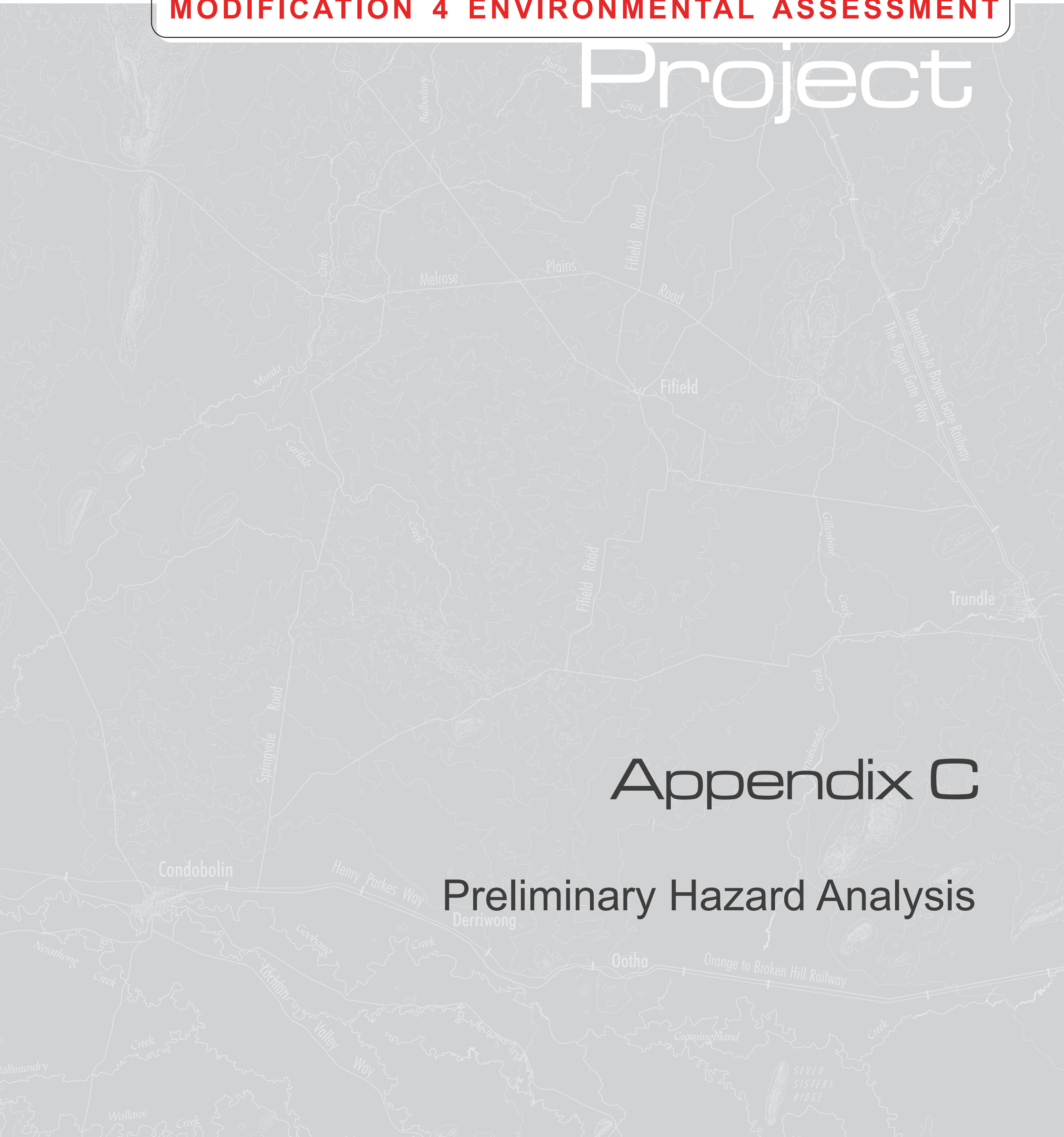
CLEAN TEQ
Powering innovation

Syerston Project

MODIFICATION 4 ENVIRONMENTAL ASSESSMENT



Appendix C

Preliminary Hazard Analysis

PRELIMINARY HAZARD ANALYSIS FOR THE SYERSTON PROJECT MODIFICATION 4, FIFIELD, NSW

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26 October 2017

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Preliminary Hazard Analysis for the Syerston Project

Modification 4

Disclaimer

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Rev	Date	Description	Reviewed By
A	7/8/17	Draft for Comment	Resource Strategies / Clean TeQ
B	6/10/17	Final Issue	Resource Strategies / Clean TeQ
C	16/10/17	Minor Updates	Resource Strategies / Clean TeQ
D	26/10/17	Minor Updates	Resource Strategies / Clean TeQ

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EXECUTIVE SUMMARY

Scanium21 Pty Ltd owns the rights to develop the approved, but not yet developed, Syerston Project. Scandium21 Pty Ltd is a wholly owned subsidiary of Clean TeQ Holdings Limited (Clean TeQ). The Syerston Project is situated approximately 350 kilometres west-northwest of Sydney, near the village of Fifield, New South Wales (NSW), and was originally approved in 2001.

A Preliminary Hazard Analysis (PHA) was performed on the original design in 2000. This PHA was approved.

Clean TeQ are proposing to modify the original design. The proposed modifications are (the Modification):

- Mining in a more selective manner to initially increase the processing facility ore feed grade;
- Addition of drilling and blasting at the mine site;
- Adoption of the resin-in-pulp (RIP) processing method option (i.e. the counter current decantation processing method option is no longer proposed)[1];
- Increased sulphur and sulphuric acid demand to leach additional nickel, cobalt and scandium from the higher grade ore;
- Increased limestone demand to neutralise the additional acid required in the acid leach circuit;
- Addition of a crystalliser to the processing facility to extract ammonium sulphate from an existing waste stream for use as a fertiliser product;
- Changes to the process input and product road transport requirements;
- Addition of a water treatment plant to the processing facility to recycle process water and minimise make-up water demand;
- Increased tailings storage facility capacity to hold increased tailings volume due to the additional limestone required for acid neutralisation;
- Reduced evaporation pond capacity due to the recycling of process water;
- Relocation of mine infrastructure to avoid resource sterilisation and improve operational efficiency;
- Addition of surface water extraction from the Lachlan River to improve water supply security;
- Minor changes to the borefield transfer station layout and water pipeline alignment;
- Short-term road transport of water from the borefield to the mine site during the initial construction phase; and

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[1] The Approved Project includes the option to use either the RIP or counter current decantation processing method.

- Reduced gas demand as the increased sulphuric acid production would generate additional steam for power generation.

The Modification would not involve changes to any aspects of the approved limestone quarry, rail siding or gas pipeline.

As part of the environmental assessment for the Modification, an updated PHA is required. This report details the results from the analysis.

The risks associated with the modified mine and processing facility have been assessed and compared against the NSW Department of Planning (now NSW Department of Planning and Environment) risk criteria.

The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5 x 10^{-6} per year	Y
Fatality risk to residential and hotels	1 x 10^{-6} per year	Y
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year	Y
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year	Y
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year	Y
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50 x 10^{-6} per year	Y
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 x 10^{-6} per year	Y
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50 x 10^{-6} per year	Y
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50 x 10^{-6} per year	Y

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reason for the low risk levels from the modified site is the separation distances between the hazards and the nearest place of residence and site boundary.

The highest contributor to off-site risk is a release of ammonia, in particular, from transfer operations to the storage vessels. The second highest risk contributor involves generic release cases for holes in vessels and piping (typical for all processing facilities). It is expected that the design review process followed by the Hazard and Operability (HAZOP) study would mitigate the generic release cases to acceptable levels. This would include designing to Australian Standard AS2022 for the ammonia storage and handling systems.

The following recommendations are made to lower the off-site risk from the main contributor, i.e. releases of ammonia.

1. Ensure that the final design includes means to automatically isolate the ammonia road tanker (or container) and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;
2. Provide Closed Circuit Television (CCTV) coverage of the ammonia transfer area to the plant's control room;
3. Provide means to isolate the ammonia flow to the plant should a release occur. This should be at each storage vessel;
4. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the transfer system, the storage vessels or the plant supply lines. Options include spray deluge for the transfers bay and fire water monitors in the transfer and storage area. The latter can be operated remotely (preferable) or manually (may require the use of a full protective suit with self-contained breathing air). Monitors can be fixed or portable;
5. Provide means for road tanker driveaway protection. This could include interlocks on the vehicles brakes or self-sealing devices in the transfer lines;
6. Include the transfer hoses and couplings (dry-break preferred) in the preventative maintenance system. The transfer hoses would need to be regularly inspected, tested and replaced as per the manufacturer's recommendations;
7. Provide means for preventing stress corrosion cracking in the ammonia storage vessels and include the vessels in the preventative maintenance system for routine internal inspections;
8. Provide wind socks at appropriate locations to allow people to decide the best means of escape from an ammonia plume;
9. Provide alternate emergency assembly areas given that an ammonia plume can travel in any direction;
10. Provide means for protection for the ammonia road tanker / container driver should a release occur, e.g. safehouse;

11. Apply good practice for building design, e.g. design buildings as safehouses, should relevant guidelines recommend this. For example, design buildings as per the recommendations in the Chemical Industries Association guideline, "Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites";
12. Provide overfill protection on the ammonia storage vessels. This system should be reviewed via a Safety Integrity Level (SIL) analysis; and
13. Provide means to prevent the vapour compressor from overpressuring the vapour return line and/or the road tanker / container.

GLOSSARY

ANE	Ammonium Nitrate Emulsion
ANSI	American National Standards Institute
API	American Petroleum Institute
AS	Australian Standard
CCPS	Centre for Chemical Process Safety
CCTV	Closed Circuit Television
cLX	Continuous Resin-In-Column
cRIP	Continuous Resin–in-Pulp
DG	Dangerous Good
DoP	NSW Department of Planning (now the Department of Planning and Environment)
ERPG	Emergency Response Planning Guidelines
EIV	Emergency Isolation Valve
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
HPAL	High Pressure Acid Leach
HSE	Health and Safety Executive (UK)
IBC	Intermediate Bulk Container
IDLH	Immediately Dangerous to Life and Health
LP	Low Pressure
MPF	Mine and Processing Facility
NiCo	Nickel Cobalt
NSW	New South Wales
PHA	Preliminary Hazard Analysis
PSV	Pressure Safety Valve
QRA	Quantitative Risk Analysis
RO	Reverse Osmosis

ROM	Run of Mine
Sc	Scandium
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SFARP	So Far As Reasonably Practicable
SIL	Safety Integrity Level
SMBS	Sodium Metabisulphate
SLOT	Specified Level of Toxicity
SSAN	Security Sensitive Ammonium Nitrate
STEL	Short Term Exposure Limit
SX	Solvent Extraction
TLV	Threshold Limit Value
TNT	Trinitrotoluene
TWA	Time Weighted Average

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Scanium21 Pty Ltd owns the rights to develop the approved, but not yet developed, Syerston Project (the Project), an approved nickel cobalt scandium mining project. Scandium21 Pty Ltd is a wholly owned subsidiary of Clean TeQ Holdings Limited (Clean TeQ). The Project is situated approximately 350 kilometres (km) west-northwest of Sydney, near the village of Fifield, New South Wales (NSW), and was originally approved in 2001.

The Project includes the establishment and operation of the following:

- Mine (including processing facility);
- Limestone quarry;
- Rail siding;
- Gas pipeline;
- Borefields and water pipeline; and
- Associated transport activities and transport infrastructure (e.g. the Fifield Bypass, and road and intersection upgrades).

The Project includes an initial scandium oxide focussed production phase (the Initial Production Phase) prior to shifting to scandium oxide and nickel and cobalt precipitate production by developing the full Project (the Full Production Phase).

The Project would transition to the Full Production Phase once scandium-rich areas of the Syerston deposit are depleted or favourable market conditions prevail for larger scale nickel cobalt scandium production.

Construction of the Project commenced in 2006 with the construction of some components of the borefields, however, Project operations are yet to commence.

Clean TeQ has completed an optimisation study for the Project that has identified a number of opportunities to optimise the Full Production Phase of the Project, as well as increase the water supply security for the Project. These opportunities will be sought through a modification to the Development Consent for the Project (Development Consent DA 374-11-00) under section 75W of the NSW *Environmental Planning and Assessment Act, 1979*. This Preliminary Hazard Analysis (PHA) has been prepared to support the Environmental Assessment prepared for the Modification.

The Modification would include:

- Mining in a more selective manner to initially increase the processing facility ore feed grade;
- Addition of drilling and blasting at the mine site;
- Adoption of the resin-in-pulp (RIP) processing method option (i.e. the counter current decantation processing method option is no longer proposed)[2];
- Increased sulphur and sulphuric acid demand to leach additional nickel, cobalt and scandium from the higher grade ore;
- Increased limestone demand to neutralise the additional acid required in the acid leach circuit;
- Addition of a crystalliser to the processing facility to extract ammonium sulphate from an existing waste stream for use as a fertiliser product;
- Changes to the process input and product road transport requirements;
- Addition of a water treatment plant to the processing facility to recycle process water and minimise make-up water demand;
- Increased tailings storage facility capacity to hold increased tailings volume due to the additional limestone required for acid neutralisation;
- Reduced evaporation pond capacity due to the recycling of process water;
- Relocation of mine infrastructure to avoid resource sterilisation and improve operational efficiency;
- Addition of surface water extraction from the Lachlan River to improve water supply security;
- Minor changes to the borefield transfer station layout and water pipeline alignment;
- Short-term road transport of water from the borefield to the mine site during the initial construction phase; and
- Reduced gas demand as the increased sulphuric acid production would generate additional steam for power generation.

The Modification would not involve changes to any aspects of the approved limestone quarry, rail siding or gas pipeline.

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[2] The Approved Project includes the option to use either the RIP or counter current decantation processing method.

The NSW Department of Planning and Environment has not issued formal Secretary's Environmental Assessment Requirements for the Modification, however, has provided some specific advice on key areas of consideration for the Department. This advice includes the following in relation to hazards:

- A detailed hazard and risk assessment should be undertaken in accordance with the State Environmental Planning Policy (SEPP) No. 33 – Hazardous and Offensive Development Application Guidelines (Ref 1); and
- The assessment should take into consideration the potential for higher grades of impurities (e.g. aluminium and manganese), and provide appropriate measures to manage, store and dispose of increased amounts of sulphuric acid and by-product ammonium sulphate.

The original, approved PHA for the Project was completed in 2000 (Ref 2). Clean TeQ has requested Pinnacle Risk Management Pty Limited revise the PHA to reflect the Modification. This PHA has been prepared in accordance with the guidelines published by the NSW Department of Planning (DoP) (now the NSW Department of Planning and Environment) Hazardous Industry Planning Advisory Paper (HIPAP) No 6 (Ref 3).

1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the Modification (including the modified processing facility);
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 4);
- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Clean TeQ to ensure that the modified Project is operated and maintained at acceptable levels of process safety and effective safety management systems are used.

1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the modified project with the potential for off-site impacts only.

Given the significant separation distances between the potentially hazardous materials and equipment at the processing facility to adjacent land users then only the events that have the potential for off-site impacts are analysed in detail in this PHA. This approach is consistent with the methodology used in the approved PHA from 2000 (Ref 2).

Off-site transport risks are separately assessed as part of this Project's environmental assessments. The transport of more hazardous materials, e.g. ammonia, are included in this PHA.

Given the Modification does not involve any changes to the limestone quarry, rail siding or gas pipeline, the risks associated with these components of the Project have not been reassessed. Notwithstanding, the potential risks of these components, as described in the original PHA, have been included for context.

1.4 METHODOLOGY

In accordance with the approach recommended by the DoP in HIPAP No 6 (Ref 3) the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the modified processing facility and its location were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the potential hazardous events are located at a significant distance from other sensitive land users, the consequences of the potential hazardous events that could have off-site impact were estimated;
- Included in the analysis is the risk of propagation within the site; and
- If adverse off-site impacts could occur, assess the risk levels to check if they are within the criteria in HIPAP No 4 (Ref 4).

1.5 RISK CRITERIA

The assessment of risks to both the public as well as to operating personnel from a potentially hazardous development requires the application of the basic steps outlined above. As per SEPP 33 (Ref 1) and HIPAP No 6 (Ref 3), the chosen analysis technique should be commensurate with the nature of the risks involved.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc. Specific incidents, identified by a variety of techniques, are assessed in terms of consequences and likelihood.

Having assembled data on the credible incidents, risk analysis requires the following general approach for individual incidents (which are then summated for all potential recognised incidents to get cumulative risk):

Risk = Likelihood x Consequence

For quantitative risk analysis (QRA) and hazard analysis, the consequences of an incident are calculated using standard correlations and probit-type methods which assess the effect of fire radiation, explosion overpressure and toxicity to an individual, depending on the type of hazard.

In this PHA, however, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment. The reason for this approach is the limited hazardous events with the potential for off-site harm, i.e. there are generous separation distances involved to sensitive receptors.

Therefore, appropriate analysis of credible scenarios is performed in this PHA. Typically, the consequences of the potential events with off-site impact are assessed first. For the events which do not contribute to off-site risk (as determined by the risk criteria in HIPAP No 4 (Ref 4), no further risk analysis is warranted. When the consequence of an event does have the potential to impact people off-site, the likelihood and hence risk is then analysed as required.

The NSW DoP risk criteria applying to developments are summarised in Table 1 below (from Ref 4).

Table 1 – Risk Criteria, New Plants

Description	Risk Criteria
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5 x 10^{-6} per year
Fatality risk to residential and hotels	1 x 10^{-6} per year
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50chances in a million per year	50 x 10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 x 10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50 x 10^{-6} per year
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50 x 10^{-6} per year

2 SITE DESCRIPTION

The Project consists of the following main components:

- Mine site (including mining areas, nickel and cobalt extraction and refining plant, and power generation plant);
- Limestone quarry;
- Rail siding;
- Water pipeline and borefields;
- Natural gas pipeline; and
- Road upgrades.

Land use surrounding the mine site is largely agricultural and is dominated by sheep farming and cropping (generally wheat).

The mine site is located near the village of Fifield in the Lachlan Shire Local Government Area in the Central Western Region of NSW. The Project is located 45 km northeast of Condobolin. See Figure 1 for location details.

The mine site is accessible by road. The nearest rail station is Kadungle which is approximately 28 km away by road. There are no ecologically sensitive areas (e.g. National Parks or wetlands) in the immediate vicinity of the mine site.

The town of Fifield is located approximately 4.5 km southeast of the mine site. Locations of nearby privately-owned dwellings from the processing plant are (Figure 2):

- ‘Sunrise’ 2.4 km southwest;
- ‘Wanda Bye’ 4.6 km south;
- ‘Slapdown’ 5.6 km east;
- ‘Currajong Park’ 5.5 km northeast; and
- ‘Flemington’ 7.2 km northwest.

Adjacent properties are Kingsdale (owned by Clean TeQ) and Sunrise (this property was being purchased by Clean TeQ when revisions A and B of this PHA were being prepared). Therefore, the distance of impact to residential areas is taken as 2.4 km, i.e to ‘Sunrise’. The PHA (revision C) results are now conservative as it is understood that the settlement for Sunrise has been concluded.

Security of the site would be achieved by a number of means. This includes site personnel and security patrols by an external security company (including weekends and night patrols). The site would operate 24 hours per day, 7 days per week. The processing plant and explosives storages would be fenced.

There would be approximately 180 people on site during day shifts and 60 people on site during night shifts.

There are no natural hazards for the site that are considered high risk.

Layout drawings showing the proposed location of the facilities are shown in Figure 3 and Figure 4.

Figure 1 - Site Location

Source: Black Range Minerals (2000); NSW Department of Industry (2017); NSW Land & Property Information (2017); Office of Environment and Heritage NSW (2107)

SYERSTON PROJECT MODIFICATION 4
Regional Location

Figure 2 – Land Ownership

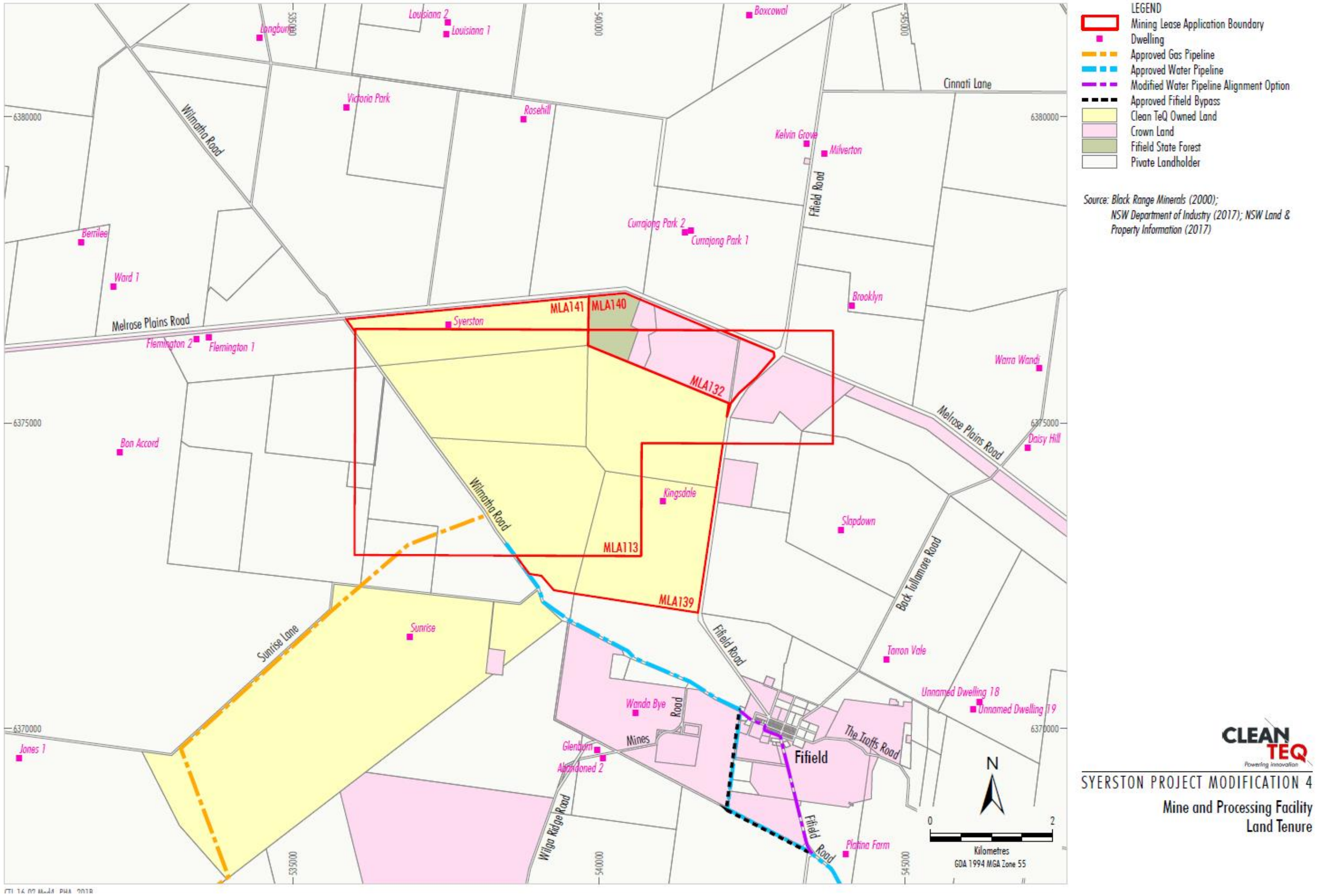
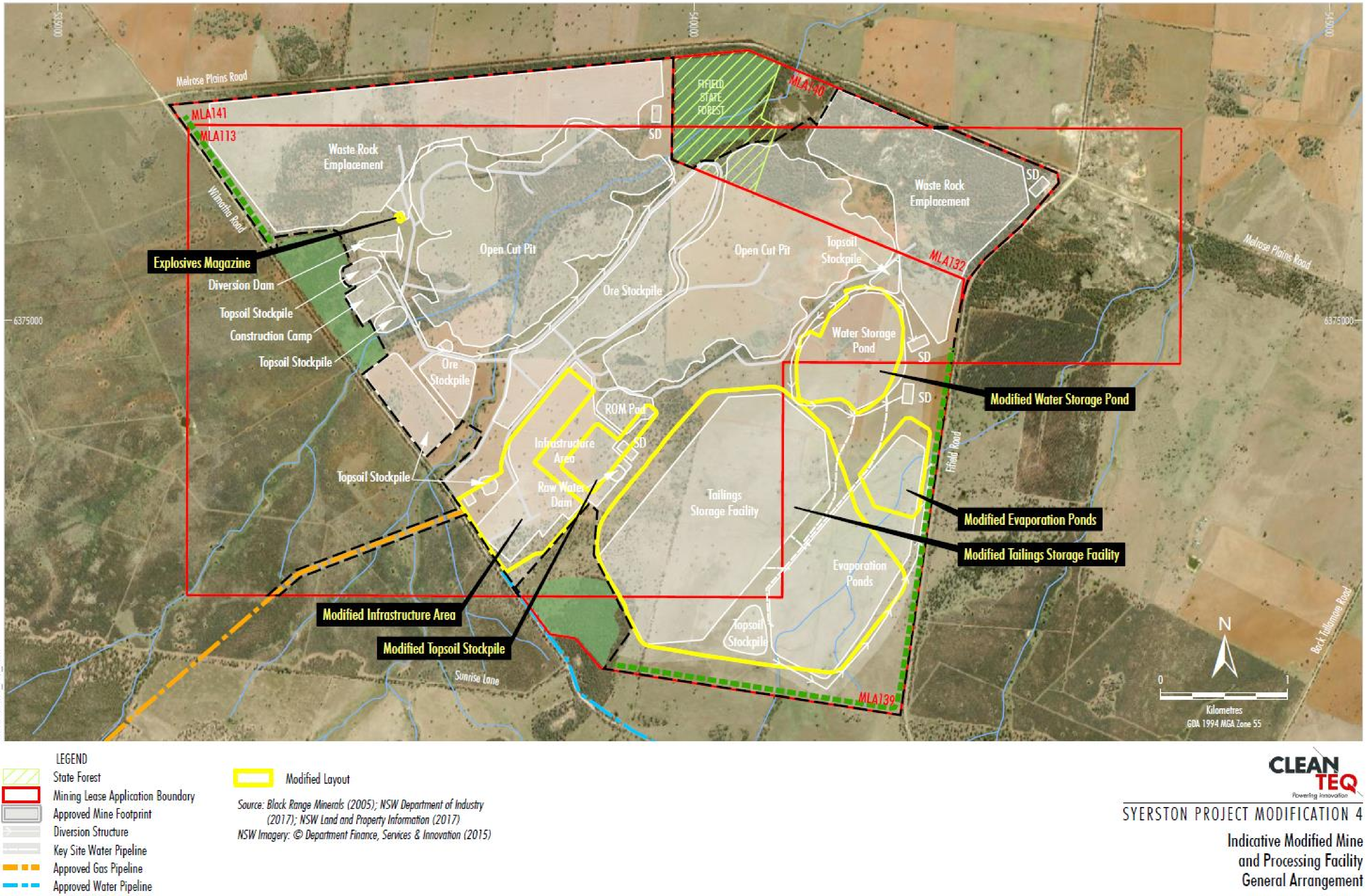
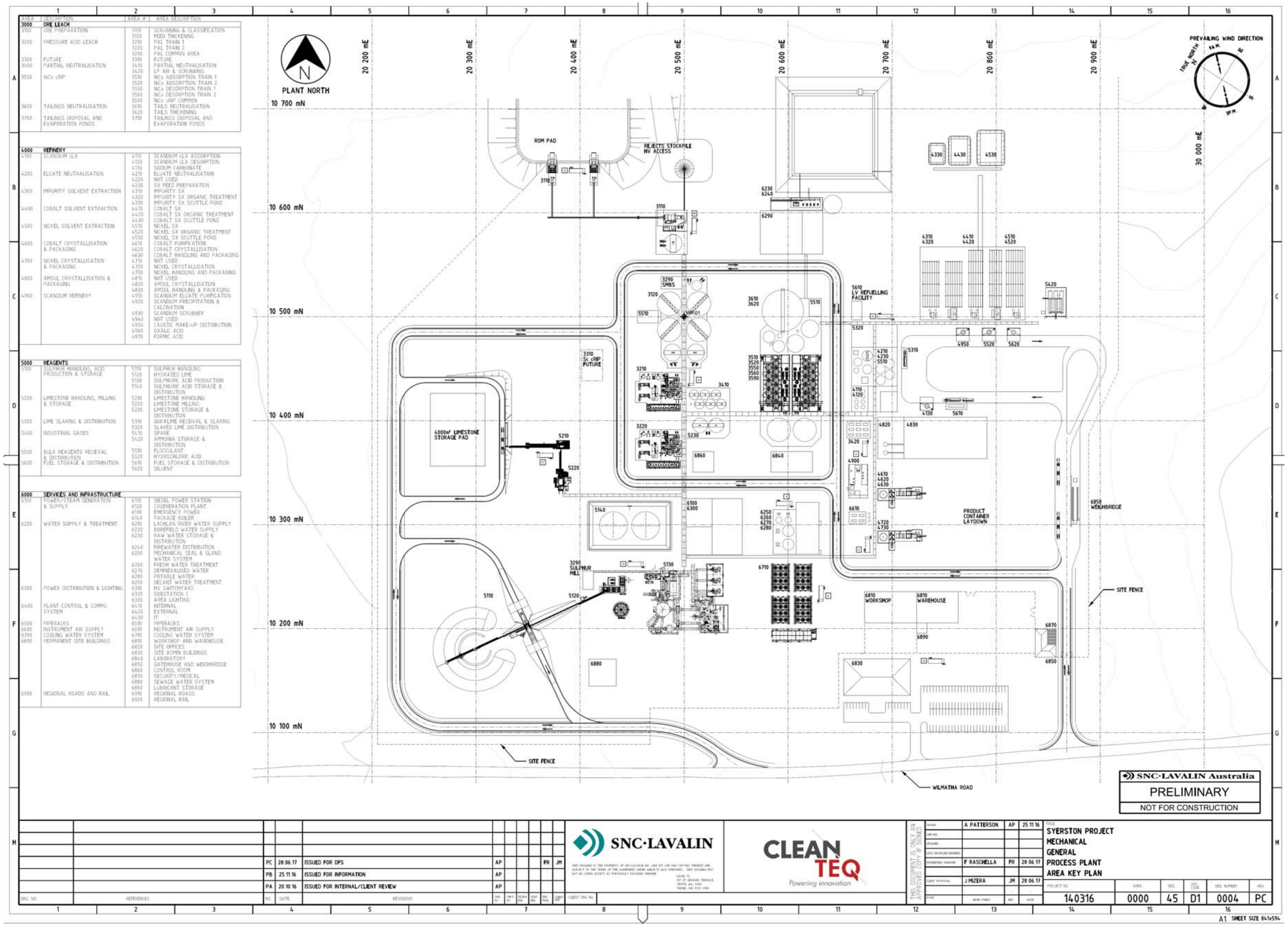


Figure 3 – Site Layout



Source: Black Range Minerals (2005); NSW Department of Industry (2017); NSW Land and Property Information (2017)
NSW Imagery: © Department Finance, Services & Innovation (2015)

Figure 4 – Processing Plant Layout



AREA	DESCRIPTION	AREA #	AREA DESCRIPTION
3000	**ORE LEACH**		
3100	ORE PREPARATION	3110	SCRUBBING & CLASSIFICATION
		3120	FEED THICKENING
3200	PRESSURE ACID LEACH	3210	PAL TRAIN 1
		3220	PAL TRAIN 2
		3290	PAL COMMON AREA
3300	FUTURE	3310	FUTURE
3400	PARTIAL NEUTRALISATION	3410	PARTIAL NEUTRALISATION
		3420	LP AIR & SCRUBBING
3500	NiCo cRIP	3510	NiCo ADSORPTION TRAIN 1
		3520	NiCo ADSORPTION TRAIN 2
		3550	NiCo DESORPTION TRAIN 1
		3560	NiCo DESORPTION TRAIN 2
		3590	NiCo cRIP COMMON
3600	TAILINGS NEUTRALISATION	3610	TAILS NEUTRALISATION
		3620	TAILS THICKENING
3700	TAILINGS DISPOSAL AND EVAPORATION PONDS	3710	TAILINGS DISPOSAL AND EVAPORATION PONDS
4000	**REFINERY**		
4100	SCANDIUM cLX	4110	SCANDIUM cLX ADSORPTION
		4120	SCANDIUM cLX DESORPTION
		4130	SODIUM CARBONATE
4200	ELUATE NEUTRALISATION	4210	ELUATE NEUTRALISATION
		4220	NOT USED
		4230	SX FEED PREPARATION
4300	IMPURITY SOLVENT EXTRACTION	4310	IMPURITY SX
		4320	IMPURITY SX ORGANIC TREATMENT
		4330	IMPURITY SX SCUTTLE POND
4400	COBALT SOLVENT EXTRACTION	4410	COBALT SX
		4420	COBALT SX ORGANIC TREATMENT
		4430	COBALT SX SCUTTLE POND
4500	NICKEL SOLVENT EXTRACTION	4510	NICKEL SX
		4520	NICKEL SX ORGANIC TREATMENT
		4530	NICKEL SX SCUTTLE POND
4600	COBALT CRYSTALLISATION & PACKAGING	4610	COBALT PURIFICATION
		4620	COBALT CRYSTALLISATION
		4630	COBALT HANDLING AND PACKAGING
4700	NICKEL CRYSTALLISATION & PACKAGING	4710	NOT USED
		4720	NICKEL CRYSTALLISATION
		4730	NICKEL HANDLING AND PACKAGING
4800	AMSUL CRYSTALLISATION & PACKAGING	4810	NOT USED
		4820	AMSUL CRYSTALLISATION
		4830	AMSUL HANDLING & PACKAGING
4900	SCANDIUM REFINERY	4910	SCANDIUM ELUATE PURIFICATION
		4920	SCANDIUM PRECIPITATION & CALCINATION
		4930	SCANDIUM SCRUBBER
		4940	NOT USED
		4950	CAUSTIC MAKE-UP DISTRIBUTION
		4960	OXALIC ACID
		4970	FORMIC ACID
5000	**REAGENTS**		
5100	SULPHUR HANDLING, ACID PRODUCTION & STORAGE	5110	SULPHUR HANDLING
		5120	HYDRATED LIME
		5130	SULPHURIC ACID PRODUCTION
		5140	SULPHURIC ACID STORAGE & DISTRIBUTION
5200	LIMESTONE HANDLING, MILLING & STORAGE	5210	LIMESTONE HANDLING
		5220	LIMESTONE MILLING
		5230	LIMESTONE STORAGE & DISTRIBUTION
5300	LIME SLAKING & DISTRIBUTION	5310	QUICKLIME RECEIVAL & SLAKING
		5320	SLAKED LIME DISTRIBUTION
5400	INDUSTRIAL GASES	5410	SPARE
		5420	AMMONIA STORAGE & DISTRIBUTION
5500	BULK REAGENTS RECIEVAL & DISTRIBUTION	5510	FLOCCULANT
		5520	HYDROCHLORIC ACID
5600	FUEL STORAGE & DISTRIBUTION	5610	FUEL STORAGE & DISTRIBUTION
		5620	DILUENT
6000	**SERVICES AND INFRASTRUCTURE**		
6100	POWER/STEAM GENERATION & SUPPLY	6110	DIESEL POWER STATION
		6120	COGENERATION PLANT
		6130	EMERGENCY POWER
		6140	PACKAGE BOILER
6200	WATER SUPPLY & TREATMENT	6210	LACHLAN RIVER WATER SUPPLY
		6220	BOREFIELD WATER SUPPLY
		6230	RAW WATER STORAGE & DISTRIBUTION
		6240	FIREWATER DISTRIBUTION
		6250	MECHANICAL SEAL & GLAND WATER SYSTEM
		6260	FRESH WATER TREATMENT
		6270	DEMINERALISED WATER
		6280	POTABLE WATER
		6290	DECANT WATER TREATMENT
6300	POWER DISTRIBUTION & LIGHTING	6310	HV SWITCHYARD
		6320	SUBSTATION 1
		6330	AREA LIGHTING
6400	PLANT CONTROL & COMMS SYSTEM	6410	INTERNAL
		6420	EXTERNAL
		6430	IT
6500	PIPERACKS	6510	PIPERACKS
6600	INSTRUMENT AIR SUPPLY	6610	INSTRUMENT AIR SUPPLY
6700	COOLING WATER SYSTEM	6710	COOLING WATER SYSTEM
6800	PERMANENT SITE BUILDINGS	6810	WORKSHOP AND WAREHOUSE
		6820	SITE OFFICES
		6830	SITE ADMIN BUILDINGS
		6840	LABORATORY
		6850	GATEHOUSE AND WEIGHBRIDGE
		6860	CONTROL ROOM
		6870	SECURITY/MEDICAL
		6880	SEWAGE WATER SYSTEM
		6890	LUBRICANT STORAGE
6900	REGIONAL ROADS AND RAIL	6910	REGIONAL ROADS
		6920	REGIONAL RAIL

NO	DATE	REVISIONS			
PC	28.06.17	ISSUED FOR DFS	AP	FR	JM
PB	25.11.16	ISSUED FOR INFORMATION	AP		
PA	20.10.16	ISSUED FOR INTERNAL/CLIENT REVIEW	AP		

	NAME	INIT	DATE
DRAWN	A PATTERSON	AP	25.11.16
ENGINEERING MANAGER	F RASCHELLA	FR	28.06.17
CLIENT APPROVAL	J MIZERA	JM	28.06.17

TITLE
SYERSTON PROJECT
MECHANICAL
GENERAL
PROCESS PLANT
AREA KEY PLAN

PROJECT NO.	AREA	DOC.	DOC CODE	SEQ. NUMBER	REV
140316	0000	45	D1	0004	PC

3 PROCESS DESCRIPTION

The primary objective of the processing plant is to produce nickel sulphate and cobalt sulphate. Scandium oxide and Amsul (ammonium sulphate – a fertiliser) would also be produced. Proposed production rates are:

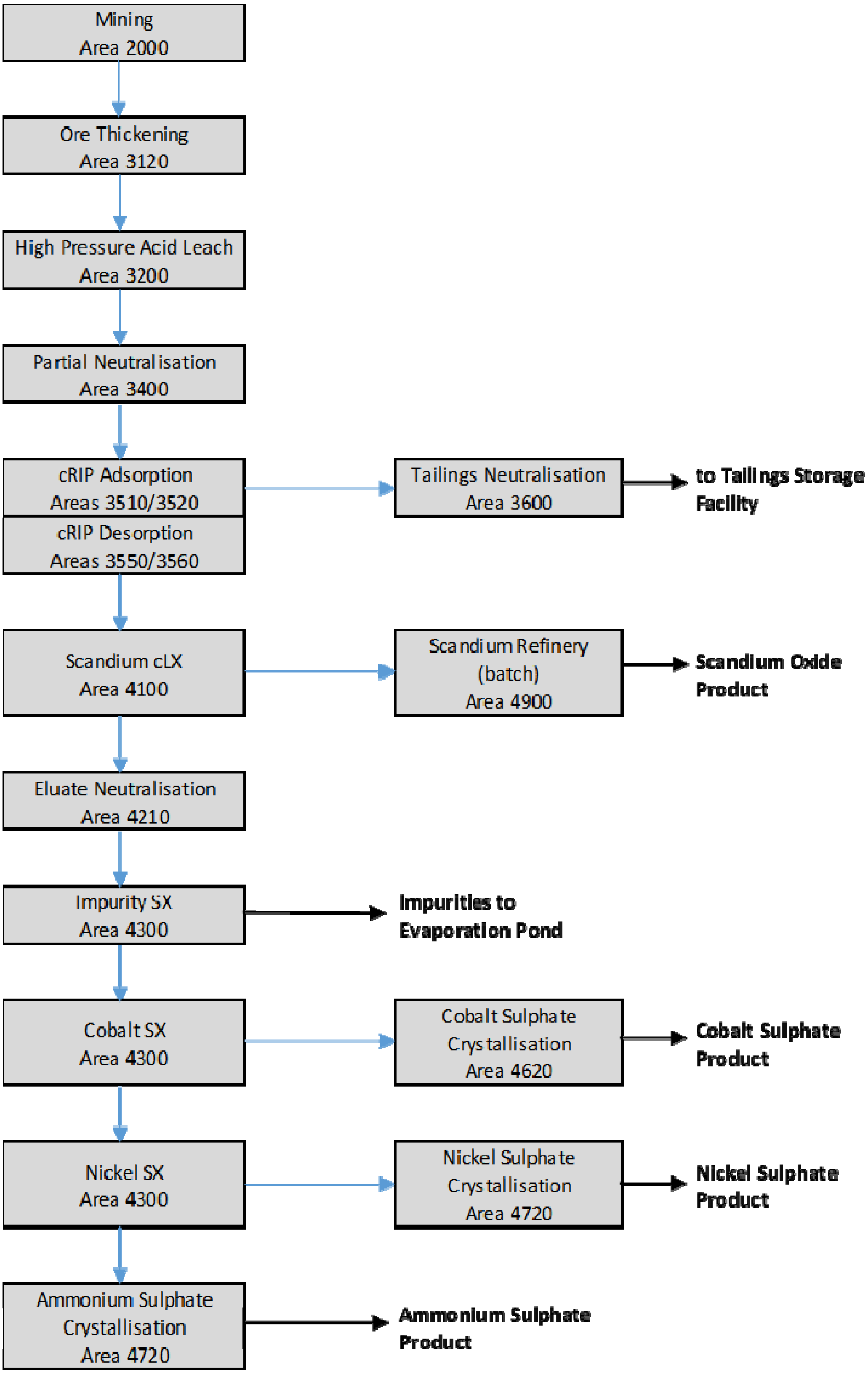
- Nickel and cobalt sulphates: 40,000 tonnes metal equivalents per year;
- Scandium Oxide: 180 tonnes per year; and
- Ammonium sulphate: 100,000 tonnes per year as $(NH_4)_2SO_4$.

The proposed processing plant would consist of the following major components:

- Ore Preparation (3100);
- High Pressure Acid Leaching (3200);
- Partial Neutralisation (3400);
- Nickel Cobalt Continuous Resin in Pulp (3500);
- Tailings Neutralisation (3600);
- Scandium Continuous Resin-in-Column (4100);
- Eluate Neutralisation (4200);
- Impurity, Cobalt, and Nickel Solvent Extraction (4300,4400,4500);
- Cobalt, Nickel and Amsul Crystallisation (4600,4700,4800); and
- Scandium Refinery (4900).

The process flow is summarised in Figure 5.

Figure 5 – Process Flow Schematic



3.1 ORE LEACH (3000)

3.1.1 Ore Preparation (3100)

Scrubbing and Classification (3110)

In the Ore Preparation Plant, the ore would be upgraded by rejecting oversize material enriched in silica. The circuit would be designed to produce a feed slurry thickened to an estimated 48w/w% solids. To achieve this density specification, the ore preparation plant requires feed that has been blended such that the slurry produced has properties that are amenable to thickening and pumping at this density.

The Ore Preparation Plant includes the following:

- The ore would be delivered to the Run of Mine (ROM) stockpile;
- Reclaim and transport via a truck to the process;
- Two crushing trains;
- Conveying, screening and magnetic separators (for tramp metal removal);
- Scrubbing (with water) to remove fines and oversized material (rejects); and
- The ore slurry from the scrubber passes through cyclones, a ball mill for further grinding and further screening.

Feed Thickening (3120)

The processes for feed thickening are as follows:

- The feed ore slurry would be stored in four Thickener Feed Tanks, i.e. each one feeds to a corresponding Feed Thickener;
- The ore feed would be thickened using coagulant and mixed with hot water and boiler blowdown;
- The thickened feed (48w/w% solids) would be stored in surge tanks which are designed to provide continuous feed to both High Pressure Acid Leach (HPAL) autoclaves for 12 hours at 100% production rates; and
- Sulphur slurry would be added to the HPAL feed surge tanks discharge and then pumped to Area 3200.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.1.2 High Pressure Acid Leach (3200)

HPAL Train 1 and 2 (3210/3220)

The function of the HPAL is to extract nickel, cobalt and scandium from the thickened slurry. The HPAL area consists of two separate operating trains. Each train comprises a two-stage direct contact heating system, a leach autoclave and three stages of flash pressure letdown and steam recovery.

The main unit operations in this area are:

- Steam heating of the feed with scrubbing of the vented gases;
- The autoclaves, which operate at a temperature of 250 degrees Celsius (°C) and pressure of 45 barg. The pressure leach process would be performed in an agitated, six compartment, horizontal, autoclave vessel;
- Sulphuric acid (98.5wt%) and supplementary steam are injected into the autoclaves;
- Because of the high working pressure of the autoclaves, it would be necessary to seal the agitator from the process. This would be accomplished with a high security, high-pressure seal system. Each agitator would have a double mechanical seal around the shaft that is attached to the autoclave agitator nozzle. This system effectively prevents depressurisation of the autoclave;
- Gases from the autoclave, e.g. carbon dioxide, are vented via the scrubber;
- The slurry from the autoclaves passes through a three-stage flash process where steam would be recovered for feed and water heating;
- Flashed slurry flows from the low pressure (LP) flash vessel to the HPAL Discharge Tank. The HPAL Discharge Tank would be fed SMBS (sodium metabisulphate) and would be capable of being fed raw water for emergency back-up/start-up; and
- Each of the three flash vessels are capable of discharging gas to a Safety Relief Blast Spool.

HPAL Common Area (3290)

SMBS would be made up in an agitated SMBS Mix Tank in which raw water would be mixed with SMBS from bulkabags.

Sulphuric acid would be pumped via the HPAL Sulphuric Acid Supply Pumps to the autoclaves.

The main process safety hazard in this area involves releases of high pressure acidic slurry. Historically, releases of corrosive material are a hazard to on-site personnel only. Large releases have caused damage to vegetation (i.e. burning) downwind, e.g. up to 100 m.

3.1.3 Partial Neutralisation (3400)

Partial Neutralisation (3410)

The slurry from the HPAL would be partially neutralised with limestone in six agitated tanks, and iron, aluminium and chromium are precipitated. Each tank has a vent that feeds to a ventilation stack for carbon dioxide release.

The partially neutralised slurry would be pumped to the Partial Neutralisation Trash Screens where oversize material would be rejected and sent to the coarse reject stockpile. The partially neutralised slurry would be pumped to the Nickel Cobalt (NiCo) Continuous Resin–in-Pulp (cRIP) Feed Tanks.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.1.4 NiCo Continuous Resin-in-Pulp (3500)

NiCo Adsorption Train 1 and 2 (3510 and 3520)

The cRIP (continuous resin in pulp) process comprises of two identical trains.

Partially neutralised slurry would be pumped to the first NiCo continuous adsorption units (known as Pachucas – air agitated reactors).

The adsorption circuit counter-currently contacts the partially neutralised slurry with resin which selectively adsorbs nickel, cobalt and scandium from the slurry.

Limestone slurry would be added to each of the 10 adsorption Pachucas for further neutralisation.

The resin would be transferred between stages using airlifts. The loaded resin discharges from Pachuca 1 onto the NiCo Loaded Resin Screen and then sent to Area 3550/3560 for desorption.

Gases are vented from all Pachucas and sent to the cRIP Scrubber.

NiCo Desorption Train 1 and 2 (3550/3560)

Loaded resin moves through the desorption process in a non-continuous manner. Small batches of resin are moved by airlifts between columns. The loaded resin would be fed to the top of the NiCo Loaded Resin Collection Column. Process water would be fed to the base and counter currently washes the resin to remove any waste pulp.

The loaded resin would then be airlifted to the NiCo Loaded Resin Wash Column where the resin would be washed to remove residual solids. The wash water would be added to the bottom of the column and moves counter currently to the loaded resin.

After passing through the NiCo Loaded Resin Wash Column, the resin would be airlifted to the NiCo Desorption U-Column where it would be fed to the top and moves counter-currently to the flow of the NiCo eluant. As the eluant flows down the resin filled column the nickel, cobalt and other elements are stripped off the resin into the eluant. The solution in the NiCo Desorption U-Columns forms two liquid products:

(1) NiCo eluate; and

(2) Desorption impurity liquor.

The desorption impurity liquor continues to rise through the column and would be removed through the inlet of the “U” column.

The NiCo eluate accumulates at the lower section of the Desorption Column and would be removed by the NiCo Eluate Extraction Pump to Area 4000, i.e. the refinery.

The barren resin would be removed from the NiCo Desorption U-Columns, washed and reused.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.1.5 Tailings Neutralisation (3600)

Tailings Neutralisation (3610)

Tailings are neutralised with slaked lime to remove free acid and precipitate the metal ions as stable hydroxides prior to being discharged to the tailings dam. The metals are thus captured in the solids, minimising any environmental impact through leaching from the tailings. Tails neutralisation involves tanks, pumps and a thickener (flocculant used - Magnafloc 1011 or equivalent).

The tailings thickener underflow would be combined with gland water and pumped to the tailings dam. The Tailings Thickener overflows into the Tailings Thickener Overflow Tank with the discharge being recycled back to the Tails Thickener and pumped to the Process Water Tank.

3.1.6 Tailings Disposal and Evaporation Ponds (3710)

The Tailings Dam would be fed underflow slurry from the tailings thickener. The Tailings Dam would also be used to store small amounts of waste material from other locations including waste carbon, solid effluent, impurity SX (solvent extraction) crud, cobalt SX crud, nickel SX crud and the tailings dam toe drain pump.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.2 REFINERY (4000)

3.2.1 Scandium Continuous Resin-in-Column (4100)

Scandium Continuous Resin-in-Column Adsorption (4110)

Continuous Resin-In-Column (cLX) is a continuous counter-current process that extracts metals from clarified leach solutions. This area of the process plant involves:

- The NiCo eluate from the NiCo Desorption Trains 1 and 2 flows through the Scandium (Sc) Adsorption Column where the scandium would be adsorbed onto resin;
- Screening (i.e. a Loaded Resin Trommel Screen);
- A Scandium Scrub Wash Column (water used);
- A Scandium Neutralisation Pachuca (caustic used); and
- The discharge of the Eluate Neutralisation Feed Tank would be the eluate neutralisation feed and would go to Area 4200 (eluate neutralisation). This stream contains the nickel and cobalt.

Scandium cLX Desorption (4120)

The desorption process involves four columns, i.e. the:

- Scandium Desorption Column (scandium eluant (sodium carbonate) would be used to desorb scandium from the resin);
- Scandium Desorption (Resin) Wash Column (reverse osmosis (RO) water used);
- Scandium Regeneration Column (regenerates the resin); and
- Scandium Regeneration (Resin) Wash Column.

Scandium eluate (containing the scandium) flows through the Scandium Desorption Column. The scandium eluate leaves from the top of the desorption column and would go to the Scandium Eluate Tank for subsequent purification (Area 4910).

The Scandium Regeneration Column would be fed resin regenerant from the Scandium Regenerant Tank which includes sulphuric acid.

The resin and scandium regenerant counter currently contact each other through the Scandium Regeneration Column. The aqueous discharge leaves the top of the column and would go to Areas 4110 and 3610 as scandium regeneration effluent. From the base of the Scandium Regeneration Column the resin would be airlifted to the Scandium Regeneration Wash Column.

The Scandium Regeneration Wash Column would be fed RO water to the base. The water and resin have counter current contact with the resin being discharged to the Barren Resin Trommel Screen with the overflow being barren resin which recycles to Area 4110. The wash water leaves the top of the Scandium Regeneration Wash Column and would go to the Scandium Regenerant Tank.

Sodium Carbonate (Scandium Eluant) (4130)

Sodium carbonate would be delivered by truck and stored in the Sodium Carbonate Silo. There are two Scandium Eluant Make Up Tanks, both of which are agitated and heated with low pressure steam. The Scandium Eluant Make Up Tanks are fed with scandium desorption wash water. The sodium carbonate feed addition would be controlled by rotary valves and screw feeders. Once leaving the Scandium Eluant Make Up Tanks the Scandium eluant would be pumped to the Scandium Eluant Storage Tank which would be agitated and heated with LP (low pressure) steam.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.2.2 Eluate Neutralisation (4200)

Eluate Neutralisation (4210)

The eluate (containing the nickel and cobalt) neutralisation circuit would reduce the excess acid concentration to a level that facilitates extraction of the valuable metals in a sulphate solution by solvent extraction. In this process, slaked lime would be used as the neutralising agent and some impurity elements (iron, aluminium and chromium) are precipitated out as hydroxides before they are filtered from the neutralised eluate stream.

The eluate neutralisation involves:

- Heating the Eluate Neutralisation Feed (this exchanger would be periodically cleaned with hydrochloric acid and raw water);
- Four agitated Eluate Neutralisation Tanks (fed slaked lime slurry and other process recycle streams);
- Discharge from the Eluate Neutralisation Tank 4 would be pumped to the Eluate Neutralisation Clarifier Feed Tank (flocculant used);
- Discharge from the Eluate Neutralisation Clarifier Feed Tank gravitates to the Eluate Neutralisation Clarifier. Part of the clarifier underflow would be recycled to Eluate Neutralisation Tank 1 and the remainder would be sent to the Eluate Neutralisation Filter Feed Tank. The overflow (containing the nickel and cobalt) flows into the Eluate Neutralisation Clarifier Overflow Tank and would be pumped to Area 4230; and
- The Eluate Neutralisation Filter Feed Tank discharge (i.e. the clarifier underflow) would be pumped to the Eluate Neutralisation Filter. The Filter Air Compressor provides pressure and RO water would be used for cake washing. The solids are periodically discharged into the Repulp Tank and are mixed with cobalt impurity ion exchange waste and process water. The eluate neutralisation repulp slurry would be recycled to Area 3410.

Solvent Extraction (SX) Feed Preparation (4230)

Nickel and cobalt are to be recovered by solvent extraction and then crystallised as high purity sulphates by evaporation and concentration.

The eluate overflow liquor from Eluate Neutralisation Clarifier feeds into the Eluate Polishing Filter. The Eluate Polishing Filter Air Compressor provides pressure and RO water would be used to wash the cake. The filtrate (containing the nickel and cobalt) would go to the SX Feed Heat Exchanger Feed Tank. The sludge discharges in a non-continuous manner to the Eluate Polishing Filter Dump Tank which would also be fed by the Eluate Polishing Filter Sump Pump. The polishing filter dump slurry would go to the Repulp Tank for recycling in the process.

Acid chloride waste and RO water are fed into the Filter Aid Tank, with filter aid also added by hand. This tank would be pumped to two locations; the Eluate Polishing Filter and the Eluate Neutralisation Filter Feed Tank, i.e. the filter aid enhances the performance of the two filters.

The discharge from SX Feed Heat Exchanger Feed Tank (containing the nickel and cobalt) flows through the SX Feed Heat Exchanger and then to the impurity SX feed (Area 4300).

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.2.3 Impurity Solvent Extraction (4300)

Impurity SX (4310)

The Extract stage removes the zinc, manganese, cobalt, iron, calcium, 1% nickel and 60% of the magnesium from the aqueous phase (i.e. the eluate containing the nickel and cobalt) and converts them into an organic phase.

The organic phase would be a mixture of diluent and Di-(2-ethylhexyl) phosphate (DEHPA) extractant (a combustible liquid).

Ammonia would be added to control pH to 3.0 to 3.8.

Each Extract stage would be made up of a mixer and a settler.

After exiting the fourth and last Extract tank, the aqueous phase containing the nickel and cobalt would go to Diluent Wash tanks.

The loaded organic (i.e. with the abovementioned impurities) would then be scrubbed to remove the impurities.

The organic then moves into a stripping process which includes hydrochloric acid. The aqueous phase strips any nickel, cobalt, magnesium, manganese, copper, zinc, and calcium from the organic phase. The organic would be washed and recycled back to the extract phase.

Impurity SX Organic Treatment (4320)

In the course of the organic solvent and aqueous phase contacting and separating, an oily film of crud forms. Crud is an emulsion made up of grit, colloidal silica, denatured solvent and extractant. Crud would be treated by agitating with sulphuric acid and then passing to a settling cone. Recovered organic would be decanted off whilst the acidified residue would be returned to the process.

Various SX streams are combined and centrifuged. The solids go to the Crud Drum and are removed via a truck. The organic phase would go to the Impurity SX Recovered Organic Tank where it would be recycled back into the process. The aqueous phase from the centrifuge would also be recycled.

Impurity SX organic treatment also involves filtering and neutralisation with the clean aqueous phase being pumped to Area 4400.

The organic phase containing the impurities would be processed (i.e. extract, scrub and strip stages) and the waste sent to Area 4330.

Impurity SX Scuttle Pond (4330)

Impurity SX scuttled (waste) organic would be sent to the Impurity SX Scuttle Pond.

The significant potential off-site hazardous event from this area is a large release of anhydrous ammonia. It would be possible that the diluent can form a pool fire but the significant radiant heat levels would not travel far from the processing plant.

3.2.4 Cobalt SX (4400)

Cobalt SX (4410)

This stage removes zinc, manganese, cobalt, iron, aluminium, copper and 16% of the magnesium from the aqueous phase containing the nickel and cobalt and converts them into an organic phase in a similar process to Area 4310.

The organic phase, however, would be a mixture of diluent and Cyanex 272 extractant (a combustible liquid).

There are two aqueous phase discharge streams from Area 4400:

- The aqueous phase (containing the nickel) is called the Cobalt SX raffinate; and
- The other aqueous phase is the cobalt SX strip product which contains the cobalt, i.e. the cobalt has been stripped out of the water stream containing the nickel (see below).

Cobalt SX Organic Treatment (4420)

The Cobalt SX raffinate (i.e. the aqueous phase containing the nickel) would go to the Extract After Settler. The organic phase from the settler feeds into the Cobalt SX Crud Tank while the aqueous phase would go to the Cobalt SX Raffinate Filter. The aqueous filter discharge would go to the Cobalt SX Clean Raffinate Tank and would be pumped to Area 4500 for nickel recovery.

The backwash from the filter, with various other streams, would be centrifuged.

The solids go to the Crud Drum and are taken by truck to the Tailings Dam. The organic phase would go to the Cobalt SX Recovered Organic Tank where it would be recycled back into the process. The aqueous phase from the centrifuge would also be recycled.

The cobalt SX strip product (containing the cobalt) from Area 4410 would be further treated via filtering and carbon columns. Cobalt SX Clean Strip Product would then be pumped to the Cobalt Neutralisation Tank and then to Area 4600 for purification, crystallisation and packaging. Waste carbon would go to Area 3700.

Cobalt SX Scuttle Pond (4430)

Cobalt SX Scuttled (waste) Organic would sent to the Cobalt SX Scuttle Pond.

As with Area 4300, the significant potential off-site hazardous event from this area is a large release of anhydrous ammonia. It would be possible that the diluent can form a pool fire but the significant radiant heat levels would not travel far from the processing plant.

3.2.5 Nickel SX (4500)

Nickel SX (4510)

This stage removes the nickel, magnesium, zinc, chromium, manganese, cobalt, iron, aluminium, copper and 10% of the calcium from the aqueous phase and converts them into an organic phase in a similar process to Area 4310.

The organic phase, however, would be a mixture of 50% diluent and 50% versatic acid (not a scheduled hazardous material).

There are two aqueous phase discharge streams from Area 4500:

- The aqueous phase that has the nickel removed is called the Nickel SX raffinate; and
- The other aqueous phase is the nickel SX strip product which contains the nickel (see below).

Nickel SX Organic Treatment (4520)

The Nickel SX raffinate (containing the amsul) would go to the Extract After Settler. The organic phase feeds into the Nickel SX Crud Tank while the aqueous phase would go to the Nickel SX Raffinate Filter. The aqueous phase continues to the Nickel SX Clean Raffinate Tank for amsul production in Area 4800.

The backwash from the filter, with various other streams, would be centrifuged.

The solids go to the Crud Drum and are taken by truck to the Tailings Dam. The organic phase would go to the Nickel SX Recovered Organic Tank where it would be recycled back into the process. The aqueous phase from the centrifuge would also be recycled.

The nickel SX strip product (containing the nickel) would be further treated via filtering and carbon columns. Nickel SX Clean Strip Product would then be pumped to Area 4700 for crystallisation and packaging. Waste carbon would go to the tailings dam.

Nickel SX Organic Treatment (4530)

Nickel SX Scuttled (waste) Organic would be sent to the Nickel SX Scuttle Pond.

As with Area 4300, the significant potential off-site hazardous event from this area is a large release of anhydrous ammonia. It would be possible that the diluent can form a pool fire but the significant radiant heat levels would not travel far from the processing plant.

3.2.6 Cobalt Crystallisation and Packaging (4600)

Cobalt Purification (4610)

Cobalt purification from the cobalt SX clean strip product involves:

- Filtration;
- Copper removal in resin filled columns;
- Manganese precipitation in agitated tanks using Caro's acid (an acid that is formed when hydrogen peroxide and sulphuric acid are mixed); and
- Further filtration with the liquid discharge being purified cobalt sulphate.

Cobalt Crystallisation (4620)

Cobalt crystallisation involves:

- Heating the cobalt crystalliser feed liquor from Area 4610 to evaporate water;
- Once the cobalt solution becomes saturated, cobalt sulphate crystals start to form; and

- The crystals are put through a centrifuge and washed to remove mother liquor.

Cobalt Handling and Packaging (4630)

The cobalt sulphate crystals would be fed into three bins, each of which would have a load cell. The cobalt sulphate product would be packaged into 1 m^3 bags and placed in shipping containers for export. The off-spec cobalt sulphate would be recycled into Area 4620.

The main process safety hazards in Area 4600 involve hydrogen peroxide and sulphuric acid. These are local hazards only.

3.2.7 Nickel Crystallisation and Packaging (4700)

Nickel Crystallisation (4720)

Nickel crystallisation from the nickel SX clean strip product involves:

- Heating the nickel crystalliser feed liquor from Area 4520 to evaporate water;
- Once the nickel solution becomes saturated, nickel sulphate crystals start to form; and
- The crystals are put through a centrifuge and washed to remove mother liquor.

Nickel Handling and Packaging (4730)

The nickel sulphate crystals would be fed into three bins, each of which would have a load cell. The nickel sulphate product will be packaged into 1 m^3 bags and placed in shipping containers for export. The off-spec nickel sulphate would be recycled into Area 4720.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.2.8 Amsul Crystallisation and Packaging (4800)

Amsul Crystallisation (4820)

Amsul crystallisation from the nickel SX clean raffinate involves:

- Heating the raffinate from Area 4520 to evaporate water;
- Once the amsul solution becomes saturated, amsul crystals start to form; and
- The crystals are put through a centrifuge and washed to remove mother liquor.

Amsul Handling and Packaging (4830)

The amsul crystals are sorted into an on-spec and off-spec stockpile. A front-end loader would be used to move the crystals into amsul transport trucks which would move the product in bulk.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.2.9 Scandium Refinery (4900)

Scandium Eluate Purification (4910)

The Scandium Eluate from Area 4120 would be purified using following processes:

- Hydrolysis (chemical breakdown with water) in heated tanks;
- Filtration to remove waste solids;
- Caustic mixing and clarification;
- The clarifier underflow would be pumped to the Scandium Caustic Precipitate Centrifuge which produces scandium hydroxide;
- Washing of the scandium hydroxide with demineralised water;
- Acid (hydrochloric acid) leaching;
- The process liquid stream from leaching would be filtered and then ammonium hydroxide and oxalic acid are added; and
- The $Sc(C_2O_4)_3$ would go to an intermediate storage bin and then moved by hand to the Intermediate Sc_2O_3 Rotary Kiln. The kiln would also be fed diesel and air. Intermediate scandium oxide would go to the Intermediate Hopper.

Scandium Precipitation and Calcination (4920)

Scandium precipitation and calcination involves the following processes:

- Mixing the intermediate scandium oxide with demineralised water and hydrochloric acid;
- Filtration. The residual solids go to the scandium formic acid digestion area. The aqueous portion would go to the Scandium Ammonium Hydroxide Precipitation Tank (which would also be fed ammonia solution);
- The discharge from the Scandium Ammonium Hydroxide Precipitation Tank would be filtered;
- The hydroxide precipitate would be transferred by hand to the Product Sc_2O_3 Rotary Kiln; and
- The scandium oxide product from the kiln would be sent to the Scandium Oxide Drumming Plant.

Scandium Scrubber (4930)

The Scandium Refinery Scrubber would be fed intermediate kiln off gas, product kiln off gas and raw water.

Caustic Make-up and Distribution (4950)

Caustic would be delivered by road tanker and pumped into the Caustic Storage Tank.

Oxalic Acid (4960)

Oxalic acid would be fed out of the Oxalic Acid Hopper to the Oxalic Acid Make Up Tank where it would be mixed with demineralised water and pumped into the Oxalic Acid Storage Tank.

Formic Acid (4970)

Formic acid would be delivered in an IBC (intermediate bulk container) by truck and pumped into the Formic Acid Dosing Tank.

There are no significant potential fire, explosion or toxic hazardous events in this area that could impact people off-site.

3.3 REAGENTS (5000)

3.3.1 Sulphur Handling, Acid Production and Storage (5100)

Sulphur Handling (5110)

Sulphur would be delivered to the Port of Newcastle by ship, transported by rail to the rail siding and then transferred to the site by truck. The truck would enter the loading road and fill the Sulphur Receival Bin with the sulphur.

Sulphur demand would be up to 350,000 tonnes per annum.

The Sulphur Receival bin splits the sulphur into two feeds. One would be the sulphur melter feed which would go onto the Sulphur Melter Feed Conveyor (this would be sprayed with raw water for dust suppression). Hydrated lime would also be fed onto this conveyor and sent to Area 5130 for sulphuric acid production.

The second sulphur feed would go onto the sulphur stockpile for reclaim to the Sulphur Mill Feed Hopper.

The Sulphur Mill Feed Hopper would also be fed from the Lignosulphonate Dosing Pump and the underflow of the Sulphur Cyclone. The Feed Hopper discharges into the Sulphur Ball Mill. The mill discharge slurry would go to the Sulphur Cyclone Feed Hopper and would be pumped into the Sulphur Cyclone. The overflow of the Cyclone would go to the Sulphur Slurry Hopper where it would be pumped into Area 3120 as part of the ore feed thickening process prior to the HPAL autoclaves.

Hydrated Lime (5120)

Hydrated lime would be delivered by Pneumatic Tanker and fed into the Lime Silo. The hydrated lime would be fed to the Sulphur Melter Conveyor.

Sulphuric Acid Production (5130)

This plant would be vendor supplied. Typically, sulphuric acid would be produced by burning the sulphur and forming sulphur dioxide. This would be converted to sulphur trioxide (typically in the presence of vanadium pentoxide catalyst) and absorbed in weak acid to produce the required 98.5% sulphuric acid.

The sulphuric acid plant production rate would be approximately 1,050,000 tonnes per annum.

Sulphuric Acid Storage and Distribution (5140)

The sulphuric acid would be stored in two bunded Sulphuric Acid Storage Tanks (each tank being 12,000 tonne capacity). The acid from the storage tank would be discharged to multiple locations across the plant.

3.3.2 Limestone Handling, Milling and Storage (5200)

Limestone Handling (5210)

The limestone would be delivered to site by a truck and fed into the Limestone Feed Bin. This feeds into the Limestone Feeder which feeds the limestone to the milling circuit.

Limestone Milling (5220)

Limestone milling involves the following processes to make the slurry:

- Screening;
- Crushing;
- Milling in a ball mill; and
- Separation via cyclones.

Limestone Storage and Distribution (5230)

The limestone slurry would be pumped to the Limestone Slurry Storage Tanks 1 and 2 for storage and then distributed to Areas 3500, 3610 and 3410.

3.3.3 Lime Slaking and Distribution (5300)

Quicklime Receival and Slaking (5310)

Quicklime (CaO) would be delivered to site by tanker truck and transferred into the Quicklime Storage. The quicklime would be combined with raw water and fed to the Quicklime Slaking Mill. The mill discharge slurry would be screened and transferred to the Quicklime Slaking Mill Discharge Hopper.

Slaked Lime Distribution (5320)

The slaked lime slurry from the Quicklime Slaking Mill Discharge Hopper would be pumped to the two Slaked Lime Slurry Storage Tanks and distributed to Areas 3610, 4210, 4320 and 6290.

3.3.4 Industrial Gases (5400)

Ammonia Storage and Distribution (5420)

Anhydrous ammonia would be delivered by road tanker and is transferred to the two Anhydrous Ammonia Storage Bullets (100 te capacity each).

Vapour from the bullets passes through the Compressor Knockout Vessels, the Ammonia Unloading Compressors and then back into the ammonia road tanker, i.e. so that liquid ammonia can be transferred into the bullets.

The liquid discharge from the bullets passes through a vaporiser before being distributed to Areas 4310, 4410, 4510 and 4920.

3.3.5 Bulk Reagents Receival and Distribution (5500)

Coagulant and Flocculant (5510)

Solid coagulant would be delivered in a container by truck and transferred into the Coagulant Storage Silo. It would be mixed with raw water and distributed to Area 3120.

Solid flocculant from the warehouse would be stored in the Flocculant Storage Silo where it would be mixed with RO water and distributed to Area 4210.

Flocculant would also be delivered in a container by truck, mixed with water and pumped to the Tails Flocculant Storage Tank. This would be distributed to Areas 3610 and 6290.

Hydrochloric Acid (5520)

Hydrochloric acid would be delivered by tanker and pumped into the Hydrochloric Acid Storage Tank. It would be distributed to Areas 4210, 4310 and 4920.

3.3.6 Fuel Storage and Distribution (5600)

Fuel and diluent are brought to site by a tanker and transferred to the relevant tanks.

The fuel farm would consist of 3 x 60 m^3 self-bunded double walled diesel tanks. Diesel would be available via either high or low speed bowsers or pumped to the power station.

A storage tank for the solvent extraction diluent (similar to diesel) would be located in an earthen bund local to the solvent extraction plant. Diluent would be pumped to the solvent extraction area directly.

An additional two bunded 60 m^3 diesel tanks would be located at the mining contractor area.

An oil/water separator would be included to capture water and oil spillage from the diesel storage area. Water would be pumped to Area 3610. Waste oil would be collected and pumped to a tanker for disposal off-site.

The fuel storage and handling areas are to be designed to meet the requirements of AS1940.

The two potential hazardous events from the reagents area that can impact people off-site are releases of sulphur oxides from the sulphuric acid plant or burning sulphur and releases of anhydrous ammonia. These two events are analysed in this PHA.

3.4 SERVICES AND INFRASTRUCTURE (6000)

3.4.1 Power/Steam Generation and Supply (6100)

Diesel Power Station (6110)

Emergency backup power supply is proposed to be provided by diesel fuelled generators with a capacity of approximately 6 MW. Fuel for the diesel generators would be sourced from the 3 x 60 m^3 plant diesel tanks and stored locally in an above ground storage tank (nominal capacity of 5 m^3) in accordance with the relevant Australian Standards for storage of flammable and combustible liquids (e.g. AS1940) (Ref 5).

Steam would be raised by the sulphuric acid plant waste heat boilers, however, there would also be a small auxiliary boiler to cater for sulphur melting and heat tracing in the acid plant and warm-up of the autoclaves upon black-start conditions.

Included in the proposed design is an option for installing a natural gas pipeline to the site. If installed, the natural gas would be combusted (rather than diesel) to produce power and steam.

The natural gas would be supplied to the site from a lateral of the Moomba to Sydney gas pipeline approximately 75 km south-southwest of the mine site. The pipeline would be approximately 90 km long and buried as per AS2885 (Ref 6). The majority of the line would run within existing road reserves and would cross the Lachlan River near Condobolin.

Cogeneration Plant (6120)

Electricity would be generated by a 25 megawatt (MW) steam turbine High pressure steam feeding the turbine would be raised in the sulphuric acid plant boiler.

The power generation and distribution system would provide electricity for the plant power requirements for both normal and emergency operations. Maximum power demand requirements for the project are anticipated to be in the order of approximately 25 MW.

Package Boiler (6140)

Supplied by Vendor.

3.4.2 Water Supply and Treatment (6200)

Lachlan River Water Supply (6210)

The river water would go over a River Inlet Screen and pumped to the River Water Backwash Filter. It would then be transferred to Area 6220.

Borefield Water Supply (6220)

Six bore water pumps feed water to the Raw Water Break Tank. This water would be pumped to Area 6230 via a water pipeline.

Raw Water Storage and Distribution (6230)

The Raw Water Storage Tank overflows into the Raw Water Storage Pond. This pond would be filled with water. Fire water would be pumped out of both the Raw Water Storage Tank and the Raw Water Storage Pond to the fire water distribution system.

Water from the Raw Water Storage Pond would also be pumped to the Construction Accommodation Camp and to the Mine Utility Water Dam.

Water from the Raw Water Storage Tank and Raw Water Storage Pond are both distributed to numerous locations throughout the processing plant and facility.

Mechanical Seal and Gland Water System (6250)

Filtered water would be stored and used as seal and gland water for rotating equipment throughout the plant.

Fresh Water Treatment (6260)

The Water Treatment Plant would be fed raw water, sulphuric acid, hypochlorite, caustic and scale inhibitor. The plant would produce RO (reverse osmosis) water, filtered water, demineralised water, potable water and RO plant waste water for distribution to different areas of the plant.

Demineralised Water (6270)

Demineralised water leaves the Demineralised Water Column and would go to the Demineralised Water Storage Tank for use throughout the plant.

Potable Water (6280)

Potable water from the Water Treatment Plant would be stored in the Potable Water Break Tank and distributed to numerous areas within the plant and facility.

Decant Water Treatment (6290)

Supplied by Vendor.

3.4.3 Instrument Air Supply (6600)

Instrument Air Supply (6610)

Supplied by Vendor.

3.4.4 Cooling Water System (6700)

Cooling Water System (6710)

Supplied by Vendor.

3.4.5 Process Plant and Site Run-off

The plant site drainage system would be designed to catch all stormwater on the plant site outside the process areas. The system would comprise a network of open earthen drains and culverts which would gravitate to the settlement ponds. The settlement ponds would capture the sediment. The water would be pumped from the settlement ponds to the process raw water pond. The drains would be designed for a 1 in 100 year event and the settlement pond would be designed to contain the rainfall run-off for the 1 in 10 year, 24 hour storm event.

Spills and rain falling on the process areas would be contained within bunded areas (which include pumps and sumps) and would be pumped into the process.

3.4.6 Fire Protection System (6240)

The entire process plant area would be serviced by double head fire water hydrants in accordance with AS2419 – Fire Hydrant Installations (Ref 7).

In addition, the solvent extraction (SX) area would be serviced by a foam deluge system. The solvent extraction area processes an organic solution that consists predominantly of a diluent called Shellsol which is a type of kerosene which has a flash point of 78°C (i.e. a combustible liquid). The SX area consists of tanks, pulsed columns, filters, mixer/settler tanks and electrically powered centrifugal pumps. In the event of a spill, a concrete bund wall that surrounds the area contains all liquid. Within this bunded area there would be partition bund walls to separate the different stages of the SX process.

The foam deluge system for the SX area would consist of hydrant mounted foam monitors, fixed low-level foam-water discharge outlets and heat activated foam-water deluge sprinklers. The entire SX area would be serviced by infrared flame detectors which automatically activate the low-level foam-water discharge outlets in the event of a fire. The flame detectors would be failsafe including wiring and associated equipment. A bladder tank proportioning system would be used for foam addition.

The system would include fire protection equipment for the mine site's diesel fuel storage tanks to meet the relevant Australian Standards for storage of flammable liquids (e.g. AS1940).

The fire water pump set would be comprised of an electrically powered 100% duty pump, a diesel powered 100% standby pump and an electrically powered pressure maintaining 'jockey' pump. The jockey pump would be used to maintain system pressure in the ring main. This would be necessary because of pressure losses caused by normal system losses. The jockey pump prevents premature starting of the main fire service pumps. Large pressure drops in the ring main caused by a hydrant being used would cause the electric fire water pump to start automatically. In the event of a power failure or the electric powered pump fails to start then the diesel-powered pump would start automatically.

A fire suppression system would be installed in the plant's central control room and in each of the plant's electrical substations. Each fire suppression system would consist of a gas storage facility, dual risk detection system, warning and evacuation alarms and distribution piping and fittings.

The system would also include hand held, manually operated fire extinguishers throughout the processing plant, administration buildings, workshop, metallurgical lab and motor control centres for first aid firefighting.

The main potential hazardous event from these services (Area 6000) that could impact people off-site would be failure of the natural gas pipeline to the site.

3.5 MINING AND PROCESSING WASTE DISPOSAL AREAS

The development of the Syerston deposit would involve conventional open pit mining methods at depths of generally 50 m below the surface. The mining method would comprise free digging by excavator. Some blasting may be required during mining. Ore and waste would be loaded directly to haul trucks for transfer to either the process, ROM pad, low grade stockpiles or the waste emplacements.

3.6 LIMESTONE QUARRY

There would be no change to the approved limestone quarry for the Modification.

3.7 RAIL SIDING

There would be no change to the approved rail siding for the Modification.

3.8 TRANSPORT

The various aspects of transport associated with the Project are:

- Rail transportation of bulk materials to, and from, the proposed rail siding using containers;
- Road transport of limestone from the limestone quarry or third party suppliers to the mine site;
- Road transport of bulk materials, chemicals, reagents and goods to the mine site;
- On-site transport and storage requirements; and
- Export of product from site.

The rail system would be used primarily for the receival of sulphur plus other reagents and supplies.

The bulk chemicals likely to be transported to the mine site by road tankers are Shellsol (the solvent extraction diluent), diesel, caustic soda (or rail), liquid nitrogen, quicklime, anhydrous ammonia, hydrated lime, sulphuric acid (for startup) and flocculant. Waste oil from the effluent separator would be transported from the mine site by road tanker. The majority of the packaged chemicals (e.g. acids, bases and reagents in bulkiboxes, and chemicals and catalysts supplied in drums, bulkabags or cylinders) are to be transported by road.

The mine site is accessible by the existing local road network. The local road network would be upgraded in accordance with the conditions of Development Consent DA 374-11-00 and Voluntary Planning Agreements with the Lachlan Shire Council, Parkes Shire Council and Forbes Shire Council. Nickel, cobalt and scandium product and Amsul by-product would be exported from the site in containers via road to the rail siding and via rail transport to a suitable port (e.g. Port Botany or Newcastle).

The sulphur transport would be a 350,000 tonne per annum operation involving bulk transport by ship to Newcastle and then by rail and road to the site.

Up to a total of 990,000 tonnes of limestone would be transported by road to the mine site, with up to 790,000 tonnes from the limestone quarry and up to 560,000 tonnes from a third party supplier.

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

The hazardous materials involved with the Modification are shown in Table 2. Given the large separation distances from the location of these materials to the nearest place of residence to the site (2.4 km) then the materials with the potential for off-site impact are:

- Natural gas due to failure of the natural gas supply pipeline with subsequent ignition. This can occur anywhere along the pipeline;
- Incident involving the explosives storages where the explosives detonate; and
- Ammonia and sulphur oxides due to a large release and dispersion downwind.

4.1.1 Natural Gas

Natural gas is a Class 2.1 Dangerous Good (DG) (flammable gas).

Natural gas is a colourless hydrocarbon fluid mainly composed of the following hydrocarbons:

- Methane (typically 88.5% or higher);
- Ethane (typically 8%);
- Propane (typically 0.2%);
- Carbon dioxide (typically 2%); and
- Nitrogen (typically 1.3%).

For a typical natural gas, the TLV (threshold limit value) is approximately 1,000 parts per million (ppm) and the STEL (short term exposure limit) is 30,000 ppm (i.e. approaching 5vol% which is the lower explosive limit).

The hydrocarbons are not considered to represent a significant environmental threat. Their hazard potential derives solely from the fact that they are flammable materials.

To enable ready leak detection, natural gas is normally odorised with mercaptans (sulphur containing hydrocarbons).

The flammability range is typically 5% to 15% by volume in air. The vapours are lighter than air and will normally disperse safely if not confined and/or ignited.

Natural gas ignition can lead to jet fires, flash fires or vapour cloud explosions.

Products of combustion include carbon monoxide and carbon dioxide.

Table 2 – Materials Summary

Material	Plant Area	Description	Annual Consumption	Storage Amount
Process Plant Raw Materials				
Sulphur Prills	5110	Prilled solids. Transported in closed containers by rail/road and unloaded to an open stockpile	350,000 te	30,000 te
98.5% Sulphuric Acid	5130 (Acid Plant) & 5140 (Acid Storage)	Produced on site in the acid plant and held in two acid storage tanks	1,050,000 te	2 x 12,000 te tanks
Hydrated Lime ($Ca(OH)_2$)	5120	Hydrated lime powder delivered by road tanker to a silo. Used to neutralise sulphur in the acid plant	1,500 te	1 x 25 te silo
Quicklime (CaO)	5310	Quicklime powder is delivered by road tanker to a silo	50,000 te	1 x 160 te silo
Anhydrous Ammonia	5420	Anhydrous ammonia transport bullets are delivered by rail and road, and the liquid ammonia is transferred into storage bullets on-site	28,000 te	2 x 100 te bullets
Flocculant (Ore prep) - BASF Magnafloc 1011 or equivalent)	5510 Flocc /3120 Ore Prep.	Powdered flocculant delivered by road tanker and unloaded to storage silo at site	300 te	1 x 30 te silo
Flocculant (Eluate Neutralisation) - BASF Magnafloc E10 or equivalent	5510 Flocc /4210 Eluate Neut.	Powdered flocculant delivered in 25 kg bags on a pallet. Pallet stored in warehouse and/or suitable storage shed local to the process area	2 te	1 pallet of 40 x 25 kg bags

Material	Plant Area	Description	Annual Consumption	Storage Amount
Flocculant (Tailings) -BASF Magnafloc 338 or equivalent	5510 Flocc /3620 Tails Thickening	Powdered flocculant delivered by road tanker and unloaded to storage silo at site	300 te	1 x 30 te silo
Flocculant (Process Water Treatment) SNF FLOPAM AN910 or equivalent	5510 Flocc /6290 Process Water Treatment	Powdered flocculant delivered by road tanker and unloaded to storage silo at site	300 te	1 x 30 te silo
Hydrochloric Acid (33%)	5520	33% hydrochloric acid is delivered by road in isotainers and unloaded to a storage tank on site	17,000 te	1 x 250 m^3 storage tank, + 1 x 50 m^3 day tank
Diluent -Shell Shellsol D70 or equivalent	5620		200 m^3	1 X 35 m^3 storage tank
Sodium Metabisulphate (SMBS)	3290	Powder SMBS delivered in either 1 te bulkabags or via truck	6,000 te	30 x 1 te bulkabags of powder 1 x 16 m^3 mix tank @ 350g/L 1 x 48 m^3 storage tank @ 350g/L
Oxalic Acid	4960	Powder delivered in 1 te bulkabags. 100 g/L oxalic acid solution is prepared on site in a mixing plant	200 te	20 x 1 te bulkabags of powder 1 x 16 m^3 mix tank @ 100g/L 1 x 48 m^3 storage tank @ 100g/L
Formic Acid	4970	99% solution delivered in either 1 m^3 IBCs or via tanker	3,500 te	1 x 50 m^3 storage tank
Resin, cRIP	3500	Resin delivered in 1 te bulkabags	800 te	30 x 1 te bulkabags

Material	Plant Area	Description	Annual Consumption	Storage Amount
Resin, Sc cLX	4100	Resin delivered in 25 kg bags and added to the process by hand via a hopper	15 te	2 pallets of 40 x 25 kg bags
Extractant - D2EHPA	4310	Solution delivered in 1 m^3 IBCs	15 m^3	2 x 1 m^3 IBCs
Extractant -Cytec Cyanex 272	4410	Solution delivered in 1 m^3 IBCs	15 m^3	2 x 1 m^3 IBCs
Extractant -Hexion Versatic Acid 10	4510	Solution delivered in 1 m^3 IBCs	60 m^3	6 x 1 m^3 IBCs
Caustic (NaOH)	4950	50%w/w caustic solution delivered in isotainers	400 te	1 x 35 m^3 storage tank
Soda Ash (Na_2CO_3)	4130	Bulk powder delivery by road tanker into a silo at site	8,000 te	1x110 te silo
Hydrogen Peroxide (70w/w%)	4610	Solution delivered in 1 m^3 IBCs or isotainer	70 te	8 x 1 m^3 IBCs or 2x20 m^3 isotainers
Sodium Hypochlorite (12.5% Av Chlorine)	6280	Solution delivered in 200 L drums	2 m^3	2 x 200 L drums
Diesel Fuel (excludes mine, refinery only)	5610	Delivered in tank trucks and stored in diesel storage tanks on site	6,500 m^3 (estimate only)	3 x 60 kL storage tanks
Mine				
Mining Diesel	Mining contractors yard	Delivered in tank trucks and stored in diesel storage tanks on site	3,700 m^3 (estimate only)	2x 60 kL storage tanks
Mining Explosives	Explosives magazine	-	-	Stored in secure magazine at site

Material	Plant Area	Description	Annual Consumption	Storage Amount
'In-Process' Fluids				**Estimates Only**
Molten Sulphur	5130	Sulphur is melted and burned in the acid plant to make sulphuric acid	-	1 x 1000 te dirty tank 1 x 2000 te clean tank
Sulphur dioxide and sulphur trioxide (SO_2/SO_3)	5130	SO_2 and SO_3 are intermediates in the production of sulphuric acid. SO_2 is produced by burning sulphur and is catalytically converted to SO_3. SO_3 is absorbed in acid to produce stronger acid. Low level SO_2/SO_3 atmospheric emissions (<250 ppm) leave the acid plant stack	-	No storage, however, large volumes exist within the acid plant
Slaked Lime Slurry	5210/5320	Quicklime is slaked on site to produce a hydrated lime slurry which used for neutralising process liquors. Slaked lime slurry is stored in the slaker and two storage tanks	-	2 x 135 m^3 slurry storage tanks (@ 30w/w% solids)
HPAL Process Slurry	3200	Acidic process slurry (40 g/L free acid) at high temperature (250°C) and pressure	-	2 x 718 m^3 autoclaves plus other piping, heaters and flash vessels
Partial Neutralisation Slurry	3410	Partially neutralised slurry (pH<4) at atmospheric temperature and pressure	-	6 x 0.5 ML tanks
Tailings Slurry	3600	Neutralised process slurry (pH ~6) at atmospheric temperature and pressure	-	Multiple large process tanks
cRIP Slurry	3500	Partially neutralised slurry (pH <4) at atmospheric temperature and pressure	-	Estimate ~20 ML of process tankage

Material	Plant Area	Description	Annual Consumption	Storage Amount
cRIP Eluate	4100	Partially neutralised pregnant liquor (pH ~2) at atmospheric temperature and pressure	-	Multiple large process tanks
Neutralised Eluate	4200	Neutralised pregnant liquor (pH ~6) at atmospheric temperature and pressure	-	Multiple large process tanks
Various Solvent Extraction Process Fluids	4300-4900	SX organic phases (combustible) SX aqueous phases (acidic)	-	Multiple large process tanks

4.1.2 Explosives (Ammonium Nitrate Emulsion)

Ammonium nitrate emulsion (ANE) is a Dangerous Good (DG) 5.1, Packing Group II, liquid (a creamy emulsion that supports combustion of other materials). A typical composition for ANE is:

- Ammonium nitrate > 60%;
- Fuels (diesel) < 10%;
- Mineral oil, hydrocarbon solvent, petroleum < 10%;
- Water 5 to 30%; and
- Non-hazardous materials < 30%.

ANE will support combustion of other materials and increase the intensity of a fire. It will decompose on heating emitting irritating white fumes (ammonium nitrate). Brown fumes indicate the presence of toxic oxides of nitrogen, e.g. nitrogen dioxide.

A major fire may involve a risk of explosion, in particular, if the ANE is confined and contaminated. An adjacent detonation may also involve the risk of explosion (i.e. sympathetic detonation). Heating can cause expansion or decomposition of the material which can lead to the containers exploding.

When molten, ANE may decompose violently due to shock or pressure.

ANE is insoluble in water, however, open fires can be fought by applying water spray.

This material is classified as Security Sensitive Ammonium Nitrate (SSAN). Within Australia, all persons who have unsupervised access to Security Sensitive Ammonium Nitrate require security clearances. The issuing of security clearances is controlled and issued through the local Government authorities. The checks include a criminal history check and a politically motivated violence check.

4.1.3 Ammonia

Anhydrous ammonia is toxic and flammable (DG Class 2.3 toxic gas). It is a gas at normal temperature and pressure but may be liquefied under moderate pressure (630 kPag at 15^{o}C) or at temperatures below -33^{o}C at atmospheric pressure.

At low concentrations in air, ammonia vapour irritates the eyes, nose and throat. Ammonia is very soluble in water, therefore as it enters the body, it is readily absorbed. Irritation is immediate and local to the point of entry. Inhalation of high concentrations produces a sensation of suffocation and quickly causes burning of the respiratory tract and may result in death.

Anhydrous liquid ammonia causes severe burns on contact with the skin and if swallowed, it will cause very severe corrosion in the mouth, throat and stomach. Severe eye damage may result from direct contact with the liquid or exposure to high gas concentrations. Long term disability is mainly due to corneal and respiratory injuries.

The exposure limits for ammonia are summarised in Table 3.

Table 3 – Ammonia Exposure Limits

Material	Odour Threshold	Exposure Limit (ppm)		IDLH (ppm)	Injury mechanism
		TWA	STEL		
Ammonia	5 to 53 ppm	25	35	300	Irritant

Ammonia is flammable in air in a concentration range of 16 - 25% by volume but it does not readily ignite (the minimum ignition energy is 100 mJ, compared with 0.29 mJ for methane). Ignition is therefore difficult and the probability of an explosion in the open air is low. The auto-ignition temperature of ammonia is 651°C (relatively high compared to hydrocarbon materials).

Ammonia decomposes into flammable hydrogen gas at approximately 450°C.

Given the difficulty of ignition, the relatively narrow flammability range and typical operating conditions, ammonia storage and distribution installations are not generally regarded as significant fire or unconfined explosion hazards.

Water spray can be used to absorb vapour releases but should not be sprayed on pools of liquid ammonia as this will cause the liquid to rapidly vaporise (ammonia dissolves exothermically in water). If water is used for vapour absorption, a minimum of 100 volumes of water must be available for each volume of ammonia.

The transport of liquefied ammonia in a tank or bulk container made of quenched and tempered steel is prohibited unless the liquefied ammonia contains not less than 0.2wt% water. Stress corrosion cracking can occur, e.g. due to the presence of oxygen in ppm, if water is not present for these materials of construction.

4.1.4 Sulphur Oxides

Sulphur dioxide and sulphur trioxide would be produced within the sulphuric acid plant at the mine site. In the sulphuric acid plant, sulphur dioxide is formed by the combustion of sulphur in a burner. The sulphur dioxide is catalytically converted to sulphur trioxide in a fixed bed reactor. The sulphur trioxide is absorbed in weak acid to produce sulphuric acid.

Both gases are toxic but non-combustible.

Sulphur dioxide is a colourless gas with a characteristic pungent and suffocating odour. The TWA (Time Weighted Average – concentration) is 2 ppm and the STEL is 5 ppm. Repeated exposure to the gas (>10 ppm) may cause lung effects including constriction and inflammation of the lungs and reduced lung function. The IDLH (immediately dangerous to life and health) is 100 ppm. Sulphur dioxide is an air contaminant and a constituent of smog. As the gas is heavier than air, it can accumulate in sumps, pits etc. In the presence of moisture, sulphur dioxide will form sulphurous acid (H_2SO_3) which is corrosive.

Sulphur trioxide, on release, will react with water in the atmosphere and form a dense cloud of visible (white) acid mist. The mist is likely to contain submicron droplets which remain airborne until they absorb additional water and rain out or are deposited onto surfaces. With regard to the effects of the acid mist formed, a LC_{50} (lethal concentration for 50% mortality) of 60 mg/m^3 for a 60 minute exposure is typical of most reported data.

4.2 POTENTIAL HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of HIPAP No 6, (Ref 3), it is necessary to identify hazardous events associated with the facility's operations. As recommended in HIPAP No 6, the PHA focuses on "atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water".

In keeping with the principles of risk assessments, credible hazardous events with ***the potential for off-site effects*** have been identified. That is, local events with limited impact or "slips, trips and falls" type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake.

Given that the nearest place of residence is approximately 2.4 km away from the hazardous materials, only a limited number of potential hazardous events can have off-site impact. This was the basis for the original approved PHA in 2000 (Ref 2). As examples, large pool fires in the solvent extraction area have the following distances to various levels of radiant heat.

Table 4 – Pool Fire Scenarios

Pool Fire Scenario	SEP (kW/m^2)	Distance to Specified Radiant Heat Level (m)		
		23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2
10 m diameter pool fire	56	4	9	19
50 m diameter pool fire	20		3	36

"SEP" is the surface emissive power (i.e. the radiant heat level of the flames).

From Table 4, there will be no adverse radiant heat impact from pool fires at the site's boundary. Therefore, these events do not contribute to the off-site risk criteria shown in Table 1 and can be ignored in this analysis (consistent with the methodology in the approved PHA from 2000, Ref 2).

Similarly for jet fires, Ref 2 included various jet fire scenarios with estimated flame lengths up to 30 m. As with pool fires, no adverse off-site impact is expected given the separation distance of greater than 1 km.

In preparation for the PHA conducted in 2000, a one day hazardous event identification exercise was conducted. For completeness, the results from this exercise are shown in Appendix 1. The events that are no longer relevant to the modified design have been removed.

The identified credible, significant incidents with the potential for off-site impacts for the proposed facility and modifications are summarised in the following Hazard Identification Word Diagram (Table 5). This diagram presents the causes and consequences of the events, together with major preventative and protective features that are to be included as part of the design.

Table 5 – Hazard Identification Word Diagram

Event Number	Hazardous Event	Causes	Consequences	Proposed Safeguards - Prevention Detection Mitigation
1	Loss of containment from the natural gas pipeline	External interference, e.g. pipe damaged by excavation activities. Corrosion. Exceeding the maximum allowable operating pressure. Weld failure. Ground movement or ground erosion by water	Potential for failure of the natural gas line and a jet fire, flash fire and/or explosion (if the gas is confined) if ignited. This can cause injury to people, and damage to property and the environment	Pipeline designed to AS2885 including signage along the pipeline route. This includes aspects associated with pipeline such as design and construction, welding, operation and maintenance, and field pressure testing. The pipeline would be buried deep to lower the risk of third party damage and recorded for Dial-Before-You-Dig purposes. Pressure monitoring for leak detection
2	Decomposition of the Ammonium Nitrate Emulsion (ANE)	ANE subjected to heat, confinement and impurities. Sympathetic detonation	Potential for the ANE to explode. This can cause injury to people, and damage to property and the environment	ANE would be delivered and stored in precursor form and only mixed at point of use. All explosives handling will be compliant to the relevant Australian Standards and by trained personnel
3	Large loss of containment of ammonia	Ammonia tank failure, e.g. due to stress corrosion cracking. Catastrophic failure of a large pipe or transfer hose conveying liquid ammonia	Release of ammonia which is both a toxic and flammable hazard. The ammonia would disperse downwind with the potential to impact people. At high concentrations, ammonia can also cause corrosive impact to vegetation	Tanks designed to AS2022. See the recommendations in this PHA for further safeguarding

Event Number	Hazardous Event	Causes	Consequences	Proposed Safeguards - Prevention Detection Mitigation
4	Release of sulphur dioxide or sulphur trioxide	Fugitive emissions from vessel holding hot molten sulphur. Leak or rupture at acid plant due to mechanical failure or impact, e.g. suction seals, valves, blower, piping, vessel or heat exchanger, transport or cranage accident. Loss of absorption in acid plant absorption tower, e.g. loss of reflux liquid	Release of sulphur dioxide or sulphur trioxide at ground level or through the stack. Toxic gases are dispersed downwind. Acute effects only (no long term effects). Corrosion of nearby structures	Regular maintenance. Computer control and monitoring of the acid plant. Stack emissions monitoring. Operator training and surveillance. Automatic shutdown of plant on upset conditions. Sulphur dioxide monitors located throughout the plant. Mechanical protection of the plant from traffic etc, e.g. bollards, walls. Appropriate materials of construction. Visual indication of release (white plume)

5 HAZARDOUS EVENTS ASSESSMENT

5.1 NATURAL GAS SUPPLY PIPELINE FAILURE

The natural gas pipeline was assessed in the 2000 PHA (Ref 2) and subsequently approved. The following is an update of the previously approved pipeline assessment.

Natural gas would be supplied to the site from a lateral of the Moomba to Sydney gas pipeline. The majority of the pipeline run would be within the road reserve. It would be laid underground and setback a minimum safety distance from all residences in accordance with Australian Standard AS2885 (Pipelines – Gas and Liquid Petroleum).

The pipe route has been selected to avoid sensitive areas, thereby taking public safety into consideration. This includes routing the pipe around the outskirts of Condobolin.

The major hazards associated with the pipe are loss of containment from leaks (e.g. due to mechanical damage) leading to fires (jet and flash) and explosions.

To reduce the likelihood of these events from occurring, the pipe is to be laid in accordance with the relevant standards and codes (e.g. AS2885). Measures recommended in this standard to reduce the likelihood of loss of containment include burial to avoid damage from hostile events (e.g. sabotage), corrosion protection features (e.g. corrosion allowance on wall thickness, approved material of construction and cathodic protection), flow monitoring (by computer controls) and fracture control plans (including means of isolation), signage, deep burial and large wall thickness to protect against common digging activities (e.g. ploughing, digging and fence post drilling), and minimisation of joints (and hence potential leak points and hazardous areas for electrical equipment selection).

Given that the natural gas pipe is to be run to avoid sensitive areas and would be installed with mitigation features as detailed in such standards as AS2885, acceptable levels of risk result would be attained.

Data for pipeline failure is available from a number of sources but one of the most recent, comparable data sets is from the United Kingdom's Health and Safety Executive (HSE) (Ref 8).

The HSE have researched pipeline releases in the United Kingdom over a 45 year period and determined a current failure rate of approximately 2.8×10^{-5}/year.km. This is for small, medium and large releases. Note the HSE data assumes the pipelines are in use 100% of the time.

The probability of ignition of flammable gas releases is dependent on the size of the release but is reported (Cox, Lees and Ang, Ref 9) as being from 1 to 30% depending on the size of the leak. As a conservative assumption, a 30% probability of ignition is taken for a leak of natural gas.

Therefore, the likelihood of a release and ignition is:

$$L = 2.8 \times 10^{-5}/\text{yr.km} \times 0.3 = 8.4 \times 10^{-6}/\text{yr.km or } 8.4 \times 10^{-9}/\text{yr.m}$$

The results from ignition include a jet fire, a flash fire and/or an explosion if the natural gas is confined.

The above low likelihood for a release and ignition supports the anecdotal evidence in Australia that gas and liquid lines built to the Australian Standards, e.g. AS2885, have a low failure rate. The low likelihood of releases and ignition plus construction to recognised codes confirms that the SFARP (So Far As Reasonably Practicable) principle is met.

5.2 EXPLOSIONS

5.2.1 Explosives

Explosives at the limestone quarry were assessed and approved in the 2000 PHA (Ref 2). The following assessment is from this report.

> *Explosives will be used at the limestone quarry. The use of explosives shall be as per standard mining and regulatory practice, e.g. detonators stored separately to explosive charges, purpose built storage facilities, static protection facilities and strict procedural control enacted by well trained personnel. Historically, these practices have proven to be adequate in avoiding unplanned explosions with off-site impacts. As such, the risk of a spurious explosion involving the explosives stored on the limestone quarry site is deemed to be acceptable. This judgement is based on the assumption that the quarry site will have a quality safety management system in place and in use for the life of the facility.*

As part of the Modification, explosives may be used at the mine site. Similarly to the limestone explosives, it would be stored and used as per the requirements of the Australian Standards.

If explosives are to be used at the mine site, initial information provides the following:

Type: Ammonium nitrate emulsion (ANE)

Quantity: Approximately 25 tes

Whilst storage and use as per the Australian Standards provides risk assurance for explosives, there are ways for it to decompose, e.g. impurities and heat whilst confined.

The TNT equivalence for ANE is approximately 0.8. For 25 tes ANE, the equivalent mass of TNT is 20 te. Using the TNT explosion model, the distances to selected explosion overpressures are shown in Table 6.

Given the distance to the nearest site boundary from the explosive storage area is approximately 920 m then the criteria shown in Table 6 are satisfied.

Table 6 – Explosive Overpressures

Explosion Scenario	Distance to Specified Overpressure Level, m		
	21 kPa	14 kPa	7 kPa
25 te ANE	206	265	410

The consequences of various levels of overpressure generated from vapour cloud explosions are shown in Table 7 (Ref 1).

Table 7 – Effects of Explosion Overpressures

Overpressure kPa	Effect
3.5	90% glass breakage No fatality and very low probability of injury
7	Damage to internal partitions and joinery but can be repaired Probability of injury is 10%. No fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort Storage tanks fail 20% chance of fatality to a person in a building
35	Houses uninhabitable Trucks and plant items overturned Threshold of eardrum damage 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open
70	Threshold of lung damage 100% chance of fatality for a person in a building or in the open Complete demolition of houses

5.2.2 Process Explosions

The 2000 PHA (Ref 2) reviewed the following potential process explosions (note that process explosions associated with the equipment that has now been removed from the design are not included):

1. Hydrogen explosions within sulphuric acid storage tanks (the tanks would be continuously vented to prevent this); and
2. Explosions within sulphur burner (or downstream equipment) in the sulphuric acid plant (robust burner management system used including trips).

As discussed in Ref 2, both these events have local impacts only and would not impact people (due to overpressures) at the nearest site boundary.

5.3 TOXIC GAS RELEASES

As identified in Section 4, large releases of sulphur oxides and ammonia have the potential to impact people off-site. The 2000 PHA (Ref 2) assessed releases of sulphur oxides and hydrogen sulphide. The latter is no longer part of the processing plant's design and hence is not included in this report.

The 2000 PHA toxic gas modelling basis is included in Appendix 2 for information.

The DoP risk criteria of importance for this rural site are:

- Irritation, injury and fatality risk at a place of residence. The nearest place of residence is the 'Sunrise' house located 2.4 km from the processing plant. Note that HIPAP No 4 defines the one in a million criterion assuming that residents would be at their place of residence (taken to be the house) and exposed to the risk 24 hours a day and continuously day after day for the whole year; and
- Fatality risk to be contained within the boundary of an industrial site, i.e. no more than 50x10-6/yr.

As the processing areas where the hazardous materials are stored and handled are a significant distance from the site's boundary and the nearest place of residence, e.g. the ammonia storage is approximately 420 m from the nearest site boundary, then only the releases that have the potential to cause irritation, injury and/or fatality at these locations are assessed (consistent with the 2000 PHA approach).

Meteorological Data

The meteorological data used in this PHA comprises an updated set of five dominant weather/wind combinations (Pasquill stability category / wind speed) for the area and has been used as the basis for all dispersion calculations. This is based on 2016 data with hourly measurements for 365 days.

The probability of the relevant combined weather/wind category and wind direction (data is split into 8 directions) is used in the calculation of toxic impact at the nearest place of residence ('Sunrise') and the nearest site boundary. Both these locations are to the southwest of the processing plant. The wind direction of interest is therefore northeast.

The meteorological data used for this risk assessment, sourced from the Condobolin Bureau of Meteorology weather station, is shown in Table 8.

Table 8 – Stability Class / Wind Speed

Wind Direction	Stability Class / Wind Speed (m/s)					
	Percentages:					
	D5.9	D2.4	E5.8	E2	F2	
N	4.5	3.1	2.4	2.9	5.0	
NE	2.7	2.4	2.5	2.7	2.9	
E	1.9	3.4	1.2	3.9	2.3	
SE	1.3	3.0	0.4	2.0	1.0	
S	1.6	3.2	0.8	1.8	1.0	
SW	5.5	3.9	2.8	3.1	2.7	
W	4.4	3.5	1.7	3.3	2.6	
NW	1.5	1.8	0.5	1.5	1.4	
Totals:	23.4	24.2	12.4	21.3	18.7	100

From a review of the data in Table 8, there is a slight bias for northern and southwestern winds.

5.3.1 Sulphur Oxides Releases

Releases of sulphur oxides were assessed in the 2000 PHA (Ref 2). The following is an update of this work, i.e. taking into consideration the 2016 atmospheric stability classes / wind speeds as well as the increased sulphuric acid plant rates.

Sulphuric acid would be produced in a conventional style, sulphur burning acid plant. After the burner, the sulphur dioxide is reacted over a fixed bed catalyst system to form sulphur trioxide. The sulphur trioxide is absorbed in acid to form the required 98 wt% sulphuric acid. Overhead gases from the absorber are vented to atmosphere.

These types of plants run at low pressure (typically 24 kPag after the burner) and hence there exists a low driving force for releases. Gas stream temperatures of 80^oC or higher are normal.

Sulphur trioxide is present in the process from the reactor to the absorption tower. Any releases from these areas (including failure of absorption reflux flow) would immediately form white clouds as the sulphur trioxide readily forms sulphuric acid when combined with atmospheric moisture. The sulphuric acid mist generated becomes a dense cloud which partly rains out on to the ground and other surfaces.

This strong affinity of sulphur trioxide with water makes accurate modelling of sulphur trioxide clouds difficult, particularly over large distances such as that to the nearest place of residence. The approach taken in this analysis is to model releases of sulphur dioxide to determine the significant effects, if any, at the nearest place of residence and site boundary. Depending on these results, off-site effects of sulphur trioxide releases can be surmised. Whilst sulphur dioxide also reacts with atmospheric moisture, the reaction is not as fast as that of sulphur trioxide and is not taken into account in the modelling of releases.

The composition of the sulphur dioxide stream varies from plant to plant (e.g. depending on the sulphur sources), and, of course, within each plant. In this study, a composition of 18vol% sulphur dioxide in air is used (typical maximum value).

Release scenarios were only performed for the cases where the plant was kept operating. Once the plant is stopped, the low pressure in the equipment minimises the flowrate of further releases.

Release conditions are summarised as follows:

Plant rate (gas stream after burner)	65 kg/s
Sulphur dioxide rate	25 kg/s
Pressure	24 kPag
Temperature (approximate)	80°C
Release height (approximate pipe rack level)	5 m

Given this temperature, the density of the sulphur dioxide stream when it is released to atmospheric pressure was calculated to be 1.22 kg/m^3. As this is approximately the same as air at 15°C (1.23 kg/m^3), the plume is treated as having neutral buoyancy and it is modelled by using the Gaussian neutral gas dispersion correlations. The simulations involving large releases are based on a release duration of one minute (at full plant rate). Large releases would become known (visual, noise and smell as well as process monitoring alarms and trips) soon after the catastrophic failure, hence it is realistic to assume shutdown within one minute. For the smaller releases (from 50 mm holes or smaller), release durations of 15 minutes are modelled (to determine the worst case effect distances). This time allows for operator intervention to manually control and/or stop the leak.

Toxic Impact of Sulphur Dioxide

The toxicity effects of sulphur dioxide are summarised in Table 9.

Table 9 - Effects of Sulphur Dioxide

Exposure Level (ppm)	Duration (minutes)	Effects
0.3	60	ERPG 1
3		ERPG 2
25		ERPG 3

The three ERPG (emergency response planning guidelines) tiers are defined as follows:

- **ERPG-3** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
- **ERPG-2** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-1** is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.

Given the above definitions, ERPG 1 (0.3 ppm) and 2 (3 ppm) are taken as the limits for irritation and injury, respectively.

One level of fatal toxicity used by United Kingdom HSE (Health and Safety Executive) in relation to the provision of land use planning advice is termed the Specified Level of Toxicity (SLOT). The HSE has defined the SLOT as:

- Severe distress to almost everyone in the area;
- Substantial fraction of exposed population requiring medical attention;
- Some people seriously injured, requiring prolonged treatment; and
- Highly susceptible people possibly being killed.

The SLOT value for sulphur dioxide is $4.655\text{x}10^6$ ppm^2.min. Hence, for a 1 minute exposure, the required average concentration is 2,160 ppm, or for a 15 minute exposure, the required average concentration is 560 ppm. The SLOT values are used to determine if fatality at the nearest place of residence and site boundary from a release is possible.

Sulphur Dioxide Release Cases Modelled

The following scenarios involving sulphur dioxide releases were modelled for the five dominant stability classes and wind speeds in Table 8. Concentrations at the nearest place of residence and site boundary are calculated.

1. Catastrophic vessel failures or full pipe fractures. The release rate is modelled as full plant rate for one minute.
2. Piping and vessels failures corresponding to the various hole sizes discussed in Appendix 2 (15 minutes duration).

The results for Scenario 1 above are shown in Table 10. Whilst there is a plantation across the road from the releases, the modelling is performed based on parkland and bushes given the land use beyond the plantation.

The distances used in the modelling have been measured from the sulphuric acid plant to the nearest residential dwelling (i.e. Sunrise) and the nearest property boundary.

Table 10 – Sulphur Dioxide Release Modelling – Catastrophic Failures

Stability Class / Wind Speed	Concentration (ppm) at Nearest Residence (2.4 km)	Concentration (ppm) at Nearest Boundary (75 m)
D5.9	18	8,600
D2.4	18	21,000
E5.8	39	13,000
E2	42	36,000
F2	123	39,600

Given the results in Table 10 then irritation and injury (but not fatality) are possible at the nearest place of residence and also fatality at the nearest site's boundary due to catastrophic equipment failures. The corresponding risks are analysed in Section 6 of this PHA.

The results for Scenario 2 above are shown in Table 11.

Table 11 – Sulphur Dioxide Hole Release Modelling

Stability Class / Wind Speed	50 mm Hole (0.2 kg/s)	
	Concentration (ppm) at Nearest Residence (2.4 km)	Concentration (ppm) at Nearest Boundary (75 m)
D5.9	0.32	70
D2.4	0.78	170
E5.8	0.73	105
E2	2	295
F2	6	310

The flowrates from 25 mm diameter or smaller holes are too low to impact people at the locations of interest.

Given the results in Table 11 then irritation and injury (but not fatality) are possible at the nearest place of residence due to releases through a 50 mm hole. The corresponding risks are analysed in Section 6 of this PHA.

The concentrations at the nearest site boundary are not expected to cause fatality.

From the 2000 PHA (Ref 2), with regard to sulphur trioxide releases, it was discussed previously that sulphur trioxide reacts readily with atmospheric moisture to form sulphuric acid which, being a dense mist, rains out significantly on to the ground and nearby structures. Given the predicted low sulphur dioxide levels from releases from 50 mm holes (or less) would only just cause impact at the nearest place of residence, it can be surmised that sulphur trioxide releases from these size holes are unlikely to have any significant off-site impacts. However, for a worst case release at full plant rates involving the sulphur trioxide steam, off-site effects can certainly be expected at the nearest site boundary. This is included in the risk analysis in Section 6 of this report.

5.3.2 Ammonia Releases

Releases of ammonia were not assessed in the 2000 PHA (Ref 2) as ammonia storage and handling was not part of the original design.

Anhydrous ammonia is to be delivered by road tanker and is transferred to the two anhydrous ammonia storage bullets (100 te capacity each).

Vapour from the bullets passes through the Compressor Knockout Vessels, the Ammonia Unloading Compressors and then back into the ammonia road tanker, i.e. so that liquid ammonia can be transferred into the bullets.

The liquid discharge from the bullets passes through a vaporiser before being distributed to the process at a rate of 1 kg/s (corresponds to approximately 31,500 te/year).

Losses of containment of ammonia can therefore be from:

- Container transfers;
- The storage bullets; and
- Piping including the vaporiser.

It is estimated that an average three ammonia deliveries per day would take place (1 container at 30 tonnes per container per delivery truck).

Ammonia is normally a heavy gas when modelled due to cooling when flashed and also absorption of water from the atmosphere. Therefore, it is modelled with the heavy gas model (SLAB) within Effects.

Toxic Impact of Ammonia

The toxicity effects of ammonia are summarised in Table 12.

Table 12 - Effects of Ammonia

Exposure Level (ppm)	Duration (minutes)	Effects
25	60	ERPG 1
150		ERPG 2
1,500		ERPG 3

The above exposure limits are quite conservative given the following information from the Australian Standard (AS2022) for ammonia (Ref 10):

Up to 100 ppm – no adverse effect for the average worker with no deliberate exposure for long periods permitted.

400 ppm – immediate nose and throat irritation with no serious effect after 30 minutes to one hour.

700 ppm – immediate eye irritation with no serious effect after 30 minutes to one hour.

1,700 ppm – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 30 minutes.

2,000-5,000 ppm – convulsive coughing, severe eye, nose, and throat irritation; could be fatal after 15 minutes.

Over 5,000 ppm – respiratory spasm, rapid asphyxia and fatal within minutes.

To be consistent with the sulphur oxides modelling, ERPG 1 (25 ppm) and 2 (150 ppm) are taken as the limits for irritation and injury.

The SLOT value for ammonia is 3.78×10^8 ppm^2.min. Hence, for a 1 minute exposure, the required average concentration is 19,440 ppm, or for a 15 minute exposure, the required average concentration is 5,020 ppm. The SLOT values are used to determine if fatality at the nearest place of residence and site boundary from a release is possible.

Ammonia Release Cases Modelled

The following scenarios involving ammonia releases were modelled for the five dominant stability classes and wind speeds in Table 8. Concentrations at the nearest place of residence and the site boundary are calculated. The location at the site boundary is adjacent to the sulphuric acid plant so that cumulative risk can be estimated.

1. Catastrophic storage bullet failures. The release quantity is taken as an average of 50 te per bullet.
2. Liquid releases from piping, transfer hose and vessel failures corresponding to the various hole sizes discussed in Appendix 2 (15 minutes duration).
3. Vapour releases from piping, transfer hose and vessel failures corresponding to the various hole sizes discussed in Appendix 2 (15 minutes duration).

Scenario 1 – Catastrophic Bullet Failure:

The results for Scenario 1 above are shown in Table 13. The modelling is performed based on regular large obstacles as the ammonia plume travels first through the plant and then through the plantation across the road.

Table 13 – Ammonia Release Modelling – Catastrophic Failures

Stability Class / Wind Speed	Concentration (ppm) at Nearest Residence (2.9 km)	Concentration (ppm) at the Boundary (510 m)
D5.9	1,230	25,900
D2.4	78	16,500
E5.8	1,920	30,600
E2	-	17,200
F2	-	21,000

Note: The distances used in the modelling have been measured from the ammonia storage and handling area to the nearest residential dwelling (i.e. Sunrise) and the nearest property boundary.

For the E2 and F2 conditions, the vapour would layer and be largely held by the plant structures and surrounding plantation without dispersing as far as the other weather / wind combinations. This has been observed with historical releases of liquid ammonia.

Given the results in Table 13 then irritation and injury (but not fatality) are possible at the nearest place of residence due to catastrophic storage bullet failures. Also, the concentrations predicted at the nearest site boundary are sufficiently high to cause fatality.

The corresponding risks are analysed in Section 6 of this PHA.

It is noted that historical releases of ammonia (including the 7,000 te release in Lithuania in 1989) have not resulted in fatalities beyond 200 m. Hence, the modelling results are very conservative.

Scenario 2 – Liquid Releases:

The results for Scenario 2 are shown in Table 14 and Table 15.

Table 14 – Ammonia (Liquid) 50 mm Hole Release Modelling

Stability Class (Wind Speed [m/s])	50 mm Hole (rate = 36 kg/s)	
	Concentration (ppm) at Nearest Residence (2.4 km)	Concentration (ppm) at the Boundary (420 m)
D (5.9)	160	2,600
D (2.4)	90	3,800
E (5.8)	350	4,300
E (2)	-	5,500
F (2)	-	9,700

This rate, i.e. 36 kg/s, is equivalent to 130 te/hr. Whilst this would exceed the transfer rate into the bullets, the results would be indicative for liquid releases from the transfer hose.

Table 15 – Ammonia (Liquid) 25 mm Hole Release Modelling

Stability Class / Wind Speed	25 mm Hole (rate = 9.3 kg/s)	
	Concentration (ppm) at Nearest Residence (2.9 km)	Concentration (ppm) at the Boundary (510 m)
D5.9	41	N/A
D2.4	28	N/A
E5.8	75	N/A
E2	-	N/A
F2	-	N/A

As above, for the E2 and F2 conditions, the vapour would layer and be largely held by the plant structures and surrounding plantation without dispersing as far as the other weather / wind combinations. This has been observed with historical releases of liquid ammonia.

Given the results shown in Table 14 and Table 15 then irritation and injury (but not fatality) are possible at the nearest place of residence due to liquid ammonia releases. There is a risk of fatality at the site boundary for some weather / wind combinations.

The corresponding risks are analysed in Section 6 of this PHA.

Scenario 3 – Vapour Releases:

The design plant vapour ammonia rate is 1 kg/s. This rate is modelled to determine the potential consequential impacts. This rate is also indicative of the vapour flow to the container when performing transfers.

The results for Scenario 3 are shown in Table 16.

Table 16 – Ammonia Vapour Release Modelling

Stability Class / Wind Speed	Rate = 1 kg/s	
	Concentration (ppm) at Nearest Residence (2.9 km)	Concentration (ppm) at the Boundary (510 m)
D5.9	4	70
D2.4	10	240
E5.8	10	210
E2	27	420
F2	82	1,600

The plant design ammonia vapour rate does not result in concentrations at the boundary sufficient to result in fatality. Irritation impact at the nearest place of residence is possible for the E2 and F2 conditions only.

The corresponding risks are analysed in Section 6 of this PHA.

5.4 TRANSPORT INCIDENTS

5.4.1 Road

Road transport was assessed in the 2000 PHA (Ref 2). The following is an update of this assessment given the modifications.

Chemicals transported by road would, where relevant, be transported in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref 11).

The expected frequency and quantity of deliveries of the bulk Dangerous Goods to the site is given in Table 17.

Hazardous materials that are less frequently delivered include flocculant, diluent, oxalic acid, extractant, caustic, hydrogen peroxide, sodium hypochlorite and explosives and are not included (typically one or less deliveries per week).

Table 17 – Bulk Chemicals Road Transport Frequencies

Material Transported	Approximate Number of Deliveries to Site	Approximate Annual Usage
Ammonia	3 single containers per day	31,500 te
Hydrochloric Acid	2 single containers per day	16,600 te
Formic Acid (IBCs)	1 every two days	3,500 te

Materials such as hydrated lime, soda ash, diesel, SMBS, the nickel, cobalt and scandium products, amsul and quicklime are not classified as dangerous goods for transport by road and rail and therefore are relatively safe to transport in bulk form (subject to road and rail usage regulations). Shellsol and diesel are both combustible liquids. The transport of these types of materials in approved road tankers throughout Australia is commonplace and of low risk.

The packaged chemicals delivered by road transport in IBCs (intermediate bulk containers), drums, bulk bags or cylinders, again, would be transported in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail. The main usage of these chemicals is for dosing systems, shutdown replacements and topping up storages. The small packaged volumes with low usage rates pose minimal transport risks due to loss of containment. Mitigation of risks is also provided by the proposed use of approved transport companies through their safety management systems and emergency response plans.

Both hydrochloric acid and formic acid are corrosive liquids. Formic acid is also a subsidiary risk flammable liquid. If these materials are involved in a traffic accident, the primary risk to people, the environment and property is the corrosive nature of the fluids (including vapours). Formic acid could also combust if ignited.

The main new road transport hazard is ammonia. If a road tanker carrying ammonia is involved in an accident and the vessel integrity is lost then there is the potential for serious injury and fatality for people involved in the accident or those nearby.

Causes for road tanker accidents are summarised in Table 18 (Ref 12).

Table 18 – Causes for Road Tanker Accidents

Human Error	Equipment Failures	System or Procedural Failures	External Events
• driver impairment, eg. alcohol or drugs • speeding • driver overtired • driver exceeding safe working hours • en-route inspection • contamination • overfilling • other vehicle's driver • taking tight turns/ramps too quickly (overturns) • unsecured loads	• non-dedicated trailer • rail road crossing guard failure • leaking valve • leaking fitting • brake failure • relief device failure • tyre failure • soft shoulder • overpressure • material defect • steering failure • sloshing • high centre of gravity • corrosion • bad weld • excessive grade • poor intersection design • road chamber/width • suspension system • tyre fire caused by friction, brakes overheating or exploding tyres give sparks due to metal in the rubber) • fuel tank fire (diesel)	• driver incentives to work longer hours • driver training • carrier selection • container specification • route selection • emergency response training • speed enforcement • driver rest periods • maintenance • inspection • time of the day restrictions	• vandalism/sabotage • rain • fog/visibility • wind • flood/washout • fire at rest area/parking areas • earthquake • existing accident • animals on road

A detailed analysis of heavy vehicle risks in NSW was performed for the Cowal Gold Project (Ref 13). This study found the following typical heavy vehicle accident rates for similar road routes:

> 0.016 - 2.96 Heavy Vehicle Accidents/Annual Million km of Heavy Vehicle Travel

This data compares well with reported data, e.g. the Centre for Chemical Process Safety (CCPS) guidelines (Ref 12) quote a figure of approximately 2 accidents/year (for all causes) per 10^6 miles, i.e. 1.2×10^{-6} accidents per kilometre per year.

In the event of an accident involving a heavy vehicle, the carried goods may or may not be released. The probability of release is dependent on factors such as speed, shipping conditions (i.e. pressurised versus non-pressurised), inadequate load securing, and strength and integrity of the container.

Various studies of release probabilities from heavy vehicles involved in an accident have been undertaken. The Guidelines for Chemical Transportation Risk Analysis (CCPS, 1995, Ref 12) indicates that the release probability for various road types is between 5 and 10% (i.e. approximately one heavy vehicle accident in every 10 to 20 would result in a release of the material). The probability of fatality then has to be taken into account but this would depend on factors such as the leak size.

Given the history of road tanker transport in NSW, compliance with the Australian Dangerous Goods Code (an indicator of achieving SFARP (so far as reasonably practicable)) and the above representative data then the risk of an accident involving a vehicle transporting a hazardous material such as ammonia to the site resulting in a release of material is therefore relatively low.

5.4.2 Rail

The following is an update of the rail assessment from the 2000 PHA (Ref 2).

For this development, rail transport primarily concerns the movement of sulphur from the stockpile in Newcastle, NSW, to the proposed rail siding. The proposed number of return train trips per week is approximately three. To avoid congestion in the Sydney rail network as well as steep grades in the crossing of the Blue Mountains (i.e. minimise the likelihood of an accident), it is proposed that trains to and from the site use a route via Muswellbrook, Ulan, Dubbo, Narromine and Parkes to Bogan Gate.

The significant hazards are the potential for the sulphur to catch alight and emit toxic fumes (e.g. sulphur dioxide). The sulphur could catch alight due to ignition whilst in transit (e.g. arson, lightning strike or static) or due to an accident involving the train.

Radiant heat effects due to burning sulphur are localised only. Any loss of containment during transport would be responded to as per the proposed emergency response plans for the site to avoid contamination of waterways etc.

Sulphur is classified as a flammable solid (4.1), Packing Group III (minor danger only). It is routinely transported in bulk around the world. Separation from non-compatible materials and elimination of ignition sources are the major measures taken to avoid incident.

Protection features for the bulk transport of sulphur by rail to the proposed siding include minimal dust in the bulk sulphur (prilled form), proposed water sprays at all transfer points, local fire brigades (for water application), electrics (such as motors) rated for the hazardous area zones, separation from non-compatible materials and static protection. Small fires can be smothered with sand or even with additional sulphur. The sulphur remains within the shipping containers until it is taken to the site.

Given the proposed protective features associated with the rail transport of sulphur, the low likelihood of ignition of sulphur within the containers and the accepted risk of transport of bulk sulphur by road or rail throughout Australia and the world, the overall risk of an incident involving sulphur with significant consequences during rail transport is considered low. No further analysis (i.e. quantification of risks) of the transport of bulk sulphur to this site is deemed necessary.

The product metals are also likely to be transported from the site by rail. The nickel and cobalt sulphates and scandium oxide products would be stored and transported in bulkabags, not as a bulk concentrate.

5.5 NATURAL AND OTHER EXTERNAL HAZARDOUS EVENTS

The site has been assessed with regard to exposure to the following external hazards:

Subsidence
Burst dam
Storm and high winds
Flood
Lightning
Vermin/insect infestation
Landslide
Earthquake
Rising water courses
Storm water runoff
Forest fire
Security

Given the current proposed location of the project components, there are no obvious significant hazards amongst this list that could result in on-site events leading to serious off-site impacts.

6 RISK ANALYSIS

6.1 HIPAP 4 RISK CRITERIA

As discussed in Section 5.3, the DoP risk criteria of importance for this rural site are:

- Irritation, injury and fatality risk at a place of residence; and
- Fatality risk to be contained within the boundary of an industrial site, i.e. no more than 50×10^{-6}/yr.

Given there are a minimal number of materials and events that can cause off-site impact, the updated analysis in this PHA was done on the same basis as the 2000 PHA (Ref 2). That is, model the sulphur dioxide and ammonia release cases for the five dominant stability class / wind directions to determine which events can contribute to off-site risk. The results are shown in Section 5.3.

These results are then analysed using event likelihoods (United Kingdom HSE 2012 data used, Ref 15), probits, the probability of use (e.g. transfer hoses) and the probability that the stability class / wind direction exists. The analysis is shown in Appendix 3 along with further explanation of the assumptions and data sources. The total estimated risks at the nearest place of residence and the site boundary are compared to the HIPAP 4 risk criteria (Ref 4) in Table 19.

Table 19 – Comparison to HIPAP 4 Risk Criteria

Risk Type	HIPAP No 4 Criteria	Estimated Risk or Likelihood	Comments
Irritation	50×10^{-6}/yr	4.7×10^{-6}/yr	Compliant
Injury	10×10^{-6}/yr	2.1×10^{-6}/yr	Compliant
Fatality	50×10^{-6}/yr	9.3×10^{-7}/yr	Compliant

The assessment was done on a conservative use of stability class / wind direction data. The above estimated risk values are likely to be conservatively high.

Given the separation distance between the processing plant and both the nearest place of residence and site boundary then all other risk criteria are satisfied. For example, it is not credible that radiant heat from a pool fire can travel over 2 km.

6.2 CUMULATIVE AND PROPAGATION RISK

Given the rural location, the generous separation distances and that significant consequential impacts largely remain on-site then it is reasonable to conclude that the modified development does not make a significant contribution to the existing cumulative risk in the area.

There is the potential for on-site propagation events, e.g. a diluent fire causing another loss of containment. However, as shown in the report, the separation distances mitigate the impacts from the potential hazardous events, either occurring in isolation or due to propagation from other events, and that the off-site risk is acceptable.

6.3 SOCIETAL RISK

Societal risk results are usually presented as F-N curves which show the frequency of events (F) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the results for different risk levels, a societal risk curve can be produced.

Societal risk is normally calculated where the 1 pmpy contour (or calculated risk level) approaches closely to residential areas or sensitive land uses or when events with very large consequence distances are being assessed. Hence, the potential exists for multiple fatalities as a result of a single accident.

In this study, there is a risk of fatality at the nearest site boundary, however, the surrounding area is rural with the nearest place of residence being 2.4 km from the processing plant. At this location, there is no estimated risk of fatality. Therefore, societal risk at residential and other types of land users is acceptable.

6.4 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations. Whereas any adverse effect on the environment is obviously undesirable, to have an incident with such consequences requires exposure of a sensitive area to either large effect, short term releases or smaller effect, long term releases. For this site, the latter includes seepage from the tailings storage facility and continuous gas emissions, e.g. from the stacks. These events are assessed separately within the Environmental Assessment for the Modification and are not included here.

Given the limited number of events (large effect, short term releases) that can occur at this site with off-site impacts and the rural nature of the surrounding area, the risk to people and other biological groups (animals and plants) is low. This has been shown by analysis in Section 6.1.

In summary, whilst off-site effects can be expected if a major release were to occur, there are no identified whole systems or populations which are at unacceptable levels of risk due to the potentially hazardous events reviewed in this PHA.

For completeness, risks to the biophysical environment due to significant loss of containment events are summarised below.

6.4.1 Escape of Materials to Atmosphere

The potential events that could lead to the escape of significant quantities of harmful materials to the atmosphere (and the effects / mitigation features available) are summarised as follows:

1. Dust release from stockpiles (water sprays and dust suppressant to be used);
2. Ammonia releases (analysis as per Section 5.3.2 of this PHA). See the recommendations in this study as the transfers to the storage vessels pose the highest off-site risk;
3. Products of combustion from fires (hydrocarbon fires typically generate carbon dioxide and water which readily disperse due to buoyancy of the plume);
4. Sulphur oxide releases (including sulphuric acid mist) from the sulphuric acid plant (generally, containment is within process piping and equipment and startup emissions etc are dispersed via the plant stack) or from sulphur fires (sulphur fires are slow burning, easy to detect and typically smothered to extinguish); and
5. Loss of containment of process gases, e.g. hydrogen and natural gas (if released, these types of gases readily disperse due to their low molecular weights).

6.4.2 Escape of Materials to Soil or Waterways

The potential events that could lead to the escape of significant quantities of harmful materials to the soil or waterways (and the effects / mitigation features available) are summarised as follows:

1. Loss of containment of acidic liquids or other hazardous liquid within the process or storage areas (all areas bunded to contain spills, disposal of spills on an as needs basis);
2. Loss of containment of hazardous liquids outside of bunded areas (site stormwater and effluent systems route all flows to the treatment plant area, thereby minimising the chance of harmful soil or waterways effects);
3. Rupture of tailings pipe (high integrity pipe design, instrumentation and visual inspection to be used to monitor flow problems); and
4. Loss of containment from the tailings storage facility, surge dam or evaporation pond (conformance to dam safety regulations including routine monitoring of dam's structural condition).

6.5 CONCLUSION AND RECOMMENDATIONS

The risks associated with the modified mine and processing facility have been assessed and compared against the DoP risk criteria.

The results are as follows and show compliance with all risk criteria.

Description	Risk Criteria	Risk Acceptable?
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5 x 10^{-6} per year	Y
Fatality risk to residential and hotels	1 x 10^{-6} per year	Y
Fatality risk to commercial areas, including offices, retail centres, warehouses	5 x 10^{-6} per year	Y
Fatality risk to sporting complexes and active open spaces	10 x 10^{-6} per year	Y
Fatality risk to be contained within the boundary of an industrial site	50 x 10^{-6} per year	Y
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50 x 10^{-6} per year	Y
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 x 10^{-6} per year	Y
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50 x 10^{-6} per year	Y
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50 x 10^{-6} per year	Y

Societal risk, area cumulative risk, propagation risk, transport risk and environmental risk are also concluded to be acceptable.

The primary reason for the low risk levels from the modified site is the separation distances between the hazards the nearest place of residence and also the site boundary.

The highest contributor to off-site risk is a release of ammonia, in particular, from transfer operations to the storage vessels. The second highest risk contributor involves generic release cases for holes in vessels and piping (typical for all processing facilities). It is expected that the design review process followed by the Hazard and Operability (HAZOP) study would mitigate the generic release cases to acceptable levels. This would include designing to AS2022 for the ammonia storage and handling systems. The following recommendations are made to lower the off-site risk from the main contributor, i.e. releases of ammonia.

1. Ensure that the final design includes means to automatically isolate the ammonia road tanker (or container) and storage vessels should a release during a transfer occur (vapour and liquid lines). Actuation should be local as well as remote;
2. Provide closed circuit television (CCTV) coverage of the ammonia transfer area to the plant's control room;
3. Provide means to isolate the ammonia flow to the plant should a release occur. This should be at each storage vessel;
4. Provide means to suppress an ammonia vapour plume. A plume could occur due to a release from the transfer system, the storage vessels or the plant supply lines. Options include spray deluge for the transfers bay and fire water monitors in the transfer and storage area. The latter can be operated remotely (preferable) or manually (may require the use of a full protective suit with self-contained breathing air). Monitors can be fixed or portable;
5. Provide means for road tanker driveaway protection. This could include interlocks on the vehicles brakes or self-sealing devices in the transfer lines;
6. Include the transfer hoses and couplings (dry-break preferred) in the preventative maintenance system. The transfer hoses would need to be regularly inspected, tested and replaced as per the manufacturers recommendations;
7. Provide means for preventing stress corrosion cracking in the ammonia storage vessels and include the vessels in the preventative maintenance system for routine internal inspections;
8. Provide wind socks at appropriate locations to allow people to decide the best means of escape from an ammonia plume;
9. Provide alternate emergency assembly areas given that an ammonia plume can travel in any direction;
10. Provide means for protection for the ammonia road tanker / container driver should a release occur, e.g. safehouse;
11. Apply good practice for building design, e.g. design buildings as safehouses should relevant guidelines recommend this. For example, design buildings as per the recommendations in the Chemical Industries Association guideline, "Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites";
12. Provide overfill protection on the ammonia storage vessels. This system should be reviewed via a Safety Integrity Level (SIL) analysis; and

13. Provide means to prevent the vapour compressor from overpressuring the vapour return line and/or the road tanker / container.

Appendix 1

Hazardous Events from the 2000 PHA

PPreliminary Hazard Analysis for the Syerston Project

Modification 4

Appendix 1 – Hazardous Events from the 2000 PHA.

Hazard Identification for the Main Ore Processing Plant

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Dust release from stockpiles	Wind blown	Siliceous geothite ore is 20-30% silicon (processed in plant after year 5) Dust release could lead to silicosis issues	Water sprays on stock piles and hoppers Dust suppressant used
Loss of process water to scrubber in high pressure acid leach (HPAL) area	Pump fails, closed valve etc	Acid mist, steam and particulates released "Red mud rain" Local effects only due to low flow and concentrations Operator exposure	Low velocity release (<2 m/s) Process alarms and trips Operation monitoring by operators
Release of sulphuric acid (either feed acid or an acidic ore solution)	Loss of autoclave seals due to corrosion, erosion (high acid velocities), weld / fabrication defect, loss of seal cooling water etc Pipe break or equipment failure due to corrosion etc Diaphragm pump failure (PAL feed pumps), eg corrosion in the casing Tanks or vessels overfilled	Loss of containment of sulphuric acid or acidic ore solution Possibility of local spraying of acid with acid mist generation (local event only) Operator exposure	Pressure vessels designed to AS 1210 Piping designed to relevant piping codes, eg ANSI B31.3 All plant areas processing sulphuric acid or acidic ore solution are bunded (either concrete or earth) Concrete bunded areas are lined (acid resistant) Bund volumes are sufficient to contain entire acid hold-up volumes within equipment and piping Pipes designed for low fluid velocities to avoid acid erosion problems Bund sump pumps installed to pump lost acid for neutralisation prior to delivery to tailings Acid supply can be stopped by closing double isolation valves Leaks from pipes carrying acid or acidic solutions outside of bunded areas flow to the dirty water pond

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
			(lined) for treatment Correct materials of construction
Lifting PSV on PAL autoclave	Autoclave overfill	Pressurised release of steam and acid	PSV vented to a safe location Delivery pumps unable to achieve PSV set pressure Instrumentation monitoring, including alarms, warning operators of the likelihood of lifting the PSV Containment philosophy as above
Internal explosion in acid storage tanks	Build-up of hydrogen due to acid reacting with metals, ignition from static etc	Equipment damage Release of acid Operator exposure Possibility of “missiles”	Tanks and process vessels are continuously vented Containment philosophy as above
Carbon dioxide release from Leach Residue Neutralisation Tanks	Neutralisation with limestone generates carbon dioxide (a simple asphyxiant)	Carbon dioxide could fill sumps, pits etc, thereby reducing the oxygen concentration	Dispersion of carbon dioxide due to height of release Confined space entry procedures which include oxygen monitoring
Rupture of tailings pipe	Erosion Corrosion Water hammer	Spillage to ground leading to soil and groundwater pollution	High integrity pipe design Instrumentation to be installed to detect loss of flow (with automatic shutdown) On-site effect only due distance to boundary Spill response procedures
Loss of containment from tailings dam, surge dam or evaporation pond	Wall failure	Environmental effects (pollution off-site)	Conformance to dam safety regulations Dams and pond designed for minimal leakage rates Monitoring bores and toe drains used Can transfer between dams and pond

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Belt fire on conveyor	Overheating of belt at pulley	Belt fire only (eg the filter concentrate is too wet to burn)	Anti-slip protection on belts Routine maintenance and inspections Fire protection, eg hydrants (contaminated firewater contained on-site)
Loss of containment of the diluent in the solvent extraction or storage areas and subsequent fire	Pipe or vessel leaks Pipe breakage Flange failure Pump leaks (eg seal failures) Tanker transfer hose failure Tanker driveaway Vessel overflows Hot pump bearing	Pool fire if liquid is ignited Products of combustion (eg carbon oxides, water)	Hazardous area controls (eg minimisation of ignition sources) Fully bunded area (storage tanks to AS 1940) Fire protection and suppression systems (eg foam for pool fires and heat activated foam-water deluge system) Contaminated firewater contained on-site Routine maintenance to detect probable leak points Operator control and instrumentation monitoring
Carbon bed fire (solvent extraction area)	Organics absorbed onto the carbon with oxygen and a source of ignition present (eg maintenance activity)	Smouldering type fire, possibility to propagate to a diluent pool fire	Control over ignition sources during maintenance Routine operations unlikely to cause fires (no oxygen present in enclosed system) Infrared detection system (sprinkler system to deluge automatically) Foam fire suppression system

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Pool fire at API water-oil separator	Oil, diesel runoff to API separator is collected and a source of ignition is present	Pool fire involving oil etc	Only combustible materials are collected in separator (low ignition risk) Electrical hazardous area safeguards Control of ignition sources, e.g. permits to work API separator isolated from other plant items (no propagation risk) Local event only – no off-site fire effects

Hazard Identification for the Steam and Power Plants

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Natural gas release from pipe or fittings outside roofed areas	Leak or failure of pipe or fittings due to: • corrosion • impact • fire/explosion • earthquake • fabrication fault	Torch fire (resulting from immediate ignition) Flash fire or explosion (resulting from delayed ignition)	Piping design (material specification, fabrication testing) and inspection Painting Pipe located away from impact sources Control of ignition sources Isolation of supply
Natural gas release from pipe or fittings inside roofed area	As above	Fire (explosion possible if gas is trapped in confined space) Damage to building Possibility of "missiles"	As above, plus, where possible, plant design and layout will encourage the dispersion of gas leaks
Steam or condensate leak	Leak or failure of pipe or fittings due to: • corrosion • impact • fire/explosion • earthquake • fabrication fault • erosion • high temperature creep	Scalding, impact damage	Piping design (material specification, fabrication testing) and inspection Pipe sections buried, other sections to be located away from impact sources Isolation of supply Control of outlet steam quality Visible nature of small leaks (allowing corrective action for small leaks)
Turbine exhaust gas leak from casing	Leak or failure of pipe or fittings due to: • corrosion • impact • fire/explosion • earthquake • fabrication fault • erosion • high temperature creep	Burns Asphyxiation Fire	Materials specifications, design and construction codes, correct installation, post fabrication testing Location away from impact sources Routine inspection and maintenance Carbon dioxide extinguisher system Local effects only

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Mechanical failure of a gas turbine	• Overspeed • Corrosion • Erosion • Fatigue/creep • Impact • Bearing failure • Lubrication failure • Deposition • Fabrication failure • Combustion zone explosion • Earthquake • External fire	Impact damage, hot gas escape, fire, burns, hydraulic oil escape	Robust automatic control and trip system Materials specifications, design and construction codes, correct installation, post fabrication testing Air and gas filtration Robust, proven casing designs Gas purity control
Mechanical failure of the steam turbine	As above for gas turbines	Impact damage, scalding	As for gas turbine except, • Erosion prevented by steam quality control and trip system • Deposition: high quality demineralised water used
Mechanical failure of boilers (heat recovery steam generator or auxiliary boiler)	• Relief system failure • Corrosion • Erosion • Impact • Fabrication failure • Combustion zone explosion • Earthquake • External fire or explosion	Impact damage, burns scalding	Routine maintenance and testing Materials specifications, design and construction codes, and correct installation Demineralised water quality, air and gas filtration Location and guard rails Automatic control and trip system Firefighting systems
Mechanical failure of diesel generators	• Overspeed • Corrosion • Impact • Bearing failure • Lubrication failure • Fabrication failure • Earthquake • External fire or explosion	Impact damage, fire	Routine maintenance and testing Materials specifications, design and construction codes, and correct installation Location and guard rails Automatic control and trip system Firefighting systems

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Loss of containment of diesel fuel or lubricating oils	Impact Tanker, hose, or storage vessel failure Tanker driveaway Handling error Overfilling Corrosion Pipe leaks	Diesel contained by bunding Pool fire (if ignited) Oil mist fire could result if hot oil mist forms and is ignited	Inspection and maintenance procedures Materials specification Operator training Instrumentation monitoring of tank levels Control of ignition sources Firefighting systems
Loss of containment of transformer insulating oil	Impact Overpressure due to overheating (e.g. due to electrical problem) inside transformer casing External fire Transformer explosion due to major electrical fault or lightning strike	Pressure released via vent causing spillage (contained by bunding) Pool fire if ignition source present or ignited by or after an explosion	Guard rails, suitable location away from likely impacts Routine electrical maintenance Control of ignition sources Appropriate electrical design to minimise the effects of lightning and electrical disturbances Firefighting systems

Hazard Identification for the Sulphur Handling and Sulphuric Acid Plants

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Release of sulphur dioxide or sulphur trioxide	Fugitive emissions from vessel holding hot molten sulphur Failure of stack fan Leak or rupture at acid plant due to mechanical failure or impact, e.g. suction seals, valves, blower, piping, vessel or heat exchanger, transport or cranage accident Loss of absorption in acid plant absorption tower, e.g. loss of reflux liquid	Release of sulphur dioxide or sulphur trioxide at ground level or through the stack Toxic gases are dispersed Acute effects (no long term effects) Corrosion of nearby structures	Regular maintenance Computer control of the acid plant Operator training and surveillance Automatic shutdown of plant on upset conditions Sulphur dioxide monitors located throughout the plant Mechanical protection of the plant from traffic etc, eg bollards, walls Appropriate materials of construction Visual indication of release (white plume)
Release of sulphuric acid	Leak at piping, valves, pumps and associated equipment inside storage tanks bund or within the acid plant boundary (impact, mechanical damage, corrosion, erosion) Sample point left open Tank overfill Damage to pumps from running against a closed head Dry pump damage Loss at tanker unloading bay (used at initial plant startup and periods of high acid demand)	Release of acid forming pools inside bunds Personnel injury if in contact If water added, production of fumes and heat Explosive reactions with non-compatible materials	Bunds can contain volume of acid within plant equipment and tanks. Also, the tanker unloading bay is a contained area Spills can therefore be neutralised prior to pumping away Storage tanks to be fitted with high level instrumentation Operators will be trained in safe handling of products and use of protective equipment Periodic maintenance and control (manual and instrumented) of lines and pumps Emergency response procedures to be prepared for handing spills Safety showers and eye wash stations to be installed Segregation from non-compatible materials (e.g. natural gas)

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Development of hydrogen vapours in sulphuric acid pipeline or storage tanks	Corrosion of steel	Possibility of hydrogen embrittlement of the steel at high points Danger of ignition of hydrogen during maintenance etc	Protective coatings in tanks Acid strength is maintained (presence of water induces corrosion) Any hydrogen developed in the storage tanks will be vented away (via the tank vent) Hydrogen detection before maintenance Earthing of pipeline prevents excessive build-up of electrostatic charges
Natural gas fire (natural gas supplied to sulphur burner for startup purposes)	Leak from piping (hole or rupture), valves, flanges, etc. (impact, mechanical damage, corrosion, stress)	Immediate ignition – local torch fire Delayed ignition – flash fire or vapour cloud explosion (explosion overpressures generated) Equipment damage Injury to personnel	Piping design to appropriate codes and standards, e.g. ANSI B31.3 Routine maintenance and inspection procedures Fire protection system, e.g. hydrants
Explosion in sulphur burner or downstream equipment	Incorrect burner startup sequence Sulphur entrainment from the burner	Build-up of natural gas and/or sulphur in burner prior to ignition Explosion when ignition takes place Equipment damage Injury to personnel Possibility of missiles	Robust, proven burner management system to be used Operator training in startup procedures Purging cycles to avoid the build-up of flammable atmospheres Most likely outcome – energy of explosion damaging local equipment only

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Sulphur fires	Ignition source at stockpiles, e.g. front end loader, hot ash from diesel engines, or at the molten sulphur tank area	Sulphur fire evolving sulphur oxides. Potential to impact people, equipment and the environment	Stockpile wetting and control Small fires typically extinguished by smothering (in some cases by adding more sulphur on top to starve the fire of oxygen) Larger fires can be flooded with water Operator training and vigilance (smell is a very early indicator of sulphur fires) Front-end loaders safety features include spark arrestors on the exhausts and heat protection around the engines

Hazard Identification for the Fuel Farm and Reagents Storage Areas

Possible Hazardous Event	Possible Initiating Events	Possible Consequences	Prevention / Protection Measures
Loss of containment of diesel fuel from a 60 000 L tank (vehicle filling) Note: The diesel supply tank (5 000 L) for the emergency generator was included in the steam and power plants section. Loss of containment from the 1 000 L tank (firewater pump) as per the 5 000 L tank but with smaller effects	Impact Tanker, hose, pump, bowser or storage vessel failure Tanker driveaway Handling error Overfilling Corrosion Pipe leaks	Diesel contained by double lined tank or bund walls Pool fire (if ignited)	Inspection and maintenance procedures Materials specification Operator training Instrumentation monitoring of tank levels Control of ignition sources Firefighting systems
Loss of containment of reagents, e.g. caustic soda, hydrochloric acid, SMBS, oxalic acid, formic acid, hydrogen peroxide or sodium hypochlorite	Impact Tanker, hose, pump or storage vessel failure Tanker driveaway Handling error Overfilling Corrosion Pipe leaks	Release of corrosive and/or oxidising fluid (contained by bunding, including the tanker unloading area)	Inspection and maintenance procedures Materials specification Operator training Instrumentation monitoring of tank levels Spill response plans including neutralisation and disposal procedures

Appendix 2

2000 PHA Toxic Gas Modelling Basis

Preliminary Hazard Analysis for the Syerston Project

Modification 4

Appendix 2 – 2000 PHA Toxic Gas Modelling Basis

Given these large distances to the nearest place of residence, the assessment approach taken in this PHA is to analyse all incidents that may have an effect (e.g. irritation, injury and/or fatality) at this location as well as at the site's nearest boundary (for fatality risk). This approach is taken as the majority of identified incidents have no effect over such a large distance, e.g. a diluent pool fire would have no thermal effects at distances of approximately 500 metres and hence rigorous analysis is unnecessary. This approach would allow detailed assessment of, and hence draw attention to, the significant hazardous events. This approach would also aid in the determination of plant design requirements to mitigate the risks from these significant hazardous incidents as well as influence the plant's safety management systems and emergency response plans.

The consequence calculations in this PHA were carried out using commercially available risk assessment software, TNO's Effects (Ref 14). The consequence models used within Effects are well known and are fully documented in the TNO Yellow Book (Ref 14).

Essentially, for each scenario defined by the analyst (e.g. those events considered significant and likely to have an impact at the nearest place of residence and boundary), an appropriate release rate is calculated by using established equations within Effects. Data pertinent to the release conditions, including the initial state of the material, is included in the calculations.

Once the release conditions and rate have been determined, the likely outcomes (e.g. toxic gas release) are modelled. The results from these simulations (e.g. plume concentrations from toxic gas releases) are used to determine the effect on people, property and/or the environment.

The scenarios identified in Section 4 are the basis of the risk assessment. The significant events that involve fires, explosions and toxic gas releases are analysed further in this PHA. The basis for each analysis is given in the corresponding section to define the conditions of release for each event. This also includes assumptions made for each scenario.

Release Sources

For gas or liquid release scenarios, piping failures have been analysed using four failure cases. These are full pipe fracture, 50 mm, 13 mm, and 3 mm holes. Gasket failure is likely to result in a gap equivalent to the area between two flange bolts and is included in the analysis where relevant. This is considered equivalent to a 13 mm diameter hole size. Vessel failures have been analysed as catastrophic rupture and leaks of 50 mm, 25 mm, 13 mm and 6 mm. These generic failure cases are comparable to those used in a number of published risk assessment studies and described in Lees (Refs 15 and 16).

Release Rates

Release rates were calculated for each release scenario using standard equations based on hole size, pressure, temperature and material state (i.e. gas or liquid). Where the calculated release rate was greater than the maximum possible process rate (for example, if the flow was limited by the sulphur burning rate), the release rate was specified as equal to the limiting production rate. The maximum release inventory was also limited to the contents of the plant equipment plus the amount lost over the duration of the leak (variable depending on the leak rate).

Release Duration

The assumed time taken to stop and control a release is based on a credible estimate of a release scenario rather than always taking a worst case approach (in accordance with quantitative risk analysis principles).

For any scenarios where automatic shutdown of the plant occurs on detection of the hazardous event, a release duration of 1 minute has been chosen. This is consistent with the reported methodologies in Lees (Ref 16) and the approach taken within the Orica ISORIS risk assessment package (Ref 17). Also, if any worst case events occur (e.g. catastrophic rupture within the sulphuric acid plant where large visible clouds occur along with numerous alarms and trips) which are immediately obvious to the operators (24 hour manning), a release duration of one minute has been chosen.

For smaller leak scenarios which rely on manual response to stop and control the release (i.e. where operator intervention is required to stop the leak, usually by shutting down production or closing valves), release duration of between 6 and 30 minutes can be expected. The duration depends on the means to alert the operators of the release (e.g. process alarms) as well as the closeness of the release to the operators (i.e. smell, sight and/or noise may indicate a release if the operator is nearby). In this assessment, release duration for small leaks is assessed individually as described in the appropriate section.

Given that the plants are to be designed to the latest design standards which would include comprehensive monitoring via programmable electronic systems, it can be expected that sufficient alarms and trips would exist to warn the operators of significant abnormal plant behaviour. This expectation can be verified in the FHA and HAZOP studies if the project goes ahead. As such, the nominated release durations are judged to be achievable.

As a further means to mitigate the release duration (and hence release quantity), it is proposed to install emergency isolation valves (EIVs) on the inlets and outlets of all equipment processing the more hazardous materials (e.g. the ammonia storage vessels). Once a plant trip is initiated, these EIVs would shut, thereby boxing in sections of pipework and equipment. Hence, the amount released and the release duration are minimised.

For the sulphuric acid plant, shutting the plant down quickly stops releases as these plants run at low pressure (typically up to 24 kPag). Hence, there is little driving force for losses once the plant is stopped.

For any process plant, once the plant is stopped, the maximum amount released (and hence maximum duration) is limited by depressurising to atmospheric pressure if a pipe or vessel failure has occurred.

Appendix 3

Risk Analysis

Preliminary Hazard Analysis for the Syerston Project

Modification 4

Appendix 3 – Risk Analysis

The risk analysis performed for this PHA is shown on the table below (pages A3.4 and A3.5)

The notes associated with the calculations and shown in the table are:

1. Liquid ammonia lines estimated to be approximately 50 m, i.e. from containers to bullets and to the vaporiser.
2. Includes the ammonia vapour supply line as well as the vapour line back to the containers.
3. United Kingdom HSE data used for all likelihoods.

This failure rate includes catastrophic failures as well as 50 mm holes.

4. Same basis as the 2000 PHA (Ref 2).
5. Transfer failure rate is (United Kingdom HSE data):

0.2×10^{-6}/operation x 3 transfers per day x 340 days per year = 2×10^{-4}/yr

Note: Allowance for shutdowns and other periods taken to be 25 days.

6. Holes can occur in the pipework and vessels.
7. Holes and failures can occur in the pipework and vessels plus transfer hose failures.
8. Probits for sulphur dioxide and ammonia (from Ref 18):

$$Y = a + b\ln(tC^n)$$

where

- Y = probit value
- C = concentration of the toxic gas in ppm
- t = duration of exposure in minutes
- tC^n is referred to as the *Toxic Load*
- a, b, n are constants (unique for each gas)

Chemical	a	b	n
Ammonia	-9.82	0.71	2.0
Sulphur dioxide	-23.70	1.14	3.7

9. The widths of the plumes are estimated to be up to 70 m at the nearest place of residence. This results in a narrow angle for the plume (i.e. in the 'Y' direction) and hence the wind direction that can cause impact. The angle of the plume is increased to 5^o to allow for modelling inaccuracies. The probability that the wind is blowing towards the nearest residence is then taken to be (5/45) times the values for wind blowing from the northeast. Outside of this arc, the plume is not expected at the place of residence.

Risk Analysis:

Scenario	Stability Class Wind Speed	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Probability of System in Use	Vessels Failure Likelihood, times/yr	Number of Vessels	Transfer Hose Failure Likelihood, times/yr	Event Likelihood, times/yr	Probit Value	Probability of Fatality	Probability of Wind Direction	Contribution to the Following Risks: (times/yr)		
												Irritation	Injury	Fatality
						Note 4:			Note 8:		Note 9:			
Sulphur Dioxide - Catastrophic Failures	D5.9				4.00E-06	8		3.20E-05	15	1	0.003	9.60E-08	9.60E-08	9.60E-08
	D2.4				4.00E-06	8		3.20E-05	18	1	0.0027	8.64E-08	8.64E-08	8.64E-08
	E5.8				4.00E-06	8		3.20E-05	16	1	0.0028	8.96E-08	8.96E-08	8.96E-08
	E2				4.00E-06	8		3.20E-05	21	1	0.003	9.60E-08	9.60E-08	9.60E-08
	F2				4.00E-06	8		3.20E-05	21	1	0.0032	1.02E-07	1.02E-07	1.02E-07
		Note 4:	Note 3:					Note 6:						
Sulphur Dioxide - 50 mm Holes	D5.9	500	1.40E-07		5.00E-06	8		1.10E-04			0.003	3.30E-07		
	D2.4	500	1.40E-07		5.00E-06	8		1.10E-04			0.0027	2.97E-07		
	E5.8	500	1.40E-07		5.00E-06	8		1.10E-04			0.0028	3.08E-07		
	E2	500	1.40E-07		5.00E-06	8		1.10E-04			0.003	3.30E-07		
	F2	500	1.40E-07		5.00E-06	8		1.10E-04			0.0032	3.52E-07	3.52E-07	
Ammonia - Catastrophic Failures	D5.9				4.00E-06	2		8.00E-06	5	0.5	0.003	2.40E-08	2.40E-08	1.20E-08
	D2.4				4.00E-06	2		8.00E-06			0.0027	2.16E-08		
	E5.8				4.00E-06	2		8.00E-06	5	0.5	0.0028	2.24E-08	2.24E-08	1.12E-08
	F2				4.00E-06	2		8.00E-06	4	0.15	0.0032	2.56E-08		3.84E-09
		Note 1:					Note 5:	Note 7:						
Ammonia (liquid) - 50 mm Holes	D5.9	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04			0.003	6.36E-07	6.36E-07	
	D2.4	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04			0.0027	5.73E-07		
	E5.8	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04			0.0028	5.94E-07	5.94E-07	
	E2	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	4	0.15	0.003			9.54E-08
	F2	50	5.00E-07	0.08	5.00E-06	2	2.00E-04	2.12E-04	5	0.5	0.0032			3.39E-07
		Note 1:												
Ammonia (liquid) - 25 mm Holes	D5.9	50	5.00E-07	0.08	5.00E-06	2		1.21E-05			0.003	3.63E-08		
	D2.4	50	5.00E-07	0.08	5.00E-06	2		1.21E-05			0.0027	3.26E-08		
	E5.8	50	5.00E-07	0.08	5.00E-06	2		1.21E-05			0.0028	3.38E-08		

Scenario	Stability Class Wind Speed	Pipe Length, m	Pipe Failure Likelihood, times/yr.m	Probability of System in Use	Vessels Failure Likelihood, times/yr	Number of Vessels	Transfer Hose Failure Likelihood, times/yr	Event Likelihood, times/yr	Probit Value	Probability of Fatality	Probability of Wind Direction	Contribution to the Following Risks: (times/yr)		
												Irritation	Injury	Fatality
		Note 2:	Note 3:				Note 5:							
Ammonia Vapour Releases	E2	150	6.00E-07		5.00E-06	2	2.00E-04	1.00E-04			0.003	3.00E-07		
	F2	150	6.00E-07		5.00E-06	2	2.00E-04	1.00E-04			0.0032	3.20E-07		
TOTALS												4.71E-06	2.10E-06	9.32E-07

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