Waratah Coal

Galilee Power Station

Preliminary Hazard Assessment

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Revision: B - CLIENT ISSUE

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Document Control Status

Revision Record:

Revision	**Date**	**Purpose**
A	27/11/2019	For review
B	28/11/2019	Final – Client issue

Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

Waratah Coal Pty Ltd proposes to construct the Galilee Power Plant (the Project) near Alpha in Central Queensland and utilise coal from its adjacent underground mine. Construction of the Project is on land currently zoned as Rural and used for cattle grazing, and requires a Material Change of Use (MCU) application. As part of the application, a review of chemicals proposed for use as part of the Project must be undertaken under State Code 21: Hazardous Chemical Facilities (SC21).

This report has been prepared in accordance with Planning Guideline State Code 21: Hazardous chemical facilities, to meet the requirements of SC21.

A review of the chemicals proposed to be stored and used at the Project shows that the maximum inventory will exceed 10% of chemicals' threshold quantities under the Work Health and Safety Regulation 2011, schedule 15, triggering an assessment under SC21.

SC21 has six performance objectives (POs) that must be satisfied. The report details how each PO will be met.

The assessment has determined that there are no specified land uses in the vicinity of the Project that will be impacted by hazards resulting from the storage or use of hazardous chemicals. The closest existing sensitive receptor is located within the Mining Lease, and will be acquired by the mining operation and will cease to be a sensitive receptor. Modelling of chemical impacts indicate that this site would probably not be impacted by the worst credible event. The closest sensitive receptor remaining after acquisitions of those located on the Mining Lease will be well outside the area that would be impacted by the worst credible event.

The Project location and site characteristics avoids the potential for impact from earthquake, flood, landslide, erosion and storm tide inundation. Design in accordance with approved codes and standards will minimise any impact on chemical storage as a result of high winds, and further reduce the risk of earthquake**.** There are areas of remnant vegetation on the Project site that give rise to moderate bushfire risk. Operating procedures to keep the rest of the site free of combustible materials and comprehensive fire monitoring systems and control facilities will minimise the risk of bushfires impacting chemical storages.

1 INTRODUCTION

Waratah Coal Pty Ltd is applying for a mining lease over coal deposits in the Galilee Basin and is proposing to construct the Galilee Power Plant (the Project) adjacent to the mine, to use a part of the coal. Construction of the Project on land currently zoned as Rural and used for cattle grazing, requires a Material Change of Use (MCU) application. As part of the application, a review of chemicals proposed for use as part of the Project is required in order to determine whether an assessment must be undertaken under State Code 21: Hazardous chemical facilities (SC21) issued by the Department of Infrastructure, Local Government and Planning as part of the State Development Assessment Provisions (version 2.0).

This report has been prepared in accordance with Planning guideline State Code 21: Hazardous chemical facilities, published by Workplace Health and Safety Queensland, to meet the requirements of SC21.

The report has been prepared for Waratah Coal Pty Ltd by Ainslie Just BSc, BEng Hons (Chem), CEng, CPEng, CSci, CEnv, FIChemE, MIEAust, NER, RPEQ.

2 PROJECT DESCRIPTION

Waratah Coal Pty Ltd is developing a coal mine in the Galilee Basin in Central Queensland and proposes to construct a power station adjoining the mine.

2.1 Location

The Galilee Power Station Project is located in Central Queensland, approximately 30km north-north-west of the township of Alpha. It is located near the north-east corner of, and adjoining, the proposed Galilee Mine, the MLA for which extends over 25km to the west of the power station site, and 33km to the south-west. The Real Property description is Lot 2 on SP136836.

The Project site is shown in the locality plan 144-2-GA-001_A.

2.2 Site Description

Sensitive receptors surrounding the proposed power station are shown in the drawing WC-GPS-Fig4-SensitiveReceptors-r1. The closest existing sensitive receptor identified is at Monklands, approximately 4.5km south-west of the main power station site. It is within the Mining Lease for the adjoining mine, and it is proposed that this receptor will be acquired by the Project as part of the adjoining mine development, when it will cease to be a sensitive receptor. The Glen Innes and Kia Ora Homesteads are located approximately 12km south-west and west-north-west of the power station and will also be acquired as part of the mine development.

Salt Bush Homestead is located 11km south-south-east of the main power station site and will not be acquired. It will become the closest sensitive receptor to the Project site. Other homesteads are located at increasing distances towards the east of the power station site.

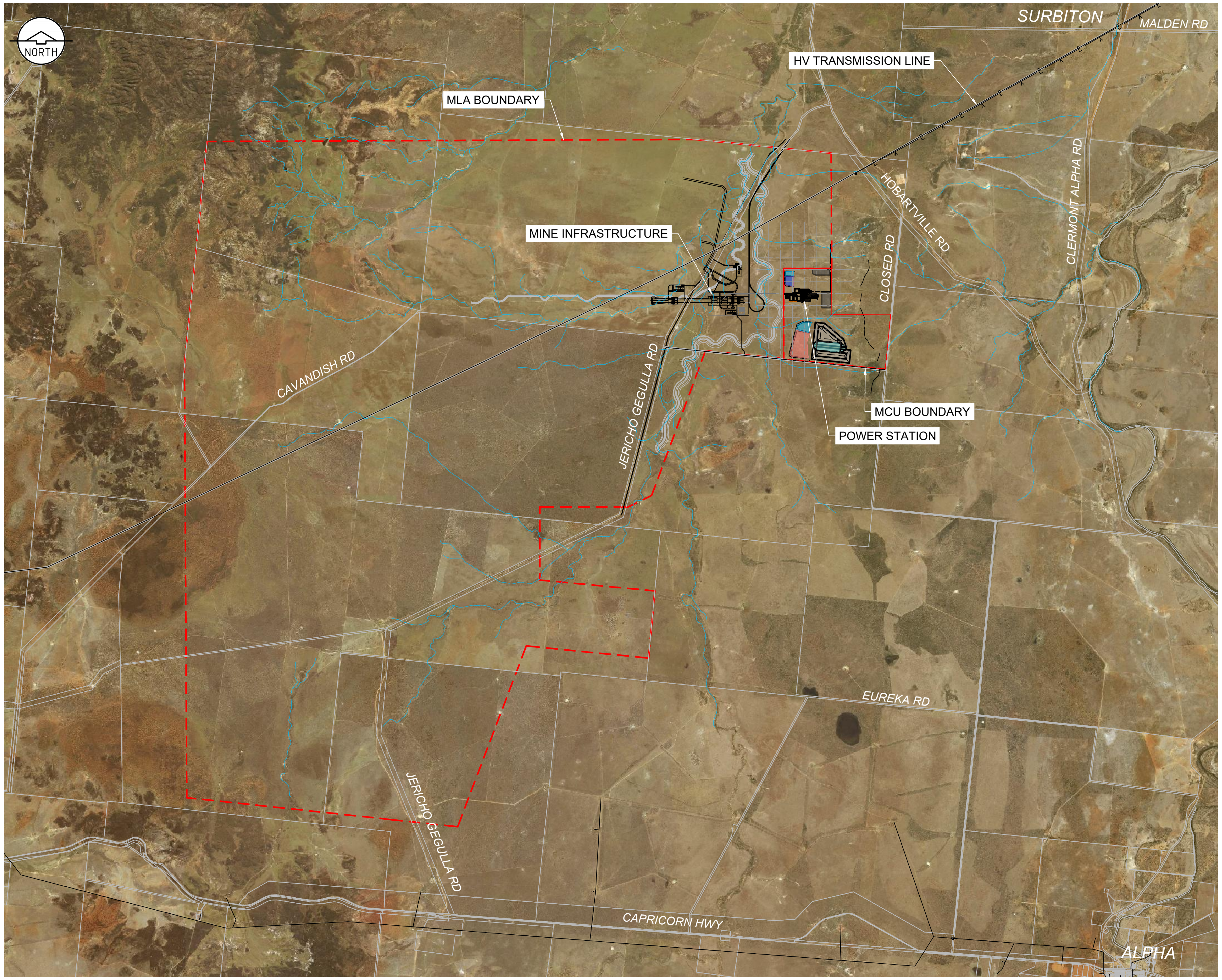
The Project site slopes down from a ridge line in the east that forms a water shed and limits the potential for site flooding. Drains from the plant area are directed through collection and sedimentation dams, with provision for stormwater diversion. The site layout is shown in drawing 144-2-GA-002_A.

The site altitude is approximately 350m.

Wind roses for Clermont and Barcaldine, the nearest available weather stations, show prevailing winds in the region typically from the NE-SE quadrant (9am and 3pm observations), with 4-8% calm conditions, typically 40-60% below 10km/h, and <10% exceeding 40km/h.

GALILEE POWER STATION PROJECT

CONCEPT DESIGN



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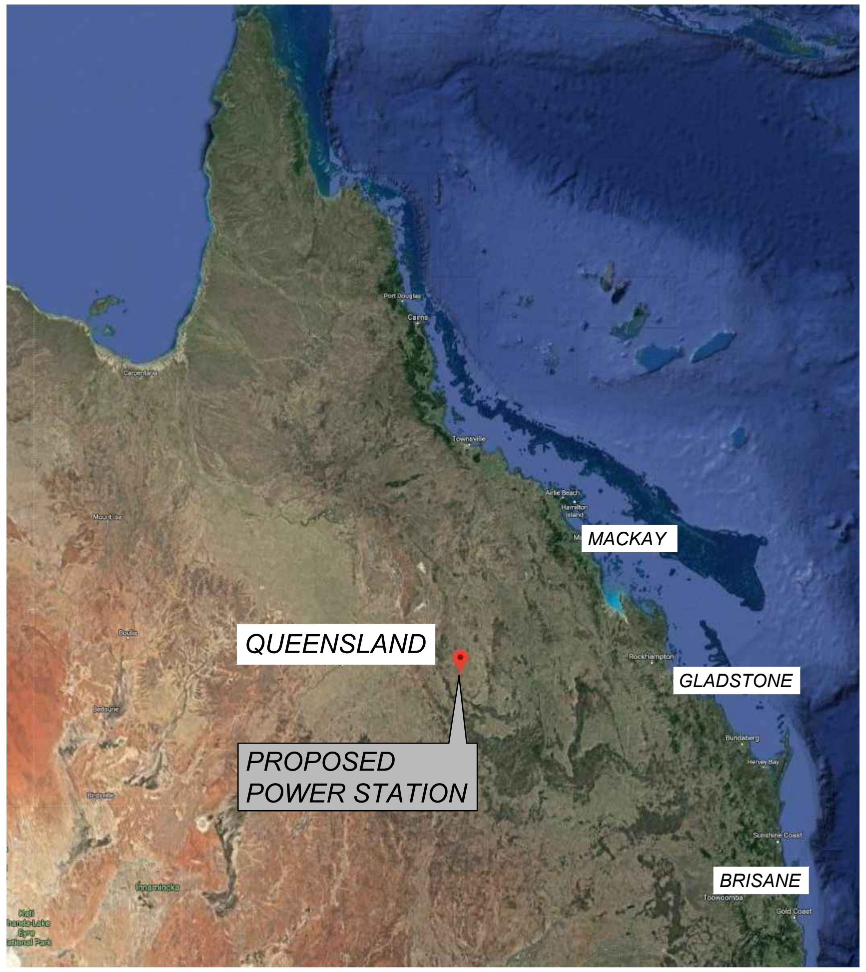

LOCALITY PLAN
NTS

DRAWING INDEX	
DRAWING No.	TITLE
144-2-GA-DWG-0001	LOCALITY PLAN
144-2-GA-DWG-0002	SITE LAYOUT PLAN
144-2-GA-DWG-0003	PLANT PLAN
144-2-GA-DWG-0004	PLANT ELEVATIONS
144-2-CI-DWG-0001	ASH STORAGE CELL 1 STAGING PLAN
144-2-CI-DWG-0002	ASH STORAGE CELL 2 STAGING PLAN
144-2-CI-DWG-0003	ASH STORAGE CELL 3 STAGING PLAN
144-2-CI-DWG-0004	ASH STORAGE CELL DETAILS PLAN
144-2-CI-DWG-0005	ASH STORAGE CELL SECTIONS

REV	DATE	BY	DESCRIPTION	CHK	APPD
A	04.10.19	SAS	PRELIMINARY ISSUE	PB	SWN

REFERENCE COORDINATION DRAWINGS

DESCRIPTION	DRAWING NO.	REV	CHK

SURVEY DATUM
HORIZONTAL DATUM:
VERTICAL DATUM:

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CLIENT:
Waratah Coal
THE NEW ENERGY IN COAL

PROJECT:
GALILEE POWER STATION PROJECT
CONCEPT DESIGN

TITLE:
GALILEE POWERSTATION
CONCEPT DESIGN
LOCALITY PLAN

DRAWING STATUS: PRELIMINARY
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SAS	PB	SWN
PROJECT No: 144-2	DRAWN: SAS	DATE: 26.09.19

DRAWING No: 144-2 - GA- DWG-0001
REV: A

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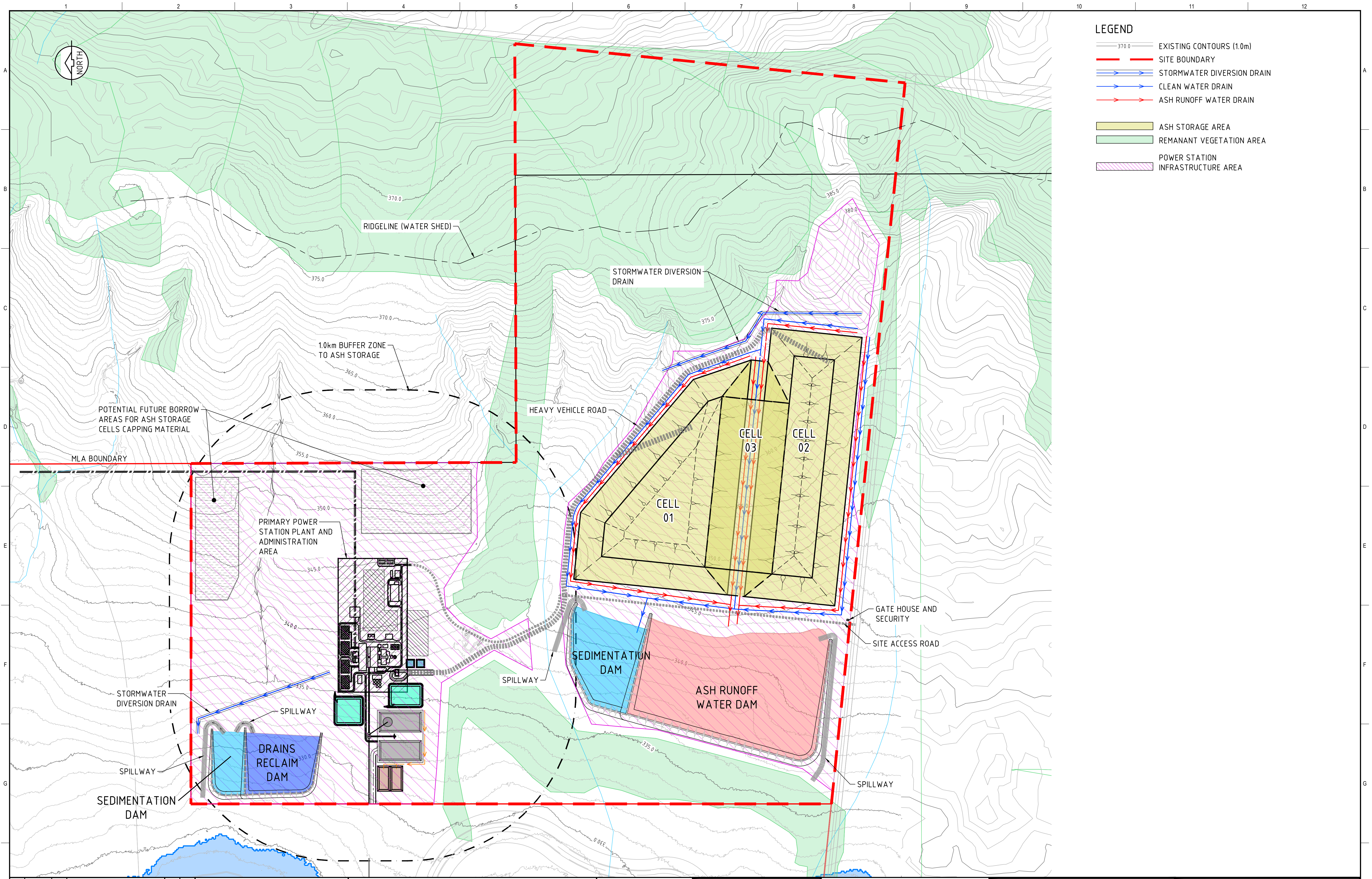
144-2-GA-DWG-0002



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PROJECT:
GALILEE POWER STATION PROJECT
CONCEPT DESIGN

TITLE:
GALILEE POWERSTATION
CONCEPT DESIGN
SITE
LAYOUT PLAN

DRAWING STATUS:
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DESIGNED:	CHECKED:	APPROVED:
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PROJECT No: 144-2	DRAWN: CG	DATE: 26.09.19

DRAWING No: 144-2 - GA - DWG - 0002

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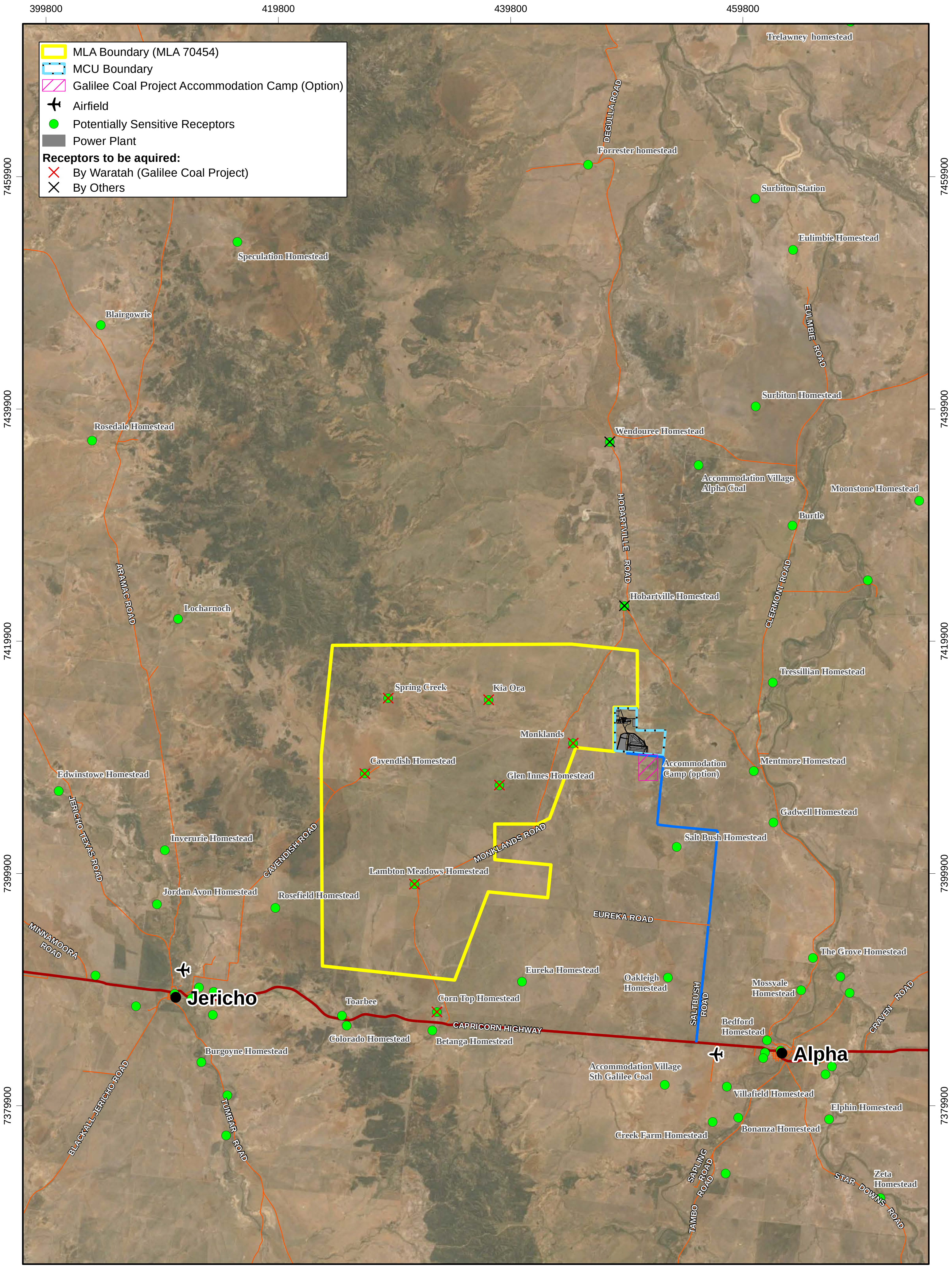


GALILEE POWER STATION

Tenement Boundary: Waratah Coal 2019
Receptors: Waratah Coal EIS/CEIS, EMCA 2019
Roads: DNRME 2018
Imagery: DigitalGlobe 2016

0 5 10 km

A4 Scale 1:400,000

GDA 1994 MGA Zone 55

N

SENSITIVE RECEPTORS IN PROXIMITY TO THE MINING LEASE

WC-GPS-06-Fig4-SensitiveReceptors-r1-191023, 23 Oct 2019

2.3 Process Description

The Galilee Power Station Project involves the construction and operation of a 1400MW ultra-supercritical coal-fired power station, located adjacent to the proposed Galilee Coal Mine which will supply the coal. The use of ultra-supercritical technology results in a high efficiency, low emission power plant when compared to the existing fleet of coal fired power plants in Australia. The chemical energy contained in the coal is converted to thermal energy by burning it in the boilers, converting water to steam, which is then used to drive turbines that in turn drive generators to produce electricity. The ultra-supercritical description refers to the fact that the steam pressures used in power plants of this sort is much higher than in older conventional power plants, resulting in greater efficiencies in the conversion of the chemical energy in coal to electrical energy. One definition of ultra-supercritical is steam up to 760°C and pressure levels of 340 bar.

The main cooling for the power station will use air cooled heat exchangers to minimise water use and avoid the requirement for the large cooling towers that are typically required on other plants. An auxiliary cooling system using evaporative cooling towers will be used to supplement the air-cooled system when required.

The plant has the option of including de-sulfurization to minimize the emission of sulfur dioxide (SO_2) in the flue gas if required.

The power plant requires a range of chemicals to ensure its safe and efficient operation.

Biocides (chlorine or bromine) are required to prevent the growth of bacteria (algae etc.) in the water circulating through the auxiliary cooling towers, cooling water distribution system, condensers, heat exchangers etc. in the plant, which could otherwise cause fouling of heat exchange surfaces and reduced plant efficiency (and potentially spread legionella if untreated).

Oxygen scavengers (hydrazine hydrate and ammonia) are required to remove traces of oxygen from the boiler feed water circulating in the power plant, so that the boilers and other equipment are protected from corrosion.

Various chemicals are required in the water treatment plant (WTP) to assist in settling and removing suspended material from raw water, to ensure that the water is maintained at the correct pH (acid level) as it passes through the treatment process, and to prevent scaling and assist in cleaning of equipment used to remove dissolved solids. Sulfuric acid will be used for pH control. Other chemicals used for water treatment are typically relatively non-hazardous solutions of mostly common chemicals; or proprietary formulations that are provided by specialist water treatment companies to address specific water quality issues, but are also relatively non-hazardous solutions.

3 PLANNING REQUIREMENTS

3.1 Planning Approval Requirements

Planning Regulation 2017 Schedule 10 Part 7 Hazardous chemical facilities, prescribes the planning approval requirements for a material change of use (MCU) for a hazardous chemical facility.

State Code 21 is the code against which an MCU application will be assessed. A proponent for a hazardous chemical facility is required to make an application to SARA in accordance with the development assessment process established under the Planning Act and addressing the requirements of SC21.

A hazardous chemical facility means the use of premises for a facility at which a prescribed hazardous chemical is present or likely to be present in a quantity that exceeds 10% of the chemical's threshold quantity under Schedule 15 of the Work Health and Safety Regulation 2011.

A review of the chemicals to be stored and used at the proposed power plant indicates that the 10% threshold has been exceeded, and a hazard assessment report is therefore required to support the MCU application.

3.2 Performance Objectives

State Code 21 (SC21) includes six Performance Objectives (PO1-6), each of which (excepting PO2 and PO6) has Acceptable Outcomes (AOs) specified. The POs and how they will be achieved, either through the relevant AOs or otherwise, are detailed in the following sections.

3.2.1 PO1

Any risk created by a hazardous chemical facility (including increasing an existing risk) is proportionate to the sensitivity of the surrounding land uses or zones.

PO1 is achieved by demonstrating (through this report) that no off-site impact from any hazard scenario will exceed AEG2 concentrations of dangerous chemicals, or heat radiation levels exceeding 4.7kW/m^2, or 7kPa overpressure, at the boundary of any vulnerable, sensitive, commercial or community activity, or any open space land use; or for industrial land use, a dangerous dose to the built environment.

The land uses referenced in this Performance Objectives are:

1. Vulnerable land uses:
    a) Childcare centre;
    b) Community care centre;
    c) Educational establishment;
    d) Health care service;
    e) Hospital; and
    f) Retirement facility.
2. Sensitive land uses:
    a) Community residence;
    b) Dual occupancy;
    c) Dwelling house;

   d) Educational establishment;
   e) Multiple dwelling;
   f) Relocatable home park;
   g) Residential care facility;
   h) Rooming accommodation;
   i) Short-term accommodation; and
   j) Tourist park.

3. Open space land use includes:
   a) Outdoor sport and recreation (not including sporting stadiums);
   b) Park;
   c) Environment facility; and
   d) Rural industry.
4. Commercial or community activity includes:
   a) Shopping centre;
   b) Shop;
   c) Office;
   d) Major sport, recreation and entertainment facility;
   e) Market;
   f) Showroom;
   g) Tourist attraction;
   h) Entertainment facility;
   i) Place of worship;
   j) Community use; and
   k) Theatre.

The closest vulnerable land use activities are located at Alpha and Jericho, at least 30km away.

The closest sensitive receptor is Monklands, approximately 4.5km to the SW of the proposed power plant. This site is to be acquired as part of the mining development, when it will cease to be a sensitive receptor. Other homesteads are located at increasing distances from the power plant, the closest of which will also be acquired. The closest remaining sensitive receptor will be located approximately 11km from the power plant. Other sensitive receptors are located at Alpha and Jericho.

There are no open space land use activities closer than the sensitive land use activities noted above. The Planning Regulations 2017 defines rural industry as storing, processing, packing or selling rural products.

The closest commercial or community activities are located at Alpha and Jericho.

3.2.2 PO2

The location and siting of a hazardous chemical facility considers and responds to any off-site effects from a hazard scenario at any existing hazardous chemical facility in the vicinity.

There are no AOs specified.

PO2 is achieved because there are no other hazardous chemical facilities in the vicinity of the proposed power station that might be impacted by it.

3.2.3 PO3

Storage and handling areas for fire risk hazardous chemicals are provided with control measures to identify a fire situation and trigger an emergency response.

PO3 will be met by complying with **AO3.1**: "Storage and handling areas for fire risk hazardous chemicals are provided with a 24 hour monitored fire detection system that has the ability to detect a fire in its early stages and notify an emergency responder at all times".

SC21, defines fire risk hazardous chemicals as a prescribed hazardous chemical that:

1. Is any of the following:
   a) A flammable gas;
   b) A flammable liquid (hazard category 1 to 3);
   c) A flammable solid;
   d) A substance liable to spontaneous combustion;
   e) A substance which, in contact with water, emits flammable gases;
   f) An oxidizing substance; and
   g) An organic peroxide.
2. Burns readily or supports combustion.

They are detailed in schedule 19 of the Work Health and Safety Regulation 2011.

The only fire risk hazardous chemical stored at the power plant will be hydrogen (DG Class 2.1). The hydrogen storage area will be provided with fire and leak detection systems to alert personnel to any emergency situation, and automatic isolation systems to shut down hydrogen distribution system in the event of any sign of fire or loss of pressure indicating a leak.

3.2.4 PO4

Storage and handling areas for liquid or solid fire risk hazardous chemicals are provided with a spill containment system which:

1. *Has a working volume capable of containing any reasonably foreseeable spill or leak within the boundaries of the development, including any resultant effluent generated in response to an emergency.*
2. *Ensures that any prescribed hazardous chemicals that, if in contact with each other, may react to produce a fire, explosion or other harmful reaction, or a flammable, toxic or corrosive vapour, are not brought together.*

PO4 is achieved because no liquid and solid fire risk hazardous chemicals are stored or used on the site. Storages for diesel fuel and/or heavy fuel oil required for plant startup but would not be classified as fire risk hazardous chemicals (diesel is combustible, not flammable). All storages of such combustible materials will be provided with appropriate bunding to ensure that any spill is fully contained.

3.2.5 PO5

The hazardous chemical facility is located and/or designed to minimise any adverse consequence of:

1. *Flood;*
2. *Bushfire;*
3. *Erosion or storm tide inundation; and*
4. *Landslide.*

On a storage and handling area.

PO5 is partly met because the hazardous chemicals storage areas of the power station site are close to, but not within, a flood prone area, the site is not an area subject to erosion or storm tide inundations, and is not an area subject to landslide.

The Queensland SPP Interactive Mapping System shows that parts of the power station site, including hazardous chemicals storage areas, are located close to (approximately 400m) medium potential bush fire areas (arising from remnant vegetation areas that are to be retained). **This element of PO5 will therefore be met** by ensuring that areas of the site not constituting remnant vegetation will be kept clear of combustible material to minimize the risk of bushfire impacting operating plant, and providing appropriate fire-fighting equipment and personnel to address any threat to the safety of the plant, personnel or adjoining land users. The site will be provided with mobile fire-fighting equipment located at a fire station, together with fixed fire monitors, sprinklers or other fire-fighting equipment as determined by an appropriate fire study of the Project.

3.2.6 PO6

The hazardous chemical facility is located and/or designed to minimise any adverse consequence of a natural hazard such as an earthquake or wind action on a storage.

PO6 is met by the location of the Project within a stable area not likely to be subject to earthquakes or strong winds. All structures (including those involved in the storage of hazardous chemicals) will be designed to the relevant earthquake and wind loading codes for the area. Other natural hazards are addressed under PO5.

4 HAZARDOUS CHEMICALS

The chemicals detailed in Table 4.1 will be stored and used at the Galilee Power Station. Maximum quantities to be stored, together with details of the hazardous properties and classification of each chemical, are provided in the table. Further details of the characteristics of these chemicals, especially toxicity data, are provided in Appendix A.

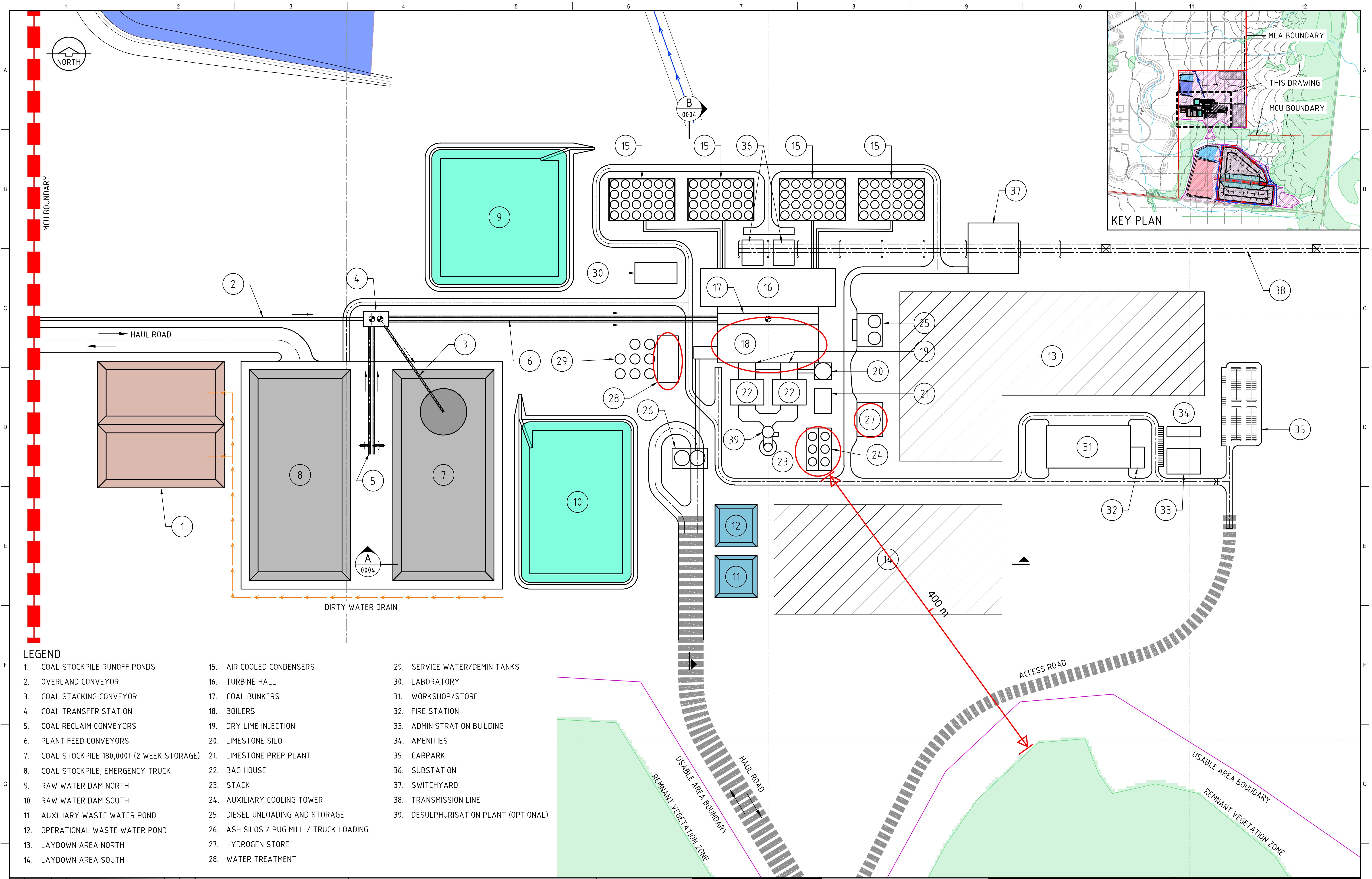
The proposed storage locations for each chemical listed is shown in drawing 144-2-GA-DWG-0003_B.

The table includes the threshold quantities of each chemical, where relevant, for a major hazard facility as detailed in Schedule 15 of the WHS Regulations. Hydrazine hydrate and sulfuric acid are not explicitly listed in Schedule 15, and their threshold quantities have been determined by comparing toxicity data obtained from sources such as Safety Data Sheets and a range of reference works with the criteria listed in Table 15.3 of the Schedule.

Table 4.1: Chemicals Used in Power Station

Chemical	UN number	DG Class	Subsidiary class	HAZCHEM code	HIN	PG	AEGL2 (60 min)	Max Quantity (tonnes)	Location	WHS Regs Sched 15 threshold quantity (tonnes)	% of threshold quantity
Chlorine	1017	2.3	5.1, 8	2XE	265	-	2.0ppm	5	Cooling towers, #24	25	20
Bromine	1744	8	6.1	2XE	886	I	0.24ppm	1	Cooling towers, #24	100	1
Ammonia solution (>50%)	1005	2.3	8	2RE	268	-	160ppm	5	Boilers, #18	200	2.5
Hydrazine hydrate	2030	8	6.1	•2X	886/ 86	I,II,III	Not available	2	Boilers, #18	200 (Toxic, see Table 15.3)	1
Sulfuric acid	1830	8		2P	80	II	8.7mg/m^3	4	WTP, #28	200 (Toxic, see Table 15.3)	2
Hydrogen	1049	2.1		2SE	23	II	n/a	2	Hydrogen Store, #27	50	4
Limestone									Limestone silo, #20		
Anti-scalant									WTP, #28		
WTP chemicals									WTP, #28		
Total contribution of all chemicals											31%

144-2-GA-DWG-0003



LEGEND

1. COAL STOCKPILE RUNOFF PONDS
2. OVERLAND CONVEYOR
3. COAL STACKING CONVEYOR
4. COAL TRANSFER STATION
5. COAL RECLAIM CONVEYORS
6. PLANT FEED CONVEYORS
7. COAL STOCKPILE 180,000t (2 WEEK STORAGE)
8. COAL STOCKPILE, EMERGENCY TRUCK
9. RAW WATER DAM NORTH
10. RAW WATER DAM SOUTH
11. AUXILIARY WASTE WATER POND
12. OPERATIONAL WASTE WATER POND
13. LAYDOWN AREA NORTH
14. LAYDOWN AREA SOUTH
15. AIR COOLED CONDENSERS
16. TURBINE HALL
17. COAL BUNKERS
18. BOILERS
19. DRY LIME INJECTION
20. LIMESTONE SILO
21. LIMESTONE PREP PLANT
22. BAG HOUSE
23. STACK
24. AUXILIARY COOLING TOWER
25. DIESEL UNLOADING AND STORAGE
26. ASH SILOS / PUG MILL / TRUCK LOADING
27. HYDROGEN STORE
28. WATER TREATMENT
29. SERVICE WATER/DEMIN TANKS
30. LABORATORY
31. WORKSHOP/STORE
32. FIRE STATION
33. ADMINISTRATION BUILDING
34. AMENITIES
35. CARPARK
36. SUBSTATION
37. SWITCHYARD
38. TRANSMISSION LINE
39. DESULPHURISATION PLANT (OPTIONAL)

REV	DATE	BY	DESCRIPTION	CHK	APPD
B	17.10.19	SAS	PRELIMINARY ISSUE	PB	SWN
A	04.10.19	SAS	PRELIMINARY ISSUE	PB	SWN

REFERENCE COORDINATION DRAWINGS

DESCRIPTION	DRAWING NO.	REV	CHK

SURVEY DATUM

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VERTICAL DATUM:

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CONCEPT DESIGN

TITLE:
GALILEE POWERSTATION
CONCEPT DESIGN
PLANT
PLAN

DRAWING STATUS:
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PROJECT No: 144-2	DRAWN: SAS	DATE: 26.09.19

DRAWING No: 144-2 - GA - DWG - 0003

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Notes to Table 4.1:

DG Classes (including subsidiary classes) for chemicals stored and used in the power plant and listed in the table are:

Class 2.1	Flammable gases
Class 2.3	Toxic gases
Class 5.1	Oxidising substances
Class 6.1	Toxic substances
Class 8	Corrosive substances

Chlorine and bromine are alternative biocides for the cooling towers: only one will be used in practice, most likely chlorine. Chlorine is a gas at ambient conditions. Bromine is a liquid at ambient conditions, so that the generation of vapour is slower than for chlorine, but the AEGL figures for bromine are much lower (AEGL2 (60 mins) is 2.0ppm for chlorine, but only 0.24ppm for bromine).

It has been assumed that ammonia solution at >50% will be used to be conservative, although in practice lower concentrations may be employed. Data is only available for 30% solutions.

Limestone will be employed as the reactant in flue gas desulfurization (if implemented). Limestone (calcium carbonate) is not hazardous (except potentially long-term as inhaled dust causing respiratory disease). The product of the desulfurization reaction will be calcium sulfate (gypsum), which is non-hazardous (and can be used as a construction material if it is economical to do so).

The anti-scalant and water treatment chemicals referred to have not been specified at this stage, and are expected to consist of proprietary compounds and mixtures in either solid or liquid form that are unlikely to pose any hazard beyond the immediate storage and plant areas where they are used.

For details of location and key, refer to Concept Design Plant Plan 144-2-GA-DWG-0003_B.

Trigger for Assessment under SC21

From the table it can be seen that the storage of up to 5 tonnes of chlorine alone will exceed 10% of the trigger level for chlorine of 25 tonnes in Schedule 15, requiring assessment under SC21.

An alternative to the use of chlorine is bromine, which would be stored in much smaller quantities and for which the trigger is higher. In this case, the aggregated total of hazardous chemicals stored slightly exceeds the 10% criterion for assessment under SC21.

5 HAZARD IDENTIFICATION AND ANALYSIS

5.1 Hazard Identification

5.1.1 Hazard Identification Methods

A representative of the Project proponent has been consulted to identify all hazardous chemicals likely to be stored and used as part of the operation of the power station. The chemicals identified, their uses within the plant and the associated storage facilities have been studied to identify scenarios representing the worst-case credible events involving all hazardous chemicals being used.

Each chemical identified as being stored and used at the power station has been listed in Section 4, with a summary of the classification and hazards posed by each chemical given in Table 4.1. The location of each storage has also been noted in the table and is shown on preliminary plant layout drawings.

Scenarios have been selected based on the hazard characteristics of each chemical involved: toxic, fire or contact hazards. Scenarios that are not considered to be able to create a credible risk beyond the site boundary have been discounted from further study.

Where a credible risk to persons at or outside the site boundary have been identified, including instances where sensitive or vulnerable receptors might potentially be impacted, further risk assessment has been undertaken. Details are provided in Section 5.3

5.2 Hazards Arising from Storage and Use of Chemicals

This section considers the sources of hazard to persons off-site and at vulnerable and sensitive receptors, and develops scenarios that may lead to credible health risks to those persons or risks to the built environment.

5.2.1 Toxic (Inhalation) Hazards

Toxic hazards are expected to be the principle source of risk to persons off-site. They arise from chemicals with DG Classes 2.3 (toxic gases) and 6.1 (toxic substances). Risks may arise from loss of containment of chlorine, bromine, ammonia or hydrazine hydrate.

Chlorine is a toxic gas at ambient conditions, stored under pressure as a liquid, which will vaporize very quickly and generate a toxic plume downwind of any release.

Bromine is a liquid at ambient conditions but vaporizes quickly to form a toxic plume downwind of any spill. Its main DG Class is 8 (corrosive), with a subsidiary class of 6.1 (toxic).

Ammonia is a toxic gas at ambient conditions. It will be stored as an aqueous solution at a high enough concentration that ammonia will evaporate from any spill and form a toxic plume downwind of any spill.

Hydrazine hydrate is a liquid at ambient conditions. It has a relatively low vapour pressure (0.7kPa) and a boiling point of 114°C. Its evaporation rate is therefore expected to be quite small. Releases are therefore not expected to generate a sufficiently large plume to have any significant health effect outside the power plant boundary. The GHS acute toxicity rating (inhalation) is category 3, for which the Acute Toxicity Estimate is 500-2500ppm (v/v). Its main DG Class is 8 (corrosive), with a subsidiary class of 6.1 (toxic). It is not within the scope of this report to determine valid package sizes for dangerous goods that comply with the ADG code. However, based on a preliminary scan of the ADG for this substance, it is expected that hydrazine hydrate will be transported and stored in packages that cannot exceed 400kg or 450L capacity, and would likely be smaller (100-200L). The maximum size of any credible spill would be limited to the size of the shipping container assuming it is not transferred to a tank for storage in the plant (which would be unlikely).

The criterion specified for meeting the PO assessment under SC21 is the Acute Exposure Guideline Level 2 (AEGL2) for human health impacts.

The prevailing winds for the site are from the NE-SE quadrant, so that any plume generated on the site is more likely to travel to the NW-SW. The sensitive receptor most likely to be affected is Monklands, but this sensitive receptor and others in the area will be acquired as part of the mining operation, and the next closest sensitive receptor is towards the SE and therefore less likely to be impacted by a hazardous chemical plume.

5.2.2 Fire and Explosion Hazards

The only chemical to be used at the power plant with a fire hazard rating is hydrogen. Its DG Class is 2.1 (Flammable gas).

Hydrogen will be delivered to the site in cylinders, which will typically be at >100 atmospheres pressure. Hydrogen is very flammable, but also diffuses very quickly and does not have a luminous flame, so thermal radiation from a fire is not likely to generate significant heat radiation effects away from the source. Hydrogen can form explosive clouds, but its low molecular weight and high diffusivity make the formation of a large cloud in the explosive range unlikely in most circumstances. If an explosive cloud were to form, significant confinement (such as might be provided inside the power plant itself) is generally required to cause it to explode. Damage is caused by the overpressure wave generated by the explosion. Away from the power plant structures it is unlikely to experience sufficient confinement for an explosion to occur. It is therefore considered very unlikely that any dangerous overpressure from a hydrogen vapour cloud explosion would impact anyone at the plant boundary or beyond.

The criterion specified for meeting the PO requirement is heat radiation levels exceeding 4.7kW/m^2, or 7kPa overpressure in the event of an explosion for human health impacts, and 12.6kW/m^2 or 14kPa for damage to the built environment.

5.2.3 Contact Hazards

The maximum quantities and characteristics of hazardous chemicals stored and used in the power plant are such that there is effectively no realistic scenario in which any of the materials identified could come in contact (at hazardous concentrations) with any person located outside the site perimeter fence. All the corrosive materials (DG Class 8) would be hazardous on contact but only sulfuric acid will be stored in quantities where there is any potential for dangerous quantities and concentrations to exceed the capacity of drains and containment systems and to reach the perimeter. With bunding around storage areas to contain any spills, the likelihood of a hazardous scenario is considered to be effectively zero.

5.2.4 Hazard Scenarios and Preliminary Risk Assessment

Table 5.1 shows the scenarios developed for each of the hazardous chemicals described in the preceding sections to describe the maximum credible incident involving those chemicals and provide an initial estimate of risk to persons located outside the Project site, based on their characteristics and the quantities involved. Actions to better characterise the extent of the consequences for each scenario are also listed. The results of these further assessments are detailed in the following sections.

Table 5.1: Hazard Scenarios and Preliminary Risk Assessment

Hazardous event	Worst case consequence (off site)	Likelihood of hazardous event occurring	Initial estimate of potential risk (to persons off-site)	Action
Isolation valve or liquid line from chlorine drum fails/damaged, release of complete drum (1 tonne) of chlorine.	Plume of chlorine gas reaches site boundary or receptor site at >AEGL2	Low	Moderate	Check dispersion model to verify possibility of plume reaching boundary or sensitive/vulnerable receptor.
Spill of bromine resulting in potential release of 100 kg of liquid bromine that evaporates.	Plume of bromine vapour reaches site boundary or receptor site at >AEGL2	Low	Moderate	Check dispersion model to verify possibility of plume reaching boundary or sensitive/vulnerable receptor.
Spill of ammonia solution that forms a pool and generates an ammonia cloud.	Plume of ammonia reaches site boundary or receptor site at >AEGL2.	Low	Low	Check dispersion model to verify possibility of plume reaching boundary or sensitive/vulnerable receptor.
Spill of hydrazine hydrate as a result of drum damage, pipework failure etc., that forms an evaporating puddle	Plume of hydrazine hydrate vapour reaches site boundary or receptor at >AEGL2 (or equivalent).	Low	Very low	Check dispersion model to verify possibility of plume reaching boundary or sensitive/vulnerable receptor.
Leak of hydrogen from high pressure bullets or pipework (continuous discharge at full storage pressure).	Vapour cloud forms and explodes, overpressure at site boundary or receptor site that exceeds 7 kPa.	Low	Very low	Check dispersion and vapour cloud model to verify possibility of a flammable vapour cloud forming and the potential for an explosion and dangerous overpressure.

5.3 Risk Assessment

5.3.1 Methodology and Assumptions

The results of the preliminary hazard identification detailed in Section 5.2 has generated a series of credible scenarios that might in the worst case give rise to potential for harm to human health outside the plant boundaries at sensitive receptors.

The relevant criteria for analysis of the resulting risks are the dangerous dose for human health detailed in SC21:

- AEGL2 for toxic materials;
- 4.7kW/m2 for flammable materials; and
- 7kPa overpressure for explosions.

For each of the scenarios presented in Table 5.1 a model has been produced using the US EPA ALOHA modelling software.

The WHS Guideline for SC21 states:

ALOHA (Areal Locations of Hazardous Atmospheres) is a software program designed especially for use by people responding to chemical incidents, and emergency planning and training. ALOHA can predict:

- The leak rates from broken gas pipes, leaking tanks, and evaporating puddles where it can predict the dispersion of the chemical after the release;
- How a toxic gas cloud might disperse in the atmosphere after a release; and
- Overpressure from explosions.

It can be used to evaluate hazardous chemical scenarios and determine the likely 'footprint' of such spills. This can help with estimating how far a toxic gas cloud may travel and where (i.e. the extent of the affected area). ... ALOHA is principally used to estimate consequences, it is generally conservative and has a wide range of ready to use chemicals in its data set.

Whilst ALOHA includes data for an extensive suite of chemical compounds, hydrazine hydrate is not included. Sufficient physical and chemical data has been obtained from an authoritative source (Yaws, 2014) to enable a model of hydrazine hydrate dispersion to be generated.

Relevant data has been obtained to locate and characterise the power station site so that the results of models can be sent to a mapping tool also provided by US EPA, MARPLOT, for integration with aerial photography if required.

ALOHA does not provide the functionality of some more sophisticated software packages, but does provide a simple means of screening for potentially hazardous situations without the need for detailed modelling. Given the current conceptual design status of the Project, it is not considered that more detailed modelling would be justified.

The scenarios modelled in ALOHA have been chosen to represent the worst credible accident, being based on the largest release that could occur in practice given the expected size of containers and storages, and on the least favourable weather conditions that are likely to be experienced. The scenarios further assume that no active controls are applied to mitigate the effect of the release: bunding is assumed to limit the spread of liquids where relevant, but it is assumed that no emergency response effort is made, for example to absorb, cover, recover or dilute spilled material, or to knock down vapour clouds for example with water sprays. All of these actions would potentially limit the rate of release of the hazardous chemical being studied, the total quantity released, the duration of the release, and the extent of the resulting impact area.

It is important to note that the modelling undertaken is necessarily only representative of likely scenarios, but will not cover every situation. Some sensitivity analysis has been undertaken to check whether the assumptions made are likely to result in significant deviations from the results reported. Maximum credible quantities of chemicals have been assumed in each case. However, results will be very dependent on the weather conditions assumed, including time of day (which will potentially affect atmospheric stability), temperature, wind speed and direction etc. Again, it is emphasised that ALOHA results are generally considered to be conservative.

The assumptions used in each model run are shown in the result summary produced by ALOHA.

5.3.2 Risk Assessment Model Results

The following sections detail the results of ALOHA models generated for each of the scenarios detailed in Table 5.1.

5.3.2.1 Chlorine Release

See Appendix B.1 for details of the ALOHA modelling for chlorine release.

The ALOHA model for a chlorine release assumes loss of the entire contents of a 1 tonne cylinder of liquid chlorine over time through a liquid offtake valve with a diameter of 10 mm located at the centre of the drum head. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

- Wind: 2 meters/second from E at 3 meters;
- Ground Roughness: open country;
- Cloud Cover: 5 tenths;
- Air Temperature: 20°C;
- Stability Class: E;
- No Inversion Height; and
- Relative Humidity: 50%.

The results of this model run are:

- Release Duration: ALOHA limited the duration to 1 hour;
- Max Average Sustained Release Rate: 46.2 kilograms/min (averaged over a minute or more);
- Total Amount Released: 424 kilograms; and
- Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

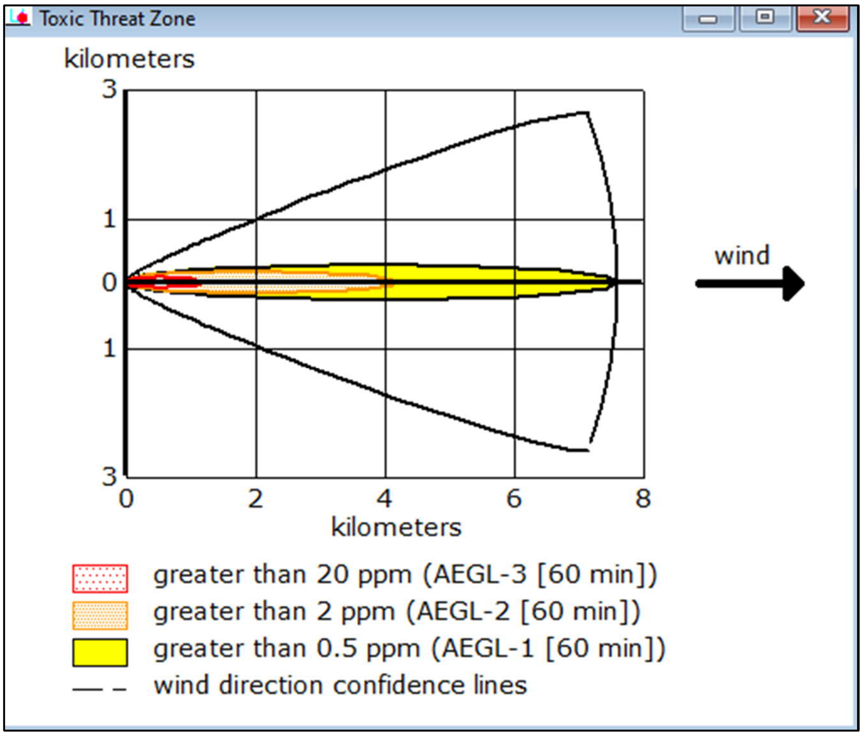
Threat Zone

- Model Run: Heavy Gas;

- Red: 1.2 kilometers --- (20 ppm = AEGL-3 [60 min]);
- Orange: 4.2 kilometers --- (2 ppm = AEGL-2 [60 min]); and
- Yellow: 7.6 kilometers --- (0.5 ppm = AEGL-1 [60 min]).

A graphical representation of the threat zone is shown in Figure 5.1.

Figure 5.1: ALOHA Results for Chlorine Release



Based on this model, the nearest (existing) sensitive receptor would not lie within the AEGL2 zone (although further checks on the sensitivity of the model might result in a longer threat zone). Following acquisition of this and other sensitive receptors as part of the mine development, Salt Bush Homestead, will be the next closest sensitive receptor at a distance of 11 km, and would be well outside the AEGL1 zone. The prevailing wind is less likely to impact this sensitive receptor. The AEGL 3 zone would probably extend just outside the power station site boundary into the mining lease.

5.3.2.2 Bromine Release

See Appendix B.2 for details of the ALOHA modelling for bromine release.

The ALOHA model for a bromine release assumes a 5m^2 puddle of liquid bromine evaporating over time. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

- Wind: 1 meters/second from E at 3 meters;
- Ground Roughness: open country;
- Cloud Cover: 0 tenths;
- Air Temperature: 25°C;
- Stability Class: F;

- Inversion Height: 50 meters; and
- Relative Humidity: 50%.

The results of this model run are:

- Release Duration: ALOHA limited the duration to 1 hour;
- Max Average Sustained Release Rate: 1.47 kilograms/min (averaged over a minute or more); and
- Total Amount Released: 65.1 kilograms.

Threat Zone

- Model Run: Heavy Gas;
- Red : 255 meters --- (8.5 ppm = AEGL-3 [60 min]);
- Orange: 2.4 kilometers --- (0.24 ppm = AEGL-2 [60 min]); and
- Yellow: 6.8 kilometers --- (0.033 ppm = AEGL-1 [60 min]).

Based on this model, the nearest (existing) sensitive receptor would not lie within the AEGL2 zone. Following acquisition of this and other sensitive receptors as part of the mine development, Salt Bush Homestead will be the next closest sensitive receptor at a distance of 11 km, and would be well outside the AEGL1 zone. The prevailing wind is less likely to impact this sensitive receptor. The AEGL 3 zone would not extend outside the power station site boundaries.

5.3.2.3 Ammonia Release

See Appendix B.3 for details of the ALOHA modelling for ammonia release.

A 30% aqueous ammonia solution has been used because this is the concentration for which ALOHA data is available, and is a common concentration for transport of aqueous ammonia solution. A higher concentration may be used in the final design.

The ALOHA model for an aqueous ammonia release assumes either a 10 or 20m^2 puddle in a concrete bund containing 1-2tonnes of solution with ammonia evaporating over time. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

- Wind: 1 meters/second from E at 3 meters;
- Ground Roughness: open country;
- Cloud Cover: 0 tenths;
- Air Temperature: 25°C;
- Stability Class: F;
- No Inversion Height; and
- Relative Humidity: 25%.

The results of this model run are:

- Release Duration: ALOHA limited the duration to 1 hour;
- Max Average Sustained Release Rate: 8.93 kilograms/min (averaged over a minute or more); and
- Total Amount Hazardous Component Released: 131 kilograms.

Threat Zone

- Model Run: Gaussian;
- Red: 270meters --- (1100 ppm = AEGL-3 [60 min]);
- Orange: 670meters --- (160 ppm = AEGL-2 [60 min]); and
- Yellow: 694meters --- (150 ppm = ERPG-2).

Based on this model, the AEGL2 zone would be completely contained within the site boundary. No sensitive receptors would be impacted.

Ammonia is also flammable when mixed with air in the correct concentrations. Flammability of the ammonia vapour cloud has been checked for the same conditions, with the following threat zones:

Threat Zone

- Threat Modeled: Flammable Area of Vapor Cloud;
- Model Run: Gaussian;
- Red: 22 meters --- (90000ppm = 60% LEL = Flame Pockets);
- Note: Threat zone was not drawn because effects of near-field patchiness;
- make dispersion predictions less reliable for short distances; and
- Yellow: 100 meters --- (15000 ppm = 10% LEL).

The extent of a flammable cloud is seen to be at most 100m, which is contained well within the site boundary.

There is the potential for a flammable cloud to generate an explosion. The threat zone for an explosion under the same conditions is:

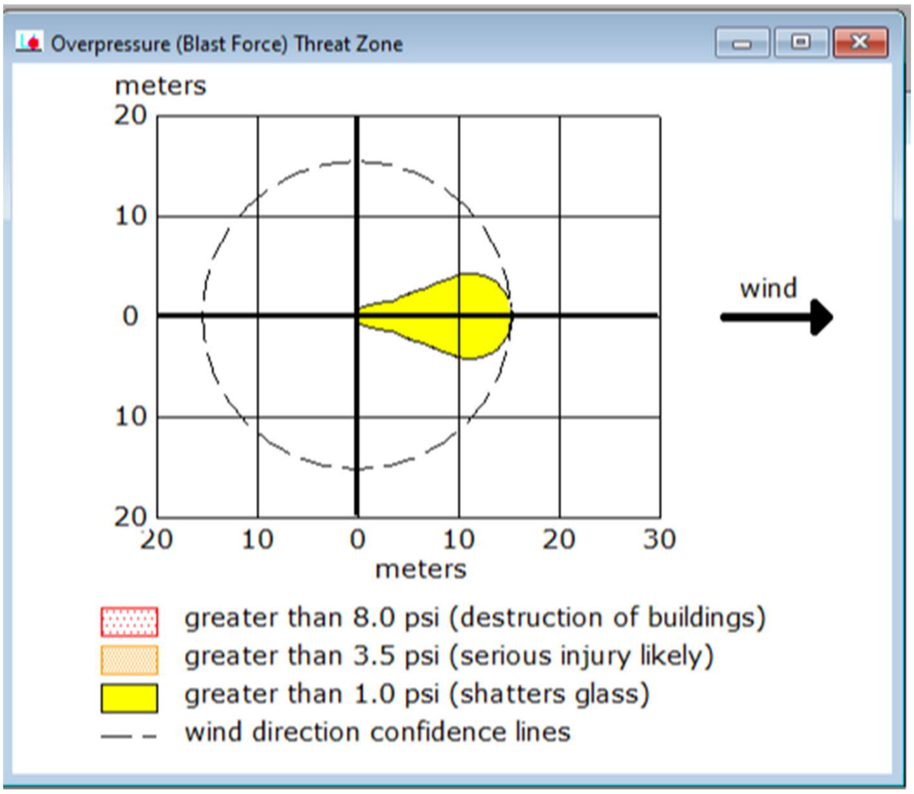
Threat Zone

- Threat Modeled: Overpressure (blast force) from vapor cloud explosion;
- Type of Ignition: ignited by spark or flame;
- Level of Congestion: congested;
- Model Run: Gaussian;
- Red: LOC was never exceeded --- (8.0 psi = destruction of buildings);
- Orange: LOC was never exceeded --- (3.5 psi = serious injury likely); and

- Yellow: 15 meters --- (1.0 psi = shatters glass).

The extent of the threat zone for a vapour cloud explosion involving ammonia is only 15m, which is contained completely within the site boundary, and the intensity of any explosion is not likely to exceed 1psi, which may cause some damage but is not likely to result in serious injury. A graphical representation of the overpressure (blast force) threat zone is shown in Figure 5.2.

Figure 5.2: ALOHA Model of Overpressure Blast from Ammonia Release



5.3.2.4 Hydrazine Hydrate Release

ALOHA does not include hydrazine hydrate in its database of chemical compounds. The ALOHA models for hydrazine hydrate release used data obtained from a database of chemical and physical properties of chemical compounds (Yaws, 2014) with cross-checks against several SDSs from manufacturers.

See Appendix B.4 for details of the data and ALOHA modelling for hydrazine hydrate.

Toxicity data found for hydrazine hydrate is somewhat inconsistent. Comparison of numbers from the Merck Index, Sax, the NIOSH Pocket Guide, the Australian Workplace Exposure Standards and various SDSs is not conclusive. It has therefore been decided to use the hydrazine AEGL values provided in the ALOHA database (and by the US EPA). This uses an AEGL 1 that is approximately 10 times the Australian workplace exposure standard for hydrazine. Some SDSs indicate that LC_{50} might be as high as 1200mg/m^3. The use of an AEGL 3 of 35ppm is therefore considered very conservative.

The ALOHA model for a spill of hydrazine hydrate assumes a 5m diameter pool containing 500L of the material on a concrete floor and slowly evaporating. Using this assumption, the worst case outcome found for a spill occurs under the following conditions at 16:00:

- Wind: 2 meters/second from E at 3 meters;
- Ground Roughness: open country;
- Cloud Cover: 5 tenths;
- Air Temperature: 35°C;
- Stability Class: C;
- No Inversion Height; and
- Relative Humidity: 25%.

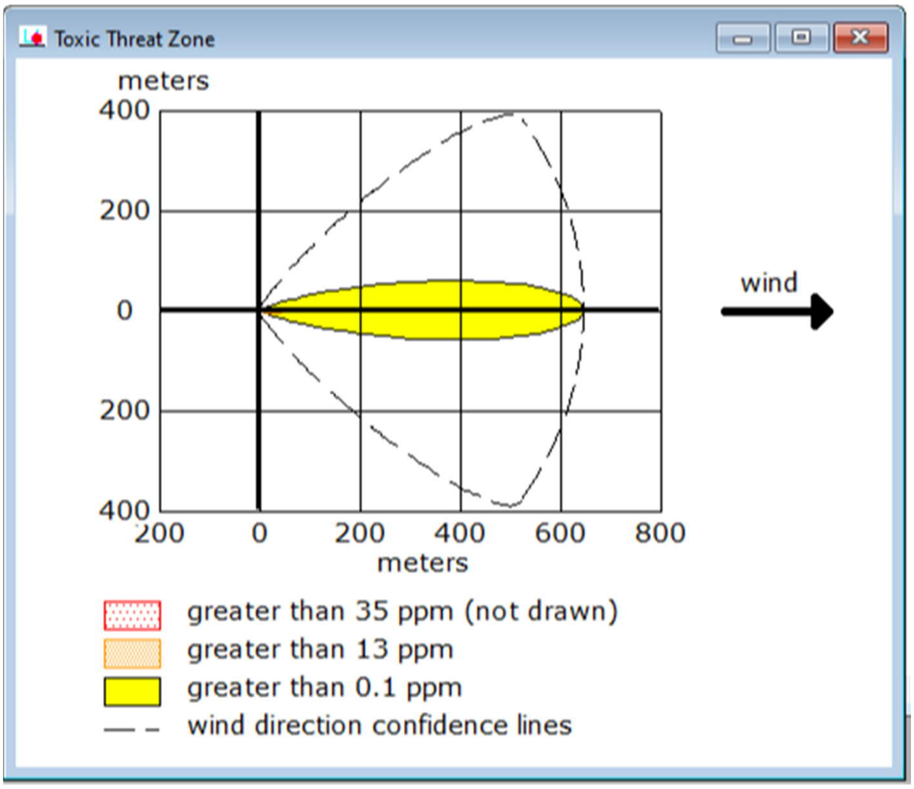
The results of this model run are:

- Release Duration: ALOHA limited the duration to 1 hour;
- Max Average Sustained Release Rate: 251 grams/min (averaged over a minute or more); and
- Total Amount Released: 14.9 kilograms.

Threat Zone

- Model Run: Gaussian;
- Red: 31 meters --- (35ppm);
- Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances;
- Orange: 53 meters --- (13ppm); and
- Yellow: 647 meters --- (0.1ppm).

Figure 5.3: ALOHA Model Results for Hydrazine Hydrate Release



It can be seen that even with conservative AEGL values, the impact area will be contained completely within the site boundary. No sensitive receptor will be affected. Based on the very limited extent of the impact area for this model run, no sensitivity checks have been undertaken. The model was run with a relatively high ambient temperature, so that the greatest evaporation rate of the hydrazine hydrate would be achieved.

5.3.2.5 Hydrogen release

See Appendix B.5 for details of the ALOHA modelling for hydrogen.

The ALOHA model created for a hydrogen release assumes a 50m pipe with diameter 25mm, open ended, connected to an effectively unlimited source of hydrogen at 100 atm. The results of the modelling are:

- Wind: 2 meters/second from E at 3 meters;
- Ground Roughness: open country;
- Cloud Cover: 5 tenths;
- Air Temperature: 35° C;
- Stability Class: C;
- No Inversion Height; and
- Relative Humidity: 25%.

The result of this model run are:

- Flammable gas escaping from pipe (not burning);
- Pipe Diameter: 2.5 centimetres;
- Pipe Length: 50 meters;
- Unbroken end of the pipe is connected to an infinite source;
- Pipe Roughness: smooth;
- Hole Area: 4.91 sq cm;
- Pipe Press: 100 atmospheres;
- Pipe Temperature: 35°C;
- Release Duration: ALOHA limited the duration to 1 hour;
- Max Average Sustained Release Rate: 33.4 kilograms/min (averaged over a minute or more); and
- Total Amount Released: 2,002 kilograms.

THREAT ZONE:

- Threat Modeled: Flammable Area of Vapor Cloud;
- Model Run: Gaussian;
- Red: 103 meters --- (24000ppm = 60% LEL = Flame Pockets); and
- Yellow: 254 meters --- (4000ppm = 10% LEL).

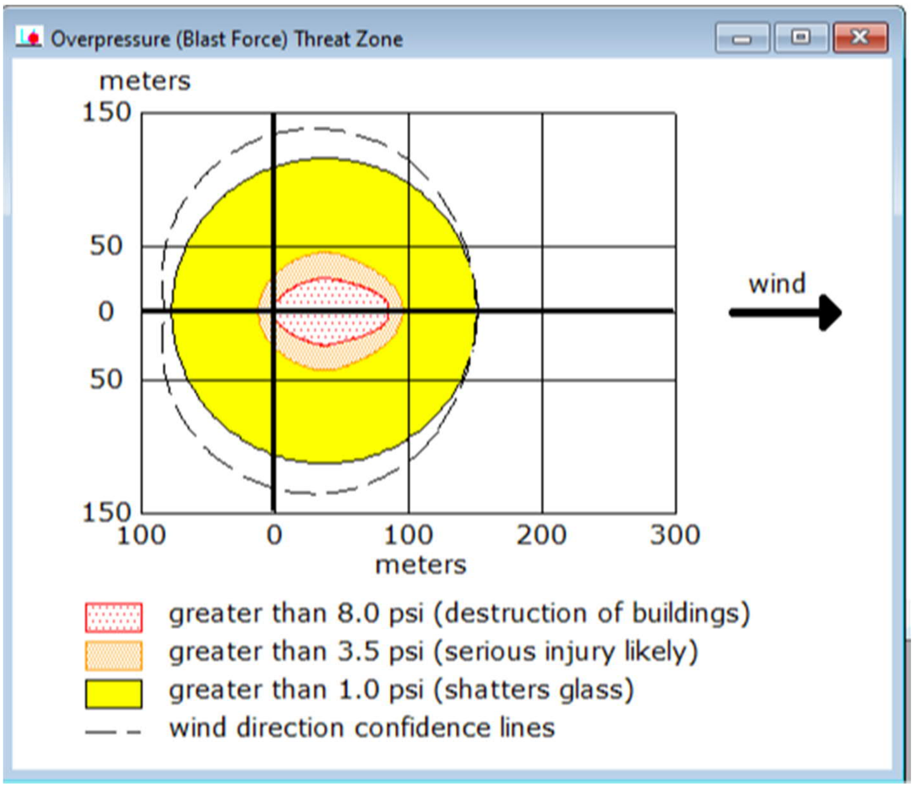
THREAT ZONE:

- Threat Modeled: Overpressure (blast force) from vapor cloud explosion;
- Type of Ignition: ignited by spark or flame;
- Level of Congestion: congested;
- Model Run: Gaussian;
- Red : 87 meters --- (8.0psi = destruction of buildings);
- Orange: 97 meters --- (3.5psi = serious injury likely); and
- Yellow: 153 meters --- (1.0psi = shatters glass).

The threat zone for generation of a flammable vapour cloud is contained completely within the site boundaries. The corresponding threat zone for a subsequent explosion of the vapour cloud shows that even the lowest impact zone, experiencing 1psi overpressure (which is unlikely to cause significant injuries), is also contained completely within the site boundaries.

Knock-on effects are of course possible as a result of an explosion, given that there is an area of 8psi overpressure extending approximately 80m from the source of the leak, which is likely to cause damage to other parts of the plant. However, such domino effects are outside the scope of this study.

Figure 5.4: ALOHA Model Results for a Hydrogen Release



5.3.3 Risk Analysis

A review of the results of the risk assessment detailed in Section 5.3.2 shows that:

- No toxic chemical stored or used at the proposed power station is likely to have an impact on any sensitive receptor or other prescribed land use at or exceeding the AEGL 2 criterion set by SC21 in the event of the maximum credible release;
- No fire- or explosion-risk chemical stored or used at the proposed power station is likely to have an impact on any sensitive receptor or other prescribed land use at or exceeding heat radiation levels exceeding 4.7kW/m^2, or 7kPa overpressure; and
- No fire - or explosion - risk chemical stored or used at the proposed power station is likely to have an impact on the built environment outside the power station site.

Because the consequences of the maximum credible events have been shown to be below the criteria set by the PO, no estimation of the probability of such events, or the risks arising, is considered necessary.

6 RISK MANAGEMENT MEASURES

The risks to human health and the built environment outside the power station site have been shown to be within the criteria set in SC21. As a result, no additional mitigation measures over and above good design conforming to all relevant codes and standards, and good operating practice, are considered necessary.

All parts of the power station design will conform strictly to relevant codes and standards for the storage and use of all hazardous chemicals. Plant will be subjected to appropriate risk studies during design, construction and operation to eliminate all hazards where possible.

Relevant systems will be put in place to ensure that handling of hazardous chemicals complies at all times with good practice, and to respond quickly and appropriately to all emergency situations. Procedures will be implemented to ensure that maintenance of all plant and equipment is at all times managed to prevent the introduction of points of failure in operating plant. A management of change procedure will be implemented to prevent unauthorised modifications to process plant and to ensure that any changes are subjected to appropriate risk studies prior to implementation.

7 CONCLUSIONS

A study has been completed of the risks arising from the storage of hazardous chemicals at the proposed Galilee Power Station, to be constructed adjacent to the Waratah Coal mine near Alpha in Central Queensland.

Hazardous chemicals identified and subjected to more detailed study are chlorine, bromine, aqueous ammonia, hydrazine hydrate, sulfuric acid and hydrogen.

The assessment has been completed to demonstrate compliance with State Code 21. SC21 specifies the six performance outcomes to be achieved by a material change of use for a hazardous chemical facility, which is an assessable activity.

Achievement of the Performance Objectives have been demonstrated as follows:

PO1, which requires that no harm will be caused to human health in specified land use areas, is achieved by demonstrating that no off-site impact from any hazard scenario will exceed AEGL 2 concentrations of dangerous chemicals, or heat radiation levels exceeding 4.7 kW/m2, or 7kPa overpressure at the boundary of any vulnerable, sensitive, commercial or community activity, or any open space land use; and for industrial land use, a dangerous dose to the built environment. Modelling of the maximum credible incident arising from each of the hazardous chemicals has shown that most impacts from hazardous chemicals are contained within the site boundaries, and that where they extend beyond the boundary they will not impact any other specified land use.

PO2, which requires that other hazardous chemical facilities are to be protected**, is achieved** because there are no other hazardous chemical facilities in the vicinity of the proposed power station that might be impacted by it.

PO3, which requires controls for the storage of fire risk hazardous chemicals, **will be met** by complying with **Acceptable Outcome 3.1.** Hydrogen is the only fire risk hazardous chemical stored on the site. The hydrogen storage area will be provided with fire and leak detection systems to alert personnel to any emergency situation, and automatic isolation systems to shut down hydrogen distribution system in the event of any sign of fire or loss of pressure indicating a leak.

PO4, which requires that spill control systems must be in place for fire risk hazardous solids and liquids, **is achieved** because no liquid and solid fire risk hazardous chemicals are stored or used on the site. Storages for diesel fuel and/or heavy fuel oil are required for plant startup but would not be classified as fire risk hazardous chemicals. All storages of such combustible materials will be provided with appropriate bunding to ensure that any spill is fully contained.

PO5, which requires that the facility not be impacted by natural hazards, **is partly met** because the hazardous chemicals storage areas of the power station site are not within a flood prone area, the site is not an area subject to erosion or storm tide inundations, and is not an area subject to landslide. Parts of the site are shown as being medium potential bush fire areas. Impacts on the hazardous chemical storage facilities will be minimised by ensuring that areas of the site not constituting remnant vegetation will be kept clear of combustible material to minimize the risk of bushfire impacting operating plant, and by providing appropriate fire-fighting equipment and personnel to address any threat to the safety of the plant, personnel or adjoining land users. The site will be provided with mobile fire-fighting equipment located at a fire station, together with fixed fire monitors, sprinklers or other fire-fighting equipment as determined by an appropriate fire study of the Project.

PO6, which requires that the facility must not be impacted by natural hazards such as earthquake and high winds, is met by the location of the Project within a stable area not likely to be subject to earthquakes or strong winds, and designing and constructing all structures to the relevant earthquake and wind loading codes for the area.

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APPENDIX A HAZARDOUS CHEMICAL PROPERTIES

A.1 Chlorine

AEGL Data

Chlorine 7782-50-5 (Final)

	10 min	30 min	60 min	4 hr	8 hr
ppm					
AEGL 1	0.50	0.50	0.50	0.50	0.50
AEGL 2	2.8	2.8	2.0	1.0	0.71
AEGL 3	50	28	20	10	7.1

www.wpa.gov/aegl/

Merck Index data

Monograph Number: 0002095

Title: Chlorine

CAS Registry Number: 7782-50-5

Literature References: Cl; at. wt 35.4527; at. no. 17; valences 1, 3, 5, 7. A halogen; Group VIIA (17). Does not occur as elemental state, Cl2, in nature. Abundance in igneous rock (95% of earth's crust): 0.031% by wt; in seawater: 1.9% by wt (primarily as NaCl). Naturally occurring stable isotopes (mass numbers): 35 (75.77%), 37 (24.23%); known artificial radioactive isotopes: 31-34, 36 (longest-lived known isotope, T½ 3.0 ´ 105 yrs; b-, EC decay), 38-46, 48. Discovered in 1774 by C. W. Scheele; recognized as an element in 1810 by H. Davy. Commercial sources: seawater, ocean derived mineral deposits, brines from lakes, wells and springs. Industrial prepn from brine in electrolytic cells. Lab prepn from MnO2 and HCl: Schmeisser in Handbook of Preparative Inorganic Chemistry vol. 1, G. Brauer, Ed. (Academic Press, New York, 2nd ed., 1963) p 272. Cosmogenic production and determn of 36Cl for geological dating: H. E. Gove, Philos. Trans. R. Soc. London Ser. A 323, 103 (1987); M. G. Zreda et al., Earth Planet. Sci. Lett. 105, 94 (1991). Reviews: Ciba Review vol. 12, no. 139 (Aug. 1960); ACS Monograph Series no. 154, entitled “Chlorine,” J. S. Sconce, Ed. (Reinhold, New York, 1962) 901 pp; MTP Int. Rev. Sci.: Inorg. Chem., Ser. One vol. 3, V. Gutmann, Ed. (Butterworths, London, 1972); A. J. Downs, C. J. Adams, “Chlorine, Bromine, Iodine and Astatine” in Comprehensive Inorganic Chemistry vol. 2, J. C. Bailar, Jr. et al., Eds. (Pergamon Press, Oxford, 1973) pp 1107-1594; Chemistry of the Elements, N. N. Greenwood, A. Earnshaw, Eds. (Pergamon Press, New York, 1984) pp 920-1041; L. C. Curlin, T. V. Bommaraju in Kirk-Othmer Encyclopedia of Chemical Technology vol. 1 (Wiley-Interscience, New York, 4th ed., 1994) pp 938-1025. Review of potential human health and environmental adverse effects of chlorine and its compounds: E. Delzell et al., Regul. Toxicol. Pharmacol. 2, S1-S1056 (1994).

Properties: Greenish-yellow, diatomic gas; suffocating odor. mp -101.00°. bp -34.05°. d20 at 6.864 atm 1.4085 (liq); d-35 at 0.9949 atm 1.5649 (liq). d (relative to air) 2.48. Heat capacity at constant pressure (gas, 25°) 8.11 cal/mole/°C. Vapor pressure data: Giauque, Powell, J. Am. Chem. Soc. 61, 1970 (1939). Critical temp 144°; critical pressure 76.1 atm; critical density 0.573. Sol in water (25°) with formation of aqueous Cl2 (0.062 moles/l), HOCl (0.030 moles/l) and Cl- (0.030 moles/l); total soly: 0.092 moles/l. More sol in alkalis. Oxidizing agent. Very reactive; E0 (aq) ½Cl2/Cl- 1.356 V; dissociation energy (25°): 57.978 kcal. Forms halides with all elements except the rare gases helium, neon and argon. Non-combustible in air; most combustible materials will burn in chlorine. Forms explosive mixtures with flammable gases and vapors. Reacts explosively or forms explosive compounds with many common chemicals, especially acetylene, turpentine, ether, ammonia gas, fuel gas, hydrocarbons, hydrogen and finely divided metals. LC50 (1 hr) in rats, mice (ppm): 293, 137 (K. C. Back et al., Reclassification of Materials Listed as Transportation Health Hazards (TSA-20-72-3; PB 214-270, 1972) pp A-182-183).

Melting point: mp -101.00°

Boiling point: bp -34.05°

Density: d20 at 6.864 atm 1.4085 (liq); d-35 at 0.9949 atm 1.5649 (liq); d (relative to air) 2.48

Toxicity data: LC50 (1 hr) in rats, mice (ppm): 293, 137 (K. C. Back et al., Reclassification of Materials Listed as Transportation Health Hazards (TSA-20-72-3; PB 214-270, 1972) pp A-182-183)

CAUTION: Potential symptoms of overexposure are burning of eyes, nose and mouth; lacrimation, rhinorrhea; coughing, choking and substernal pain; nausea, vomiting; headache, dizziness; syncope; pulmonary edema; pneumonia; hypoxemia; dermatitis; direct contact with liquid may cause frostbite. See NIOSH Pocket Guide to Chemical Hazards (DHHS/NIOSH 97-140, 1997) p 58. See also Patty's Industrial Hygiene and Toxicology vol. 2F, G. D. Clayton, F. E. Clayton, Eds. (Wiley-Interscience, New York, 4th ed., 1994) pp 4483-4505.

Use: Manuf of organic and inorganic chemicals. As oxidizing and bleaching agent in pulp and paper industry, and for textiles. As disinfectant for water purification, industrial waste, sewage, swimming pools. In the extraction and refining of metals. 36Cl for determining geological age of natural samples such as meteorites, surface rocks, polar ice and ground water. Has been used as a military poison gas under the name bertholite.

A.2 Bromine

AEGL Data

Bromine 7726-95-6 (Final)

	10 min	30 min	60 min	4 hr	8 hr
ppm					
AEGL 1	0.033	0.033	0.033	0.033	0.033
AEGL 2	0.55	0.33	0.24	0.13	0.095
AEGL 3	19	12	8.5	4.5	3.3

www.wpa.gov/aegl/

Merck Index Data

Monograph Number: 0001394

Title: Bromine

CAS Registry Number: 7726-95-6

Literature References: Br; at. wt 79.904; at. no. 35; valences 1, 3, 5, 7. A halogen; Group VIIA (17). Does not occur as elemental state, Br2, in nature. Abundance in igneous rock: 1.6 ´ 10-4% by wt; in seawater: 0.0065% by wt. Extracted commercially from natural brines (salt lakes) and seawater. Naturally occurring stable isotopes (mass numbers): 79 (50.69%), 81 (49.31%); known artificial radioactive isotopes: 69-76, 77 (longest-lived known isotope, T½ 57.036 hr; EC decay), 78, 79m, 80, 80m, 82-94. Discovery: A. J. Balard, Ann. Chim. Phys. 32, 337 (1826). Books: Bromine and its Compounds, Z. E. Jolles, Ed. (E. Benn, London, 1966) 940 pp; Bromine Compounds: Chemistry and Applications, D. Price et al., Eds. (Elsevier, Amsterdam, 1988) 422 pp. Reviews: MTP Int. Rev. Sci.: Inorg. Chem., Ser. One vol. 3, V. Gutmann, Ed. (Butterworths, London, 1972); A. J. Downs, C. J. Adams, “Chlorine, Bromine, Iodine and Astatine” in Comprehensive Inorganic Chemistry vol. 2, J. C. Bailar, Jr. et al., Eds. (Pergamon Press, Oxford, 1973) pp 1107-1573; Chemistry of the Elements, N. N. Greenwood, A. Earnshaw, Eds. (Pergamon Press, New York, 1984) pp 920-1041; P. F. Jackish in Kirk-Othmer Encyclopedia of Chemical Technology vol. 4 (Wiley-Interscience, New York, 4th ed., 1992) pp 536-560.

Properties: Dark reddish-brown, volatile, mobile, diatomic liquid; suffocating odor; vaporizes rapidly at room temp. Only nonmetallic element liquid at standard conditions. Nonflammable, but may ignite combustibles on contact. Corrosive material. mp -7.25° (265.90 K); bp 59.47° (JANAF Thermochemical Tables); 58.78° (Mellor's Suppl. II, Part I, “The Halogens”); d425 3.1023; crit temp: 315°; crit pressure: 102 atm. Heat capacity at constant pressure (liq, 25°) 18.089 cal/mole deg: Hildenbrand et al., J. Am. Chem. Soc. 80, 4129 (1958). Vapor pressure data: A. N. Nesmeyanov, Vapor Pressure of the Chemical Elements, R. Gary, Ed. (Elsevier, New York, 1963) pp 354-58. Total soly in water (25°): 0.2141 moles/l with formation of 0.00115 moles/l of HOBr; freely sol in alc, ether,

$CHCl_3$, CCl_4, CS_2, concd HCl, aq solns of bromides. Oxidizing agent; less reactive than chlorine; E^0 (aq) ½Br_2/Br^- 1.065 V; dissociation energy (25°): 46.072 kcal. Keep sealed or glass-stoppered.

Melting point: mp -7.25° (265.90 K)

Boiling point: bp 59.47° (JANAF Thermochemical Tables); 58.78° (Mellor's Suppl. II, Part I, "The Halogens")

Density: d425 3.1023

CAUTION: Potential symptoms of overexposure are dizziness, headache; lacrimation, epistaxis; coughing, feeling of oppression, pulmonary edema and pneumonia; abdominal pain, diarrhea; measle-like eruptions; direct contact may cause severe burns of eyes and skin. See NIOSH Pocket Guide to Chemical Hazards (DHHS/NIOSH 97-140, 1997) p 32. See also Patty's Industrial Hygiene and Toxicology vol. 2B, G. D. Clayton, F. E. Clayton, Eds. (Wiley-Interscience, New York, 4th ed., 1994) pp 4505-4513.

Use: Manuf of organic and inorganic chemicals, such as fuel additives, fire retardants, pesticides, oil well drilling fluids, pharmaceuticals, dyestuffs. In water disinfection; as bleaching agent, surface disinfectant.

A.3 Ammonia

AEGL Data

Ammonia 7664-41-7 (Final)

	10 min	30 min	60 min	4 hr	8 hr
ppm					
AEGL 1	30	30	30	30	30
AEGL 2	220	220	160	110	110
AEGL 3	2,700	1,600	1,100	550	390

www.wpa.gov/aegl/

Merck Index data

Monograph Number: 0000492

Title: Ammonia

CAS Registry Number: 7664-41-7

Molecular Formula: H3N

Molecular Weight: 17.03

Percent Composition: H 17.76%, N 82.25%

Line Formula: NH3

Literature References: Manufactured from water gas (obtained by blowing steam through incandescent coke) as source of hydrogen, and from producer gas (obtained from steam and air through incandescent coke), as source of nitrogen by the Haber-Bosch process. Manuf from natural gas: Faith, Keyes & Clark's Industrial Chemicals, F. A. Lowenheim, M. K. Moran, Eds. (Wiley-Interscience, New York, 4th ed., 1975) pp 83-92. Historical monograph: A. Mittasch, Geschichte der Ammoniaksynthese (Verlag Chemie, 1951). Reviews of prepn, properties and chemistry: Several authors in Mellor's Vol. VIII, supplement I, Nitrogen part 1 (1964) pp 240-369; Jones in Comprehensive Inorganic Chemistry Vol. 2, J. C. Bailar, Jr. et al., Eds. (Pergamon Press, Oxford, 1973) pp 199-227; J. R. LeBlanc et al., in Kirk-Othmer Encyclopedia of Chemical Technology vol. 2 (Wiley-Interscience, New York, 3rd ed., 1978) pp 470-516. Review of toxicology and human exposure: Toxicological Profile for Ammonia (PB2004-107331, 2004) 269 pp.

Properties: Colorless gas; very pungent odor (characteristic of drying urine). Lower limit of human perception: 0.04 g/cubic meter or 53 ppm. One liter of the gas weighs 0.7714 g. d 0.5967 (air = 1).

mp -77.7°. bp760 -33.35°. Densities of liq NH_3 (temp; press.): 0.6818 (-33.35°; 1 atm); 0.6585 (-15°; 2.332 atm); 0.6386 (0°; 4.238 atm); 0.6175 (15°; 7.188 atm); 0.5875 (35°; 13.321 atm). Critical temp 132.4°; critical press. 111.5 atm. Heat capacity (25°) 8.38 cal/mole/deg. Mixtures of ammonia and air will explode when ignited under favorable conditions: Angew. Chem. 43, 302 (1930), but ammonia is generally regarded as nonflammable. Corrosive, alkaline gas. pH of 1.0N aq soln 11.6; of 0.1N aq soln 11.1; of 0.01N aq soln 10.6. Water at 0° holds 47%, at 15° 38%, at 20° 34%, at 25° 31%, at 30° 28%, at 50° 18%. d420 (aq solns): 0.9939 (1%); 0.9811 (4%); 0.9651 (8%); 0.9362 (16%); 0.9229 (20%); 0.9101 (24%); 0.8980 (28%). fp (aq solns): -2.9° (4%); -8.1° (8%); -23.1° (16%); -34.9° (20%); -44.5° (24%); -69.2° (28%). Solution of NH_3 in water is exothermic. 95% alcohol at 20° holds 15%, at 30° 11%. Abs ethanol at 0° 20%, at 25° 10%. Methanol at 25° 16%. It is also sol in chloroform and ether. Liquid ammonia produces low temps by its own evaporation. Heat of vaporization: 5.581 kcal/mole. It is a good solvent for many elements and compds. Usually marketed in liquefied form in steel cylinders or as ammonia water (aqua ammonia, ammonium hydroxide) in drums and bottles.

Melting point: mp -77.7°

Boiling point: bp760 -33.35°

Density: d 0.5967 (air = 1); Densities of liq NH_3 (temp; press.): 0.6818 (-33.35°; 1 atm); 0.6585 (-15°; 2.332 atm); 0.6386 (0°; 4.238 atm); 0.6175 (15°; 7.188 atm); 0.5875 (35°; 13.321 atm); d420 (aq solns): 0.9939 (1%); 0.9811 (4%); 0.9651 (8%); 0.9362 (16%); 0.9229 (20%); 0.9101 (24%); 0.8980 (28%)

CAUTION: Potential symptoms of overexposure are eye, nose and throat irritation; dyspnea, bronchospasm and chest pain; pulmonary edema; pink frothy sputum; skin burns, vesiculation; direct contact with liquid may cause frostbite. See NIOSH Pocket Guide to Chemical Hazards (DHHS/NIOSH 97-140, 1997) p 14. See also Patty's Industrial Hygiene and Toxicology vol. 2B, G. D. Clayton, F. E. Clayton, Eds. (Wiley-Interscience, New York, 3rd ed., 1981) pp 3045-3052.

Use: Fertilizer, corrosion inhibitor, purification of water supplies, component of household cleaners, as refrigerant. Manuf nitric acid, explosives, synthetic fibers, fertilizers. In pulp and paper, metallurgy, rubber, food and beverage, textile and leather industries.

A.4 Hydrazine hydrate

In the absence of consistent data specific to hydrazine hydrate, it is proposed to use the AEGLs for hydrazine, which gives AEGL 1 values that are not inconsistent with workplace exposure guidelines.

AEGL Data

Hydrazine 302-01-2 (Final)

	10 min	**30 min**	**60 min**	**4 hr**	**8 hr**
ppm					
AEGL 1	0.1	0.1	0.1	0.1	0.1
AEGL 2	23	16	13	3.1	1.6
AEGL 3	64	45	35	8.9	4.4

The Australian Workplace Exposure Standards specify a TWA of 0.01 ppm. An AEGL 1 of 0.1 ppm seems reasonable.

Merck Index Data

Monograph Number: 0004771

Title: Hydrazine Hydrate

CAS Registry Number: 7803-57-8

Molecular Formula: H6N2O

Molecular Weight: 50.06

Percent Composition: H 12.08%, N 55.96%, O 31.96%

Line Formula: H2NNH2.H2O

Literature References: Prepd from hydrazine sulfate by the action of NaOH, followed by distn under nitrogen.

Properties: Fuming refractive liquid, faint characteristic odor. Violent poison! d21 1.03. mp -51.7° or below -65° (two eutectics). bp740 118-119°; bp26 47°. nD20 1.42842. Strong base, very corrosive, attacks glass, rubber, cork, but not stainless V2A steel or Allegheny stainless 304 and 347. Molybdenum steels such as Allegheny stainless 316 should not be used. Very powerful reducing agent. Miscible with water and alcohol. Insol in chloroform and ether.

Melting point: mp -51.7° or below -65° (two eutectics)

Boiling point: bp740 118-119°; bp26 47°

Index of refraction: nD20 1.42842

Derivative Type: Mixture with methanol

Additional Names: C-Stuff

CAUTION: Causes delayed eye irritation.

Use: Reducing agent, solvent for inorganic materials. Manuf “Helman” catalyst, consisting of 80% hydrazine hydrate, 19.5% ethanol, 0.5 to 0.05% copper, used to dec hydrogen peroxide in V-2 type rockets. Mixture with methanol as propellant for rocket engines.

Sax, 6ed. reference

..., and cork. Very powerful reducing agent. Misc with water and alc; insol in chloroform and ether. SYNS: HYDRAZINE AQUEOUS SOLUTIONS, with not >64% hydrazine, by weight (DOT) HYDRAZINE HYDRATE , with not >64% hydrazine, … ihl-rat LCLo: 10 µg/m3/2H. skn-rat LDLo: 70 mg/kg

WHSReg Sched 15 Table 15.3:

Description	**Oral Toxicity[1] LD_{50} (mg/kg)**	**Dermal Toxicity[2] LD_{50} (mg/kg)**	**Inhalation Toxicity[3] LC_{50} (mg/L)**	
Very Toxic	$LD_{50} \leq 5$	$LD_{50} \leq 40$	$LC_{50} \leq 0.5$	
Toxic	$5 < LD_{50} \leq 50$	$40 < LD_{50} \leq 200$	$0.5 < LC_{50} \leq 2$	
Hydrazine hydrate (Sax)		70 mg/kg (LDLo)	10 mg/L (LCLo, 2H)	
CDH MSDS	108		0.75 mg/L	
Oxford MSDS	83 (mouse)		570ppm = 1.2 mg/L	

A.5 Sulfuric acid

AEGL Data

Sulfuric acid 7664-93-9 (Interim)

	10 min	**30 min**	**60 min**	**4 hr**	**8 hr**
(mg/m3) 11/30/06					
AEGL 1	0.20 mg/m3	0.20 mg/m3	0.20 mg/m3	0.20 mg/m3	0.20 mg/m3
AEGL 2	8.7 mg/m3	8.7 mg/m3	8.7 mg/m3	8.7 mg/m3	8.7 mg/m3
AEGL 3	270 mg/m3	200 mg/m3	160 mg/m3	110 mg/m3	93 mg/m3

Merck Index data

Title: Sulfuric Acid

CAS Registry Number: 7664-93-9

Additional Names: Oil of vitriol

Molecular Formula: H2O4S

Molecular Weight: 98.08

Percent Composition: H 2.06%, O 65.25%, S 32.69%

Line Formula: H2SO4

Literature References: Prepd by the Contact Process according to the reactions 2SO2 + O2 □ 2SO3, and SO3 + H2O □ H2SO4; by the Chamber Process according to the reactions 2NO + O2 □ 2NO2, and NO2 + SO2 + H2O □ H2SO4 + NO. Sulfuric acid of commerce contains 93-98% H2SO4; the remainder is water. Monograph: W. W. Duecker, J. R. West, The Manufacture of Sulfuric Acid (Reinhold, New York, 1959) 515 pp. Review of manuf: Pearce, “Sulphuric Acid: Physico-Chemical Aspects of Manufacture” in Inorganic Sulphur Chemistry, G. Nickless, Ed. (Elsevier, New York, 1968) pp 535-561; Faith, Keyes & Clark's Industrial Chemicals, F. A. Lowenheim, M. K. Moran, Eds. (Wiley-Interscience, New York, 4th ed., 1975) pp 795-806. Toxicity data: H. F. Smyth et al., Am. Ind. Hyg. Assoc. J. 30, 470 (1969). Review of toxicology and human exposure: Toxicological Profile for Sulfur Trioxide and Sulfuric Acid (PB99-122038, 1998) 224 pp.

Properties: Clear, colorless, odorless, oily liquid. Very corrosive! Has a very great affinity for water, abstracting it from the air and also from many organic substances; hence it chars sugar, wood, etc. d ~1.84. bp ~290°; dec 340° into sulfur trioxide and water. mp 10° (anhydrous acid). 98% H2SO4 freezes at +3°; 93% at -32°; 78% at -38°; 74% at -44°; 65% at -64°. Misc with water and alcohol with the generation of much heat and with contraction in vol. When diluting, the acid should be added to the diluent. Keep tightly closed. Handle with caution. Avoid contact with skin. LD50 orally in rats: 2.14 g/kg (Smyth).

Melting point: mp 10° (anhydrous acid)

Boiling point: bp ~290°

Density: d ~1.84

Toxicity data: LD50 orally in rats: 2.14 g/kg (Smyth)

Derivative Type: Sulfuric acid, fuming

CAS Registry Number: 8014-95-7

Properties: H_2SO_4 with free SO_3, designated in commerce as oleum. Available grades contain up to about 80% free SO_3. Colorless or slightly colored, viscous liquid, emitting choking fumes of sulfur trioxide. Extremely corrosive. Handle with great care. Avoid contact with skin. Keep tightly closed in glass-stoppered bottles.

CAUTION: Potential symptoms of overexposure are eye, skin, nose and throat irritation; pulmonary edema, bronchitis; emphysema; conjunctivitis; stomatis; dental erosion; tracheobronchitis; skin and eye burns; dermatitis. See NIOSH Pocket Guide to Chemical Hazards (DHHS/NIOSH 97-140, 1997) p 290. See also Clinical Toxicology of Commercial Products, R. E. Gosselin et al., Eds. (Williams & Wilkins, Baltimore, 5th ed., 1984) section III, pp 8-12. Occupational exposure to strong inorganic acid mists containing sulfuric acid is listed as a known human carcinogen: Report on Carcinogens, Eleventh Edition (PB2005-104914, 2004) p III-234.

Use: In manuf of fertilizers, explosives, dyestuffs, other acids, parchment paper, glue, purification of petroleum, pickling of metal.

Therap-Cat: Dil acid formerly in treatment of gastric hypoacidity. Concd acid formerly as a topical caustic.

Description	**Oral Toxicity1 LD50 (mg/kg)**	**Dermal Toxicity2 LD50 (mg/kg)**	**Inhalation Toxicity3 LC50 (mg/L)**	
Very Toxic	LD50 ≤ 5	LD50 ≤ 40	LC50 ≤ 0.5	
Toxic	5 < LD50 ≤ 50	40 < LD50 ≤ 200	0.5 < LC50 ≤ 2	
Merck	2,140		0.85 (4h)	
NIOSH			REL TWA: 0.001 mg/L	

APPENDIX B HAZARDOUS CHEMICAL RELEASE MODELS

B.1 Chlorine

All ALOHA models for chlorine release used the following information:

Chemical Data

Chemical Name: CHLORINE

CAS Number: 7782-50-5

Molecular Weight: 70.91g/mol

AEGL-1 (60 min): 0.5ppm

AEGL-2 (60 min): 2ppm

AEGL-3 (60 min): 20ppm

IDLH: 10ppm

Ambient Boiling Point: -34.9°C

Vapor Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000ppm or 100.0%

The ALOHA model for a chlorine release assumes loss of the entire contents of a 1 tonne cylinder of liquid chlorine over time through a liquid offtake valve with a diameter of 10mm located at the centre of the drum head. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

Atmospheric Data: (Manual Input of Data)

Wind: 2 meters/second from E at 3 meters

Ground Roughness: open country

Cloud Cover: 5 tenths

Air Temperature: 20°C

Stability Class: E

No Inversion Height

Relative Humidity: 50%

The result of the model run is:

Source Strength

Leak from short pipe or valve in horizontal cylindrical tank

Non-flammable chemical is escaping from tank

Tank Diameter: 1 meters

Tank Length: 1.27 meters

Tank Volume: 1 cubic meters

Tank contains liquid

Internal Temperature: 20° C

Chemical Mass in Tank: 1000 kilograms

Tank is 70% full

Circular Opening Diameter: 1 centimeters

Opening is 0.50 meters from tank bottom

Note: RAILCAR predicts a stationary cloud or 'mist pool' will form.

Model Run: traditional ALOHA tank

Release Duration: ALOHA limited the duration to 1 hour

Max Average Sustained Release Rate: 46.2 kilograms/min (averaged over a minute or more)

Total Amount Released: 424 kilograms

Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

Threat Zone

Model Run: Heavy Gas

Red: 1.2 kilometers --- (20 ppm = AEGL-3 [60 min])

Orange: 4.2 kilometers --- (2 ppm = AEGL-2 [60 min])

Yellow: 7.6 kilometers --- (0.5 ppm = AEGL-1 [60 min])

Based on this model, the nearest (existing) sensitive receptor would not lie within the AEGL2 zone (although further checks on the sensitivity of the model might result in a longer threat zone). Following acquisition of this and other sensitive receptors as part of the mine development, Salt Bush Homestead, will be the next closest sensitive receptor at a distance of 11 km, and would be well outside the AEGL1 zone. The prevailing wind is less likely to impact this sensitive receptor. The AEGL 3 zone would probably extend just outside the power station site boundary into the mining lease.

B.2 Bromine

All ALOHA models for bromine release used the following data:

Chemical Data

Chemical Name: BROMINE

CAS Number: 7726-95-6

Molecular Weight: 159.81g/mol

AEGL-1 (60 min): 0.033ppm

AEGL-2 (60 min): 0.24ppm

AEGL-3 (60 min): 8.5ppm

IDLH: 3ppm

Ambient Boiling Point: 57.5°C

Vapor Pressure at Ambient Temperature: 0.42 atm

Ambient Saturation Concentration: 440,760 ppm or 44.1%

The ALOHA model for a bromine release assumes a 5m^2 puddle of liquid bromine evaporating over time. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

Atmospheric Data: (Manual Input of Data)

Wind: 1 meters/second from E at 3 meters

Ground Roughness: open country

Cloud Cover: 0 tenths

Air Temperature: 25°C

Stability Class: F

Inversion Height: 50 meters

Relative Humidity: 50%

Source Strength:

Evaporating Puddle

Puddle Area: 5 square meters

Puddle Mass: 100 kilograms

Ground Type: Concrete

Ground Temperature: 25°C

Initial Puddle Temperature: Ground temperature

Release Duration: ALOHA limited the duration to 1 hour

Max Average Sustained Release Rate: 1.47 kilograms/min (averaged over a minute or more)

Total Amount Released: 65.1 kilograms

Threat Zone

Model Run: Heavy Gas

Red: 255 meters --- (8.5ppm = AEGL-3 [60 min])

Orange: 2.4 kilometers --- (0.24ppm = AEGL-2 [60 min])

Yellow: 6.8 kilometers --- (0.033ppm = AEGL-1 [60 min])

Based on this model, the nearest (existing) sensitive receptor would not lie within the AEGL2 zone. Following acquisition of this and other sensitive receptors as part of the mine development, Salt Bush Homestead will be the next closest sensitive receptor at a distance of 11 km, and would be well outside the AEGL1 zone. The prevailing wind is less likely to impact this sensitive receptor. The AEGL 3 zone would not extend outside the powerstation site boundaries.

B.3 Ammonia

All ALOHA models for ammonia release used the following data:

Chemical Data

Chemical Name: AQUEOUS AMMONIA

Solution Strength: 30% (by weight)

Ambient Boiling Point: 24.7°C

Partial Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000ppm or 100.0%

Hazardous Component: AMMONIA

CAS Number: 7664-41-7

Molecular Weight: 17.03g/mol

AEGL-1 (60 min): 30ppm

AEGL-2 (60 min): 160ppm

AEGL-3 (60 min): 1100ppm

IDLH: 300ppm

LEL: 150000ppm

UEL: 280000ppm

A 30% solution has been used because this is the concentration for which ALOHA data is available and is a common concentration for transport of aqueous ammonia solution. A higher concentration may be used in the final design.

The ALOHA model for an aqueous ammonia release assumes a 10 or 20m2 puddle in a concrete bund containing 1-2 tonnes of solution with ammonia evaporating over time. Within this constraint, the worst model outcome found is for the following conditions at 02:00:

Atmospheric Data: (Manual Input of Data)

Wind: 1 meters/second from E at 3 meters

Ground Roughness: open country

Cloud Cover: 0 tenths

Air Temperature: 25°C

Stability Class: F

No Inversion Height

Relative Humidity: 25%

Source Strength

Evaporating Puddle (Note: chemical is flammable)

Puddle Area: 20 square meters

Puddle Mass: 2 metric tons

Ground Type: Concrete

Ground Temperature: 25°C

Initial Puddle Temperature: 24.7°C

Release Duration: ALOHA limited the duration to 1 hour

Max Average Sustained Release Rate: 8.93 kilograms/min (averaged over a minute or more)

Total Amount Hazardous Component Released: 131 kilograms

Threat Zone

Model Run: Gaussian

Red: 270 meters --- (1100ppm = AEGL-3 [60 min])

Orange: 670 meters --- (160ppm = AEGL-2 [60 min])

Yellow: 694 meters --- (150ppm = ERPG-2)

Based on this model, the AEGL2 zone would be completely contained within the site boundary. No sensitive receptors would be impacted.

Ammonia is also flammable when mixed with air in the correct concentrations. Flammability of the ammonia vapour cloud has been checked for the same conditions, with the following threat zones:

Threat Zone

Threat Modeled: Flammable Area of Vapor Cloud

Model Run: Gaussian

Red: 22 meters --- (90000ppm = 60% LEL = Flame Pockets)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Yellow: 100 meters --- (15000ppm = 10% LEL)

The extent of a flammable cloud is seen to be at most 100 m, which is contained well within the site boundary.

There is the potential for a flammable cloud to generate an explosion. The threat zone for an explosion under the same conditions is:

Threat Zone

Threat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

Model Run: Gaussian

Red: LOC was never exceeded --- (8.0psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5psi = serious injury likely)

Yellow: 15 meters --- (1.0psi = shatters glass)

The extent of the threat zone for a vapour cloud explosion involving ammonia is only 15 m, which is contained completely within the site boundary, and the intensity of any explosion is not likely to exceed 1 psi, which may cause some damage but is not likely to result in serious injury.

B.4 Hydrazine Hydrate

ALOHA does not include hydrazine hydrate in its database of chemical compounds. The ALOHA models for hydrazine hydrate release used data obtained from a database of chemical and physical properties of chemical compounds (Yaws, 2014) with cross-checks against several SDSs from manufacturers, resulting in the following characteristics:

Chemical Data

Chemical Name: HYDRAZINE HYDRATE

Molecular Weight: 50.06 g/mol

Ambient Boiling Point: 113.9°C

Vapor Pressure at Ambient Temperature: 0.020 atm

Ambient Saturation Concentration: 20,983ppm or 2.10%

Toxicity data found for hydrazine hydrate is somewhat inconsistent. Comparison of numbers from the Merck Index, Sax, the NIOSH Pocket Guide, the Australian Workplace Exposure Standards and various SDSs is not conclusive. It has therefore been decided to use the hydrazine AEGL values provided in the ALOHA database (and by the US EPA). This uses an AEGL 1 that is approximately 10 times the Australian workplace exposure standard for hydrazine. Some SDSs indicate that LC50 might be as high as 1200 mg/m3. The use of an AEGL 3 of 35 ppm is therefore very conservative.

The ALOHA model for a spill of hydrazine hydrate assumes a 5 m diameter pool containing 500 L of the material on a concrete floor and slowly evaporating. Using this assumption, the worst case outcome found for a spill occurs under the following conditions:

Atmospheric Data: (Manual Input of Data)

Wind: 2 meters/second from E at 3 meters

Ground Roughness: open country

Cloud Cover: 5 tenths

Air Temperature: 35°C

Stability Class: C

No Inversion Height

Relative Humidity: 25%

Source Strength

Evaporating Puddle (Note: chemical is flammable)

Puddle Diameter: 5 meters

Puddle Mass: 500 kilograms

Ground Type: Concrete

Ground Temperature: 35°C

Initial Puddle Temperature: Ground temperature

Release Duration: ALOHA limited the duration to 1 hour

Max Average Sustained Release Rate: 251 grams/min (averaged over a minute or more)

Total Amount Released: 14.9 kilograms

Threat Zone

Model Run: Gaussian

Red: 31 meters --- (35ppm)

Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Orange: 53 meters --- (13ppm)

Yellow: 647 meters --- (0.1ppm)

It can be seen that even with conservative AEGL values, the impact area will be contained completely within the Project site boundary. No sensitive receptor will be affected. Based on the very limited extent of the impact area for this model run, no sensitivity checks have been undertaken. The model was run with a relatively high ambient temperature, so that the greatest evaporation rate of the hydrazine hydrate would be achieved.

B.5 Hydrogen

All ALOHA models for ammonia release used the following data:

Chemical Data

Chemical Name: HYDROGEN

CAS Number: 1333-74-0

Molecular Weight: 2.02 g/mol

PAC-1: 65000ppm

PAC-2: 230000ppm

PAC-3: 400000ppm

LEL: 40000ppm

UEL: 750000ppm

Ambient Boiling Point: -252.9°C

Vapor Pressure at Ambient Temperature: greater than 1 atm

Ambient Saturation Concentration: 1,000,000ppm or 100.0%

The ALOHA model created for a hydrogen release assumes a 50 m pipe with diameter 25 mm, open ended, connected to an effectively unlimited source of hydrogen at 100 atm. The results of the modelling are:

Atmospheric Data: (Manual Input of Data)

Wind: 2 meters/second from E at 3 meters

Ground Roughness: open country

Cloud Cover: 5 tenths

Air Temperature: 35°C

Stability Class: C

No Inversion Height

Relative Humidity: 25%

Source Strength

Flammable gas escaping from pipe (not burning)

Pipe Diameter: 2.5 centimeters

Pipe Length: 50 meters

Unbroken end of the pipe is connected to an infinite source

Pipe Roughness: smooth

Hole Area: 4.91 sq cm

Pipe Press: 100 atmospheres

Pipe Temperature: 35°C

Release Duration: ALOHA limited the duration to 1 hour

Max Average Sustained Release Rate: 33.4 kilograms/min (averaged over a minute or more)

Total Amount Released: 2,002 kilograms

Threat Zone

Threat Modeled: Flammable Area of Vapor Cloud

Model Run: Gaussian

Red: 103 meters --- (24000ppm = 60% LEL = Flame Pockets)

Yellow: 254 meters --- (4000ppm = 10% LEL)

Threat Zone

hreat Modeled: Overpressure (blast force) from vapor cloud explosion

Type of Ignition: ignited by spark or flame

Level of Congestion: congested

Model Run: Gaussian

Red: 87 meters --- (8.0psi = destruction of buildings)

Orange: 97 meters --- (3.5psi = serious injury likely)

Yellow: 153 meters --- (1.0psi = shatters glass)

The threat zone for generation of a flammable vapour cloud is contained completely within the site boundaries. The corresponding threat zone for a subsequent explosion of the vapour cloud shows that even the lowest impact zone, experiencing 1 psi overpressure which is unlikely to cause significant injuries, is also contained completely within the site boundaries.

Knock-on effects are of course possible as a result of an explosion, given that there is an area of 8 psi overpressure extending approximately 80 m from the source of the leak, which is likely to cause damage to other parts of the plant. However, such domino effects are outside the scope of this study.

APPENDIX C SUMMARY OF ALOHA MODEL RUNS

C.1 Chlorine

Time	Wind speed m/s	Wind speed km/h	Stability class	Temp °C	Humidity %	Cloud	Inversion m	Release kg	Duration mins	AEGL1 km	AEGL2 km	AEGL3 km
16:15	2	7.2	C	35	25	0.5		473	51	5.2	3.1	1.1
02:00	2	7.2	E	20	50	0.5		424	60	7.6	4.2	1.2
02:00	1	3.6	E	15	50	0.5		407	51	6.7	3.5	1.1
02:00	3	10.8	E	15	25	0		407	51	7.1	3.6	1
02:00	1	3.6	F	15	25	0	100	407	51	7.1	3.7	1.2
09:00	0.85	3.06	B	25	50	0	50	440	56	4.8	2.9	1.1

C.2 Bromine

Time	Wind speed m/s	Wind speed km/h	Stability class	Temp °C	Humidity %	Cloud	Inversion m	Release kg	Duration mins	AEGL1 km	AEGL2 km	AEGL3 km
16:15	2	7.2	C	35	25	0.5		100	39	4	1.5	0.259
16:15	1	3.6	B	25	25	0		68.8	60	2.9	1.1	0.169
02:00	1	3.6	F	25	50	0	50	65.1	60	6.8	2.4	0.255

C.3 Ammonia

Time	Wind speed	Wind speed	Stability class	Temp	Humidity	Cloud	Inversion	Puddle size	Release	Duration	AEGL1	AEGL2	AEGL3	ERPG2
	m/s	km/h		°C	%		m	m2	kg	mins	km	km	km	
16:15	2	7.2	C	35	25	0.5		10	94.9	60	0.348	0.149	0.056	
16:15	1	3.6	B	25	25	0		10	66.1	60	0.233	0.103	-	
16:15	1	3.6	B	35	25	0		20	107	60	0.307	0.141	0.053	
16:15	2	7.2	C	35	25	0		20	138	60	-	0.193	0.072	0.199
02:00	1	3.6	F	25	25	0		20	131	60		0.67	0.27	0.694

C.4 Hydrazine Hydrate

Time	Wind speed	Wind speed	Stability class	Temp	Humidity	Cloud	Inversion	Puddle size	Release	Duration	AEGL1	AEGL2	AEGL3	ERPG2
	m/s	km/h		°C	%		m	m	kg	mins	km	km	km	
16:15	2	7.2	C	35	25	0.5		5	14.9	60	0.647	0.053	0.031	

C.5 Hydrogen

Time	Wind speed	Wind speed	Stability class	Temp	Humidity	Cloud	Inversion	Puddle size	Release	Duration	AEGL1	AEGL2	AEGL3	ERPG2
	m/s	km/h		°C	%		m	m2	kg	mins	km	km	km	
16:15	2	7.2	C	35	25	0.5		10	2002	60	0.348	0.149	0.056	