administration) •Daily monitoring of bushfires in the region during periods of high fire danger (administration) •Annual fire frequency mapping using the Northern Australia Fire Information fire history database (administration)	•Fire hazard reduction strategies (such as back burning) to be implemented to reduce the risk of fire ignition/ impact as required (Elimination) •Where a bushfire is started and cannot be controlled, Origin to engage with pastoralist to coordinate response activities	3	2	M	Yes	Fire is a common occurrence within the Barkly Region. A fire is likely to have a serious impact, with moderate term reversible impacts (years). With the appropriate controls, such as separation distances, firebreaks, and adherence to total fire bans, the likelihood of causing a fire from drilling, stimulation and well testing is anticipated to be highly unlikely, with a predicted occurrence of <10%	Yes	Low
43			Flowback tank structural failure.	A.4.1 Site selection and planning A.4.7 Containment of Contaminants C.5.2 Management of produced water from petroleum wells C.8.2 Spill Management Plan	3	1	L	•Tanks designed and engineered to AS3990 Mechanical Equipment- Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating) (Engineering) •Wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10-9 m/s permeability, 120N picture resistance and 49N tear resistance (Engineering) •Covered wastewater tanks and condensate tanks to have vents to prevent pressure build up. (Engineering) •The leases is compacted to above 100kpa to achieve a permeability of approximately 1x10m-7/s (Engineering) •The site is earthen bunded to prevent offsite release of flowback. This is considered an additional level of containment, as the primary and secondary containment is the principle spill risk control. (Engineering) •The site earthen bund has a minimum bund wall height of 300mm capable of managing at least 110% of the largest wastewater tank volume. The actual Kyalla 117 N2 bund capacity is 9.6ML, approximately 200% the largest wastewater tank volume. (Engineering) •The earthen bund is constructed in a manner to withstand a tank failure scenario with appropriate compaction and stabilisation applied.(Engineering) •No sacred sites in the vicinity of the Kyalla 117 N2 site.	•Weekly wastewater tank integrity inspections during wastewater storage to detect (administration) •Routine level monitoring and alarms (Engineering)	•Wastewater tank structural defects to be rectified as soon as practicable. (Engineering) •Wastewater to be transferred from defective tanks to alternative tanks onsite until repairs completed. (Engineering) •Pumps located onsite to recover fluid and transfer into existing tanks, with spills and leaks to be cleaned up and rectified immediately (Engineering) •Earth moving equipment available regionally to clean up spills (Engineering) •Emergency response plan implemented (Administration) •Any contamination event to be characterised and have remediation plans developed and executed in accordance with the process outlined in schedule A of the National Environmental Protection (Assessment of site Contamination) Measures (Engineering)	3	1	L	Yes	The consequences of a tank failure are negated through the use of double lined, engineered above ground tank which have continuous leak detection and alarms. Tanks and their liners are designed with sufficient structural integrity to withstand cyclonic winds, extreme temperatures and loading stress forces under a range of conditions. A spill management pan is in force to detect, prevent and respond to potential spills of wastewater. If a storage failure was to occur, the wastewater would be restricted to the lease pad, limiting the impact on adjacent pastoral activities and community.. Flowback would be pumped into available enclosed and open tank storage, with contaminated soil removed from site. The consequences are likely to be "serious", being locally restricted, moderate duration (weeks) and reversible (requiring rehabilitation). The likelihood is reduced by the COP requirements , tank design separation distances to the underlying aquifer. The likelihood is considered Remote, with a probability less than 1%.	Yes	Low
44			Personnel unauthorised access to sacred site.	A.4.1 Site selection and planning	2	2	L	•Restricted work areas are not located in close proximity to explorational activities (access tracks or lease pads) (Elimination) •All staff to be inducted covering restricted work areas and cultural heritage (Administration) •Access off lease not permitted. (Elimination)	•Origin completes 6 monthly assurance programs to confirm access to sacred sites has not occurred.	• N/A- no access to sacred sites anticipated. (Elimination)	2	2	L	Yes	All sites of the proposed activity must have Traditional Owner clearance via the NLC.. AAPA certificates are required for all activities to ensure sacred sites are not impacted by activities. The remote location of the activity, lack of sacred sites in the vicinity of the Kyalla 117 N2 lease pad and access tracks and contractual requirements prohibiting access reduce the likelihood down to "highly unlikely", with a probability lower than 10%.	Yes	Low
45	Community impact	Loss of visual amenity, experience and sense of place for landholder, community members and tourists.	Industrialisation of landscape.	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection	1	1	L	•Existing location used to reduce footprint, with multi- well pads needed to minimise the impact of a future development (if feasible) •Site is located away from major roads and not clearly visible: slight glow may be experienced during well testing (similar to a small town) (Elimination) •Level of clearing for infrastructure is small.(Elimination) •Progressive rehabilitation to occur when sites are no longer required for future operations (engineering) •Activity intensity is restricted to specific periods, with most activity restricted to the lease pad. •Workers are flown in and out of Daly waters from Darwin. Busses are used to limit vehicle transport movements between the Daly Waters airport and remote camps- there is limited Drive In/Drive Out workers into the Beetaloo- except where local or regional contractors are utilised. •Camps utilised to minimise impact on local accommodation and tourism.	•Ongoing community engagement to monitor performance and identify potential impacts from activity on local amenity.	•N/A- site location and activity intensity is unable to be changed.	1	1	L	Yes	The proposed explorational activities are located away from major transport routes, homesteads and communities. The consequences of activities may result in minor changes in to aesthetics through visibility of exploration activities (flare glows at night, presence of workers and vehicles). The probability that the activity will result in an industrialisation of the landscape is considered remote, with a probability less than 1%.	Yes	Low
46			Increased traffic.	A.4.1 Site selection and planning	2	1	L	•Traffic impact assessment completed assessing the increased traffic levels as negligible: reflective of limited size and scope of activity. •Traffic impacts are expected to small and temporary with Rig located onsite or moved via internal road. •Access route is away from the main homestead of Hayfield Shenandoah station. •Capacity of road and level of service will not be impacted materially. •Workers are flown in and out of Daly waters from Darwin. Busses are used to limit vehicle transport movements between the Daly Waters airport and remote camps- there is limited Drive In/Drive Out workers into the Beetaloo- except where local or regional contractors are utilised. •Traffic issues were not identified during the Kyalla 117 N2-1 well drilling and stimulation campaign.	•Ongoing community engagement to monitor performance and identify potential impacts from activity on traffic.	•Complaints regarding traffic will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaints (such as changes to vehicle load movements etc.)	2	1	L	Yes	The increased traffic from the activity is likely to be short term and within the Level of service of the existing roads. Increases in traffic are anticipated to have a "moderate" consequence (increase in traffic observable, but temporary). The likelihood of causing a loss of experience from the E&A activities is considered "Highly unlikely", with an anticipated probability of less than 10%.	Yes	Low

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					Consequence	Likelihood	Risk Rating				Consequence	Likelihood	Risk Rating				
47			Light emissions impact on sensitive receptor (such as pastoralist)	A.4.1 Site selection and planning	1	1	L	•Site is located 20km away from the Stuart Highway and the nearest homestead although a visible hue may be present during flaring. This is likely to be consistent with a small town and only visible during the night. (Elimination) •Flaring is of short duration, generally less than 90 days. (Elimination) - No complaints received from Amungee Nw-1 flaring, which were located adjacent to the Carpentaria highway.	•Ongoing pastoralist engagement to monitor performance and identify potential impacts from activity on local amenity. (Administration)	•Complaints regarding light emissions will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaints (such as shrouds, Changes to flare configuration etc.)	1	1	L	Yes	The remote location and separation distances between receptors is likely to result in minor light emissions. Light may be visible from activities (such as flaring), but will not be of sufficient intensity to cause any material impact to the health and wellbeing of community members. The likelihood of impacts is a function of separation distance and is therefore predicted to be remote, with a probability less than 1%	Yes	Low
48			Influx of workers to region		2	1	L	•Work temporary in nature and utilises existing regional contractors where available (elimination) •Engagement with the pastoralists and directly affected community completed to communicate scope of work (administration) •Site camps utilised to minimise workers within local community (elimination)	•Ongoing community engagement to monitor performance and identify potential impacts from activity on local communities.	•Complaints regarding work influx are unlikely and will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaints.	2	1	L	Yes	The limited scope and duration of activities reduces the risk and uncertainty associated with risk. Most workers will be located away from communities, meaning there is unlikely to be a major increase in people.	Yes	Low
49			Noise emissions from activities.	A.4.1 Site selection and planning A.4.2 Noise	1	1	L	•Site is located 20km away from the Stuart Highway and the nearest homestead. Noise impacts will not reach sensitive receptors, with QLD experience on rig and stimulation noise indicating noise levels approaching background levels approximately<2km from the activity. (Elimination) •No complaints received from Amungee Nw-1 flaring, which were located adjacent to the Carpentaria highway.	•Ongoing pastoralist engagement to monitor performance and identify potential impacts from activity on local amenity. (Administration)	•Complaints regarding noise emissions will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaints (such as shrouds, changes to flare configuration etc.)	1	1	L	Yes	The remote location and separation distances between receptors is likely to result in "minor" noise impacts. The likelihood of impacts is a function of separation distance and is therefore predicted to be remote, with a probability less than 1%	Yes	Low
50		Reduction in land productivity.	Introduction and spread of weeds in the area.	A.4.5 Weed management	2	3	M	•All equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site (Elimination) •Areas of proposed exploration have been surveyed and are deemed to have low weed abundance (elimination) •Activity will be restricted to defined lease pads and camp pads (Elimination)	•6 monthly monitoring implemented around infrastructure to detect the spread/ introduction of weed species (administration) •Origin assurance activities to target equipment wash-down certificates to ensure standards are being met. (Administration)	•Where weed outbreaks are identified associated with Origin's activities, infestations will be treated in accordance with the Weed Management Plan	2	3	M	Yes	The area in the vicinity of the Kyalla 117 N2 site is free of weeds. Weeds are present across the broader property. Any introduction of weeds is likely to result in localised impact, with weed management requirements likely to reduce the consequence down to "moderate, short term. Due to the inherent nature of weed prevention the risk likelihood is considered unlikely, with a probability less than <30%	Yes	Low
51			Over extraction of groundwater.	A.4.1.1 Well pad specific site selection requirements B.4.17 Groundwater monitoring	1	1	L	•Groundwater extraction for activities to be restricted to the minimum water required. (Elimination) •Groundwater bores are metered for groundwater take. (Engineering) •All water take licenced in accordance with NT Water Act under Water Extraction Licence (WEL) GRF 10285 (Administration) •Drawdown from activity and other users assessed by DEPWS as a part of WEL; impacts to closest receptor not anticipated (Administration/ Elimination) •Karst system is under allocated, with sufficient available capacity to support proposed water extraction requirements. (Elimination) •Closest receptor is ~16km from extraction point (Elimination)	•Continuous flow meters to monitor take and water balance implemented to ensure compliance with WEL (Administration) • Groundwater monitoring completed to identify impacts associated with water extraction (Engineering)	•Groundwater extraction to cease where sustained drawdown post pumping exceeds 1 m (Administration)	1	1	L	Yes	The extraction of groundwater for hydraulic fracturing activities requires all take to be licenced. The proposed take is assessed as a part of the licence application, with the assessment considering current and future water take levels. Based on this assessment, it was determined that the extraction rate would not impact upon adjacent users. The risk consequence is determined to be "serious"- given any impact is likely to cause pastoralist and broader community concern. The likelihood of such a consequence from occurring is considered remote (probability <1%) due to the quality of the Cambrian limestone aquifer, separation distance from surrounding users and under utilisation of aquifer.	Yes	Low
52			Impact to surface hydrology changes water flows impacting the land use/productivity	A.4.3 Erosion and sediment control and hydrology A.4.1 Site selection and planning	1	1	L	•No clearing of vegetation proposed (Elimination) •Lease pad located away from watercourses and regional flow paths. (Elimination) •Lease pads designed to divert stormwater around, without impeding natural surface water flows (Engineering) •Stockpiled debris to be used to discourage water concentration, with vegetation establish on stockpiles to reduce exposed surfaces •Area is remote with closest watercourse approximately 45km away. (Elimination) •The lease area is flat, with water to be diverted around the perimeter of the site. (Elimination)	•Erosion and Sediment Control Plan in place with routine pre and post wet season inspection and maintenance (administration)	•Maintenance to be undertaken on erosion and sediment controls to ensure ongoing functionality and the controls are adequate (Engineering)	1	1	L	Yes	The existing lease pad will be utilised for all activities, with no additional construction required. The existing lease pad has been located outside the major regional flow paths and designed to divert stormwater around the infrastructure. The consequence is anticipated to be minor, with the likelihood remote (based on the site being existing)..	Yes	Low
53			Bushfire from accidental ignition by site activities (civil works, drilling, flaring grinding) or personnel.	A.4.6 Fire management	3	2	M	•Bushfire management plan implemented to prevent and respond to bushfires- including establishment of communication and fire response protocols with pastoralists (Administration) •Bushfire awareness included in site inductions. (Administration) •Designated smoking areas on-site (Elimination) •Firefighting equipment to be available to deal with fires (Engineering). •Fire breaks have been constructed around the Kyalla 117 N2 lease and camp pads (Engineering) •Minimum of 45m separation distances between flares and surrounding vegetation (Engineering) •Ignition sources placed outside of the hazardous area. (Elimination) •Intrinsically safe equipment used in hazardous area. (Elimination) •Hazardous area drawing will provide classification of hazardous zones while drilling. (Elimination) •No flaring during periods of total fire ban (Elimination) •Activities will comply with landholder and regional bushfire management plans. (Elimination) •Area in the vicinity of Kyalla 117 N2 lease has had recent (within 1-2 years) fire activity, reducing the fuel load (Elimination)	•Annual fire preparedness assurance activities completed where activities are proposed during high fire risk periods (administration) •Daily monitoring of bushfires in the region during periods of high fire danger (administration) •Annual fire frequency mapping using the Northern Australia Fire Information fire history database (administration)	•Fire hazard reduction strategies (such as back burning) to be implemented to reduce the risk of fire ignition/ impact as required (Elimination) •Where a bushfire is started and cannot be controlled, Origin to engage with pastoralist to coordinate response activities	3	2	M	Yes	Fire is a common occurrence within the Barkly Region. A fire is likely to have a serious impact, with moderate term reversible impacts (years). With the appropriate controls, such as separation distances, firebreaks, and adherence to total fire bans, the likelihood of causing a fire from drilling, stimulation and well testing is anticipated to be highly unlikely, with a predicted occurrence of <10%	Yes	Low
54			Poor rehabilitation of exploration infrastructure.	A.4.8 Rehabilitation	2	2	L	•A site specific Rehabilitation Plan has been developed and will be implemented progressively (Engineering) •Areas will have infrastructure and wastes removed, sumps and pits backfilled, topsoil respread and vegetation re-introduced. (Engineering) •Rehabilitation timing will consider seasonal constraints, with rehab completed prior to the wet season to maximise revegetation chance (Engineering)	•Rehabilitation monitoring to be undertaken to track rehabilitation progress (Administration)	•Maintenance will be undertaken periodically to fix any defects (Engineering)	2	2	L	Yes	Rehabilitation success will be determined through the timing of rehabilitation, with rehab activities undertaken before the wet season to maximise success. Ongoing monitoring and maintenance of rehabilitated areas will be critical to identify and repair areas where rehabilitated success is poor. Consequences are likely to be moderate, with impacts likely to have moderate, locally restricted and medium to long term (1-5 years). The likelihood is influenced by the requirement for security provisions, rehabilitation plan requirements and COP conditions. The likelihood is anticipated to be highly unlikely, with a probability below 10%.	Yes	Low

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					Consequence	Likelihood	Risk Rating				Consequence	Likelihood	Risk Rating				
55			Disruption of agricultural operations due to ongoing access, traffic, helicopter movements etc.	A.4.1 Site selection and planning A.4.2 Noise	1	3	L	- All activities require engagement with pastoralists (Administration) - Lease site has been located to avoid disruption to agriculture operations and infrastructure. (Elimination) - Engagement will be undertaken in accordance with NT Petroleum (Environment) Regulations (Administration) - Traffic levels are anticipated to be small- as per Traffic Impact Assessment.(Elimination) - Helicopter movements to be restricted to wet season when landholder activities are minimal (Elimination) - Helicopter movements to be undertaken in consultation with leaseholder to avoid impacts to livestock, cattle yards, watering points, homesteads and other sensitive areas as advised by leaseholder. (Elimination)	Ongoing pastoralist engagement to monitor performance and identify potential impacts from activity on local amenity. (Administration)	Complaints regarding Origin's activities will be dealt through Origins complaint resolution process. Where complaints are received, Origin will investigate if additional controls are needed and implement to address the complaint (such as shrouds, Changes to flare configuration etc.) (administration/engineering)	1	3	L	Yes	Origin has extensive experience in co-existing its activities with agricultural users. Consultation with pastoralists is undertaken to ensure impacts on their activities are mitigated. These impacts are addressed in the compensation agreements and access guidelines. It is noted that there is an impact on stakeholder in regards to working with proponents to plan E&A activities. this is unavoidable and required to ensure the activities can be designed to accommodate the activities of both parties. Consequences are anticipated to be minor for E&A activities, with the likelihood unlikely. The likelihood is reduced through compensation agreements which consider the pastoralist time when negotiating agreements.	Yes	Low
56		Safety hazard to pastoralists, community and tourists from increased traffic levels	Increased risk of vehicle accident	A.4.1 Site selection and Planning	3	1	L	- Traffic impact assessment completed, with traffic levels are anticipated to be small (Elimination) - Fatigue management policy implemented for transport companies, with breaks required every two hours (Administration) - Alcohol and drug policy implemented with zero tolerance (0.00% BAC and no illicit substances) (Elimination) - Workers are flown in and out of Daly waters from Darwin. Busses are used to limit vehicle transport movements between the Daly Waters airport and remote camps- there is limited Drive In/Drive Out workers into the Beetaloo- except where local or regional contractors are utilised. (Elimination) - The camp is located away from major roads with most movements internal between camp lease and drill site (Elimination) - Stuart highway intersection design approved by DIPL with appreciate line of site provided for vehicles to identify turning vehicles. (Engineering) - Origin has completed 100,000's of transport movements each in QLD with transports incidents extremely rare. (Elimination)	Ongoing community engagement to monitor performance and identify potential impacts from activity on local amenity. (Administration)	Complaints regarding Origin's activities will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaint (Administration)	3	1	L	Yes	E&A activities will increase traffic levels up to 44 vehicles per day during the peak. This traffic volume is well below the Level of Service for the highway, which is estimated to be above 1100 vehicles per hour. Accidents from truck turning into access tracks or from general vehicle accidents are anticipated to have a serious consequence, with an injury to community members/ tourist requiring hospitalisation. Given Origin completed 100,000's of heavy vehicle movements each year with serious incidents extremely rare, smaller volume of traffic required for Beetaloo, the lack of road users, traffic management plan for the access track turn in, Zero tolerance for alcohol and drugs and use of trained drivers, the likelihood is considered Remote, with a probability less than 1%	Yes	Low
57		Labour competition with local businesses and agricultural procedures.	Exploration activities compete with agricultural industry for resources.		1	1	L	- Proposed activity is temporary with no major labour requirements- stakeholders engaged to ensure they know the temporal nature of work (Administration) - Local and regional contractors will be utilised where available (Elimination) - All work to be short-term with predominantly skilled workforce sourced regionally/interstate. - Contracts will be structured to reduce 'boom and bust' cycle (clear understanding of limited scope of work).	Ongoing community engagement to monitor performance and identify potential impacts from activity on local amenity. (Administration)	Complaints regarding Origin's activities will be dealt through Origins complaint resolution process. Where valid complaints are received, additional controls will be implemented to address community complaint (Administration)	1	1	L	Yes	Labour competition is a consequence that may occur in a full scale shale development and is not anticipated to have a major impact during exploration. Exploration activities are generally short term campaigns and are completed similar to most small infrastructure projects (such as road upgrades). Local contractors are to be used where available, with a priority on using Tn businesses. The consequence of labour competition during E&A is minor, with a likelihood of remote (<1% probability)	Yes	Low
58	Air Quality	Reduction in air quality associated with exploration emissions (civil, Drilling, Stimulating and Well Testing).	Emissions from the combustion of diesel.	A.4.1 Site selection and planning D.5.1 Baseline assessment	1	2	L	- Low emission equipment to be utilised (Engineering) - All equipment to be maintained in accordance with the manufacturer's recommendations (Engineering) - Exsisting Flares onsite to combust hydrocarbons (Engineering) - No sensitive receptors within 20km (Elimination)	- Equipment condition and maintenance to be built into contract (Administration) - Routine site inspections and assurance undertaken to ensure equipment is maintained and operated as per manufacturers requirements. (Engineering)	All equipment defects identified by site inspection and assurances to be rectified promptly.(Engineering)	1	1	L	Yes	Impacts to sensitive receptors are not anticipated, with the closest receptor over 20km away. Flares will be utilised to minimise the release of VOC's. The potential consequence from E&A activities is predicted to be minor. The likelihood is a function of source (lack of) and separation distance between receptors. the likelihood of a sensitive receptor being exposed to emissions from E&A activities above the NEPM guidelines are remote (<1%).	Yes	Low
59			Air emissions from gas and condensate flaring.	A.4.1 Site selection and planning D.5.1 Baseline assessment B.4.13 Hydraulic Stimulation and flowback operations D.5.8 Venting and flaring	1	2	L	- Flares have been designed and will be operated in compliance with the US EPA 40 CFR § 63.18 to achieve a 98% combustion efficiency (Engineering) - Emissions of NOx, CO and TVOC are small and not anticipated to reduce ambient air quality as there are no regional sources (Elimination) - Vertical flare stack used for gas- maximising dispersion. (Engineering) - Flares to be designed and operated to minimise smoking (Engineering) - Site located away from receptors (Elimination) - No sensitive receptors within 20km (Elimination)	Flares will be inspected as a part of weekly routine site inspection to rectify any excessive smoke production from flares (noting condensate flaring may produce small quantities of ongoing smoke due to the higher molecular weight of the hydrocarbons). (Administration)	Where excessive smoking of flares is identified, the flare operating status will be reviewed and optimise to reduce particulate generation (Engineering)	1	2	L	Yes	Risks associated with emissions from flares are well known within literature, and Australia and International policy/standards exist (such as NGERs and various US EPA technical guidance notes). The location of the activity is likely to limit the potential exposure to receptors, with consequences likely to be minor, localised and short term (days base on wind direction and atmospheric boundary conditions). The likelihood is predominantly reduced through the separation distance between the activity and receptors, with a likelihood of remote (<1% predicted)	Yes	Low
60			Air emissions from chemical releases during drilling and stimulation activities.	A.4.1 Site selection and planning B.4.16 Well site layout and housekeeping b.4.13 Hydraulic Stimulation and flowback operations	1	1	L	- National Occupational Health and Safety Codes: Code of Practice for the Control of Workplace Hazardous Substances. (Administration) - Chemical Risk Assessment completed on all chemicals used for stimulation (Elimination/Administration) - Chemical handling and mixing practices to reduce particulate emissions. (Engineering) - No sensitive receptors within 20km. (Elimination)	Routine site inspections and assurance undertaken to ensure ongoing chemical handling and mixing practices do not result in an offsite release of substances (Administration)	Corrective actions implemented to address poor chemical handling and mixing practices. (Engineering)	1	1	L	Yes	Risks associated with air emissions from petroleum activities are well known, with various risk assessment and emissions estimation technical guidance notes available within Australia and internationally (such as the National Pollutant Inventory and the US EPA). Due to overriding occupational health safety requirements to limit worker exposure and lack of local receptors, the consequence is anticipated to be minor. The likelihood is reduced to remote, given the large separation distances between the activity and closest receptors.	Yes	Low
61		Increased nuisance from dust and particulate emissions associated with exploration activities caused impacts to regional ecosystems and fauna	Civil activities, drilling operations, well testing.	A.4.1 Site selection and planning	1	5	M	- Water trucks will be used to decrease dust emissions. (Engineering) - Roads maintained to prevent built dust generation (Engineering) - No sensitive receptors within 20km (Elimination)	Routine site inspections and assurance undertaken to identify and rectify high dust emissions (Administration)	Dust control to be implemented where unacceptable dust from transport activities occur (Engineering)	1	5	M	Yes	Dust will be generated through transport movements along access tracks and around lease pads. The consequence of dust is anticipated to be moderate, with localised, short term impacts to areas immediately adjacent to access tracks. The likelihood of the risk is reduced through the isolated location (lack of sensitive receptors), regionally extensive vegetation communities (good outside refuge away from access tracks and use of dust suppression . As dust generation has been observed, and is commonly associated with dirt tracks, the likelihood of an impact is considered likely.	Yes	Low

Ref	Environmental Factor	Risk scenario description	Risk Source	Code of Practice	unmitigated (CoP implemented) Risk Rating			Risk mitigation Measures			Residual Risk Rating			ALARP criteria achieved?	Residual risk ALARP and Acceptable Statement	Acceptable criteria achieved?	Scientific Uncertainty Ranking
					Consequence	Likelihood	Risk Rating				Consequence	Likelihood	Risk Rating				
62			Bushfire from accidental ignition by site activities (civil works, drilling, flaring, grinding) or personnel.	A 4.6 Fire management	3	2	M	- Bushfire management plan implemented to prevent and respond to bushfires- including establishment of communication and fire response protocols with pastoralists (Administration) - Bushfire awareness included in site inductions. (Administration) - Designated smoking areas on-site (Elimination) - Firefighting equipment to be available to deal with fires (Engineering). - Fire breaks have been constructed around the Kyalla 117 N2 lease and camp pads (Engineering) - There is a minimum of 45m separation distances between flares and surrounding vegetation (Engineering) - Ignition sources placed outside of the hazardous area. (Elimination) - Intrinsically safe equipment used in hazardous area. (Elimination) - Hazardous area drawing will provide classification of hazardous zones while drilling. (Elimination) - No flaring during periods of total fire ban (Elimination) - Activities will comply with landholder and regional bushfire management plans. (Elimination) - Area in the vicinity of Kyalla 117 N2 lease has had recent (within 1-2 years) fire activity reducing the fuel load (Elimination)	- Annual fire preparedness assurance activities completed where activities are proposed during high fire risk periods (administration) - Daily monitoring of bushfires in the region during periods of high fire danger (administration) - Annual fire frequency mapping using the Northern Australia Fire Information fire history database (administration)	- Fire hazard reduction strategies (such as back burning) to be implemented to reduce the risk of fire ignition/ impact as required (Elimination) - Where a bushfire is started and cannot be controlled, Origin to engage with pastoralist to coordinate response activities (Administration/ engineering)	3	2	M	Yes	Fire is a common occurrence within the Barkly Region. A fire is likely to have a serious impact, with moderate term reversible impacts (years). With the appropriate controls, such as separation distances, firebreaks, and adherence to total fire bans, the likelihood of causing a fire from drilling, stimulation and well testing is anticipated to be highly unlikely, with a predicted occurrence of <10%	Yes	Low
63	Greenhouse Gas Emissions	Unsustainable Greenhouse Gas emissions from the activity.	Combustion of diesel for exploration activities.	A.4.1 Site selection and planning	2	1	L	- Australian emission standards for equipment ensures minimum operating efficiency (Engineering) - All equipment to be maintained in accordance with the manufacturer's recommendations (Engineering) - No sensitive receptors within 20km (Elimination)	- Equipment condition and maintenance to be built into contract (Administration) - Routine site inspections and assurance undertaken to ensure equipment is maintained and operated as per manufacturers requirements. (Engineering)	All equipment defects identified by site inspection and assurances to be rectified promptly.(Engineering)	2	1	L	Yes	The risks associated with Greenhouse Gas generation through diesel combustion are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC). The consequences of GHG generation from exploration activities is moderate, with less than 1% of the NT emissions generated. The likelihood of the level of GHG production being unsustainable is considered remote, with a probability less than 1%	Yes	Low
64			Flaring of gas and condensate during well testing.	B.4.13 Hydraulic Stimulation and flowback operations D.5.8 Venting and flaring	2	2	L	- Venting to be minimised with all venting reported under NGERS. - Flares have been designed and will be operated in compliance with the US EPA 40 CFR § 63.18 to achieve a 98% combustion efficiency. - Emissions from source rock during drilling are negligible. - Condensate will be transported offsite for sale if permissible. - Total worst case emissions from activity are not significant- being less than 0.38% of NT's Total GHG emissions and 0.011% of Australia's GHG emissions	Flares will be inspected as a part of weekly routine site inspection to rectify any excessive smoke production from flares (noting condensate flaring may produce small quantities of ongoing smoke due to the higher molecular weight of the hydrocarbons). (Administration)	Where excessive smoking of flares is identified, the flare operating status will be reviewed and optimise to reduce particulate generation (Engineering)	2	2	L	Yes	The risks associated with Greenhouse Gas generation through diesel combustion are well documented in literature and domestic/international greenhouse policy (such as NGERS and IPCC). The consequences of GHG generation from exploration activities is moderate, with less than 1% of the NT emissions generated. The likelihood of the level of GHG production being unsustainable is considered remote, with a probability less than 1%. The well testing will also allow for natural gas to be used as a transition fuel	Yes	Low
65			Uncontrolled release of gas encountered during drilling, stimulation, barrier failure, operator error or vehicle collision under a multi-well scenario	B.4.1 Well integrity management B.4.3 Well design and barriers B.4.13 Hydraulic Stimulation and flow back operations D.5.8 Venting and flaring	2	2	L	- Drilling overbalanced to reduce the inflows of hydrocarbons (Engineering) - Blow out prevention in place to manage well failure and uncontrolled gas influxes (Engineering) - Blow out preventor pressure rating and testing - All equipment will be API compliant to handle expected conditions (Engineering) - Site manned during operation (Administration) - Well suspended with multiple cement and casing barriers in place- with 4 casing section utilised (conductor, surface, intermediate and production).(Engineering) - Barricading to be used to protect each exploration well from vehicle collision during multi-well drilling activities. (Engineering)	- Process monitoring to detect events that could potentially result in a uncontrolled release of gas (such as fluid balances, well head pressure etc.) (Engineering) - Routine (monthly) well inspections (Administration)	- An emergency as diverter and flare to be used during drilling to manage gas ingress (Engineering) - Contracts in place with emergency well intervention specialists (such as Boots and Cootes) (administration) - Emergency response plan implemented (administration)	2	2	L	Yes	The COP and standard drilling, stimulation and well testing safety controls are designed to prevent the uncontrolled release of hydrocarbons. Flares are used during drilling and well testing to manage any encountered hydrocarbons The consequence are anticipated to be moderate, with impacts likely to be moderate, restricted in duration (minutes to hours). The likelihood is considered highly unlikely with a occurrence probability less than 10%, based on the well designed, construction and operations requirements mandated by the COP.	Yes	Low
66			Uncontrolled release of gas from well due to sabotage.	D.5.8 Venting and flaring	2	2	L	- Multiple barriers used during well suspension/operation- including downhole suspension plugs, suspension fluid and surface valves (Engineering) - Sites manned during operation (Administration) - Security cameras located on sites (Engineering) - Sites locked (Engineering) - Valves locked (Engineering)	Routine (monthly) well inspections (Engineering)	- Contracts in place with emergency well intervention specialists (such as Boots and Cootes) Administration) - Emergency response plan implemented (Administration)	2	2	L	Yes	The risks associated with Greenhouse Gas generation through well sabotage is anticipated to be moderate, with impacts likely to b restricted in duration (hours to days). The likelihood is considered remote (probability <1%), with the site remoted and multiple valves locked on the well to prevent tampering	Yes	Low
67			Leak of gas from wells.	B.4.1 Well integrity management B.4.3 Well design and barriers D.5.4 Emission detection and management D.5.5 Leak remediation and notification	1	2	L	- Well design considers multiple (4) specifically-engineered cement and steel casing barriers in place between hydrocarbon-bearing zone and surface. This includes conductor casing, surface casing, intermediate casing and production casing intervals (Engineering) - Well design and Well Barrier Integrity Validation reports submitted to DITT as part of Well Operations Management Plan (WOMP). (Administration/ engineering) - Wells constructed and suspended with barriers in place and verified as per governing code (engineering) - Limited gas production time only to extended production test. (Elimination)	- Routine 6 monthly well leak detection (Engineering) - Routine (monthly) well inspections (Administration)	Any leaking wells to be reported and remediated at a frequency consistent with the COP depending on severity (Engineering)	1	2	L	Yes	The consequence of a well leak are anticipated to be minor with impacts likely to be small (<1000L/hour) and restricted in duration (days to weeks). The likelihood is considered highly unlikely with a occurrence probability less than 10%, based on the well designed, construction and operations requirements mandated by the COP. Leak detection and reporting requirements are also controls to ensure any leaks are promptly identified and fixed.	Yes	Low
68	Cumulative Risk	Cumulative impacts on groundwater quantify.	Groundwater take from surrounding land users exceeds the natural recharge rate of the Basin.	Water extraction licences under the NT Water Act	2	1	L	- Groundwater extraction volumes to be monitored and kept below WEL (Elimination) - Groundwater extraction assessments include an estimate of current extraction levels at a regional scale. - No intensive users of groundwater within the region, with stock and domestic being the major usage. (elimination) - Cumulative impacts considered in the water extraction licence under the NT Water Act. (Elimination) - Strategic Regional Environmental Baseline Assessment (SREBA) completed to collected baseline environmental data, with Environmental Impact Assessments completed to address cumulative impacts from industry (Administration/ Engineering/ elimination)	Groundwater monitoring of control and impact monitoring bores will detect localised groundwater depressurisation before regional impacts occur (Engineering)	- Where sustained groundwater depletion is observed in regional aquifers, alternative water supplies may be required, such as deeper aquifers with limited extraction (Elimination) - Water Act make good provisions to ensure any impacts on users from exploration activities are "made good"	2	1	L	Yes	The regional understanding of the CLA is sufficient to understand the risks associated with groundwater extraction. The absence of users and small exploration take reduces the uncertainty of the activity. This risk has been assessed as a part of the WEL application and approval. Due to the lack of receptors, the consequence is considered moderate (i.e. 1 user within 16km) and likelihood remote (probability less than 1%	Yes	Low

Ref	Environmental Factor	Risk scenario description	Risk Source	Code of Practice	unmitigated (CoP implemented) Risk Rating			Risk mitigation Measures			Residual Risk Rating			ALARP criteria achieved?	Residual risk ALARP and Acceptable Statement	Acceptable criteria achieved?	Scientific Uncertainty Ranking
					Consequence	Likelihood	Risk Rating				Consequence	Likelihood	Risk Rating				
69		Cumulative impacts on terrestrial ecology.	Impacts from exploration activities and existing agricultural activities results in impacts to vegetation communities, fragmentation and poses a threat to protected flora and fauna.	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection A.4.4 Biodiversity Protection	2	1	L	•Existing site with no new clearing proposed. •Area has limited development with no widespread land clearing or other pressures from agriculture or other users. (elimination) •Petroleum activity is limited in scale and will not material decrease availability of habitat across the region (Elimination) •Strategic Regional Environmental Baseline Assessment (SREBA) completed to collected baseline environmental data, with Environmental Impact Assessments completed to address cumulative impacts from industry (Administration/ Engineering/ elimination)	•N/A- No increased risk to cumulative regional impacts.	N/A.	2	1	L	Yes	The region has low land clearing pressure with no applications for large scale land clearing present. The level of disturbance proposed is small, with field ecological scouting confirming ecological communities present.	Yes	Low
70		Cumulative impacts on amenity.	Exploration activities further reduces amenity (visual, noise, traffic and lighting) through additional landscape modification, dust, noise, light and traffic.	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection	1	2	L	•Activity is located away from major transportation routes and is not visible from roads. (Elimination) •Rig equipment located onsite/ within the adjacent property (Elimination) •Flaring may create a visible hue on the horizon consistent with that of a small town. •Traffic volumes are anticipated to be small and well below existing industries. (Elimination) •A Traffic Management Plan covering the intersection upgrade work has been submitted to DPIL for approval . (Elimination) •Low level of development activity within the region, with activity unlikely to cause declines in amenity. (Elimination)	•Community complaints regarding nuisance (including dust, traffic etc.) to be used to detect cumulative impacts (Administration)	•Complaints are to be investigated and additional controls implemented where appropriate. (Administration/ engineering)	1	2	L	Yes	The region is underdeveloped with the activity located away from major transportation routes, homesteads and communities. The activity is of a small size and unlikely to result in any loss of amenity. Any loss of amenity is therefore likely to be minor, with a likelihood of highly unlikely.	Yes	Low
71		Cumulative impacts on surface water quality.	Exploration activities in addition to existing surrounding land use (agriculture) reduces surface water quality.	A.4.1 Site selection and planning A.4.1.1 Well pad specific site selection A.4.3 Erosion and sediment control and hydrology	1	1	L	•Area has limited development with no widespread land clearing pressures from agriculture or other users likely to reduce water quality. (Elimination) •Activity will largely occur on existing disturbed areas with limited additional clearing. (Elimination) •No surface water take or wastewater releases permitted. (Elimination) •Strategic Regional Environmental Baseline Assessment (SREBA) completed to collected baseline environmental data, with Environmental Impact Assessments completed to address cumulative impacts from industry (Administration/ Engineering/ elimination)	N/A- no increased impact o surface waters anticipated	N/A- no increased impact o surface waters anticipated	1	1	L	Yes	The region is underdeveloped with the activity located away from major flow pathways with limited topographic variation.. The activity is of a small size and unlikely to result in any material increase in sediment loads to surface waters.	Yes	Low
72		Cumulative impacts- greenhouse gas emissions	Exploration activities materially increase Northern Territory's and Australia Greenhouse Gas emissions	B.4.1 Well integrity management B.4.3 Well design and barriers B.4.13 Hydraulic Stimulation and flow back operations D.5.8 Venting and flaring	2	1	L	•Activities required to prove up natural gas resources, with all available technology utilised to reduced emission intensity of exploration activities •Flaring required to mitigate emissions from the activity (Engineering) •Full development (if technically and commercially viable) likely to provide a viable transition fuel with up to 50% emissions of coal (Engineering) •Total greenhouse gas emissions for the Beetaloo Sub-basin are low compared to total NT and Broader Australia Greenhouse gas emissions. The worst case percentage of total NT and Australian GHG emissions is estimated at 2.6% and 0.078% respectively. •Strategic Regional Environmental Baseline Assessment (SREBA) completed to collected baseline environmental data, with Environmental Impact Assessments completed to address cumulative impacts from industry (Administration/ Engineering/ elimination)	N/A- Greenhouse gas emissions are approved prior to commencement of activity	N/A- Greenhouse gas emissions are approved prior to commencement of activity	2	1	L	Yes	The role natural gas plays as a low carbon intensity transition fuel to support renewable energy use is well known. Broad adoption of natural gas within the US has replaced coal in energy production and has been responsible for a continued decline in carbon emissions. The use of natural gas is one of the low carbon intensity fuels required to reduce carbon emissions.	Yes	Low