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Report

Preliminary Hazard Analysis

Acid Alkaline Neutralisation Process

Toxfree

26 Apr 2016
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Report Details

Preliminary Hazard Analysis - Acid Alkaline Neutralisation Process

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TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

Advitech Pty Limited (Advitech) was engaged by PEP Consulting (PEP) on behalf of ToxFree Pty Ltd (Toxfree) to undertake a Preliminary Hazard Analysis (PHA) primarily concerning the Toxfree St Marys Acid Alkaline Neutralisation (AAN) process.

The AAN treatment system aims to consolidate acid and alkali packaged wastes currently received at the site. The proposed AAN process combines corrosive liquids to create a neutral pH solution. Once quantified, the risk profile of the AAN has been added to the quantified risk profile associated with the existing operations for comparison with accepted risk criteria thresholds.

It should be noted that this report was prepared by Advitech Pty Limited for PEP Consulting ("the customer") in accordance with the scope of work and specific requirements agreed between Advitech and the customer. This report was prepared with background information, terms of reference and assumptions agreed with the customer. The report is not intended for use by any other individual or organisation and as such, Advitech will not accept liability for use of the information contained in this report, other than that which was intended at the time of writing.

1.1 Site Location and Surrounding Land Users

Toxfree operates a Chemical Waste Storage and Treatment Facility at 40 Christie Street, St Marys in New South Wales (NSW) (Lot 431 DP854814) (**Figure 1**).

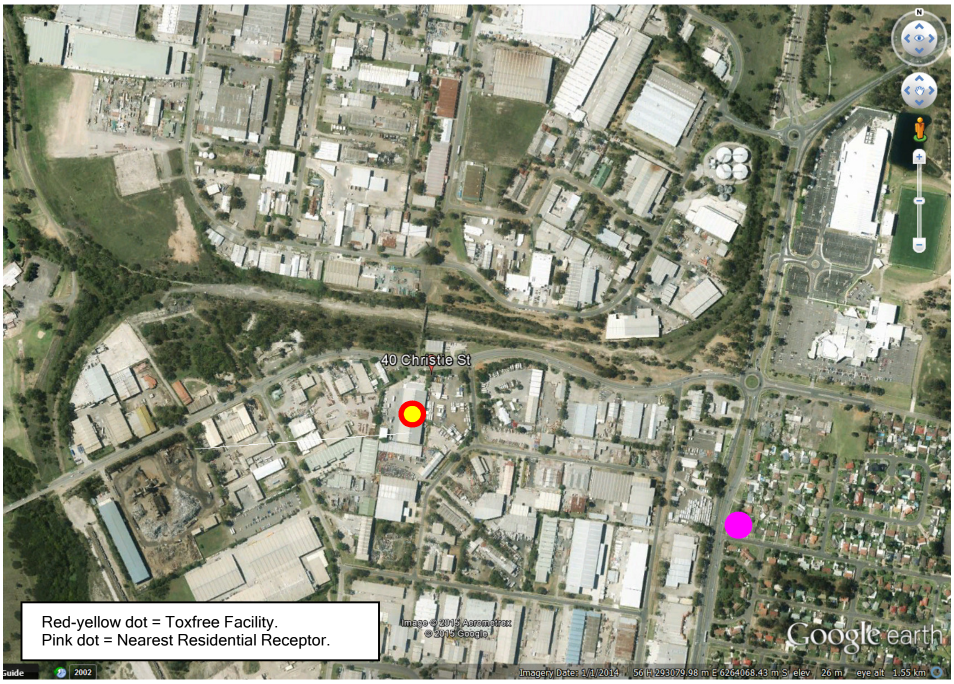

Figure 1: Site Location (courtesy of Google Earth)

The allotment is part of Precinct 2 Dunheved/St Marys (Industrial Land) under the *Penrith Development Control Plan*, 1996. It is zoned 4(a) General Industry. The surrounding land use is primarily industrial; with the closest residential property approximately 600 metres to the east of the site.

1.2 Project Description

In 2015 a Modification Application (MP 06_0095 MOD 3) was submitted by Toxfree to the NSW Department of Planning & Environment (DoPE) requesting proposed modifications to the following treatment processes:

- AAN;
- Chemical Immobilisation and Stabilisation; and
- Solidification Bins.

The Director General's requirements request further assessment of the AAN process, in particular, chemical reaction and chemical products (including any intermediates) and the probability of formation of toxic gases.

The Toxfree facility currently undertakes the storage, and limited processing of waste chemicals. Toxfree is proposing to incorporate the AAN process for the consolidation of collected discrete acid and alkali liquid wastes.

A wide range of waste chemicals are currently transported to the Toxfree facility by road transport. The trucks are unloaded within the bunded "unloading area" of the warehouse building. The waste chemicals are sorted into the relevant warehouse or processing area.

The Toxfree facility currently undertakes a limited number of processes on site including:

- Flammable processing, can crusher and paint recovery;
- Laboratory services; and
- Fluorescent lamp resource recovery.

These processes have been previously subjected to hazard and operability (HAZOP) studies, and are not the primary focus of this PHA. However, the composite risk profile for the site is to be calculated and compared to the relevant DoPE acceptance criteria.

In addition to these processes, a number of dedicated storage locations are used to collect and store hazardous and dangerous goods. These storage depot locations will be changed following the proposed development.

The proposed development will utilise the existing structures and bunded areas located within the warehouse area on the site. Currently Toxfree management are evaluating three possible AAN process locations within the existing warehouse structure. The three AAN process locations under consideration are:

1. "Sorting Area". This is due to the chlorine and cyanide detectors as a gas control measure;
2. "Oil Decant Area". Away from main handling/weigh-in area; or
3. "Existing Caustic Area".

The current site layout and proposed locations of the AAN process is shown in **Figure 2**.

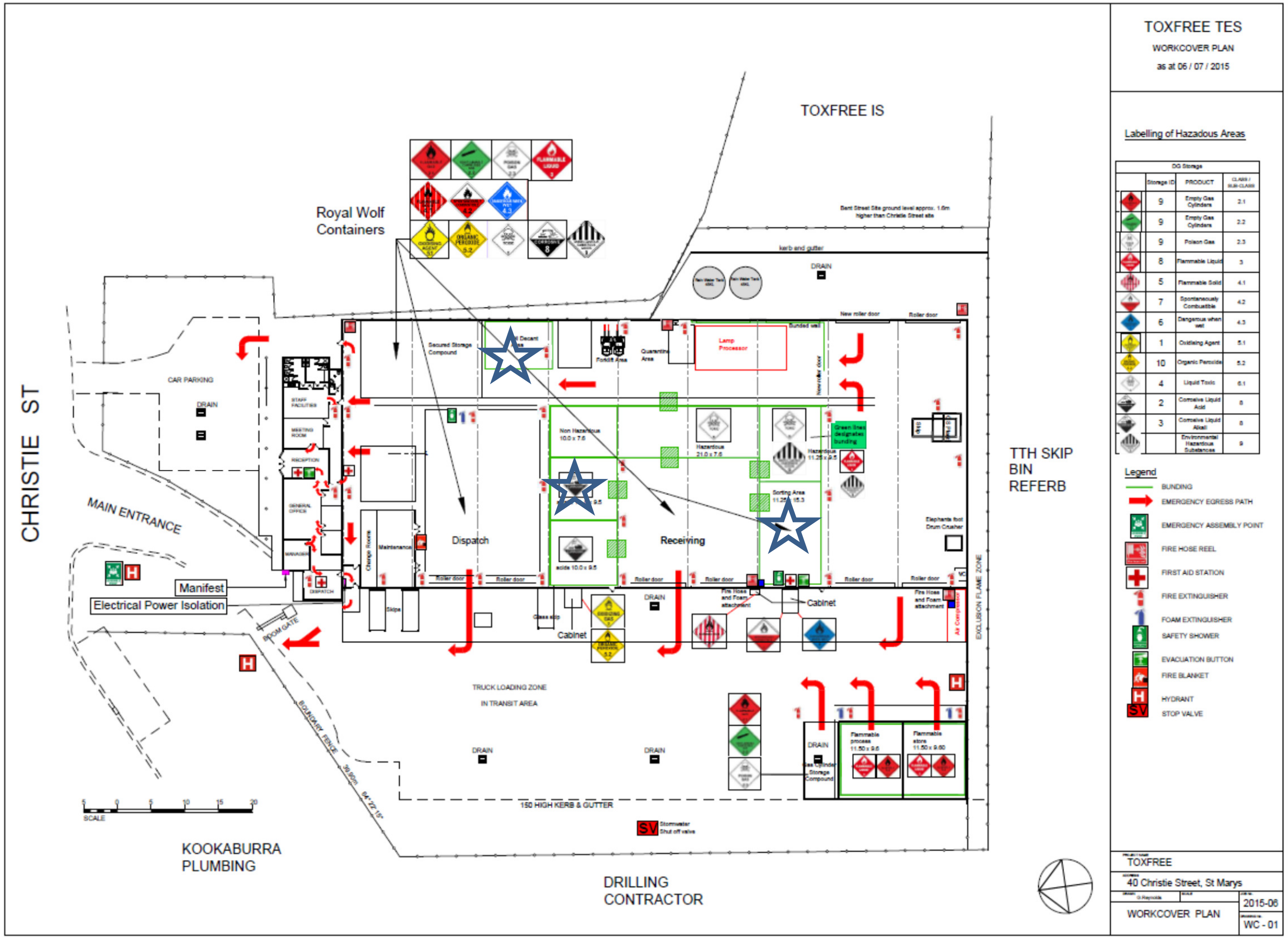

Figure 2: Current Site Layout and Proposed AAN Processing Locations (stars)

1.3 Process Description - AAN Process

The AAN treatment system aims to consolidate packaged wastes currently received at the site. Containers of acids or alkalis are received from schools, laboratories, universities and households via NSW Environment Protection Authority (EPA)/local council collections. Acids received typically include sulphuric acid (H_2SO_4), hydrochloric acid (HCl) and acidic based cleaners. Alkalis include lime (calcium hydroxide (CaOH) or calcium oxide (CaO)), sodium hypochlorite (NaHOCl), and sodium hydroxide (NaOH). Currently, containers are received, packed onto pallets and transported to the Toxfree Links Road facility where they are decanted into acid or alkali intermediate bulky containers (IBCs). The AAN process combines acid and alkali liquid wastes in a monitored and controlled process to create a neutral pH solution. The current process and instrumentation diagram (PID) is attached in **Appendix V**.

The AAN process will not treat any type of isocyanate or cyanide type liquid wastes. These wastes, under adverse conditions, can generate very toxic hydrogen cyanide gas. Toxfree will segregate these wastes using trained chemists with treatment and disposal undertaken at an off-site facility.

The AAN process is at the preliminary design stage. It is expected that the outcomes of the PHA will be a useful technical reference for the final design. After discussion and consultation with Toxfree, Advitech understands the following AAN size and capacity constraints, as listed in **Table 1** will apply.

Table 1: Proposed AAN Process Parameters

Identifier	Value	Units	Comments
Acid Waste	500	L	Pre-consolidated into acid waste bulk storages prior to neutralisation mixing. Introduced at a maximum rate of 10 L/min.
Alkali Waste	500	L	Pre-consolidated into alkali waste bulk storages prior to neutralisation mixing. 500 L of alkali waste added to AAN Mixing Tank prior to neutralisation reactions.
AAN Mixing Tank	1,500	L	Larger to accommodate mixing turbulence. Tank includes a mechanical mixer and is covered. Total batch volume at end of consolidation process is approximately 1,000 L. The AAN Mixing Tank includes a fume extraction system. Heat of neutralisation reactions removed through refrigerative cooling system.
Caustic Scrubber	2	m^3/min	Receives fumes from acid and alkali IBCs and AAN Mixing Tank. Caustic scrubber packed tower using 18 to 22% sodium hydroxide solution. Countercurrent flow. Assumed toxic gas stripping efficiency of >95% (refer to **Section 6.1.4**). Exothermic reactions (if encountered) removed through refrigerative cooling system.
Caustic Scrubber Exhaust	4.2	m/s	Assumed to discharge at least three metres above roof height to limit building downwash effects. Ducting transition fitted onto exhaust to increase efflux velocity to 10 m/s. This is in accordance to best operating practice (refer to reference 11, **Section 8**)

1.4 Dangerous Goods Storage

1.4.1 Current and Proposed Storage Quantities

Toxfree has advised that a range of reagents classified as dangerous goods will be stored on the site. **Table 2** contains the current and proposed dangerous goods manifest outlining the maximum storage capacity and package size within each dangerous goods class.

Table 2: Current Reagent Storage Quantities

Dangerous Goods Class/Type	Category Descriptor	Maximum Storage Quantity Currently Approved[1]	Proposed Maximum Storage Quantity	Maximum Individual Package Size[2]
Class 2.1	Flammable gases	0.5 tonne	15 tonne	55 kg
Class 2.2	Non-flammable, non-toxic gases	Not currently approved	5 tonne	55 kg
Class 2.3	Toxic gases	Not currently approved	100 kilograms	55 kg
Class 3	Flammable liquids	92,000 litres	92,000 litres	1,000 L
Class 4.1	Flammable solids, self-reacting	10 kilograms	3 tonne	205 L
Class 4.2	Substances liable to spontaneous combustion	10 kilograms	3 tonne	205 L
Class 4.3	Substances with water that emit flammable gases	10 kilograms	1 tonne	205 L
Class 5.1	Oxidising substances	200 kilograms	5 tonne	1,000 L
Class 5.2	Organic peroxides	200 kilograms	1 tonne	20 L
Class 6.1	Toxic substances	10.5 tonne	25 tonne	1,000 L
Class 6.2	Infectious substances	Not currently approved	5 tonne	1,000 L
Class 8 - Acidic	Corrosive substances	5,000 litres	35,000 litres	1,000 L
Class 8 - Basic	Corrosive substances	5,000 litres	25,000 litres	1,000 L
Class 9	Misc dangerous substances and articles	500 kilograms	25 tonne	1,000 L
C2 - Combustible liquid	Combustible liquids	2,000 litres	5,000 litres	1,000 L
Cyanide (Toxic Organic Liquid NOS)	Cyanides	9,900 litres	10,000 litres	1,000 L

[1] Project Approval 06_0095 as modified on 3rd March 2010.

[2] Maximum package size relates to the package size of incoming goods. Aggregating storage tanks for some classes exceed the maximum input package size.

Toxfree propose to increase the current storage quantity limits as part their Modification Application (MP 06_0095 MOD 3). Details of the increased storage quantities are outlined in PEP Consulting, August 2015, Environmental Assessment MP 06_0095 Mod3 Modification to existing development consent for additional treatment technologies, Table 2-2.

1.4.2 Further Information Regarding Dangerous Goods of DG Class 2.3 and DG Class 6.1

The nature of the waste chemical management industry involves a degree of uncertainty regarding the exact species to be managed, their specification and the timing of their generation. However, there are a number of chemical types that routinely require handling by Toxfree at the Christie Street facility.

With regard to toxic gases of dangerous goods Class 2.3 and other toxic substances of dangerous goods Class 6.1, **Table 3** summarises the types and UN numbers for the materials/categories routinely stored and managed on-site. Note the goods and UN numbers provided in **Table 3** are not intended to be an exhaustive listing of toxic substances potentially on-site.

Table 3: Anticipated Chemical Types (DG Class 2.3 and DG Class 6.1)

Dangerous Goods Class/Type	Category Descriptor	Specific Goods Descriptor	UN Number(s)
Class 2.3	**Toxic gases**	Compressed Gas, Toxic, NOS	UN 1955
Class 6.1	**Toxic substances**	Toxic Solid, Inorganic, NOS	UN 3288
		Tetrachloroethylene	UN 1897
		Toxic Liquid, Inorganic, NOS	UN 3287
		Toxic Liquid, Organic, NOS	UN 2810
		Toxic Liquid, Flammable	UN 2929
		Mercury Compound Solid, NOS	UN 2025
		Toxic Solid, Organic, NOS	UN 2811
		Arsenic	UN 1556 UN 1557 UN 1558
		Cyanide	UN 1588

2. STATUTORY REQUIREMENTS

Preliminary risk screening of the proposed development is required under *NSW State Environmental Planning Policy No 33 (SEPP 33).* SEPP 33 requires potentially hazardous and/or offensive developments to undertake a PHA to determine the level of risk to people, property and the environment at the proposed location and in the presence of controls. Should the risk level exceed the criteria of acceptability, or if the controls are assessed as inadequate to prevent offensive impacts on the surrounding land users, the development is classified as 'hazardous industry' or 'offensive industry' respectively and may not be permissible within most industrial zones in NSW.

2.1 Objectives

The objectives of the PHA include:

- Identification of hazard scenarios associated with the proposed AAN processes at the St Marys facility;
- Identification of hazard scenarios with existing operations and proposed inventories at the St Marys facility;
- Analysis of the consequences (effects) for people and the environment and their probability (likelihood or frequency) of occurrence for each hazard scenario;
- Qualitative assessment of relative risks to the surrounding land users and environment to provide guidance within subsequent semi-quantitative or quantitative risk assessments;
- Ensure that the proposed safeguards are adequate, and thus demonstrate that the operation will not impose a level of risk that is intolerable with respect to its surroundings; and
- Meet the requirements for inclusion of the hazard identification session minutes within the development assessment.

3. METHODOLOGY

3.1 General

A PHA aims to provide sufficient information and assessment of risks to demonstrate that a project satisfies the risk management requirements of the proponent company and the relevant public authorities. Within this context the primary role of the PHA is to demonstrate that the residual risk levels are acceptable in relation to the surrounding land use and that risk will be appropriately managed.

This is done by systematically:

- Identifying hazards and abnormal process conditions that could lead to hazards.
- Identifying inherent and existing safeguards.
- Assessing the risks by determining the probability (likelihood) and consequence (severity) of hazardous events for people and the surrounding land uses and environment.
- Identifying opportunities to reduce the risks by elimination, minimisation and/or incorporation of additional protective measures. This will demonstrate that the operation will not impose a level of risk that is intolerable with respect to its surroundings.

3.2 Preliminary Risk Screening

A preliminary risk screening was not undertaken. The need for a PHA was determined as outlined in the NSW Government letter to Toxfree 2nd September 2015 (MP 06_0095 MOD 3).

3.3 Risk Classification and Prioritisation

The Department of Planning and Environment (DoPE) document *Multi-Level Risk Assessment* (May 2011) suggests the use of preliminary analysis of the risks related to a proposed development to enable the selection of the most appropriate level of risk assessment in the PHA. This preliminary analysis includes risk classification and prioritisation based on a risk assessment undertaken during review of the design for the proposed installation.

There are three levels of risk assessment. A level one assessment is essentially qualitative identifying all possible risk scenarios and their relevant consequences and probabilities. An evaluation of the risks should be completed in conjunction with the qualitative criteria in *HIPAP No. 4* (January 2011). It should demonstrate that adequate safeguards are in place to ensure the ongoing safety of the proposal. A level two assessment is semi-quantitative and should include sufficient quantification of any significant off-site consequences to determine that the relevant risk criteria will be met. A level three assessment is a full quantification of the relevant risk scenarios and should be conducted in accordance with *HIPAP No. 6*.

This study has undertaken a semi-quantitative level two assessment to understand if any significant off-site consequences will result from the AAN process or existing operations. The assessment will also determine whether the relevant risk criteria will be met. According to the NSW Government letter to Toxfree 2nd September 2015 (MP 06_0095 MOD 3), the following specific reporting requirements are necessary:

- Estimate the risks from the proposed modification, the existing site and the overall site;
- Identify the hazards, arising out of the proposed modification and the existing site as well as any external hazards (i.e. natural hazards) to determine the potential for off-site impacts (refer to **Appendix I**);
- Provide more detailed information on the AAN process and equipment (refer to **Section 1.3**);
- Critically review the chemical reaction and the chemical products (including any intermediates) related to the AAN and establish the probability of formation of toxic gases (refer to **Section 6**);
- Evaluate the probability of a failure of the proposed scrubber and estimate the potential impacts (refer to **Section 6.4**, **Appendix II**, and **Appendix IV**);
- Details of the gases which would be treated within the proposed scrubbing system and potential air emissions following treatment (refer to **Section 6.1.4**, and **Section 6.4**); and
- Demonstrate the proposed development complies with the criteria set out in Hazardous Industry Planning Advisory Paper HIPAP No 4 - Risk Criteria for Land Use Safety Planning (refer to **Section 6.2.5**, **Section 6.3.3** and **Section 6.4**).

4. RISK ASSESSMENT

In order to identify the potential hazards involved in the proposal, facilitated risk assessments were conducted at the St Marys Toxfree office on 20 October 2015 and 25 February 2016.

4.1 Objective

The objective of the risk assessments was:

- To identify and evaluate any risks introduced to the site with respect to the operation of the AAN process on and off the site;
- To identify and evaluate any risks introduced to the site with respect to the storage of acid and alkali goods on the site;
- To identify and evaluate any risks introduced to the site with respect to the AAN gas scrubber treatment process; and
- To identify risk scenarios involving existing facility operations and the proposed increased inventories.

4.2 Assumptions

4.2.1 AAN Process

In undertaking the risk assessment and quantitative modelling a number of assumptions were made. These include:

- Pre-consolidation of acid and alkali liquid wastes occur. Each liquid waste stream is consolidated into a separate 1,000 L IBC. The air within the air space within each IBC is extracted using an air ventilation system. Air removed from the IBC air space report to the gas scrubber unit (refer to **Appendix V**).
- The AAN Mixing Tank is 1,500 L in volume.
- The AAN Mixing Tank is prefilled with 500 L of consolidated alkali liquid waste prior to acid alkali neutralisation activities.
- The maximum rate of acid added (via a venturi eductor) is 10 L/min. Mixing of the added acid and recirculated alkali occurs within the venturi eductor immediately prior to entering the AAN Mixing Tank.
- Continuous pH and temperature monitoring on the AAN Mixing Tank and gas scrubber.
- Acid addition activities are immediately stopped if the AAN Mixing Tank bulk temperature exceeds 60 degrees Celsius or any other observable fault (e.g. leak or fume emission) is observed by the operator.
- The AAN process is continuously manned by an operator. The operator wears full PPE and includes Tyvek overalls, face shield, poly-vinyl gloves and appropriate respiratory protection.
- The caustic gas scrubber and ventilation extraction system must be operating normally before the AAN neutralisation process commences. Appropriate engineering controls and mechanical safeguards are installed to avoid any situation where this might occur.
- Quantitative modelling predicts on-site and off-site impacts for chlorine (Cl_2) and sulphur dioxide (SO_2) based upon the gas scrubber unit off-line or the ventilation system unavailable. A worst-case chemical reaction is between a concentrated acid and alkali has been modelled that results in the maximum evolution of Cl_2 or SO_2.
- Toxfree operating hours are from 5 am to 10 pm daily.
- The AAN process is not a continuous process. Batches of pre-consolidated acid and alkali liquid wastes will be processed daily. Four 1,400 kg batches will be processed every day.
- Meteorological data from Bureau of Meteorology Horsley Park weather station for the year 2006 has been used to characterise wind direction frequency and atmospheric stability class.
- AAN process ventilation stack velocity is 10 m/s and is released at a height of 15 metres above ground level. The stack discharge point is three metres above the roof to minimise any building downwash effects.
- AAN Mixing Tank is well mixed.

- Reaction chemistry proceeds instantaneously and is characterised by the reaction between a strong acid and strong alkali. Scenarios consider 38 wt% HCl reacting with 33 wt% NaOCl or 98 wt% H_2SO_4 reacting with 33 wt% NaOCl.
- An emergency stop (E-stop) button is easily available to the AAN operator locally. The E-stop button is activated should the operator notice any abnormal AAN operation (i.e. ventilation fan off-line, caustic scrubber off-line, emission of gas/fume from the AAN Mixing Tank etc.). The E-stop immediately stops the addition of acid into the AAN Mixing Tank and sounds an alarm notification.

4.2.2 Existing Operations at Proposed Inventory Levels

In undertaking the risk assessments and quantitative modelling a number of assumptions were made. These include:

- All incoming consignments are characterised and declared (with signatories) by the waste generator.
- All incoming consignments are fully packaged and placed in protective containers supplied by Toxfree.
- All incoming consignments are checked/inspected by qualified industrial chemists to ensure classification/characterisation of the substances is correct.
- Inert absorbent is placed in the base of each protective container to ensure any internal protective container spillages absorbed internally.
- Upon inspection, packages within protective containers are moved to the storage area appropriate to the DG Class and sub-classification (i.e. acid or alkali of Class 8).
- All protective containers containing hazardous chemicals remain in their appropriate areas until ready for dispatch in a consignment of compatible goods or treatment.
- A minimum of three qualified industrial chemists attend site at all times when operations are being conducted.

4.3 Methodology

The risk assessment was conducted in the form of a structured workshop, facilitated by Advitech and attended by Toxfree personnel involved in the AAN's design, development and operation. A systematic approach within the framework of *AS/NZS ISO 31000:2009 Risk management - Principles and guidelines* was used to identify risk scenarios and minimise the possibility of missing important information. The minutes of the meeting provide a record of the procedure used and the information obtained (refer to **Appendix I**).

4.4 Terms and Definitions

At the commencement of the workshop, the team was briefed on the context of the risk assessment and the methodology that would be used. The terms and definitions shown in **Table 4** were discussed at relevant stages during the workshop.

Table 4: Risk Assessment Terms and Definitions

Term	Definition
Risk Assessment	The formalised means by which hazards are systematically identified, assessed, ranked according to perceived risk, and addressed by means of appropriate and effective controls. Such an assessment is generally undertaken by a group with extensive knowledge of the system or area being reviewed.
Asset	Tangible and intangible items of value or processes, procedures or tasks performing as intended.
Hazard	A source of potential harm or a situation with the potential to cause loss.
Risk Scenario	An identified situation where an asset and hazard could come together to create a risk event.
Barrier	The current intended systems, procedures or equipment in place (or included as part of the design) or actions taken to eliminate or mitigate a hazard, or render the risk of occurrence acceptable.
Consequence	The outcome of a risk scenario expressed qualitatively, being a loss, injury, disadvantage or gain.
Probability	The likely frequency of a risk scenario occurring.
Risk	The chance of a potential hazard being realised that will have an impact on a desired outcome. It is measured in terms of consequence and probability.

4.5 Key Elements

The focus of the risk assessments was the equipment and processes relating to the AAN process, the transport of acid and alkali liquid wastes to and from the site and the proposed equipment and processes. These elements were considered as individual assets.

Toxfree provided some generic hazard guidewords to enable risk scenarios with off-site implications to be comprehensively identified. The hazard guidewords used during the risk assessment of the upgraded facility are listed in **Table 5**.

Table 5: Guidewords

Hazard Guidewords
Loss of containment
Chemical/Hazardous Substance
Exposure to Hazardous Substances, Energy and Vectors
Community
Visual impact
Air Emissions (including dust and odour)
Vibration
Fire/explosion
Transport/Mobile Equipment
Services
Sensitive areas
Maintenance
Timing
Materials of construction
Access
Natural hazards

4.6 Risk Identification

The risk identification process was conducted in a comprehensive and systematic manner, so that as far as practicable, all possible risk scenarios were identified. Each section of the risk assessment (the asset) was paired systematically with each hazard guideword (refer to **Table 5**).

For each asset - hazard pair, the workshop team determined whether a plausible risk scenario existed. If a risk scenario did exist, it was further studied according to **Section 3.3**. If no scenario existed, the team moved on to the next pair.

For each risk scenario identified, the workshop team described the possible causes and potential consequences of the risk scenario, and the current barriers in place to prevent the risk scenario occurring or minimise the consequences. Each risk scenario was then scored, and actions to eliminate or mitigate the risk were proposed. Consequences were scored according to **Table 6**, and then probability was scored according to **Table 7**. The resulting risk was scored according to **Table 8.**

It should be noted that when determining consequence scores for each risk scenario, the 'most probable' consequence was scored, with all current barriers deemed to have failed. The probability score for each scenario was then assessed presuming the current barriers were in place. Toxfree's Risk Classification System was used for this risk assessment.

Table 6: Classification of Consequence

Category	Equipment and Operations	Environmental Impact	Personal Injury
5	More than $10M loss	Irreversible damage to ecosystem/species of significant importance	Multiple Fatalities, Significant Irreversible Effects To Multiple (10+) Persons
4	Up to $1M loss	Long term and widespread environmental damage	Fatality, Terminal Illness, Permanent Disability
3	Up to $100,000 loss	Significant harm to the local environment. Needless/increased resource usage waste generation	Major Injuries Requiring Hospitalisation, Long Term Incapacity, Inability To Return To Work
2	Up to $10,000 loss	Minimal and short term harm to the local environment beyond immediate job site	Lost Time Injury, Illness
1	Less than $10,000 loss/no damage	Brief pollution but no environmental harm beyond immediate job site	Medical Treatment Injury, First Aid Treatment Injury

Table 7: Classification of Probability

Category		Description	Probability
5	Almost Certain	Occurs regularly	1 in 10 or greater
4	Likely	Occurs occasionally	1 in 100 or greater
3	Possible	Occurs in unusual circumstances	1 in 1,000 or greater
2	Unlikely	Is conceivable but only in extremely unusual circumstances	1 in 10,000 or greater
1	Rare	Has been known to occur in exceptional circumstances	1 in 100,000 or greater

Table 8: Risk Assessment Matrix

		PROBABILITY				
		1	2	3	4	5
CONSEQUENCE	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	2	6	8	10
	1	1	2	3	4	5

Ranking	Range
Extreme	+20
High	10-19
Medium	4-9
Low	2-3
Negligible	1

4.7 Risk Treatment

In general, each identified risk scenario had actions assigned by the workshop team, to treat the risk. In some cases, the workshop team deemed current barriers to be adequate to address the risk, and no further action was required.

Risk treatment actions recorded in the workshop aimed to reduce the identified risk to **As Low As Reasonably Practicable** (ALARP). Most identified risks cannot be eliminated, but can be mitigated or reduced in some way. The preferred method of risk treatment uses engineered (physical) barriers to prevent the risk occurring, otherwise procedural controls may be proposed to prevent the risk, or respond appropriately if the risk scenario does occur.

It should be noted that in a workshop setting, it is inefficient to discuss detailed design issues when determining the most appropriate treatment for a risk scenario. As such, the actions recorded tend to be general in nature, e.g. “investigate further”, “consider issue in final design”, etc. The project team is responsible for designing suitable solutions, as well as ensuring that personnel are assigned responsibility for actions, and that every identified risk scenario is addressed.

5. ASSESSMENT OUTCOMES

Results of the risk assessments were recorded directly into a Toxfree spreadsheet template during the workshop(s). The spreadsheet is treated as the formal minutes of the workshop(s), and ultimately forms the risk register for the project. The risk assessment spreadsheets are contained in **Appendix I**.

Each hazard scenario was evaluated in terms of consequence and probability using the scoring methodology from **Table 6** and **Table 7**. A qualitative assessment of the resultant risk was then made using **Table 8**. The hazards identified are a result of deviation from normal operations and the qualitative risk assigned to each scenario takes into account the inherent and proposed physical, operational and organisational safeguards designed to reduce the consequence and probability of these hazards.

There were no risk scenarios identified with an extreme or high risk score (i.e. with a cumulative risk score of 10 to 20). All remaining risk scenarios were identified with a medium risk score (i.e. with a cumulative risk score of 4 to 9). The identified medium risk scenarios involve possible off-site and onsite impacts to personnel and the development and are related in all cases (with the exception of one – traffic collision) to the AAN process. Those risk scenarios associated with the AAN process specifically related to the release of toxic gas as a result of the mixing of incompatible chemicals (e.g. HCl and NaHOCl). It is considered adequate that engineering controls associated with an appropriate mist eliminator would control any emission of NaOH aerosols. The remaining two hazard scenarios considered further in this report are:

1. Gas release resulting in off-site impacts; and
2. Gas release resulting in on-site impacts.

In accordance to the specific instructions of the NSW Government (refer to letter 2nd September 2015 (MP 06_0095 MOD 3)), Advitech undertook additional quantitative assessment to evaluate the potential impacts associated with an off-site process gas release. It should be noted that the risk assessment process documented the residual risk for these scenarios, after the implementation of a risk control measure, to a low risk ranking score.

6. QUANTITATIVE ANALYSIS

HIPAP No. 4 articulates fatality risk criteria for exposure to toxic clouds including vapour, gas and smoke. Consideration of the likelihood and frequency of toxic gas from Toxfree operations and the AAN process is necessary to understand the risk, with potential human fatality, due to exposure of evolved gases. This section examines the individual fatality risk for the key toxic gas emission scenario considered in **Appendix IV**. By definition 'individual fatality risk' is the risk of death to a person at a particular point.

Table 9: Fatality Risk Criteria for Various Land Uses[1]

Land Use	Suggested Criteria (risk in a million per year)
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial	50

[1] - NSW Department of Planning *Risk Criteria for Land Use Safety Planning* (2011, Section 2.4.2)

The individual fatality risk for industrial developments, should not be greater than 50×10^{-6} fatalities per year. Given the traffic and public utilisation of Christie Street, a lower threshold (closer to 5×10^{-6}) may be considered more appropriate by DoPE. It should be noted that, irrespective of numerical risk criteria proposed, the broad aim should be to avert avoidable risk.

Risk calculations presented in **Appendix IV** provide an understanding into potential on-site impacts due to toxic gas formation.

The United States EPA air dispersion heavier-than-air dispersion model SLAB has been used to predict Cl_2 and SO_2 concentrations to understand, in particular, off-site impacts associated with the identified risk scenarios identified in **Section 5**. The SLAB model handles release scenarios including ground level and elevated jets, liquid pool evaporation, and instantaneous volume sources.

6.1 Process Chemistry

The purpose of the AAN system is a pH neutralisation process involving a wide spectrum of pre-consolidated acid and alkali liquid wastes. Given that the AAN process may experience a wide spectrum of acid base neutralisation reactions, there is the potential for a large variety of secondary salt products to be formed. A number of these by-products are toxic and may be formed in quantities of concern.

Consultation with Toxfree and Advitech process engineering experience suggests that the overwhelming species of formation that are potentially of concern are the formation of Cl_2, SO_2 and Nitrogen Dioxide (NO_2).

Acid-base neutralisation can be described by the following generalized net ionic equation.

$$H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H2O_{(l)} + \text{heat} \qquad \textbf{Equation 1}$$

6.1.1 Chlorine Chemistry

The source of Cl_2 is most likely from the contact of sodium hypochlorite (e.g. NaOCl alkali solutions of bleach) in contact with strong acids. Commercial grade sodium hypochlorite solutions typically have a pH of around 12 to 13. The release of Cl_2 would occur during the introduction of consolidated acid into the AAN Mixing Tank. A number of factors influence the formation of Cl_2 and include:

- Concentration of acid introduced into the AAN Mixing Tank.
- The amount of hypochlorous acid (sodium hypochlorite in equilibrium in water) in the AAN Mixing Tank.
- The AAN Mixing Tank acid buffering capacity and absolute pH (a low pH drives the reaction chemistry toward Cl_2 formation).
- Degree of solution mixing within the AAN Mixing Tank to neutralize regions of low pH and likelihood of Cl_2 formation.

The reaction chemistry is described below. When the pH is lowered (i.e by adding HCl), the reaction chemistry moves to the right and the rate of Cl_2 gas in increased.

$$NaOCl_{(aq)} + H_2O_{(l)} \leftrightarrow HOCl_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \qquad \textbf{Equation 2}$$

and

$$HOCl_{(aq)} + HCl_{(l)} \leftrightarrow H_2O_{(aq)} + Cl_{2\,(g)} \qquad \textbf{Equation 3}$$

6.1.2 Sulphur Dioxide Chemistry

The source of SO_2 is most likely from the contact of sodium hypochlorite (e.g. NaOCl alkali solutions of bleach) in contact with sulphuric acid. Commercial grade sodium hypochlorite solutions typically have a pH of around 12 to 13. The release of SO_2 would occur during the introduction of quantities of sulphuric acid into the AAN Mixing Tank. The reaction chemistry also liberates toxic hydrogen chloride (HCl) gas. However, HCl gas should not be emitted into the environment because it readily reacts with available water within the AAN Mixing Tank to form hydrochloric acid. The formation of this byproduct and its end products are described in **Section 6.1.1**.

The reaction chemistry is described below.

$$H_2SO_{4\,(aq)} + 2NaOCl_{(aq)} \rightarrow Na_2SO_{4\,(aq)} + 2HCl_{(g)} + SO_{2\,(g)} \qquad \textbf{Equation 4}$$

6.1.3 Nitrogen Dioxide Chemistry

The amount of NO_2 present or evolved is considered to be very small. The formation of NO_2 within the AAN process originates from the decomposition of nitric acid (HNO_3) in the presence of sunlight. Partial decomposition of nitric acid may have occurred prior to Toxfree receipt of the acid waste. However it is expected that continued decomposition of nitric acid will not occur given that acid liquid wastes are removed from contact with sunlight. Any residual NO_2 released during acid pre-consolidation activities will be captured by a local ventilation system fitted onto the acid storage tank. Emission of NO_2 gas will not be considered further in this PHA study.

Nitric acid is a reactive substance and will react with metal oxides, hydroxides and carbonates containing basic anions to form aqueous nitrate salts. These by-products are contained within approved inherently safe storage containers to avoid an unnecessary risk scenario. The reaction chemistry is described below.

$$4HNO_{3\,(aq)} + \text{sunlight (UV)} \rightarrow 4NO_{2\,(g)} + 2H_2O_{(l)} + O_{2\,(g)} \qquad \textbf{Equation 5}$$

6.1.4 Gas Scrubber Chemistry

Toxfree propose to install a sodium hydroxide (NaOH) packed tower chemical scrubbing system to remove toxic gases that are potentially created during AAN neutralisation and pre-consolidation activities. At the time of preparing this PHA no detailed design information was available. The information listed in **Table 1** presents known information about the scrubber system. **Appendix V** describes how the gas scrubber system integrates with the AAN process.

Without a detailed design available for the packed tower chemical scrubbing system to be used by ToxFree, Advitech's current opinion is that a toxic gas removal efficiency afforded by the gas scrubber would be greater than 95%. A higher stripping efficiency may be achievable but will largely depend upon a good design and with enforced periodic inspections.

NaOH solutions are able to absorb Cl_2 and SO_2 from the AAN Mixing Tank and the pre-consolidation tank air spaces. The reaction chemistry is described below.

$$2NaOH_{(aq)} + Cl_{2\,(g)} \rightarrow NaOCl_{(aq)} + NaCl_{(aq)} + H_2O_{(l)} \quad + \text{heat} \qquad \text{Equation 6}$$

and

$$2NaOH_{(aq)} + SO_{2\,(g)} \rightarrow Na_2SO_{3\,(aq)} + H_2O_{(l)} \qquad \text{Equation 7}$$

6.2 Chlorine Gas or Sulphur Dioxide Gas Emission With Off-Site Impacts

6.2.1 From AAN Mixing Tank

The Cl_2 or SO_2 gas emission scenario is described as follows:

- The gas scrubber ventilation fan operating as normal at rate of 2 m^3/min.
- Failure of the sodium hydroxide gas scrubbing system as described as one of the following:
  - A blocked pipe preventing sodium hydroxide from entering the packed tower; or
  - A recirculating sodium hydroxide pump failure preventing sodium hydroxide from being introduced into the packed tower.
- Failure of the scrubber management system to either detect or communicate, the scrubber is inoperative.
- Human operator error (by omission) associated with not discovering abnormal sodium hydroxide gas scrubbing system operation.
- Addition of either concentrated hydrochloric or sulphuric acid at a rate of 10 L/min into a pre-filled AAN Mixing Tank containing 500 L of concentrated sodium hypochlorite solution. The reaction chemistry is described in **Section 6.1.1** and **Section 6.1.2** respectively.

The underlying assumptions and calculations that determine the rate of Cl_2 and SO_2 emission and expected emission duration before a mitigation intervention occurs, are described in **Appendix IV**.

6.2.2 From Existing Operations With Increased Inventory

The Toxfree business at St Marys is currently processing around 4,000 tonnes/annum of waste chemicals, paints, gases, etc. The average package size across the 4,000,000 kg each year is approximately 2 kg with a small quantity being in drums or IBCs but with the vast majority resulting from the handling of small packages. Toxfree site management suggests that less than 10% of the 2,000,000 packages each year exceeds 10 kg in weight.

The increased inventories sought for the various classes of goods will mean that more packages are stored simultaneously but for shorter periods on average. The shorter average storage times will result from the decreased time required to assemble consignments of goods of each particular Dangerous Goods class. The increased inventories will assist with the logistics and the logistics cost by facilitating the assembly/aggregation of full containers/semi-trailer loads for outgoing consignments.

The greatest risk of the inadvertent mixing of incompatible substances is recognised as being associated with incoming consignments and the segregation of each package of chemical agent into its appropriate Dangerous Goods class and storage area. All incoming consignments are separated/segregated by qualified chemists with a minimum of three being on-site whenever the plant is operational. It is considered unlikely that inadvertent mixing will occur due to the extent of the oversight associated with relatively small package sizes.

In general each package of an incoming consignment is declared by the waste generator prior to it being loaded into transport containers lined with vermiculite absorbent to ensure any internal spillage remains within the transport container.

The single identified plausible failure mode for the mixing of concentrated reagents in significant quantities to result in off-site impacts, is where larger packages (>10 kg) are stored simultaneously in transport containers, at least one of the packages has been incorrectly identified and a fork-truck incident results in the simultaneous compromising of more than one package.

6.2.3 Chlorine Exposure Guideline Level

The PHA has applied the following United States Acute Exposure Guideline Levels (AEGLs) to determine human fatality risk.

Table 10: Chlorine Acute Exposure Guideline Levels (AEGLs)[1]

Identifier	Ten Minute Averaging Time (ppm)	End Point Reference
AEGL-1 (non-disabling)	0.5	The airborne concentration which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
AEGL-2 (disabling)	2.8	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL-3 (lethality)	50	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

[1] - Acute Exposure Guideline Levels for Selected Airborne Chemicals- Committee on Toxicology Board on Environmental Studies and Toxicology, National Research Council USA - Volume 4.

6.2.4 Sulphur Dioxide Exposure Guideline Level

The PHA has applied the following AEGLs to determine human fatality risk.

Table 11: Sulphur Dioxide Acute Exposure Guideline Levels (AEGLs)[1]

Identifier	Ten Minute Averaging Time (ppm)	End Point Reference
AEGL-1 (non-disabling)	0.2	The airborne concentration which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
AEGL-2 (disabling)	0.75	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL-3 (lethality)	30	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

[1] - Acute Exposure Guideline Levels for Selected Airborne Chemicals- Committee on Toxicology Board on Environmental Studies and Toxicology, National Research Council USA - Volume 8.

6.2.5 Frequency and Probability

As discussed in **Section 6.2.3** and **Section 6.2.4**, the threshold concentrations for fatality and injury for Cl_2 and SO_2 exposure are different. However, for those particular substances, the fatality and injury risk as a function of distance from the facility look remarkably similar. Given this similarity, the off-site impacts of scenarios involving either Cl_2 or SO_2 plumes can be considered jointly. From this point, discussion of off-site impacts resulting from the emission of toxic gas from the Toxfree site can be taken to include both gases.

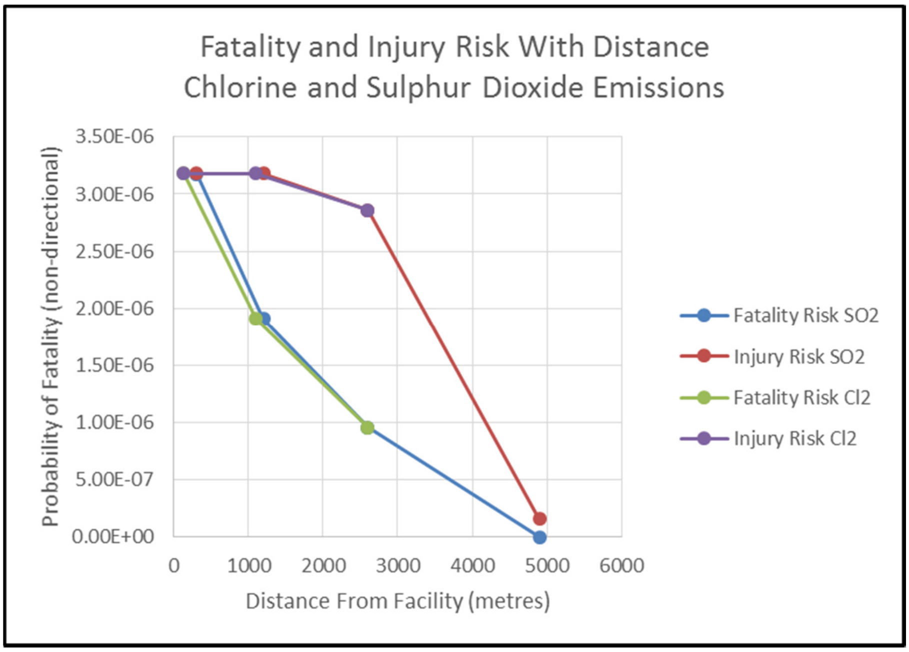

Figure 3: Non-Directional Fatality and Injury Risk Vs Distance

Even though the anticipated exposure time is likely to be 2 minutes or less, the data presented in **Figure 3** is based upon the following assumptions:

- The probability of a fatality or injury resulting from exposure to concentrations of gas equal to or above the corresponding AEGL-3 guideline is assigned a value of 1.0.
- The probability of a fatality resulting from exposure to concentrations of gas corresponding to 50% of the relevant AEGL-3 guideline is assigned a value of 0.6.
- The probability of an injury resulting from exposure to concentrations of gas corresponding to 50% of the relevant AEGL-3 guideline is assigned a value of 1.0.
- The probability of a fatality resulting from exposure to concentrations of gas corresponding to the relevant AEGL-2 guideline is assigned a value of 0.3.
- The probability of an injury resulting from exposure to concentrations of gas corresponding to the relevant AEGL-2 guideline is assigned a value of 0.9.
- The probability of a fatality resulting from exposure to concentrations of gas corresponding to the relevant AEGL-1 guideline is assigned a value of 0.0.
- The probability of an injury resulting from exposure to concentrations of gas corresponding to the relevant AEGL-1 guideline is assigned a value of 0.05.

The assignment of these probabilities is therefore considered conservative, on the basis of the AEGL guideline definitions.

Analysis of likelihood and frequencies for the identified worst-case scenario using a fault tree approach was undertaken. The fault tree for off-site toxic gas emission with no safety systems present, is shown in **Figure 6** in **Section 6.4**.

In estimating the initiating event frequencies and probabilities, no account was taken of any of the electrical safety-related systems (e.g. thermal cut-off switch, programmable logic controller function) or other risk reduction measures that might be present or possible with the equipment. **Table 12** shows the frequencies of initiating events and probabilities potentially involved in a release with off-site impacts.

Table 12: Data/Assumptions for Off-Site Fatality Analysis

Assumption/Basis	Assigned Value	Unit	Source	Comments
AAN Scrubber Circuit				
Pipe blockage in scrubber alkali circuit	2.0 E-01	events/year	HSE Failure Rate and Event Data for Use Within Risk Assessments 30 x 10^{-6} failures/hr	Based upon pipe being full for 15 hrs/day, 365 days/year
Pump failure while running	5.14 E-01	events/year	Process Equipment Reliability Data American Institute of Chemical Engineers, Center for Process Safety 1989 Taxonomy No. 3.3.7.2.1.1 pp192	Mean failure frequency of 292 occurrences/10^6 hours. Based upon 1,760 operating hours per year

Assumption/Basis	Assigned Value	Unit	Source	Comments
Liquid distribution failure in scrubber	0.00 E+00	events/year	-	Mean failure frequency is effectively zero as scrubber is a packed tower and not a spray tower. Maldistribution of liquid is not possible unless the tower supports fail.
AAN Scrubber Control Failure				
Circuit breaker sticks	3.08 E-03	events/year	Process Equipment Reliability Data American Institute of Chemical Engineers, Center for Process Safety 1989 Taxonomy No. 1.2.3.1 pp144	Mean failure frequency of 1.75 occurrences/10^6 hours. Based upon 1,760 operating hours per year
Flow switch failure	4.72 E-02	events/year	Process Equipment Reliability Data American Institute of Chemical Engineers, Center for Process Safety 1989 Taxonomy No. 2.1.4.1.1 pp164	Mean failure frequency of 26.8 occurrences/10^6 hours. Based upon 1,760 operating hours per year
Alarm annunciator failure	1.36 E-03	events/year	Process Equipment Reliability Data American Institute of Chemical Engineers, Center for Process Safety 1989 Taxonomy No. 2.2.2 pp179	Mean failure frequency of 0.77 occurrences/10^6 hours. Based upon 1,760 operating hours per year
Independent Probabilities				
Operator fails to observe independent visual clues/procedures re scrubber operation	1.00 E-02	probability	HIPAP #6 Hazard Analysis - 2011 NSW Department of Planning Appendix III Table 3 pp 44	-
Reagent Concentrations are sufficiently strong to produce clouds with off-site impacts	2 .0 E-01	probability	According to Toxfree data on concentrated reagents in consignments J Brown, Feb 2016	-
Other Facility Operations				
Goods inwards wrongly labelled or classified	8.0 E03	events/year	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	Avge 4,000,000 kg handled/annum Avge 2 kg/pack Avge 1 pack per 250 incorrectly labelled and assigned by customer
Proportion of goods inwards packages with potential to	1.0 E-01	proportion	According to Toxfree data on concentrated reagents in consignments J Brown, Feb 2016	Product mix is only about 10% where sufficiently concentrated toxics

Assumption/Basis	Assigned Value	Unit	Source	Comments
create toxic clouds/fumes				or acids/alkalis potentially generating fume.
Proportion of goods inwards of sufficient package quantity (>10L)	1.0 E-01	proportion	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	-
Accidents with forklift compromising multiple packages	1.43 E-01	events/year	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	2,000,000 packages/annum on average Avge 10 packs/tote 1 tote in 7 years has been dropped such that multiple packs are compromised.
Meteorology				
F Class meteorological conditions during operational hours	2.7 E-01	proportion	Based upon one years local meteorological data for Horsley Park 2006	(refer to **Appendix III**)
Sensitive receptors downwind	5.1 E-01	proportion	Judgement based upon one years local meteorological data for Horsley Park 2006 and directionality of potential receptors	(refer to **Appendix III**)
Receptor Locations				
Probability of Sensitive Receptor present 6pm to 6am.	1.0 E-01	proportion	Judgement based upon one years local meteorological data for Horsley Park 2006 and directionality of potential receptors	Corresponding to meteorological conditions that result in gas concentrations in excess of the AEGL-3 guideline
Probability of failure to escape plume	9.0 E-01	-	Judgement based upon concentration and disorientation of off-site persons	-

Section 6.4, **Figure 6** details the calculation method using a fault tree approach to arrive at the frequency of an off-site fatality as a result of emission of Cl_2 or SO_2 gas. The off-site fatality frequency, was calculated at 1.62 x 10^{-6}/year. This is significantly below the NSW government maximum fatality risk criteria for industrial land use area of 50 x 10^{-6}/yr.

The individual off-site fatality risk arising from the modelled Cl_2 or SO_2 release scenario has been determined using the SLAB dispersion model. **Figure 4** shows the calculated 1 x 10^{-6} off-site fatality contour and **Figure 5** shows the calculated1 x 10^{-6} off-site injury contour. The SLAB model outputs for Cl_2 and SO_2 gas release are contained within **Appendix II**.

The fatality risk contours are based upon the overall annualised wind direction distribution and the F class stability dispersion characteristics (the meteorological condition that will lead to Cl_2 or SO_2 gas concentrations in excess of the AEGL-3 guideline (refer to **Table 10** and **Table 11**)) in order to provide the most conservative estimate of consequences potentially resulting from exposure to a Cl_2 or SO_2 plume.

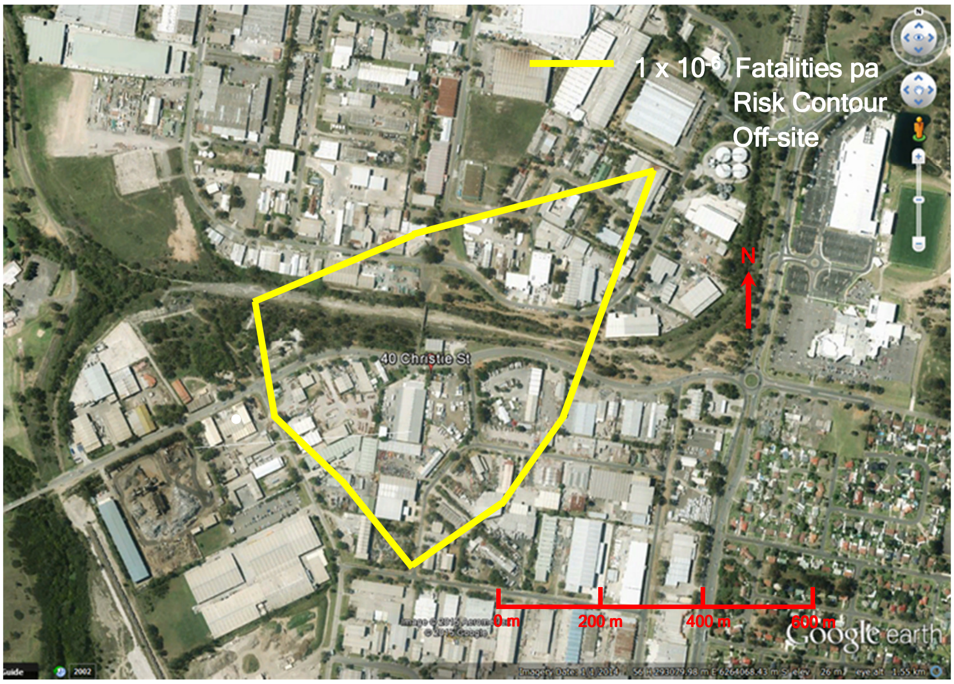

Figure 4: Off-site Cl_2 and SO_2 Individual Risk Contours (Fatality) for Modelled Scenario

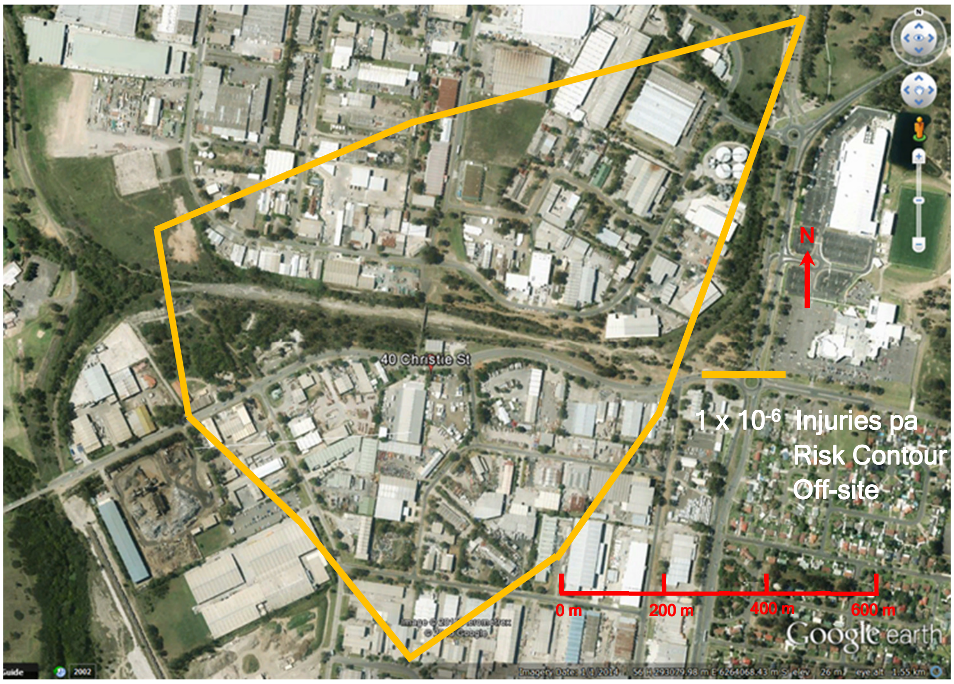

Figure 5: Off-site Cl_2 and SO_2 Individual Risk Contours (Injury) for Modelled Scenario

6.3 Chlorine Gas or Sulphur Dioxide Gas Emission With On-Site Impacts Only

The modes of operational failure for a Cl_2 or SO_2 gas release (restricted to on-site impacts), are similar in many respects to those associated with the off-site impacts analysis described in **Section 6.2.5**. However, some important differentiation exists between scenarios resulting in off-site impacts and those restricted to on-site impacts alone.

6.3.1 From AAN Mixing Tank

Failure of the AAN Mixing Tank ventilation system will be the mode by which gases/fume originating in the AAN Mixing Tank may be released into the main facility building. Given the sizes of the pipework and ducting involved (blockage is unlikely in a well-designed and well-drained ventilation duct), failure of the AAN Mixing Tank ventilation will be dominated by risks associated with the failure of the ventilation fan.

6.3.2 From Existing Operations With Increased Inventory

With respect to the existing operations, the major difference between an event limited to on-site impacts, and events having off-site impacts, is the reduced quantity necessary to result in the consequences being realised. For off-site impacts (See **Section 6.2.2**) to result, packages in excess of 10 kg (<10% of consignment packages handled) were necessarily involved. For on-site impacts alone, it is considered that the mixing of packages containing incompatible or toxic goods in excess of 2 kg in size (around 50% of consignment packages handled) is sufficient to result in the realisation of adverse consequences.

6.3.3 Frequency and Probability

Analysis of likelihood and frequencies for the identified worst-case scenario using a fault tree approach was undertaken. The fault tree for toxic gas emission with no safety systems present resulting in only on-site impacts, is shown in **Figure 6** in **Section 6.4**.

In estimating the initiating event frequencies and probabilities, no account was taken of any of the electrical safety-related systems (e.g. thermal cut-off switch, programmable logic controller function) or other risk reduction measures that might be present or possible with the equipment. **Table 13** shows the frequencies of initiating events and probabilities potentially involved in a release with on-site impacts alone.

Table 13: Data/Assumptions for On-Site Fatality Analysis

Assumption/Basis	Assigned Value	Unit	Source	Comments
AAN Mixing Tank Ventilation				
Operator fails to respond to observed clues/procedures re scrubber ventilation failure	1.00 E-02	probability	HIPAP #6 Hazard Analysis - 2011 NSW Department of Planning Appendix III Table 3 pp 44	-
Ventilation fan fails while running	1.60 E-02	events/year	Process Equipment Reliability Data American Institute of Chemical Engineers, Center for Process Safety 1989 Taxonomy No. 3.3.4 pp191	Mean failure frequency of 9.09 occurrences/10^6 hours. Based upon 1,760 operating hours per year
Independent Probabilities				
Reagent Concentrations are sufficiently strong to produce clouds with off-site impacts	2 .0 E-01	probability	According to Toxfree data on concentrated reagents in consignments J Brown, Feb 2016	-
Other Facility Operations				
Goods inwards wrongly labelled or classified	8.0 E03	events/year	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	Avge 4,000,000 kg handled/annum Avge 2 kg/pack Avge 1 pack per 250 incorrectly labelled and assigned by customer
Probability of goods inwards packages with potential to create toxic clouds/fumes	1.0 E-01	probability	According to Toxfree data on concentrated reagents in consignments J Brown, Feb 2016	Product mix is only about 10% where sufficiently concentrated toxics or acids/alkalis potentially generating fume.
Probability of goods inwards of sufficient package quantity (>2L)	5.0 E-01	probability	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	-
Accidents with forklift compromising multiple packages	1.43 E-01	events/year	According to Toxfree data on concentrated reagents in consignments J Brown, A Hajinakitas Feb 2016	2,000,000 packages/annum on average Avge 10 packs/tote 1 tote in 7 years has been dropped such that multiple packs are compromised.
Receptor Locations				

Assumption/Basis	Assigned Value	Unit	Source	Comments
Probability of Sensitive Receptor present 6pm to 6am.	1.0 E-00	probability	Judgement based upon I years local meteorological data for St Marys 2xxx to 2yyy and directionality and timing of potential receptors being present	Corresponding to meteorological conditions that result in gas concentrations in excess of the AEGL-3 guideline
Probability of failure to escape plume	1.0 E-01	probability	Judgement based upon likely rapid response of site personnel experienced in emergency drills	-

Section 6.4, **Figure 7** details the calculation method using a fault tree approach to arrive at the frequency of an on-site fatality as a result of emission of Cl_2 or SO_2 gas. The on-site fatality frequency was calculated to be 31.8×10^{-6}/year. This is below the NSW government industrial fatality risk criteria of 50×10^{-6}/yr.

6.4 Fault Tree Analysis

6.4.1 Off-site Impact Scenario

In this scenario, either the AAN waste gas scrubbing process fails or an unplanned mixing of significant quantities of strong acids and bases occurs, resulting in the release of toxic gas.

The fault tree analysis applies to both Cl_2 and SO_2 toxic gas scenarios.

6.4.2 On-site Scenario

In this scenario, either the AAN waste gas exhaust system fails or an unplanned mixing of lesser quantities of strong acids and bases occurs, resulting in the release of toxic gas internal to the facility.

The fault tree analysis applies to both Cl_2 and SO_2 toxic gas scenarios.

6.5 ALARP Analysis – Societal Risk Assessment

HIPAP No. 4 also provides guidance with respect to societal risk criteria. The guidance or indicative societal risk criteria is reflected in three societal risk bands as presented on a frequency (F) vs number of fatalities (N) chart : negligible, As Low As Reasonably Practicable (ALARP) and intolerable. These three regions are indicated in **Figure 8**. It should be noted, *HIPAP No. 4* emphasises the criteria are indicative only. *HIPAP No. 4* indicates that “below the negligible line, provided other individual criteria are met, societal risk is not considered significant. Above the intolerable level, an activity is considered undesirable, even if individual risk criteria are met. Within the ALARP region, the emphasis is on reducing risks as far as possible toward the negligible line. Provided other quantitative and qualitative criteria of *HIPAP 4* are met, the risks from the activity would be considered tolerable in the ALARP region.”

The distribution and density of surrounding populations and guidance threshold data published by NSW DoPE forms the basis of the examination of the societal risk impacts.

The overall societal risk based on the methodology described in *HIPAP No. 4* is presented in **Figure 8**. The risk F vs N function remains within the ALARP region when all of the risk scenarios are aggregated. The commitments and undertakings forwarded by NPC and the further actions outlined in discussed in the Hazard Assessment Workshop (See minutes in **Appendix I**) are considered to reduce the risks toward the negligible region. It is considered the societal risk function, in combination with the actions and commitments already presented, constitute risk mitigation to the lowest level practicable for this development.

In this particular instance, each off-site event scenario has approximately the same chance of resulting in multiple fatalities as it does to resulting in only one fatality. Fatalities will result where the emission event occurs when F Class stability conditions coincide with operational hours within the industrial estate. An outcome involving multiple fatalities is therefore equal in probability to a single fatality occurring. As a consequence the ALARP/Societal Risk chart is unusual in appearance.

It is considered the description “as low as reasonably practical” applies to societal risks associated with the Toxfree St Marys facility, provided the following factors are maintained:

- The level of supervision of operations involving hazardous chemicals at the site;
- The management practices associated with identifying and segregating the various classes of dangerous goods; and
- The limited size of most packages being handled.

Significant changes to these practices/factors would be considered to introduce greater risk than changes to inventory levels alone.

Based upon the observed population densities, the maximum anticipated distances to the AEGL-3 contours, the limited quantities involved and the likely limited duration of a toxic emission event, it is difficult to conceive of an adverse event resulting in greater than 20 fatalities. For this reason, the number of casualties is limited to 20 in **Figure 8**.

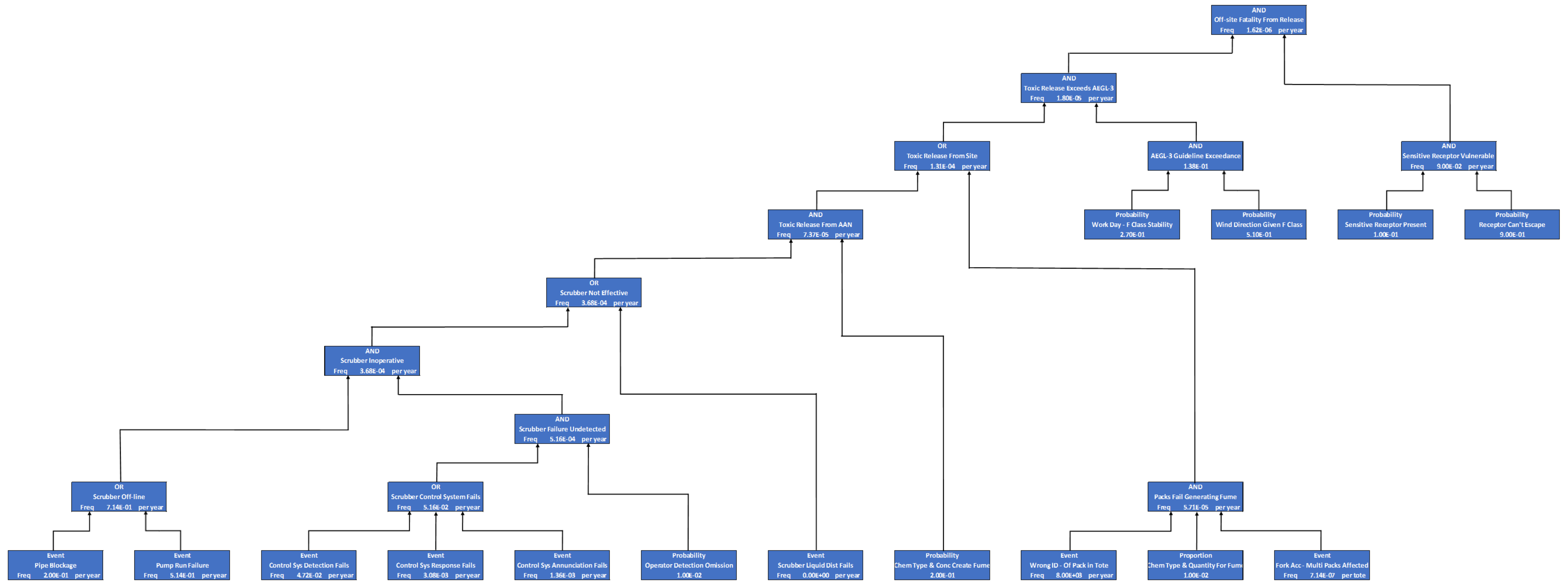

Figure 6: Fault Tree for Toxic Gas (Cl_2 or SO_2) Emission Leading to Off-site Fatality

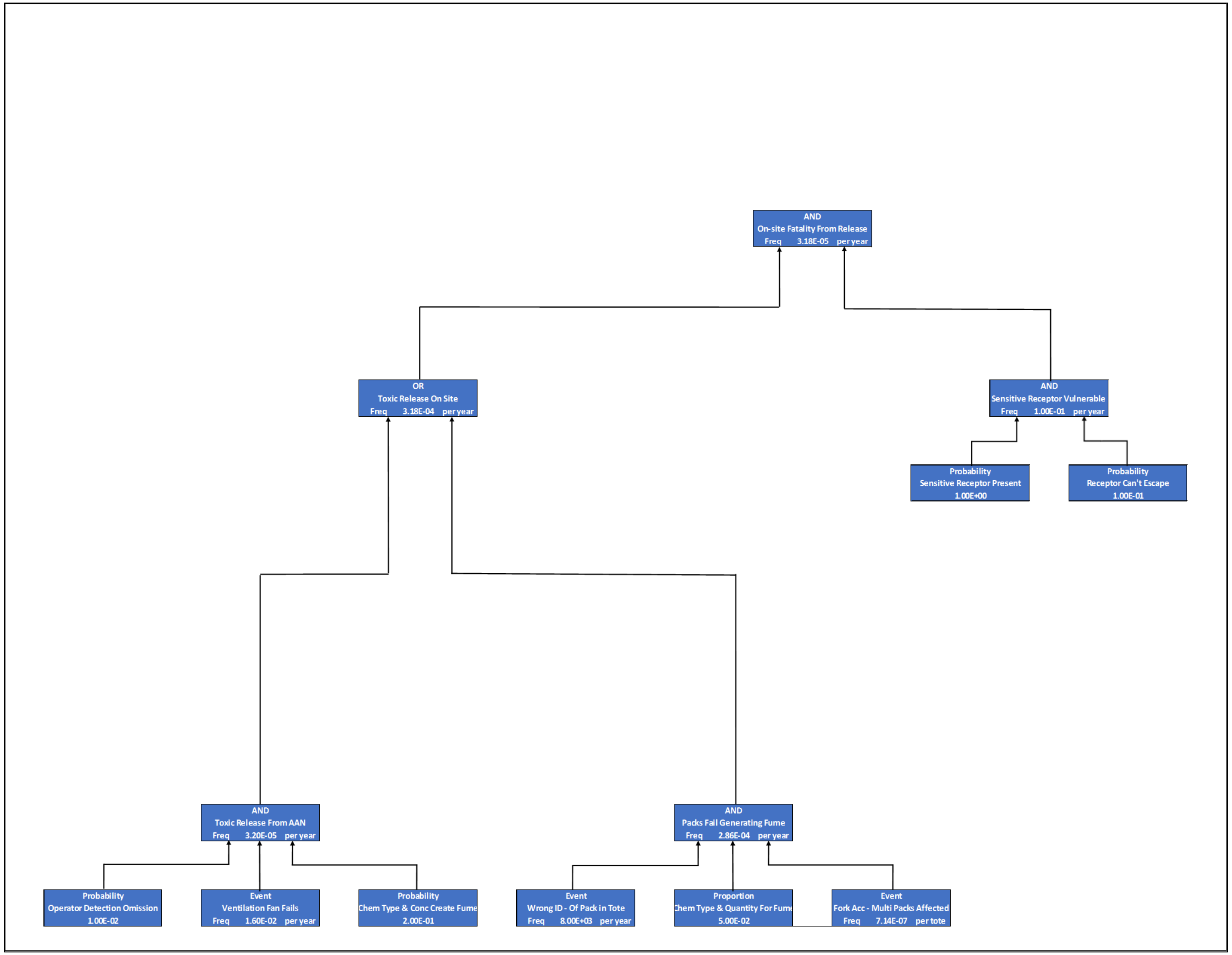

Figure 7: Fault Tree for Toxic Gas (Cl_2 or SO_2) Emission Leading to On-site Fatality

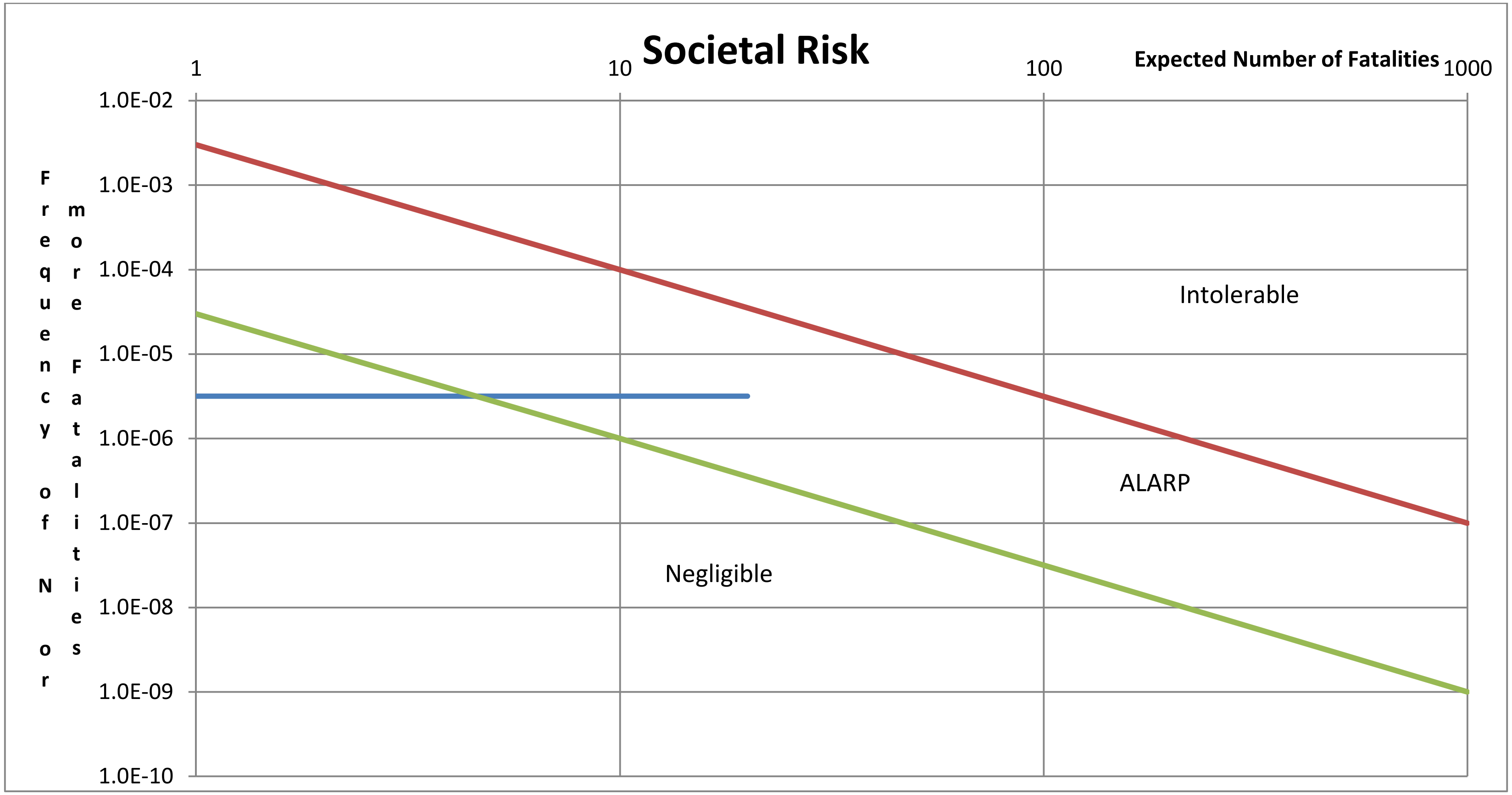

Figure 8: ALARP/Societal Risk Chart For Toxfree St Marys Cl_2 or SO_2 Emission

7. CONCLUSION

All risks identified during the PHA have been qualitatively assessed. Hazard scenarios that have the potential to cause off-site impacts were further quantified to determine if they had the potential to present an unacceptable risk to the surrounding land users. This report has determined that on-site and off-site Cl_2 and SO_2 toxic gas impacts, as an outcome of current operational practice or malfunction of the AAN process, is within (i.e. less than) the maximum risk acceptability criteria (i.e. 50×10^{-6} fatalities per year) as outlined by the NSW hazard planning guidelines. Under the scope of this assessment the proposed AAN development and inventory increases proposed for the site will not increase the overall risks involved in the operations at the site sufficiently, to warrant rejection of the application by Toxfree Pty Ltd.

8. REFERENCES

The following information was used in the preparation of this report:

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2. PEP Consulting, August 2015, Environmental Assessment MP 06_0095 Mod3 Modification to existing development consent for additional treatment technologies.
3. AS/NZS ISO 31000:2009 Risk management - Principles and guidelines.
4. AS 61508:2011 2nd Edition - Functional safety of electrical / electronic / programmable electronic safety-related systems.
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7. Department of Planning and Infrastructure, 2011, *Multi-level Risk Assessment*, New South Wales Government.
8. Failure Rate and Event Data for use within Risk Assessments, 2012, Health and Safety Executive, United Kingdom.
9. Input Meteorological data file for AUSPLUME Horsley Park, 2006, pDs Consultancy.
10. Acute Exposure Guideline Levels for Selected Airborne Chemicals- Committee on Toxicology Board on Environmental Studies and Toxicology, National Research Council USA – Volume 4 and Volume 8.
11. Department of Environment and Conservation NSW. Local government air quality toolkit. http://www.epa.nsw.gov.au/air/aqt.htm.

Appendix I

Risk Assessment Minutes

RISK ASSESSMENT CONTEXT

SITE/SCOPE OF ASSESSMENT: Toxfree NSW St Marys (Christie Street)

Acid Alkali Neutralisation Process. A PHA aims to provide sufficient information and assessment of risks to demonstrate that a project satisfies the risk management requirements of the proponent company and the relevant public authorities. Within this context the primary role of the PHA is to demonstrate that the residual risk levels are acceptable in relation to the surrounding land use and that risk will be appropriately managed.

TIME FRAME OF ASSESSMENT:

Advitech was engaged by Toxfree Services to conduct a risk assessment on a acid alkali neutralisation process at Toxfree's Christie Street site. The risk assessment workshop was held on 20/10/2015.

GOALS AND OBJECTIVES: Hazards were defined as "sources of potential harm or situations with the potential to cause a loss".
The hazard guidewords used to assist in risk identification were relevant to PHAs.

Ref		Type
Storage, Transport. Loading and Unloading	Compliance to site licences Ensure the Safety and Welfare of Staff and Contractors and off-site sensitive receptors	OHS
Decanting processes	Compliance to site licences Ensure the Safety and Welfare of Staff and Contractors	OHS
Acid Alkali Neutralisation process	Compliance to site licences Ensure the Safety and Welfare of Staff and Contractors and off-site sensitive receptors	OHS

SCOPE OF ASSESSMENT

Ref	Description	Type
1	AAN - Process Description Neutralisation Plant	Process
2	Documents as received by Advitech 20-10-2015	

EXTERNAL REQUIREMENTS, REFERENCES, LIMITATIONS

Ref	Description	Type
Storage, Transport. Loading and Unloading	EPA Site Licence 12628 and 12943 Australian Dangerous Goods Code (ADG) 7.3 Edition Dangerous Goods (Road and Rail Transport) Act 2008 Dangerous Goods (Road and Rail Transport) Regulation 2009 Protection of the Environment Operations Act 1997 Work Health and Safety Act 2011 Work Health and Safety Regulations2011	Regulations
Decanting Process	EPA Site Licence 12628 and 12943 Work Health and Safety Act 2011 Work Health and Safety Regultions 2011 AS1940 - The Storage and Handling of Flammable & Combustible Liquids	

STAKEHOLDERS

Name	Role	Involvement
Jesse Brown	Manager- TES Sydney	
Aaron Hajinakitas	Operations Manager	
Lisa Gatt	HSEQ Manager - TES-National	
Neville Taylor	Sailor Solutions (external - ex ToxFree (electrical engineer). Via phone.	
Colin Barker		Advitech - Manager Process Engineering and Sustainability (Facilitator)
Carl Fung		Advitech - facilitator in training. Lead Consultant Process Engineering and Sustainability

EXTERNAL REQUIREMENTS, REFERENCES, LIMITATIONS

Ref	Description	Type

Name	Date Assessed	Objective/s Impacted	Event or Uncertainty Creating Risk	Specific Consequence And How It Influences The Objective	Type Of Risk Being Assessed:	Why Could This Occur	Implemented/Existing Controls	Consequence Rank	Likelihood Rank	Current Risk		Tolerable	Proposed Risk Controls
Gas release (external/off-site)	20-Oct-15		Incompatible materials are mixed together within the AAN process. The mixing of concentrated acid into the caustic solution may give rise to fume generation. Anticipated to be more likely Cl2. But possibly NOx and SOx. These are considered most likely byproducts of AAN neutralisation process.	Licence Breach Injury/disease	OHS	That incompatible materials react causing an emission of AAN tank mixing fume from the discharge emission point (i.e. stack).	Trained Chemists undertake sorting and segregation Staff are knowledgeable on the DG requirements for storage and handling AAN caustic scrubber system is routinely checked to be operating as per original design specification to ensure/maintain efficient stripping of any generated mixing fume. AAN scrubber ventilation system is routinely checked to be operating as per original design specification to ensure/maintain optimum gas dispersion. AAN process control interlocks are in-place to ensure continued addition of acid into neutralisation immediately stops should gas scrubber device or AAN scrubber ventilation system encounters an operating fault. Ensure AAN scrubber stack relase is well above roof requirements to prevent building downwwash. Emergency response equipment and emergency response plans Pollution Incident Response Plan in place Emergency contact details at site and in trucks	Minor	Unlikely	4 Medium	4	Tolerable	
Gas release (internal)	20-Oct-15		Incompatible materials are mixed together within the AAN process. The mixing of concentrated acid into the caustic solution may give rise to fume generation. Anticipated to be more likely Cl2. But possibly NOx and SOx. These are considered most likely byproducts of AAN neutralisation process. SOx, NOx, Cl2 considered most likely byproducts of AAN process. Gas release from AAN process openings within Toxfree operational area (i.e. Tank lid penetrations).	Licence Breach Injury/disease	OHS	That incompatible materials react causing excessive fume generation within the AAN mixing tank. The AAN scrubber ventilation system is not operating as per original design specification to ensure/maintain fumes within the tank are contained such that there is always a slight negative pressure within the AAN mixing tank. Designated AAN mixing tank openings are too large. The AAN mixing tank manhole access lid on top of the AAN mixing tank is left open during neutralisation mixing. That incompatible materials react causing an fume emission.	Trained Chemists undertake sorting and segregation Staff are knowledgeable on the DG requirements for storage and handling AAN scrubber ventilation system is routinely checked to be operating as per original design specification to ensure/maintain optimum gas dispersion. AAN process control interlocks are in-place to ensure continued addition of acid into neutralisation immediately stops should gas scrubber device or AAN scrubber ventilation system encounters an operating fault. Operators are geared-up to 'Red Zone' PPE requirements. Emergency response equipment and emergency response plans Pollution Incident Response Plan in place Emergency contact details at site and in trucks	Minor	Unlikely	4 Medium	4	Tolerable	Procedural controls to be rigidly implemented to ensure AAN mixing tank lid is closed to ensure that ventilation system captures fumes generated in the tank.
Release of hazardous aerosol(s)	20-Oct-15		Caustic aerosols from caustic scrubber system are entrained in scrubber ventilation system air flow path and exit the discharge stack as droplets. Caustic droplets may 'drop-out' onto roof area or ground level areas where workers or public may be.	Injury/disease Licence Breach	OHS	Caustic solution is sprayed into the scrubbing device. Depending on the atomisation process, very small caustic droplets may be entrained in upflow air stream. These aerosols may not coalescese and could be discharged through the scrubber system exhaust stack.	AAN caustic scrubber system is routinely checked to be operating as per original design specification to ensure/maintain efficient spray patterns of caustic stripper. AAN scrubber ventilation system is routinely checked to be operating as per original design specification to ensure/maintain optimum gas dispersion. AAN process control interlocks are in-place to ensure continued addition of acid into neutralisation immediately stops should gas scrubber device or AAN scrubber ventilation system encounters an operating fault.	Minor	Unlikely	4 Medium	4	Tolerable	A mist eliminator (or equivalent) to be installed on the outlet of the caustic scrubber.

Name	Date Assessed	Objective/s Impacted	Event or Uncertainty Creating Risk	Specific Consequence And How It Influences The Objective	Type Of Risk Being Assessed:	Why Could This Occur	Implemented/Existing Controls	Consequence Rank	Likelihood Rank	Current Risk	`	Tolerable	Proposed Risk Controls	Residual Consequen
Flammable fluid spill/loss of containment	20/10/2015		Explosion / Fire as a result of flammable spill source	Licence Breach Serious injury	OHS	Vapour cloud generated from a spill finds an ignition source. I.e. static, flame etc.	Earthing of Plant, Equipment and the Room Re-training and review of SWMS for the Area taking into account earthing. Re-training of Chemists Anti-static clothing for operators Elimination of mobile phones in the area Site security and vetting protocols	Major	Unlikely	8 Medium	8	Tolerable		
Pool Fire of flammables	20/10/2015		Fire and radiation emission resulting in bleve of drums.	Licence Breach Serious injury	OHS	Pool fire caused by flammable fluid spill/loss of containment. Pool fire located in the wrong area. I.e. warehouse.	Safe work procedures, Staff training, Process overseen by operations manager, Site supervisors who are familiar with licence conditions	Moderate	Unlikely	6 Medium	6	Tolerable		
Gas release	20/10/2015		Forktruck impact initiates a spill within the warehouse. Leaks from IBS container valves. Incompatible materials react causing an emission of fume. Incorrectly labelled and classified goods are stored in a single transport container that is compromised during a transfer incident.	Serious injury, mixing of incompatible materials leading to fire/explosion or toxic cloud release etc.	OHS	Poor Traffic Management Untrained forklift drivers Unfamiliar with site layout Poorly maintained plant and equipment Incorrectly labelled/identified goods on clients manifest declarations.	Traffic Management Plan (walking pace for all persons and vehicles) Line marking Licenced forklift drivers Maintained Plant and Equipment Visitors escorted Clients trained and retrained in the importance of correctly identifying and labelling goods in each shipment and on each manifest. Staff inductions and training site security and vetting protocols	Major	Unlikely	8 Medium	8	Tolerable	Continuous improvement	

Appendix II

Consequence Modelling

```
============
SLAB REPORT Cl2 Scenario
============

Run: 25/11/2015 3:14:28 PM
Project File: C:\Lakes\SLAB View\14141-200-A Slab Cl2 offsite\14141-200-A Slab Cl2 offsite.slb
Generated By: SLAB View - Lakes Environmental Software

--------------------------------------------------------------
INPUT DATA
--------------------------------------------------------------

SOURCE PARAMETERS

Source type                        Vertical Jet
X Coordinate:                       293512.20 m
Y Coordinate:                       6263549.70 m

CHEMICAL PROPERTIES

Chemical Name                          CHLORINE
Molecular weight (WMS)                     70.9 g/mole
Vapor heat capacity (CPS)                  498.1 J/kg-K
Boiling point temperature (TBP)              239.1 K
Heat of vaporization (DHE)                 287840 J/kg
Liquid heat capacity (CPSL)                926.3 J/kg-K
Liquid density (RHOSL)                   1574 kg/m**3
Saturation pressure constant (SPB)          1978.34
Saturation pressure constant (SPC)          -27.01

SPILL PARAMETERS

Initial liquid mass fraction (CMEDO)        0
Temperature of the source material (TS)      333 K
Mass source rate (QS)                      0.1433 kg/s
Source Area (AS)                         0.00553 m**2
Continuous source duration (TSD)            120 s
Instantaneous source mass (QTIS)             0 kg
Source height (HS)                       15.00 m

FIELD PARAMETERS

Concentration averaging time (TAV)          600 s
Maximum downwind distance (XFFM)             10000.00 m
Height of concentration calculation (ZP(1))   0.00 m
Height of concentration calculation (ZP(2))   0.00 m
Height of concentration calculation (ZP(3))   0.00 m
Height of concentration calculation (ZP(4))   0.00 m
```

```
METEOROLOGY PARAMETERS

MET CONDITION 1
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               1.6 m/s
Ambient temperature (TA)              294.4 K
Relative humidity   (RH)            50 %
Stability class (STAB)             1 (A)

MET CONDITION 2
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               2.9 m/s
Ambient temperature (TA)              283 K
Relative humidity   (RH)            50 %
Stability class (STAB)             2 (B)

MET CONDITION 3
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               3.6 m/s
Ambient temperature (TA)              291.8 K
Relative humidity   (RH)            50 %
Stability class (STAB)             3 (C)

MET CONDITION 4
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               4.8 m/s
Ambient temperature (TA)              290.9 K
Relative humidity   (RH)            50 %
Stability class (STAB)             4 (D)

MET CONDITION 5
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               3.2 m/s
Ambient temperature (TA)              290.4 K
Relative humidity   (RH)            50 %
Stability class (STAB)             5 (E)

MET CONDITION 6
Surface roughness height (ZO)           1 m
Ambient measurement height (ZA)           10.00
Ambient wind speed (UA)               1.7 m/s
Ambient temperature (TA)              287.2 K
Relative humidity   (RH)            50 %
Stability class (STAB)             6 (F)

--------------------------------------------------------------
```

```
OUTPUT RESULTS
--------------------------------------------------------------

FOOTPRINT - MET CONDITION 1

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                        234.48
2.8                         93.98
50                           0.00

FOOTPRINT - MET CONDITION 2

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                        315.44
2.8                          0.00
50                           0.00

FOOTPRINT - MET CONDITION 3

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                        565.08
2.8                          0.00
50                           0.00

FOOTPRINT - MET CONDITION 4

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                        679.28
2.8                          0.00
50                           0.00

FOOTPRINT - MET CONDITION 5

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                       1266.24
2.8                        445.22
50                           0.00

FOOTPRINT - MET CONDITION 6

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.5                       2638.53
2.8                       1071.25
50                         131.97
```

```
============
SLAB REPORT SO2 Scenario
============

Run: 25/11/2015 8:29:46 PM
Project File: C:\Lakes\SLAB View\14141-201-A Slab SO2 offsite\14141-201-A Slab SO2 offsite.slb
Generated By: SLAB View - Lakes Environmental Software

------------------------------------------------------------
INPUT DATA
------------------------------------------------------------

SOURCE PARAMETERS

Source type                     Vertical Jet
X Coordinate:                    293512.20 m
Y Coordinate:                    6263549.70 m

CHEMICAL PROPERTIES

Chemical Name                       SULFUR DIOXIDE
Molecular weight (WMS)                 64.06 g/mole
Vapor heat capacity (CPS)              622.6 J/kg-K
Boiling point temperature (TBP)          263 K
Heat of vaporization (DHE)             386500 J/kg
Liquid heat capacity (CPSL)             1331 J/kg-K
Liquid density (RHOSL)                1462 kg/m**3
Saturation pressure constant (SPB)         2302.35
Saturation pressure constant (SPC)         -35.97

SPILL PARAMETERS

Initial liquid mass fraction (CMEDO)        0
Temperature of the source material (TS)       333 K
Mass source rate (QS)                    0.0757 kg/s
Source Area (AS)                       0.00317 m**2
Continuous source duration (TSD)           300 s
Instantaneous source mass (QTIS)            0 kg
Source height (HS)                     15.00 m

FIELD PARAMETERS

Concentration averaging time (TAV)          600 s
Maximum downwind distance (XFFM)            10000.00 m
Height of concentration calculation (ZP(1))   0.00 m
Height of concentration calculation (ZP(2))   0.00 m
Height of concentration calculation (ZP(3))   0.00 m
Height of concentration calculation (ZP(4))   0.00 m

METEOROLOGY PARAMETERS
```

```
MET CONDITION 1
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              1.6 m/s
Ambient temperature (TA)             294.4 K
Relative humidity   (RH)           50 %
Stability class (STAB)            1 (A)

MET CONDITION 2
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              2.9 m/s
Ambient temperature (TA)             283 K
Relative humidity   (RH)           50 %
Stability class (STAB)            2 (B)

MET CONDITION 3
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              3.6 m/s
Ambient temperature (TA)             291.8 K
Relative humidity   (RH)           50 %
Stability class (STAB)            3 (C)

MET CONDITION 4
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              4.8 m/s
Ambient temperature (TA)             290.9 K
Relative humidity   (RH)           50 %
Stability class (STAB)            4 (D)

MET CONDITION 5
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              3.2 m/s
Ambient temperature (TA)             290.4 K
Relative humidity   (RH)           50 %
Stability class (STAB)            5 (E)

MET CONDITION 6
Surface roughness height (ZO)          1 m
Ambient measurement height (ZA)          10.00
Ambient wind speed (UA)              1.7 m/s
Ambient temperature (TA)             287.2 K
Relative humidity   (RH)           50 %
Stability class (STAB)            6 (F)

--------------------------------------------------------------
OUTPUT RESULTS
```

```
----------------------------------------------------------------

FOOTPRINT - MET CONDITION 1

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                      441.96
0.75                      224.39
30                         0.00

FOOTPRINT - MET CONDITION 2

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                      605.25
0.75                      291.02
30                         0.00

FOOTPRINT - MET CONDITION 3

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                     1119.36
0.75                      523.22
30                         0.00

FOOTPRINT - MET CONDITION 4

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                     1403.15
0.75                      600.63
30                         0.00

FOOTPRINT - MET CONDITION 5

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                     2535.70
0.75                     1170.04
30                         0.00

FOOTPRINT - MET CONDITION 6

Concentration (ppm)      Downwind Distance (m)
----------------------------------------------
0.2                     4922.00
0.75                     2585.35
30                       294.18
```

Appendix III

Meteorological Data

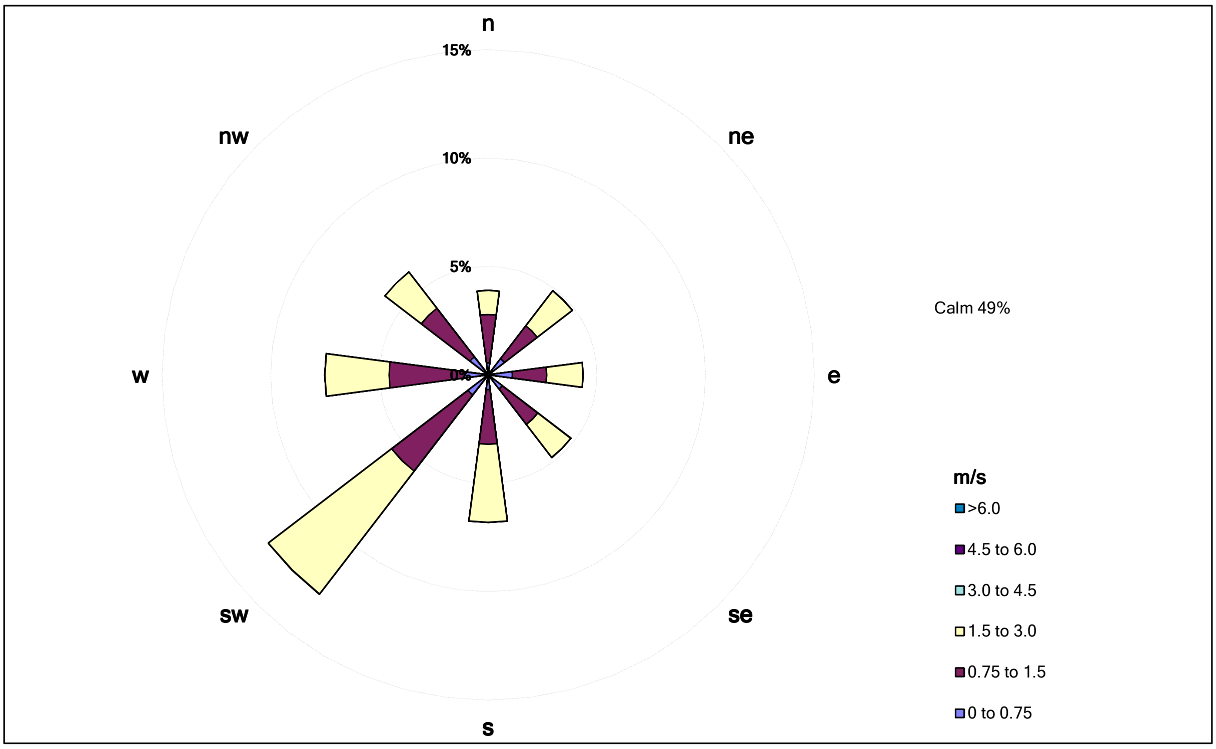


Figure 3: St Marys F Class Stability Wind Roses (based on 2006 Horsley Park Meteorological Data)

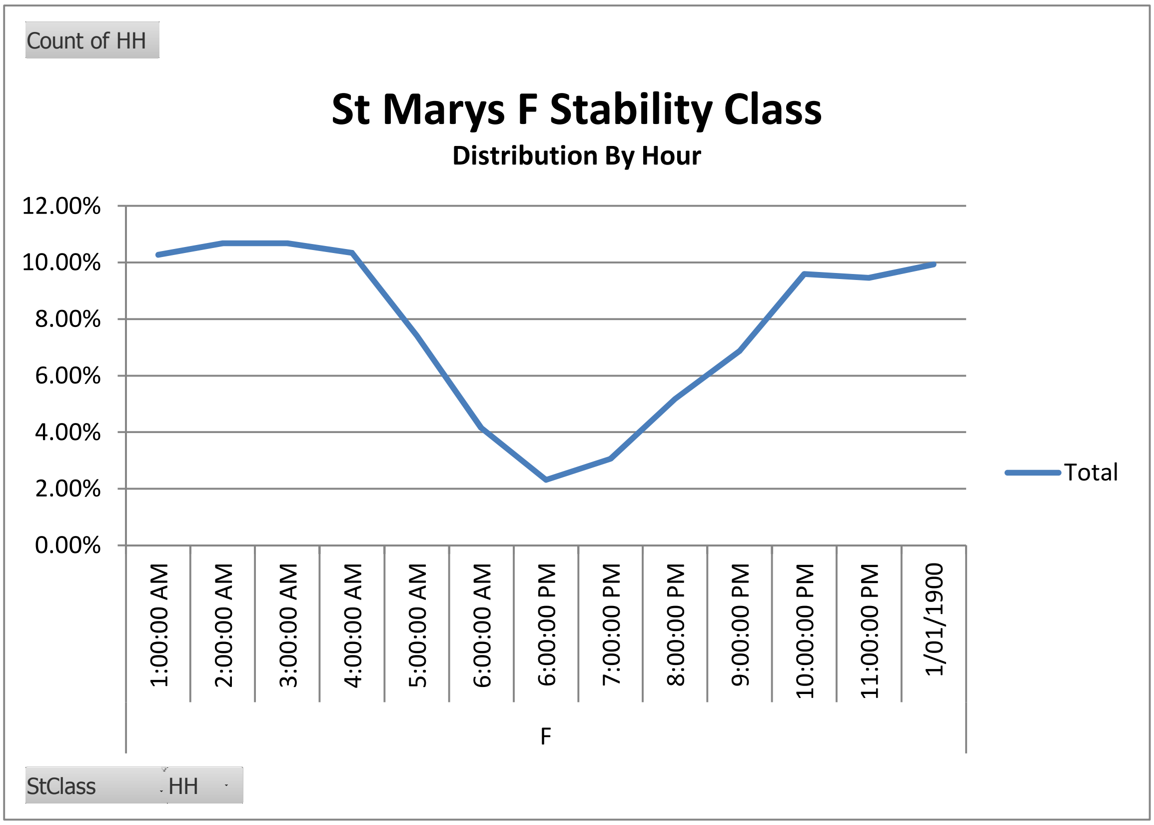


Figure 4: St Marys F Class Stability Distribution by Hour of Day (Zero all other times)

Input Meteorological data file for AUSPLUME

Horsley Park–2006

This file was exclusively compiled for Advitech Pty Ltd By pDs MultiMedia & Consultancy Service.

pDs Consultancy
@2008

Introduction

Gaussian plume models require hourly averaged meteorological data from a single site which is preferably in the model domain (site-specific data). While site-specific data is preferred, data from the nearest off-site meteorological station can be used when on-site data are not available. This data should represent the area of concern and the meteorological parameters should chracterise the transport and dispersion conditions of the area of concern.

Meteorological input is crucial in Gaussian plume modeling. Therefore compilation of input meteorological data files should be done meeting the procedures and algorithms set by environment regulators. It is always preferred to collect mandatory data such as wind speed, direction, sigamatheta (Calculated from Wind Direction measurements) and ambient temperature onsite. And again instrumentations and siting should meet Australian Standard (2923 –ambient air guide for measurement of horizontal wind for air quality applications).

Horsley Park weather station found to be the best available data source maintained by Bureau of Meteorology to prepare input meteorological data file for **Minchinbury** (NSW).

This file was complied following the set procedure and the algorithms recommended by EPA, Victoria.

LOCATION:

Location: Horsley Park

Longitude :150.85 E
Latitude :-33.85 S

Data Source
EPA,NSW
BoM NCC,Melbourne

DATA PROCESSING

Data Source

1. **Horsley Park** AWS Data- BoM, NSW (Regional Office).

2. **Sydney Airport Cloud** data and Vertical temperature Profiles -National Climate Centre- Bureau of Meteorology, Melbourne.

Input Information

- Onsite (**Horsley Park**) parameters
    a. Wind speed (km/h)
    b. Wind direction
    c. Ambient Temperature (C)
    d. Dewpoint
    e. Rainfall
- Offsite (**Sydney Airport**)
    f. Surface Pressure
    g. Total Clod amount

Wind was measured at 10m (Anemometer Height), surface roughness assumed to be 0.4m

- **Sydney Airport (NSW)**
    1. Vertical temperature profiles; Temperature, Dew point (2 profiles per day)

Other Info:

Land use category: Mixed Rural/Residential
Surface Roughness: 0.4 m
Anemometre Height :10m

QA/QC ON RAW DATA

This data set was treated as follows

- Incomplete days removed
- Suspected wind stalls (both wind direction and speed) removed
- Small gaps filled with previous or following data
- Hourly rainfall rate calculated from accumulated rainfall records

- Pressure, Dew point Temperature and cloud amount were checked for unusual values

SYDNEY AIRPORT (BOM)VERTICAL TEMPERATURE PROFILES

- Gaps in vertical temperature profiles were filled with previous or following day data for the completeness.

DETERMINATION OF SECONDARY PARAMETERS

VERTICAL STABILITY

Solar Radiation for day time and Modified Pasquill Stability Class outlined in the reference, Davis and Singh, Jl of Hazardous Materials, 11 was used to determine night-time stability class. Solar radiation was theoretically calculated using off site cloud observations.

Table 1 for daytime and part of Table 2 for night-time were used.

TABLE 1: STABILITY CLASSIFICATION FOR DAYTIME USING SOLAR RADIATION AND WIND SPEED

	Solar Radiation (W/m²)			
Wind Speed(m/s)	≥925	≥675	≥175	< 175
< 2	A	A	B	D
< 3	A	B	C	D
< 5	B	B	C	D
< 6	C	C	D	D
≥ 6	C	D	D	D

Table 2: Modified Pasquill stability calsses

Surface Wind Speed (m/s) At 10m	Daytime incoming solar radiation				Within 1 Hour before sunset or after sunrise	Night-time cloud amount (Octas)		
	Strong (>600)	Moderate (300–600)	Slight (<300)	Overcast		0–3	4–7	8
< 2	A	A–B	B	D	D	F	F	D
< 3	A–B	B	C	D	D	F	E	D
< 5	B	B–C	C	D	D	E	D	D
< 6	C	C–D	D	D	D	D	D	D
≥ 6	C	D	D	D	D	D	D	D

MIXING HEIGHT (CONVECTIVE & MECHANICAL)

DEFINITION:

The mixing height, the depth of the surface mixed layer is the height of the atmosphere above the ground, which is well mixed due either to mechanical turbulence or convective turbulence. The air layer above this height is stable.

The mixing height was determined by using the methodology of Benkley and Schulman (Journal of Applied Meteorology, Volume 18, 1979,pp 772-780). **Sydney Airport** upper air observation containing temperature and moisture profiles were used to determine daytime mixing height.

Surface wind speeds and roughness are used to calculate the depth of the mechanically forced boundary layer during the night time.

MixHm=0.185* Ustar/Cterm

Where Ustar=.35*Usfc/Ln (Htanemo/Z0)

Cterm = Coriolis Term =2 Ω Sin(ϕ)

Where Ω is the angular velocity of the earth

ϕ is the latitude

Htanemo= Anemometer Height, Z0 is the roughness

Height of the convective boundary layer was determined using daytime temperature sounding (Vertical temperature and dewpoint profiles) in between sunrise and sunset. Evening sounding for the same day is used to compensate daytime sounding to calculate convective mixing height at different daylight hours (Temperature difference at 700 hPa layer is used to allow advection). Larger value of the mechanical turbulence or convective turbulence was taken as Mixing height for the daylight hours.

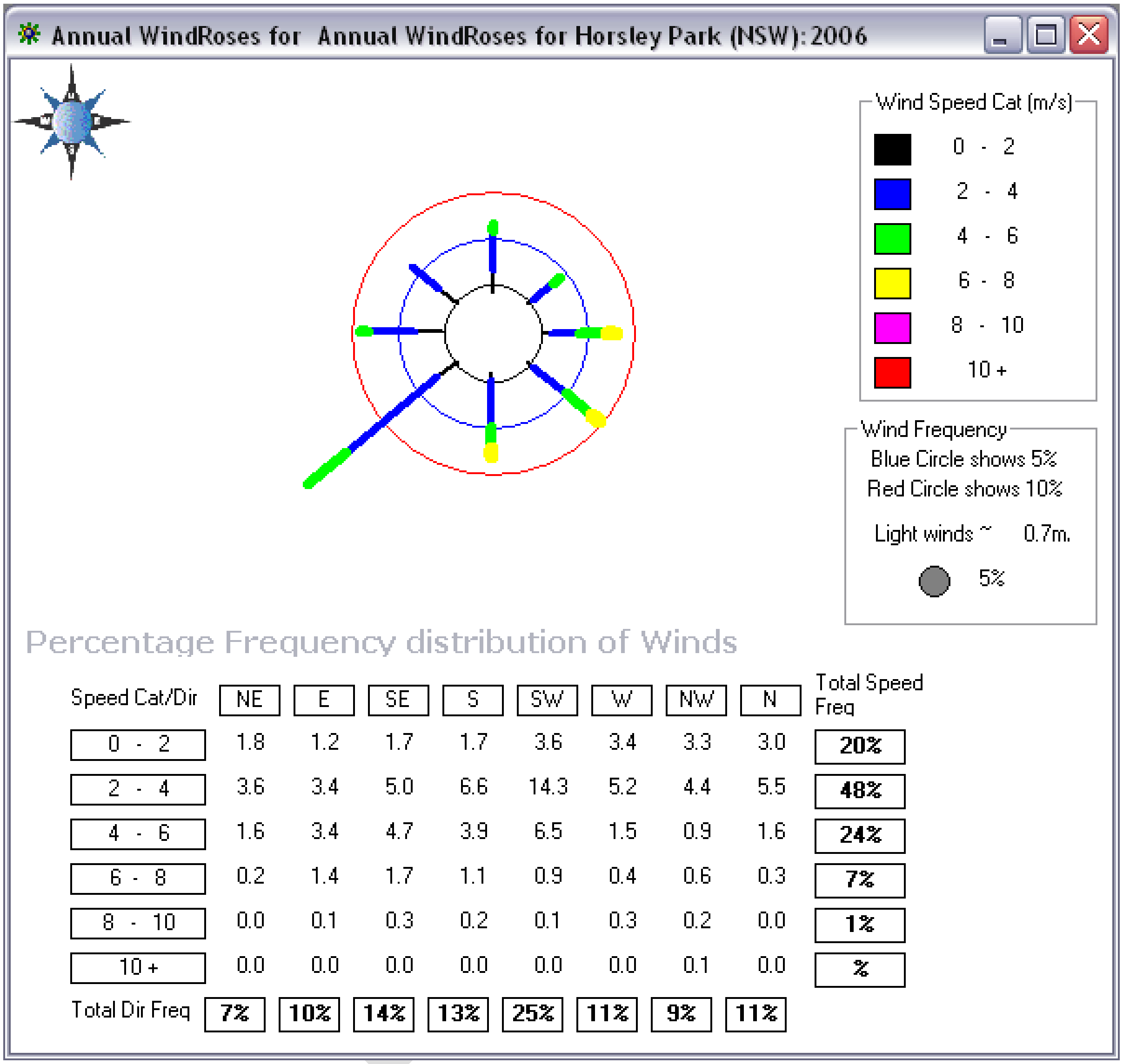
ANALYSIS

DATA COVERAGE

Season	No. of Days	Percentage
Summer (90 days)	89	97%
Autumn (92 days)	92	100%
Winter(92 days)	92	100%
Spring (91 days)	91	100%
Annual (365 days)	364	99%

All seasons are well represented.

ANNUAL WINDROSES



Annual WindRoses for Annual WindRoses for Horsley Park (NSW): 2006

Wind Speed Cat (m/s)

■	0 - 2
🟦	2 - 4
🟩	4 - 6
🟨	6 - 8
🟪	8 - 10
🟥	10 +

Wind Frequency
Blue Circle shows 5%
Red Circle shows 10%

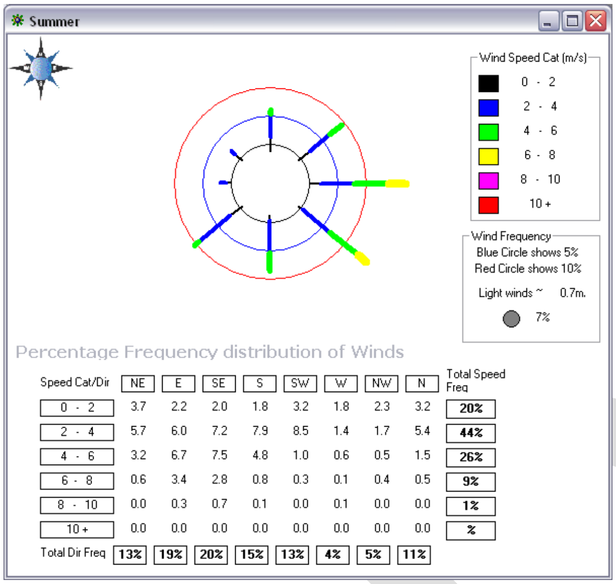
Light winds ~ 0.7m.

● 5%

Percentage Frequency distribution of Winds

Speed Cat/Dir	NE	E	SE	S	SW	W	NW	N	Total Speed Freq
0 - 2	1.8	1.2	1.7	1.7	3.6	3.4	3.3	3.0	**20%**
2 - 4	3.6	3.4	5.0	6.6	14.3	5.2	4.4	5.5	**48%**
4 - 6	1.6	3.4	4.7	3.9	6.5	1.5	0.9	1.6	**24%**
6 - 8	0.2	1.4	1.7	1.1	0.9	0.4	0.6	0.3	**7%**
8 - 10	0.0	0.1	0.3	0.2	0.1	0.3	0.2	0.0	**1%**
10 +	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	**%**
Total Dir Freq	**7%**	**10%**	**14%**	**13%**	**25%**	**11%**	**9%**	**11%**	

SEASONAL WINDROSES



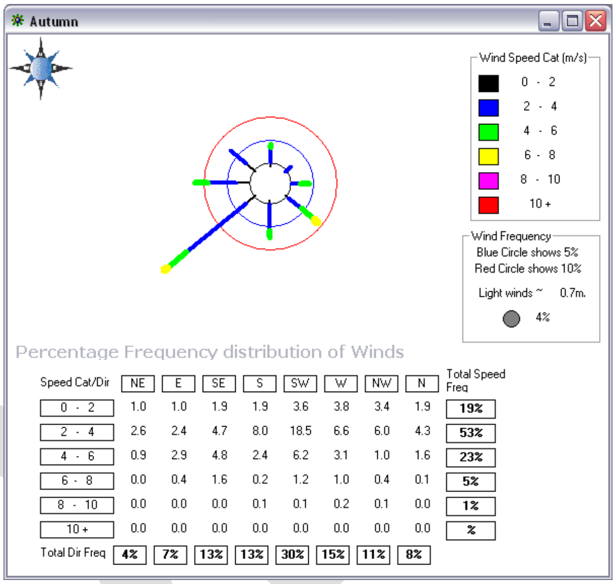
Wind Speed Cat (m/s)

- ■ 0 - 2
- 🟦 2 - 4
- 🟩 4 - 6
- 🟨 6 - 8
- 🟪 8 - 10
- 🟥 10 +

Wind Frequency
Blue Circle shows 5%
Red Circle shows 10%
Light winds ~ 0.7m.
● 7%

Percentage Frequency distribution of Winds

Speed Cat/Dir	NE	E	SE	S	SW	W	NW	N	Total Speed Freq
0 - 2	3.7	2.2	2.0	1.8	3.2	1.8	2.3	3.2	**20%**
2 - 4	5.7	6.0	7.2	7.9	8.5	1.4	1.7	5.4	**44%**
4 - 6	3.2	6.7	7.5	4.8	1.0	0.6	0.5	1.5	**26%**
6 - 8	0.6	3.4	2.8	0.8	0.3	0.1	0.4	0.5	**9%**
8 - 10	0.0	0.3	0.7	0.1	0.0	0.1	0.0	0.0	**1%**
10 +	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**%**
Total Dir Freq	**13%**	**19%**	**20%**	**15%**	**13%**	**4%**	**5%**	**11%**	



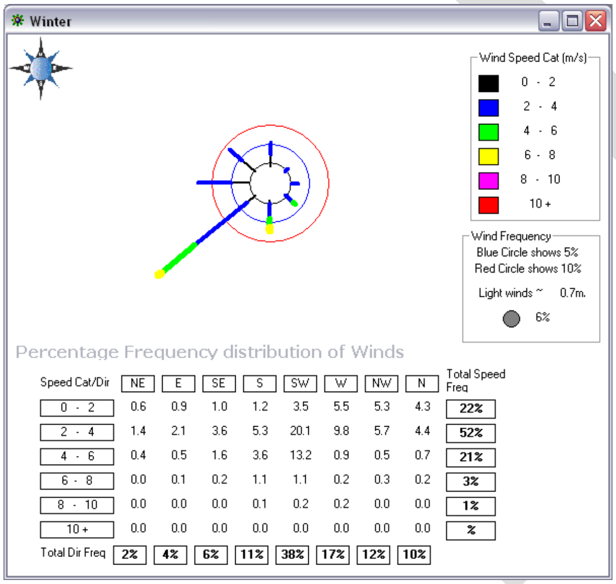
Wind Speed Cat (m/s)

- ■ 0 - 2
- 🟦 2 - 4
- 🟩 4 - 6
- 🟨 6 - 8
- 🟪 8 - 10
- 🟥 10 +

Wind Frequency
Blue Circle shows 5%
Red Circle shows 10%
Light winds ~ 0.7m.
● 4%

Percentage Frequency distribution of Winds

Speed Cat/Dir	NE	E	SE	S	SW	W	NW	N	Total Speed Freq
0 - 2	1.0	1.0	1.9	1.9	3.6	3.8	3.4	1.9	**19%**
2 - 4	2.6	2.4	4.7	8.0	18.5	6.6	6.0	4.3	**53%**
4 - 6	0.9	2.9	4.8	2.4	6.2	3.1	1.0	1.6	**23%**
6 - 8	0.0	0.4	1.6	0.2	1.2	1.0	0.4	0.1	**5%**
8 - 10	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	**1%**
10 +	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**%**
Total Dir Freq	**4%**	**7%**	**13%**	**13%**	**30%**	**15%**	**11%**	**8%**	



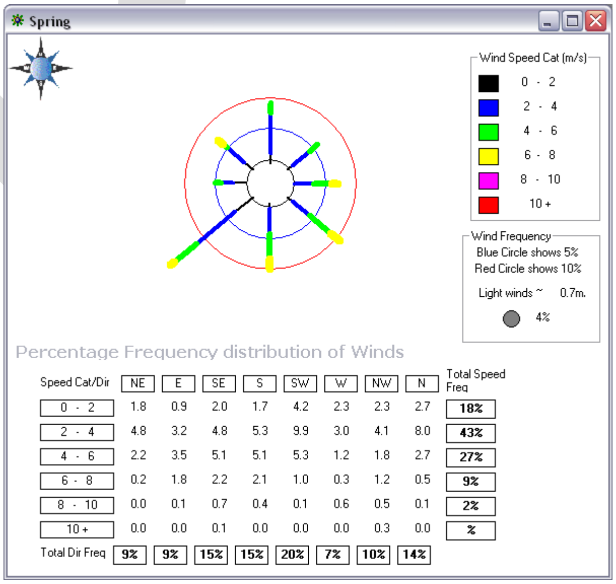
Wind Speed Cat (m/s)

- ■ 0 - 2
- 🟦 2 - 4
- 🟩 4 - 6
- 🟨 6 - 8
- 🟪 8 - 10
- 🟥 10 +

Wind Frequency
Blue Circle shows 5%
Red Circle shows 10%
Light winds ~ 0.7m.
● 6%

Percentage Frequency distribution of Winds

Speed Cat/Dir	NE	E	SE	S	SW	W	NW	N	Total Speed Freq
0 - 2	0.6	0.9	1.0	1.2	3.5	5.5	5.3	4.3	**22%**
2 - 4	1.4	2.1	3.6	5.3	20.1	9.8	5.7	4.4	**52%**
4 - 6	0.4	0.5	1.6	3.6	13.2	0.9	0.5	0.7	**21%**
6 - 8	0.0	0.1	0.2	1.1	1.1	0.2	0.3	0.2	**3%**
8 - 10	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0	**1%**
10 +	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**%**
Total Dir Freq	**2%**	**4%**	**6%**	**11%**	**38%**	**17%**	**12%**	**10%**	



Wind Speed Cat (m/s)

- ■ 0 - 2
- 🟦 2 - 4
- 🟩 4 - 6
- 🟨 6 - 8
- 🟪 8 - 10
- 🟥 10 +

Wind Frequency
Blue Circle shows 5%
Red Circle shows 10%
Light winds ~ 0.7m.
● 4%

Percentage Frequency distribution of Winds

Speed Cat/Dir	NE	E	SE	S	SW	W	NW	N	Total Speed Freq
0 - 2	1.8	0.9	2.0	1.7	4.2	2.3	2.3	2.7	**18%**
2 - 4	4.8	3.2	4.8	5.3	9.9	3.0	4.1	8.0	**43%**
4 - 6	2.2	3.5	5.1	5.1	5.3	1.2	1.8	2.7	**27%**
6 - 8	0.2	1.8	2.2	2.1	1.0	0.3	1.2	0.5	**9%**
8 - 10	0.0	0.1	0.7	0.4	0.1	0.6	0.5	0.1	**2%**
10 +	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	**%**
Total Dir Freq	**9%**	**9%**	**15%**	**15%**	**20%**	**7%**	**10%**	**14%**	

ANNUAL STABILITY DISTRIBUTION

Stability Category	**% Distribution**	**Avg Wind Speed**	**Avg Temperature**	**Avg Mixing Height**
A	3	1.6	21.4	727
B	12	2.9	20.5	1024
C	16	3.6	18.8	1110
D	42	4.8	17.9	1213
E	11	3.2	17.4	806
F	16	1.7	14.2	446

STATISTICS OF HORSLEY PARK (NSW) INPUT METEOROLOGICAL DATA FILE–2006

Stability Class	Stat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
A	Max of Temp	35.0	37.0	29.0	29.0	19.0			18.0	25.0	36.0	33.0	37.0	37.0
	Min of Temp	20.0	19.0	19.0	17.0	17.0			14.0	13.0	14.0	10.0	14.0	10.0
	Average of Temp	26.5	25.8	24.0	24.5	18.0			15.9	19.3	22.9	21.4	20.4	23.1
	Max of WS	2.5	2.5	2.5	1.4	1.4			1.4	2.5	2.5	2.5	2.2	2.5
	Min of WS	0.6	0.6	0.6	1.1	1.4			0.6	0.6	0.6	0.6	0.6	0.6
	Average of WS	1.3	1.3	1.5	1.3	1.4			1.2	1.3	1.7	1.7	1.5	1.4
	Max of MixH	1572	2115	2679	2437	667			982	1961	1770	1721	1903	2679
	Min of MixH	149	199	298	428	481			328	275	283	180	267	149
	Average of MixH	729	895	1204	1348	574			594	735	740	719	911	825
B	Max of Temp	35.0	38.0	33.0	31.0	24.0	20.0	19.0	21.0	28.0	36.0	36.0	36.0	38.0
	Min of Temp	18.0	16.0	13.0	5.0	10.0	3.0	4.0	5.0	8.0	8.0	8.0	11.0	3.0
	Average of Temp	24.7	25.4	23.2	19.8	17.3	11.4	11.2	15.0	18.9	21.2	21.4	22.0	20.4
	Max of WS	4.7	4.7	4.7	4.7	4.7	1.4	1.4	4.7	4.7	4.7	4.7	4.7	4.7
	Min of WS	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.1	0.6	0.6	0.6
	Average of WS	2.3	2.5	2.3	2.8	1.7	1.2	1.0	2.4	2.8	3.1	2.7	3.1	2.5
	Max of MixH	2056	2635	2327	2309	1544	1543	1112	1656	2227	2741	2148	2165	2741
	Min of MixH	149	149	248	348	248	180	149	199	180	273	149	199	149
	Average of MixH	900	1029	1019	1108	858	557	430	826	1000	1147	872	1106	962
C	Max of Temp	41.0	37.0	34.0	32.0	24.0	18.0	20.0	24.0	27.0	36.0	37.0	39.0	41.0
	Min of Temp	17.0	13.0	14.0	8.0	7.0	5.0	4.0	6.0	9.0	7.0	9.0	12.0	4.0
	Average of Temp	22.3	23.5	21.6	19.2	15.9	12.7	13.3	14.6	17.3	17.9	20.8	20.5	18.4
	Max of WS	7.8	6.7	5.8	5.8	5.8	5.0	5.0	5.8	5.8	7.8	9.7	7.8	9.7
	Min of WS	0.6	1.1	1.1	2.2	1.4	0.6	1.1	1.4	2.2	0.6	0.6	0.6	0.6
	Average of WS	3.4	3.5	3.2	3.5	3.2	3.0	3.1	3.3	3.5	3.5	3.9	3.5	3.4
	Max of MixH	2957	2618	2286	2618	1882	2261	2316	2024	2570	2085	2408	2575	2957
	Min of MixH	248	478	397	478	348	273	397	428	496	416	348	201	201
	Average of MixH	1051	1053	1014	1222	985	820	905	992	1185	1067	1105	1112	1037
D	Max of Temp	43.0	37.0	34.0	32.0	25.0	19.0	22.0	25.0	33.0	37.0	38.0	38.0	43.0
	Min of Temp	17.0	14.0	14.0	3.0	3.0	1.0	1.0	3.0	6.0	6.0	9.0	11.0	1.0
	Average of Temp	22.3	22.9	21.5	17.6	14.1	11.4	11.9	13.3	16.3	17.6	19.7	20.7	17.6
	Max of WS	10.3	9.7	8.3	8.6	9.2	9.2	9.2	8.3	13.3	12.2	11.4	9.2	13.3
	Min of WS	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Average of WS	3.9	4.4	4.2	4.2	4.0	3.6	3.8	4.0	5.0	4.4	4.9	4.5	4.3
	Max of MixH	2948	2821	2166	2312	2503	2246	2073	2366	3103	2521	2636	2753	3103
	Min of MixH	149	149	199	230	199	199	149	149	149	199	149	248	149
	Average of MixH	985	1119	1046	1063	1012	887	941	1012	1283	1124	1227	1173	1079
E	Max of Temp	39.0	31.0	33.0	27.0	19.0	15.0	19.0	23.0	25.0	32.0	31.0	33.0	39.0
	Min of Temp	17.0	16.0	15.0	9.0	7.0	5.0	5.0	6.0	10.0	8.0	10.0	13.0	5.0
	Average of Temp	22.9	21.0	19.9	15.9	12.2	9.4	11.0	12.0	16.5	17.4	18.3	19.7	15.1
	Max of WS	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	Min of WS	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	Average of WS	3.2	3.0	3.1	3.4	3.1	3.4	3.2	3.4	3.4	3.3	3.1	3.1	3.2
	Max of MixH	1353	1185	1254	1235	1223	1185	1191	1359	1378	1223	1204	1235	1378

	Min of MixH	428	428	397	397	447	348	496	379	478	447	484	515	348
	Average of MixH	816	744	763	839	766	827	772	822	838	811	761	782	798
F	Max of Temp	27.0	28.0	31.0	26.0	20.0	14.0	19.0	19.0	23.0	30.0	23.0	28.0	31.0
	Min of Temp	17.0	15.0	14.0	4.0	4.0	2.0	2.0	3.0	9.0	7.0	10.0	11.0	2.0
	Average of Temp	21.4	20.2	19.6	14.1	11.6	8.7	9.1	9.7	13.3	14.2	16.0	16.5	13.6
	Max of WS	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Min of WS	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Average of WS	1.4	1.7	1.5	1.7	1.8	1.8	1.5	1.7	1.6	1.6	1.8	1.6	1.7
	Max of MixH	726	1067	980	757	949	832	763	794	844	770	863	757	1067
	Min of MixH	149	149	149	149	149	149	149	149	149	149	180	149	149
	Average of MixH	375	459	416	467	480	495	410	442	437	435	481	426	445

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Appendix IV

Risk Calculations

Risk calculations are presented for potential off-site impacts only. The following risk calculations are presented:

a) Calculation of worst-case Cl_2 gas release due to the mixing of incompatible quantities of acid and alkali solutions.

b) Calculation of worst-case SO_2 gas release due to the mixing of incompatible quantities of acid and alkali solutions.

Assessment Bases		Neutralisation tank			Chem characteristics		
Neutralisation tank is filled with concentrated sodium hypochlorite (i.e. bleach 33% by volume). Volume 500 L		33%	tank volume of bleach		52.46	g/mol	**HOCl**
Addition of hydrochloric acid at a rate of 10 L/min.					36.458	g/mol	**HCL**
Operator process E-stop response time of one minute after evidence of Cl2 evolution/ instrumentation alarm. Acid addition is stopped.		22	L of acid added before E-stop		18.016	g/mol	**H_2O**
Temperature of neutralisation contents (and generated gas) is 60 degrees. This is the max temperature before any type of control interlock is activated.		10	L/min rate of addition of acid		70.9	g/mol	**CL_2**
The free air space within the AAN neutralisation tank is at atmospheric pressure.		2.2	minutes before E-Stop		16.00	Molar mass	**O**
A ventilation system is connected to the AAN Mixing Tank and operates at a rate of 2 m3/min. Replacement air enters the AAN Mixing Tank via loose fitting lids/ small gaps in the AAN Mixing Tank lid.		2	m3/min Ventilation		1.008	Molar mass	**H**
Reaction rate is instant and not limited by pH (which it will). All acid reactes with HOCl. HOCl is not limiting.		0.03	m3/s Ventilation		35.45	Molar mass	**Cl**
AAN Mixing Tank is well mixed		33.33	L/s Ventilation				
Cl2 fumes generated are emitted at 60 degrees		10.0452824	m/s stack discharge				
Cl2 formation reaction type (HOCl + HCl resulting in $H_2O + Cl_2$)		0.065	stack diameter (m)				
Assume reaction reaches completion (not just some equilibrium)		0.003318307	Area stack diameter (m2)				
Caustic/ NaOH scrubber is off-line. All Cl2 emitted via stack.							
AAN Mixing Tank is 1.5 m3 total volume.							
10m/s stack velocity to observe recommended practice from NSW EPA.		Density		Source:			
		1163.5	g/L 38% wt/wt solution HCl liquid density@60°C	http://www.handymath.com/cgi-bin/hcltble3.cgi?submit=Entry			
		2.59	kg/m^3 Cl gas density at 60C	http://encyclopedia.airliquide.com/Encyclopedia.asp?GasID=13			
		Acid Concentration					
		38%	common commercial conc	https://www.labchem.com/media/acids-and-bases.pdf			

Calculation			
Determine the Cl2 emission volume and rate of emission.			
	38	%	
	22	L of HCl added based on addition rate	
	26	kgs of HCl	
	267	g Moles of HCl	
Therefore assume identical HOCl Moles	267	g Moles of HOCl	
	4807	g of H_2O	
	18916	g of Cl_2	
	5	kg of H_2O	
	19	kg of Cl_2	
Cl_2 emission volume	7.3	m^3	
Cl_2 rate of emission over time period before E-stop	0.055329	m^3/s	
Cl_2 rate of emission	3.32	m3/min	
Cl2 mass emission rate over time period before E-stop	0.1433	kg/s	
Look for max volume without ventilation			
Seeing as ventilation rate is less than generation rate then max volume of gas will be when E-stop is triggered		4.4	m^3 ventilated in 'x' mins. Refer to Cell C6.
		7.3	m^3 Cl2 generated in x mins. Refer to Cell C6.
		2.9	m^3 max volume of Cl_2 gas

"10M" sulfuric acid (the modern equivalent of chamber acid, used in many titrations) . 10M H2SO4 is approximately 70% wt/wt. [https://en.wikipedia.org/wiki/Sulfuric_acid]

HCl max composition is 38% wt/wt. [https://en.wikipedia.org/wiki/Hydrochloric_acid]

Yellow fields = input fields

Green fields = calculated fields

Cell: C5

Comment: Carl Fung:

User input

Cell: C6

Comment: Carl Fung:

1.1 minutes before Cl2 begins to emit from lid penetrations plus additional minute for operator to either see or smell CL2 and force stop. Additional 1 minute to ventilate all Cl2 out of system. Time used 2 minutes.

Slab model uses 2minute release rate at 0.1422 kg/s.

Cell: C7

Comment: Carl Fung:

from design data

Cell: D12

Comment: Carl Fung:

to achieve 10 m/s

Cell: C17

Comment: Carl Fung:

MB 3.71 incorrect. Should be at 60c which is 2.59 kg/m3.

Cell: B24

Comment: Carl Fung:

HCl acid wt/wt concentration.

Cell: B29

Comment: Carl Fung:

HOCl is not limiting reactant.

Cell: C44

Comment: Carl Fung:

The available free air space within the AAn Mixing tank is approximately 1.5m3 at the commencement of acid addition. At approximately 1.1 minutes the ventilation system will preferrentially exhaust Cl2 at a rate of approximately 2 m3/min with the surplus being emitted from AAN Mixing tank openings.

+ve number means Cl2 generation rate exceeds ventilation extration rate. Fume to emit out of lid penetrations etc. Calculation (simple) 19-11-2015 suggest about 0.95 m3 air free space before CL2 starts to escape. This is the probable CL2 cloud release from the AAN Mixing tank into the local area.

Can use this volume information to calculate chamber pressure and thus likely emission rate from AAn Mixing Tank using orifice type equation.

Assessment Bases		Neutralisation tank			Chem characteristics		
Neutralisation tank is filled with concentrated sodium hypochlorite (i.e. bleach 33% by volume). Volume 500 L		33%	tank volume of bleach		64.06	g/mol	SO2
Addition of sulphuric acid at a rate of 10 L/min.					98.076	g/mon	H2SO4
Operator process E-stop response time of one minute after evidence of toxic gas evolution/ instrumentation alarm. Acid addition is stopped.		50	L of acid added before E-stop		52.46	g/mol	**HOCl**
Temperature of neutralisation contents (and generated gas) is 60 degrees. This is the max temperature before any type of control interlock is activated.		10	L/min rate of addition of acid		36.458	g/mol	**HCL**
The free air space within the AAN neutralisation tank is at atmospheric pressure.		5	minutes before E-Stop		18.016	g/mol	**H_2O**
A ventilation system is connected to the AAN Mixing Tank and operates at a rate of 2 m3/min. Replacement air enters the AAN Mixing Tank via loose fitting lids/ small gaps in the AAN Mixing Tank lid.		2	m3/min Ventilation		70.9	g/mol	**CL_2**
Reaction rate is instant and not limited by pH. All acid reactes with HOCl. HOCl is not limiting.		0.03	m3/s Ventilation		16.00	Molar mass	**O**
AAN Mixing Tank is well mixed		33.33	L/s Ventilation		1.008	Molar mass	**H**
HCl and SO2 fumes generated are emitted at 60 degrees		10.0452824	m/s stack discharge		35.45	Molar mass	**Cl**
SO2 formation reaction type (HOCl + H2SO4 resulting in SO2 + HCl)		0.065	stack diameter (m)		32.06	Molar Mass	S
Assume reaction reaches completion (not just some equilibrium)		0.003318307	Area stack diameter (m2)				
Caustic/ NaOH scrubber is off-line. All SO2 emitted via stack.							
AAN Mixing Tank is 1.5 m3 total volume.							
All HCl is converted to hydrochloric acid (aqueous) due to available water in the AAN Mixing Tank.		Density		Source:			
98% wt/wt sulphuric acid is added to AAN Mixing Tank.		1830	g/L HCl density@60°C	http://www.handymath.com/cgi-bin/hcltble3.cgi?submit=Entry			
10m/s stack velocity to observe recommended practice from NSW EPA.		2.39	kg/m^3 SO2 gas density at 60C	http://encyclopedia.airliquide.com/Encyclopedia.asp?GasID=13			
AAN Mixing Tank is 1.5 m3 total volume.		Acid Concentration					
		38%	common commercial conc	https://www.labchem.com/media/acids-and-bases.pdf			
Calculation							
Determine the SO2 emission volume and rate of emission.							
	38	%					
	50	L of H2SO4 added based on addition rate					
	92	kgs of H2SO4					
	355	g Moles of H2SO4					
Based on reaction stiochimetry	709	g Moles of HOCl					
	22711	g of SO_2					
	23	kg of SO2					
SO2 emission volume	9.5	m^3					
SO2 rate of emission over time period before E-stop	0.031674	m^3/s					
SO2 rate of emission	1.90	m3/min					
SO2 mass emission rate over time period before E-stop	0.0757	kg/s					
Look for max volume without ventilation							
Seeing as ventilation rate is less than generation rate then max volume of gas will be when E-stop i triggered		10	m^3 ventilated in 'x' mins. Refer to Cell C6.				
		9.5	m^3 SO2 generated in x mins. Refer to Cell C6.				
		-0.5	m^3 max volume of Cl_2 gas				

"10M" sulfuric acid (the modern equivalent of chamber acid, used in many titrations) . 10M H2SO4 is approximately 70% wt/wt. [https://en.wikipedia.org/wiki/Sulfuric_acid]

HCl max composition is 38% wt/wt. [https://en.wikipedia.org/wiki/Hydrochloric_acid]

Yellow fields = input fields

Green fields = calculated fields

Cell: C5
Comment: Carl Fung:
User input

Cell: C6
Comment: Carl Fung:
E-stop instigated on gas sensor or odour threshold exceeded.

Cell: C7
Comment: Carl Fung:
from design data

Cell: D12
Comment: Carl Fung:
to achieve 10 m/s

Cell: C16
Comment: Carl Fung:
The 98% grade is more stable in storage, and is the usual form of what is described as "concentrated sulfuric acid." 1.83 kg/L at 98% grade.

Cell: C17
Comment: Carl Fung:
SO2 Gas density (1.013 bar and 15 °C (59 °F)) : 2.7633 kg/m3

Cell: B24
Comment: Carl Fung:
HCl acid wt/wt concentration.

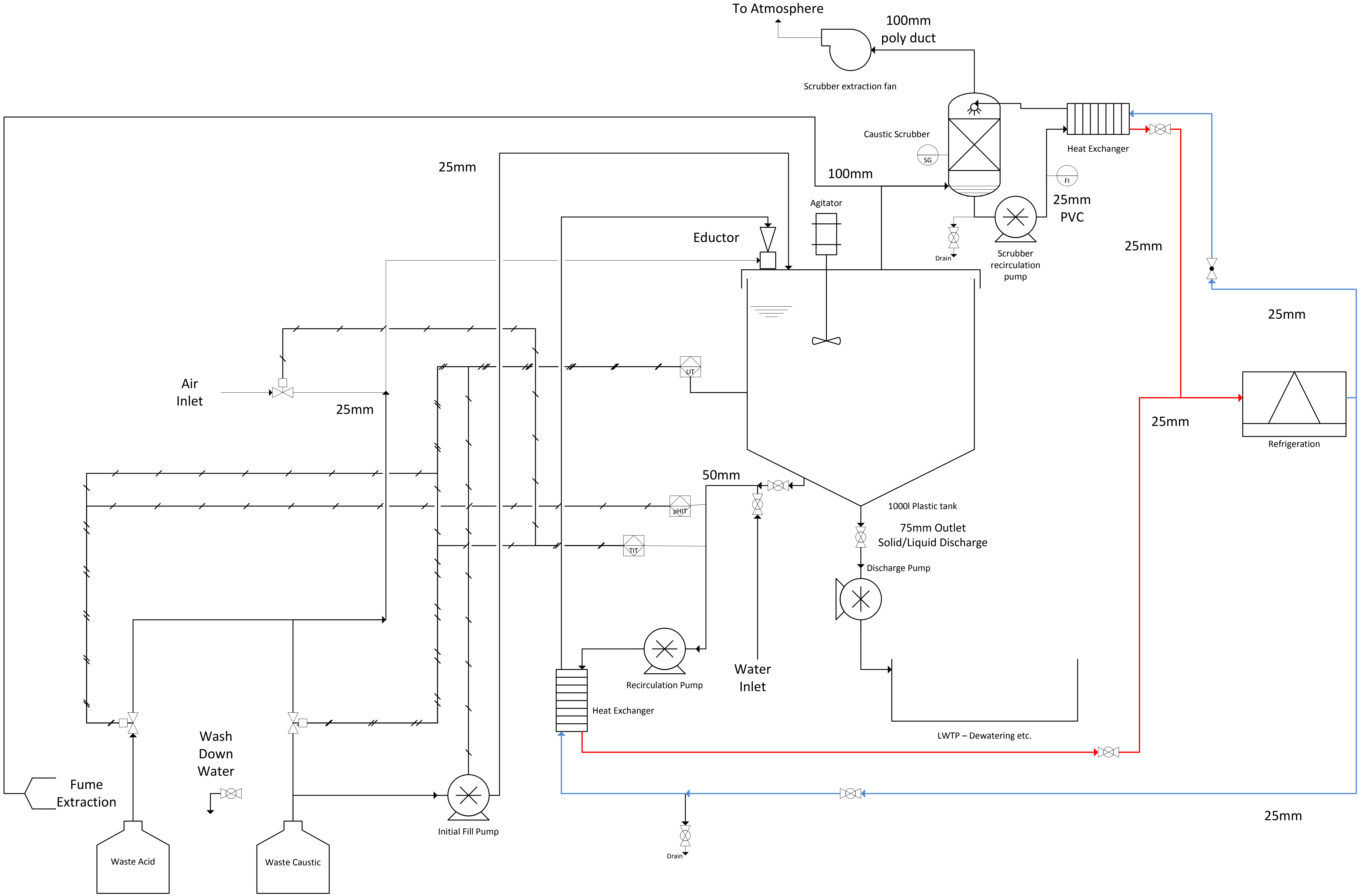
Cell: B29
Comment: Carl Fung:
HOCl is not limiting reactant.

Cell: C44
Comment: Carl Fung:
+ve number means SO2 generation rate exceeds ventilation extration rate.

-ve value suggests not likely to have SO2 emission into local work area. I.e. Ventilation system capacity able to extract all emission

Appendix V

AAN Process PID


To Atmosphere
100mm
poly duct
Scrubber extraction fan
Caustic Scrubber
Heat Exchanger
SG
FI
100mm
25mm
PVC
Agitator
Drain
Scrubber
recirculation
pump
25mm
25mm
Eductor
25mm
LIT
Air
Inlet
25mm
Refrigeration
25mm
50mm
pHIT
1000l Plastic tank
75mm Outlet
Solid/Liquid Discharge
TIT
Discharge Pump
Recirculation Pump
Water
Inlet
Heat Exchanger
LWTP – Dewatering etc.
Wash
Down
Water
Fume
Extraction
Initial Fill Pump
Drain
25mm
Waste Acid
Waste Caustic