

CLYDE REFINERY FCCU

REACTOR AND REGENERATOR PROJECT

PRELIMINARY HAZARD ANALYSIS

REPORT

SHELL REFINING (AUSTRALIA) PTY LTD

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ABBREVIATIONS

ASO	Acid Soluble Oil
C4	Butane
CCTV	Closed Circuit Television
Cr-Mo	Chrome Molybdenum
DCS	Distributed Control System
DoP	Department of Planning
EPA	Environment Protection Agency
(F)CCU	(Fluidised) Catalytic Cracking Unit
HAZID	Hazard Identification
HIPAP	Hazardous Industry Planning Advisory Paper
MAE	Major Accident Event
MHF	Major Hazard Facility
NDT	Non Destructive Testing
PHA	Preliminary Hazard Analysis
ppm	Parts per million
QRA	Quantitative Risk Assessment
R&R	Reactor and Regenerator
SEPP 33	State Environment Planning Policy No. 33
SRAP	Shell Refining Australia Pty Ltd

HOLDS

There are no HOLDS in this document.

1. EXECUTIVE SUMMARY

1.1. Background

Shell Refining (Australia) Pty Ltd (SRAP) owns and operates the Clyde Refinery located at Durham Street, Rosehill NSW. The site is in an industrial zoned area and has been in operation since the 1920s.

One process within the refinery is the Fluidised Catalytic Cracking Unit (FCCU). The heart of the FCCU is the Reactor and Regenerator (R&R) section. In this section heavy fuel oil is converted (cracked) into petrol in the presence of a catalyst at elevated temperatures. The FCCU has been in operation since 1962 and critical components of the R&R section are approaching the end of their design life.

SRAP has requested Sherpa Consulting Pty Ltd (Sherpa) to prepare a Preliminary Hazard Analysis (PHA) in support of a Development Application for a project (the R&R Rejuvenation Project) to replace these critical components.

Specifically, the R&R Rejuvenation project (hence forth referred to as the R&R project) will replace the reactor and stripper vessel associated with the Reactor/Regeneration section. This is essentially a “like for like” replacement (the design and operation intent of the unit remains unchanged); however modern reactor/stripper technology will be employed to provide operational efficiency and HSE improvements. The replacement reactor/stripper design is approximately 1/3 of the existing inventory, thereby significantly improving the inherent safety of the unit. Other scope associated with this project is the “like for like” replacement of cyclones within the regenerator, replacement of large bore piping and control valves associated with the unit, and modifications to the No. 8 Waste heat boiler to marginally increase its capacity.

This study was triggered by the Environmental Assessment Requirements outlined in a letter from the Department of Planning to SRAP. Specifically the letter identified the need to undertake a preliminary screening in accordance with State Environmental Planning Policy No. 33 – Hazardous and Offensive Developments (SEPP33) and Applying SEPP33 (Ref. 1) and, based on the outcome of the screening, prepare a suitable level of Preliminary Hazard Analysis (PHA) in accordance with Hazardous Industry Planning Advisory Paper No.6 – Guidelines for Hazard Analysis (HIPAP No 6)(Ref 2))

The PHA is a joint study undertaken by SRAP and Sherpa. All technical calculations have been completed by SRAP.

1.2. Scope

This document details both the SEPP33 screening and the PHA for the proposed R&R project. The primary purpose of the study is to assess the risk levels associated with the operation of the FCCU after the R&R project is complete and present the findings

in the context of the existing refinery risk profile and the NSW land use planning risk acceptance guidance.

1.3. Findings

The key findings of the PHA are summarised as follows:

- The “like for like” replacement will not introduce any new process hazards to the facility.
- The only change in process conditions is an increase in temperature and throughput of flue gas. The flue gas is sufficiently dilute to be non-flammable and non-toxic.
- The consequences associated with a release from the reactor section are reduced from the current arrangement due a significant decrease in inventory.
- No releases from the R&R section have the potential for offsite impact.
- The likelihood of a release from the reactor and regenerator section is reduced from the current arrangement due to the application of welded membrane seals for ~25% of the new flanges on the new reactor/stripper.
- On the basis that both the consequences and likelihood of releases from the FCCU are reduced as a result of this project, it is concluded that there will be a decrease in risk associated with completing the R&R project.

1.4. Conclusions

The project is primarily a “like for like” replacement of equipment that is approaching the end of its design life. The project provides the opportunity to significantly reduce hydrocarbon inventory, and apply a modern reactor/stripper design incorporating modern design/safeguarding standards. It also allows for improved operability and process efficiency, as well as ensuring the long term viability of the refinery given the importance of the FCCU in providing petrol for the Sydney and wider NSW market.

The only significant changes from a risk perspective are the overall reduction in process inventory of flammable material (from 890 m³ to 300 m³) and the selective application of flanges with welded membrane seals for some parts of the plant.

In the context of SEPP 33 the refinery as a whole is considered as being a potentially hazardous and potentially offensive development on the basis of the types and quantities of material that are processed and stored.

This PHA has demonstrated on a semi-quantitative basis that the overall risk profile of the refinery will reduce as a result of the R&R Project through a reduction in inventory and leak frequencies. In addition the PHA has demonstrated that the risk profile associated with the FCCU is below the NSW land use planning risk criteria.

1.5. Recommendations

The following recommendations are made as a result of this PHA. These recommendations are in line with the Seven Stage Planning process adopted by the NSW Department of Planning.

1. As the design develops the project is required to complete a number of other safety and risk studies, e.g. Fire Safety Study (to HIPAP 2, Ref. 3), a Construction Safety Study (to HIPAP 7, Ref. 4) and an update of the PHA to a Final Hazard Analysis (FHA). It is noted that the project has completed the HAZOP component of the seven stage planning process.
2. It is recommended that the project review the Refinery Health, Safety, Security and Environment Management System to include the proposed changes. The proposed development should be fully integrated into the Refinery system including any planned audit schedule.
3. The proposed changes should be included in any activities undertaken in response to the pending NSW Major Hazard Facility (MHF) legislation.

2. INTRODUCTION

Shell Refining (Australia) Pty Ltd (SRAP) propose to undertake a project to replace the Reactor and Regenerator (R&R) Section of the Fluidised CCU at their refinery at Durham Street, Rosehill, NSW. The works will be undertaken as part of a project called the R&R project.

The project will reduce the inventory of the reactor to 1/3 of its current level, whilst bringing this critical part of the refinery up to modern standards.

2.1. Study Objectives

The objectives of this study are to:

- Conduct a suitable level of Preliminary Hazard Analysis for the project with reference to the Department of Planning (DoP) Multi-level Risk Assessment guide.
- Assess the proposed development against the DoP Land-Use Safety Planning Risk Criteria.
- Determine if the proposal is “hazardous” and/or “offensive” in the context of SEPP33.

2.2. Scope of Study

The scope of the study includes the proposed changes as a result of the R&R project. These are detailed in Section 3.2.

2.3. Report Overview

This report follows the methodology described in *Applying SEPP33* (Ref.1), *Multi-level Risk Assessment* (Ref 5) and the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 *Guidelines for Hazard Analysis* (Ref.2) published by the DoP.

The PHA process assesses the potential impact of the facility on the surrounding area and can be summarised into the following steps:

- Description of proposed development;
- Hazard identification;
- Selection of an appropriate level of assessment;
- Analysis of the consequences of a hazard, should it be realised;
- Analysis of the frequency of hazards occurring, noting that the depth of analysis will be dependent on the results of the consequence analysis;
- Assessment of the potential offensive nature of the unit;
- Calculation of overall risk results;
- Comparison of risk results against NSW Land-Use Planning risk tolerability criteria;
- Discussion of risk management approach; and

- Discussion and conclusion on risk levels.

Each stage of the process is reported in this PHA report. Detailed calculations, where they have been undertaken, are contained within the relevant section of this report. The intention is to provide sufficient detail in the report to allow an objective assessment of the risk.

2.4. Risk Context

This risk assessment has been conducted in the context of the overall site risk assessment with regards to immediate (acute) effect on people. Environmental impacts are addressed in the Environmental Assessment (Ref. 6), completed by others.

3. DESCRIPTION

3.1. Project Background

Shell Refining (Australia) Pty Ltd (SRAP) owns and operates the Clyde Refinery, Durham Street, Roseville NSW. The site is located in an industrial area and has been in operation as an oil refinery since the 1920's.

One process within the refinery is the Fluidised Catalytic Cracking Unit (FCCU). The heart of the FCCU is the Reactor and Regenerator (R&R) section. In this section heavy fuel oil is converted (cracked) into petrol in the presence of a catalyst at elevated temperatures. The FCCU has been in operation since 1962 and critical components of the R&R section are approaching the end of their design life.

Specifically, the project will replace the reactor and stripper vessel associated with the Reactor/Regeneration section. This is essentially a "like for like" replacement (operation and design intent of the unit remains unchanged); however modern reactor/stripper technology will be employed with the design. This allows for a new reactor/stripper design/inventory which is approximately 1/3 of the existing inventory, thereby significantly reducing the hydrocarbon inventory in the unit. Other scope associated with this project is the "like for like" replacement of cyclones within the regenerator, replacement of large bore piping and control valves associated with the unit, and modifications to the No. 8 Waste heat boiler to marginally increase its capacity (5-10%).

The existing unit has been in operation since 1962 and has undergone numerous small projects to improve its reliability, operability and safety. The existing unit is therefore very mature with respect to operating procedures, instrumented safeguarding, fire fighting facilities and emergency procedures.

The proposed FCCU process is a developed technology used by approximately 30-40 other sites within Shell, and many more outside of Shell. Experience and lessons learned from operational upsets and incidents at these units are shared freely amongst the petroleum community, and used to set standards within Shell for the appropriate level of design, safeguarding requirements and fire safety equipment.

Therefore, though this project is essentially a "like for like" replacement of aged equipment, it provides the opportunity to significantly reduce hydrocarbon inventory, and apply a modern reactor/stripper design incorporating modern design/safeguarding standards. It also allows for improved operability and process efficiency, as well as ensuring the long term viability of the Refinery given the importance of this unit in providing Petrol for the Sydney and broader NSW market.

3.2. Project Description

Shell Refining (Australia) Pty Ltd (SRAP) proposes to design and construct a new reactor/stripper to replace the existing reactor/stripper vessel within the R&R section of

the FCCU complex, located within their existing refinery at Durham Street, Rosehill NSW. The Environmental Assessment (EA) document (Ref. 6) shows the key dimensions of the existing and new reactor/stripper.

3.2.1. Process Description

Unit feed (long residue) and catalyst are mixed and fed into the reactor, where cracking to valuable petrol/diesel products occurs. During the process, coke forms on the catalyst. The catalyst is separated from reactor products using cyclone devices with the recovered catalyst (+coke) sent to a stripper, while reactor products are directed to downstream units for separation into sales products.

Recovered catalyst from reactor (with coke within catalyst pores) is sent to the stripper where steam is used to strip remaining hydrocarbons/reactor product from the catalyst. The stripping process improves the overall efficiency of the process as hydrocarbon products would otherwise be lost or combusted in the regenerator. Steam and the stripped reactor products are routed back to the reactor and then downstream fractionation unit for recovery of hydrocarbons and steam as water.

Stripped catalyst from the stripper is sent to the regenerator where air is injected to burn/remove coke from catalyst. This regenerated catalyst from the Regenerator is returned to the reactor, noting that this catalyst is hot (due to heat of combustion). This heat is used to supply heat for the reaction process.

Flue gas from the regenerator passes through 4 stages of cyclonic devices to remove catalyst fines from the flue gas down to very low levels, as per license requirements. This flue gas is directed to a waste heat boiler to generate steam.

3.2.2. Critical Equipment

Table 1 details the critical FCCU equipment and the normal operating conditions. The table includes the existing conditions and the proposed operating conditions. The table shows that the increase in inventory associated with the longer riser section is vastly offset by the decrease in volume of the main reactor.

The current volume of the reactor and riser is of the order of 890m³; this will reduce to 300m³ following the R&R project.

TABLE 1 PROCESS CONDITIONS FOR CRITICAL EQUIPMENT

Equip No	Name	Vessel Type	Existing				Proposed			
			Dimensions		P (barg)	T (°C)	Dimensions		P (barg)	T (°C)
			Diameter (m)	Length (m)			Diameter (m)	Length (m)		
R301/R311	Riser (replaced)	Vertical Pipe	1.0	31.87	2.0	535	1.2	43.5	2.0	535
R312	Reactor (replaced)	Vertical Vessel	7.62	15.9	2.0	535	3.125	14.7	2.0	535
R313	Stripper (replaced)	Vertical Vessel	4.57	13.5	2.0	535	3.25	20.0	2.0	535
A316A-C	3 x Cyclones (replaced)	Vertical Vessel	N/A*	N/A*	2.0	535	1.87	6.1	2.0	535
R303	Regenerator	Vertical Vessel	10.0/12.7	18.5	2.0	695	10.0/12.7	18.5	2.0	720
A303	Third Stage Separator	Vertical Vessel	4.83	3.5	2.0	690	4.83	3.5	2.0	720
V342	Orifice Chamber	Horizontal Vessel	1.93	14.0	0.5	650	1.93	14.0	0.5	720
V343	Fourth Stage Separator	Vertical Vessel	1.07	4.0	0.5	650	1.07	4.0	0.5	720

3.2.3. Design

Shell Global Solutions International, located within the Netherlands, is undertaking the new process and mechanical design of the reactor/stripper. The design is based on a copy of an existing Shell unit in the UK, which has been in operation since 1988. This design was chosen on the basis of demonstrated reliability and operating performance, including safety performance. Experience from ~20 years of plant operation has been captured and incorporated into the design. The reactor/stripper vessel will be designed to comply with the relevant Australian Standards and Industry codes and standards. It will be made from Cr-Mo material, including the connecting piping and valving.

3.2.4. Safeguarding

The existing unit is well safeguarded by pressure relief valves, instrument protective functions and proper piping/equipment design. As part of this project, some minor deficiencies against modern safeguarding standards (for example, certain Instrumented Protective Functions) were identified and these will be upgraded as follows as part of this scope:

- Installation of Tight shut off valve on the torch oil (fuel) supply to the regen, which closes on loss of air flow.
- Installation of a low pressure differential trip on the stripper/regen slide valve to prevent back flow of air into the stripper (partial hydrocarbon environment).

The existing unit is, and will continue to be, monitored by operator patrols and formally inspected at 4 year intervals. Between the 4 yearly inspection intervals, the unit will be inspected monthly, through selective external inspection (visual/other).

The unit is equipped with existing fire hydrants located at the base of the R&R unit, as well as three hydrants located within the structure to aid fire fighting. These facilities will remain. The unit is also equipped with CCTV, fixed gas monitors as well as Remotely Operated Valves and deluge systems for critical hot pumps. For the reactor circuit, flanges are minimised, and where used, selective application of flanges with weld membrane seals are used to minimise leak sources. Due to the temperature of the unit (500°C), fire fighting is best achieved using localised snuffing steam, as using fire water can cause unsymmetrical/rapid cooling of equipment/piping leading to excessive piping/equipment nozzle stresses. Steam utility stations, in addition to the fire water hydrants are provided at strategic locations within the structure for the above purpose.

3.2.5. Environmental Controls

Flue gases from the regeneration section are currently routed to 4 stages of catalyst clean up equipment, followed by directing to a waste heat boiler for the recovery of the waste heat from the flue gas. The flue gas from the boiler, including the regen flue gas after heat extraction, is directed to a stack. The emissions from the stack are

monitored via a combination of on-line analysers and periodic test campaigns, with the stack being part of the existing EPA license.

3.2.6. Operational Controls

Operation of the R&R unit will be controlled by 3 systems,

- Monitoring and control through the existing Refinery Distributed Control System (DCS),
- Instrumented safeguarding provided by existing high integrity safeguarding system (HIMA),
- Monitoring and advanced control via the Plant supervisor system (Infoplus), a high level system, which allows trending, and multivariable control capabilities.

3.2.7. Surrounding Land Use

A brief description of the facilities is provided in the Environmental Assessment (Ref.6). Of particular relevance to this study it is noted that the closest off site point from the unit is the corner of Devon Street and Durham Street, located 90m from the unit.

4. HAZARD IDENTIFICATION

4.1. Introduction

Hazard Identification (HAZID) is the first step in a risk analysis, since it provides the hazardous scenarios that are to be assessed for consequences (severity and impact) and likelihood of occurrence. HAZID is considered to be the most important step in risk assessment, since hazards that are not identified will not be evaluated and cannot be demonstrated to be managed to an acceptable level.

In anticipation of the NSW Major Hazard Facilities Legislation, SRAP facilitated HAZID workshops for the Clyde Refinery and Gore Bay Terminal during 2005. The findings of the HAZID workshops undertaken for FCCU formed the basis for this report.

4.2. Objectives

The main objective of the HAZID study was to identify scenarios that cover all of the potential hazards and initiating events associated with the R&R operation. Through this process, the following objectives were identified:

- Determine possible Major Accident Events (MAEs);
- Determine potential causes;
- Identify existing barriers (safeguards);
- Perform a risk ranking exercise using the Shell Risk Matrix approach;
- Generate a list of MAEs to be carried forward for detailed technical analyses in the Safety Assessment and assessment under the Demonstration of Adequacy (ALARP) process;
- Compare the Hazard Register with previous studies for Clyde Refinery, Gore Bay Terminal, Geelong Refinery, Lara Terminal, Pinkenba Terminal, Trammere Terminal (UK), and Stanlow Refinery (UK);
- Compare the Hazard Register with incident histories within Shell and outside; and
- Generate the final MAE Register.

While this was conducted for the whole site, part of the analysis included the Catalytic Cracking Unit located in Process East. The R&R is an integral part of this unit.

It is noted that the hazard register was compared to similar studies for the Stanlow Refinery. This site is comparable to the Clyde refinery, given that the new reactor/stripper configuration will be a copy of the Stanlow installation. Additionally Stanlow falls under the UK COMAH regime which places an emphasis on a risk based approach to hazard management.

4.3. Methodology

The core of the Hazard Identification process was a series of HAZID workshops conducted by the Safety Case Advisors. The workshops followed a structured guide

word approach to identify hazards and potential hazardous scenarios. Appendix 1 details the methodology, attendees and results of the hazard identification process.

4.4. R&R Major Accident Events

The Major Accident Events (MAEs) that relate to the R&R project are summarised in Table 2. The table includes an assessment of the potential change in risk associated with the R&R project. The MAEs are discussed briefly below:

4.4.1. Flammable Liquid Releases (CCU-1, CCU-2 and CCU-3)

Scenarios CCU-1, CCU-2 and CCU-3 describe leaks of flammable liquids, viz. residue feed to the reactor, HVU flash distillate and Acid Soluble Oil (ASO) feed from V-1300.

Residue feed to the reactor is a mixture of fuel-oil type (similar to crude oil) residue from the Refinery processes. HVU flash distillate and ASO are diesel-type materials. The liquids are considered flammable since they are handled near (or above) their flash points.

A leak of these flammable feed liquids may lead to spray fire (for small release hole sizes) or pool fire, if ignited immediately. The effects of spray and pool fires are discussed in Section 6.

Unignited pools may evaporate to form flammable vapour clouds, which have the potential to lead to flash fire, or Vapour Cloud Explosion (VCE) if ignited within a congested area. The potential for pool evaporation and vapour cloud formation are discussed in Section 6.

4.4.2. Flammable Vapour Releases (CCU-6)

The gaseous reactor products are a mixture of fuel oil, diesel, gasoline and other lighter components. The reactor is operated at 2 barg pressure and a temperature of 535°C. Under these operating conditions, the reactor vapour mixture is above its auto-ignition temperature.

Therefore, releases from the reactor will ignite immediately following release and lead to jet fires. Vapour cloud formation is not likely to occur. The effects of jet fires are discussed in Section 6.

4.4.3. Flue Gas Releases (CCU-9)

The flue gas composition indicates that it is non-flammable; preliminary fire modelling indicated that the material was not capable of combustion. The hazard of concern, therefore, is the potential for personnel to be exposed to high temperature flue gas.

This scenario will result in localised effects and would not have the potential for off-site impact; it is not considered further in this study.

TABLE 2 R&R PROJECT RELATED MAJOR ACCIDENT EVENTS

MAE Item	MAE Reference	HAZARD	CONSEQUENCE	Change in MAE
1	CCU-1	Heavy hydrocarbon (fuel oil type material) leak from reactor feed piping system.	Spray/ pool fire Unignited pool evaporation	No Change –
2	CCU-2	Leak from remote cooling of HVU flash distillate	Spray/ pool fire Unignited pool evaporation	No change
3	CCU-3	Leak from the Acid Soluble Oil feed line piping to Reactor (diesel type material with trace hydrogen fluoride <1% and propane)	Spray/ pool fire Unignited pool evaporation and potential HF release	No Change –
4	CCU-6	Leak/Release of Reactor product vapours from R311 (mixture of catalyst/fuel oil, diesel, gasoline and lighter) above auto-ignition temperature	Jet fire	Reduction in inventory and flange count
5	CCU-6	Leak/Release of Reactor product vapours from R312 (mixture of catalyst/fuel oil, diesel, gasoline and lighter) above auto-ignition temperature	Jet fire	Reduction in inventory and flange count
6	CCU-6	Leak/Release of Reactor product vapours from R313 (mixture of catalyst/fuel oil, diesel, gasoline and lighter) above auto-ignition temperature	Jet fire	Reduction in inventory and flange count
7	CCU-6	Leak/Release of Reactor product vapours from A316A-C (mixture of fuel oil, diesel, gasoline and lighter) above auto-ignition temperature	Jet fire	Reduction in inventory and flange count
8	CCU-9*	Leak/Release of Regenerator flue gas product from R303 (mixture of catalyst and flue gas including CO)	Hot flue gas & catalyst release	Increase in throughput and temperature
9	CCU-9*	Leak/Release of flue gas product from A303 (mixture of catalyst and flue gas including CO)	Hot flue gas & catalyst release	Increase in throughput and temperature
10	CCU-9*	Leak/Release of flue gas product from V342 (flue gas including CO)	Hot flue gas & catalyst release	Increase in throughput and temperature
11	CCU-9*	Leak/Release of flue gas product from V343 (mixture of catalyst and flue gas including CO)	Hot flue gas & catalyst release	Increase in throughput and temperature

* Release was modelled in FRED and it was found that it is not capable of combustion due to the low concentration. The high temperature of the release is a personal safety issue.

4.5. Other Scenarios Discussed in HAZID

During the hazard identification workshop, vessel rupture (burst) was raised as a guideword (part of the Shell HAZID Methodology). The potential for such a scenario was dismissed by the workshop team as it has never occurred in the industry for a similar vessel in low pressure service. This is discussed further below.

As mentioned in this study, the reactor design is proven technology and is a copy of an existing unit that has been operated by Shell in the UK since 1988. Experience from 20 years of plant operation has been captured and incorporated into the design, which was selected on the basis of demonstrated safety, reliability and operating performance. (The FCC process has actually been in commercial use since the 1940's)

The reactor is operated at relatively low pressure (2 barg) and the reactions which occur are largely endothermic. The unit will be provided with appropriate pressure and temperature protection, as well as second layers of instrumented safeguarding to prevent temperature/pressure excursions. Such defences include:

- Reactor, Stripper and Regenerator are fitted with numerous temperature/ pressure indicators/ alarming (i.e. adequate installed redundancy) to warn of temperature/ pressure excursions allowing appropriate response by operations.
- Reactor/stripper is protected from overpressure by relief valves installed on the downstream vessel, with an open system maintained between the two pieces of equipment.
- Regenerator and downstream equipment is protected from overpressure by providing an open path to the boiler stack at all times.
- Low pressure differential trips (2 out of 3 voting system) installed on main control valves between reactor and regenerator to prevent intermixing of air and hydrocarbons, with such trips initiating feed (hydrocarbons) to be removed from unit.
- Panel activated feed trips to allow hydrocarbons to be removed from feed remotely and instantaneously.

The unit will be constructed from new materials and will be subjected to rigorous Quality Assurance processes (from fabrication through to commissioning). The unit will be monitored by operator patrols and will be formally inspected at 4-yearly internals. Between the 4-yearly inspection intervals, the unit will be inspected monthly, through selective external inspection (visual/other). Therefore, it is considered that process safeguarding or material failures are more likely to result in the releases described by CCU-6 (up to 100mm hole in vessel), rather than instantaneous vessel burst.

4.6. Review of HAZID and Conclusions

The results of the HAZID were reviewed and the results are summarized as follows:

- No new hazardous materials are being introduced as a result of the project.
- No new release scenarios will be created during operations (note that construction will be assessed in a separate study).
- Inventories of hazardous (flammable) materials will be reduced.
- The increase in temperature and throughput of the flue gas systems do not result in an increase in risk offsite as the material is not flammable and hence has no offsite impact.
- Leak sources will be minimised through the selective application of flanged joints with welded membrane seals on the reactor / stripper as appropriate.
- There is no reduction in the level of safeguarding provided for the identified hazards.

5. PRELIMINARY RISK SCREENING

5.1. Background

The SEPP33 process is set out in “Applying SEPP33” (Ref 5). Key to the process is the requirement to undertake a screening exercise based on the inventory of hazardous material and the distance to site boundaries and, based on the outcome of the screening, complete a suitable level of Preliminary Hazard Analysis (PHA).

The initial SEPP33 screening is intended to differentiate between developments that are “potentially hazardous” (and/ or “potentially offensive”) and hence require further assessment from those developments that require no further assessment.

5.2. Screening

Where a proposed development is part of an existing facility, the guidance in Applying SEPP33 requires that the existing inventories of hazardous materials are included in the screening process. Based on the inventories of dangerous goods and activities at the refinery it has been assumed that the site will exceed the SEPP33 screening criteria and hence will be potentially hazardous and potentially offensive.

It is not considered credible that a refinery located in an industrial area would fall into the category of “no further assessment required”. Hence the refinery is considered to be potentially hazardous in the context of SEPP33.

On the basis that the development is “potentially hazardous” there is a requirement to undertake a Preliminary Hazard Analysis to determine risk associated with the development and to compare the risk with published criteria.

The document “Multi-level Risk Assessment” provides guidance on the level of risk assessment required in the PHA. The selection of the level of assessment chosen for this study is detailed in the next section.

5.3. Level of Assessment

The DoP document *Multi Level risk Assessment* was consulted to identify the level of assessment required. The DoP document sets out three levels of risk assessment that may be appropriate for the PHA. These are:

Level	Type Of Analysis	Comments
1	Qualitative	Where there are no major offsite consequences and societal risk is negligible.
2	Partly Quantitative	Where there are offsite consequences but with a low frequency of occurrence.
3	Quantitative	Where level 1 and 2 are exceeded.

Section 3.1.4 of the Multi-Level Risk Assessment Guidance advises that

“A fully quantitative risk assessment is advisable where the scale and nature of an activity creates a significant potential for a major accident. Examples of such activities would include large scale manufacture of chemicals, petroleum refining, and storage and distribution terminals involving large quantities of dangerous goods”.

In line with this guidance a level 3 PHA (fully quantitative) has been prepared for the project.

5.4. Criteria for use in the Assessment

Risk assessment, in terms of acceptability of risk, is of greatest value when the results can be compared against a set of criteria. The results of the risk analysis will be assessed against the criteria detailed in Hazardous Industries Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning (Ref. 7). The following criteria are summarized from HIPAP No 4.

5.4.1. Impairment Criteria

The impairment criteria for off-site populations are summarised in Table 3.

TABLE 3 IMPAIRMENT CRITERIA OFFSITE

Impediment	Fatality
Flammable Gas	LFL and ignition (i.e. within flash fire)
Thermal Radiation	4.7 kW/m ² (injury) 4.7 – 14 kW/m ² (50% chance of fatality) > 14 kW/m ² (100% chance of fatality)
Vapour Cloud Explosion	Within fireball (more onerous than overpressure calculation, see justification in Appendix 2)

5.4.2. Individual Risk of Fatality

The individual risk per annum (IRPA) criteria adopted by NSW is shown in Table 4. The figures quoted represent the peak individual risk for an occupant at each site. The basis of the criteria is the 1 in 1 million per year limit for residential areas.

The approach adopted in HIPAP No 4 assumes 24 hour exposure with fixed impairment criteria. To reflect the differences in the vulnerability of populations and the likely exposure time for individuals HIPAP No 4 includes a range of criteria for other situations. (The approach is an alternative to allowing occupancy factors and specific vulnerabilities to be included in the risk calculations.)

TABLE 4 NSW INDIVIDUAL RISK CRITERIA

Risk Levels (per annum)	Limit of Exposure at the Following Locations
0.5 x 10 ⁻⁶	Hospitals, child-care facilities and old age housing developments.
1 x 10 ⁻⁶	Residential developments and places of continuous occupancy such as hotels and tourist resorts.
5 x 10 ⁻⁶	Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres.
10 x 10 ⁻⁶	Sporting complexes and active open space areas.
50 x 10 ⁻⁶	Industrial. Site boundary

5.4.3. Risk of Injury

In addition to the fatality risk levels described above, HIPAP No 4 also set out criteria for injury risk levels. This is in recognition of the fact that society is concerned with the risk of injury as well as death and that certain members of the community are more vulnerable. The injury risk criteria are discussed in more detail in the following paragraphs.

Heat Radiation

DoP proposes that a heat radiation level of 4.7 kW/m² be considered high enough to lead to injury in people who cannot escape or seek shelter. This level of heat radiation will cause injury after 30 seconds. A risk of injury criteria of 50x10⁻⁶ p.a. is suggested for fire events. Within the guidelines, this is stated as:

Incident heat flux at residential areas should not exceed 4.7 kW/m² at frequencies of more than 50 chances in a million years.

Explosion Overpressure

DoP proposes that an overpressure of 7kPa be considered high enough to lead to injury in people who cannot escape or seek shelter. A risk of injury criteria of 50x10⁻⁶ p.a. is suggested for explosion events. Within the guidelines, this is stated as:

Incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million years.

Toxic criteria are not assessed as no toxic incidents were identified in the HAZID.

5.4.4. Risk of Accident Propagation

HIPAP No 4 also presents criteria covering accident propagation. The guidelines are aimed at ensuring the risk of an accident at one plant triggering an accident at another neighbouring plant is low and that adequate safety separation distances exist. The criteria for accident propagation are set out below.

Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed a risk of 50 in a

million per year for the 23 kW/m² heat flux level (23 kW/m² is considered the level at which unprotected steel may start to fail).

Incident Explosion Overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings should not exceed a risk of 50 in a million per year for the 14 kPa explosion overpressure level.

5.4.5. Societal Risk

HIPAP No 4 suggests that judgements on societal risk be made on the basis of a qualitative approach rather than on specifically set numerical criteria.

The contours generated in the risk analysis will be assessed for their proximity to dense or vulnerable populations.

5.4.6. Risk to the Biophysical Environment

The risk tolerability criteria suggested in HIPAP No 4 for sensitive environmental areas relate to the potential effects of an accidental emission on the long-term viability of the ecosystem or any species within it. HIPAP No 4 expresses these criteria as follows:

- Industrial developments should not be sited in proximity to sensitive natural environmental areas where the effects of the more likely accident emissions may threaten the long-term viability of the ecosystem or any species within it.
- Industrial developments should not be sited in proximity to sensitive natural environmental areas where the likelihood of impacts that may threaten the long-term viability of the ecosystem, or any species within it, is not substantially lower than the background level of threat to the ecosystem.

5.5. Conclusion

The project is considered to be “potentially hazardous” and “potentially offensive” under the SEPP33 screening process. In line with the requirements of SEPP33 a PHA (this document) has been prepared.

A level 3 (fully quantitative) PHA has been prepared in line with HIPAP No 6 with impairment criteria from HIPAP No 4.

The results of the PHA are compared with the NSW land use planning criteria provided in HIPAP no 4 and reported in this document.

6. CONSEQUENCE ANALYSIS

6.1. Introduction

Consequence analysis involves the analysis and quantification of a potential hazardous scenario to cause injury, fatality, damage or loss. The consequence of an incident is assessed independently of the likelihood. The consequence analysis was undertaken by the SRAP HSE group.

6.2. Screening

The results of the Hazard Identification qualitatively show that there are no new hazards introduced as a result of the project and that the consequence and likelihood of the existing hazards reduce as a result of the project.

In order to quantify the potential change in risk, the consequences of the following events were calculated:

- CCU-1 Leak of residue feed to cracker
- CCU-2 Leak from remote cooling of HVU flash distillate
- CCU-3 Leak of ASO, LCO feed from V-1300
- CCU-6 Release of reactor vapour

Flue gas product release from regenerator section CCU-9 has not been carried forward for consequence assessment as combustion is not possible due to the low flammable concentration. A release remains an onsite personnel safety issue due to the high temperature of any release.

6.3. Physical Consequence Models

The following physical models were used for the study:

- Release rate models
- Dispersion
- Jet Fire
- Pool Fire

The appropriate models from the Shell FRED Version 4.0 or Shell Shepherd Desktop Version 2.0 program were selected. Details of the models are not repeated here. Reference should be made to the user manuals for details of the modelling undertaken.

Table 5 shows a matrix of the typical hazardous materials and the modelling that was undertaken.

TABLE 5 MATERIALS AND MODELLING

Model	Major Hazardous Material Groupings			
	Light Hydrocarbons (C ₁ to C ₂)	Medium Hydrocarbons (C ₃ and C ₄)	Heavy Hydrocarbons (C ₅₊) inc. refined products	Toxic Components
Release Rate	Yes	Yes	Yes	Yes
Gas Dispersion	Yes	Yes	Yes (volatile components)	Yes
Jet Fire	Yes	Yes	Yes	No
Pool Fire	No	Yes (C ₄)	Yes	No

6.4. Impacts of R&R Replacement

The only significant change in process conditions that required modifications to the QRA was a vessel inventory reduction in the reactor/stripper from 890 m³ to 300 m³ and an increase in process temperatures from 695°C to 720°C in the regenerator section. All other relevant process/operating parameters remain the same.

6.5. Modelling Results

The consequence modeling is detailed in Appendix 2. The results are summarized in Table 6.

6.5.1. Pool Evaporation and Vapour Cloud Dispersion (CCU-1, CCU-2 and CCU-3)

Unignited liquid pools resulting from the release described in CCU-1, CCU-2 and CCU-3 were found to not have the potential to evaporate to form sustained flammable vapour clouds. Therefore, flash fire and vapour cloud explosion are not a credible consequence of these releases and have not been considered further in this study.

6.5.2. Toxic HF Dispersion (CCU-3)

Acid Soluble Oil may contain trace concentrations of hydrogen fluoride (up to 0.7%). Dispersion modelling undertaken for unignited liquid pools resulting from the release described in CCU-3 were found to not have the potential to form toxic HF vapour clouds to ERPG-2 levels (i.e. 20 ppm for HF). Therefore, toxic gas dispersion is not a credible consequence of CCU-3 and is not considered further in this study.

6.5.3. Release of Vapour Above Auto-Ignition Temperature (CCU-6)

Flash fire and Vapour Cloud Explosion (VCE) have not been assessed for releases from the FCCU (MAE CCU-6). Flammable vapour cloud formation following a release from the reactor is not considered a credible event as the material is above its auto ignition temperature. Any release from the FCCU will be immediately ignited and, therefore, not have the potential to develop into a gas cloud that can be subsequently ignited.

TABLE 6 CONSEQUENCE MODELLING RESULTS

MAE	Hole diameter (mm)	R&R Project				Existing			
		Distance (m)				Distance (m)			
		Flame Length	23 kW/m ²	14 kW/m ²	4.7 kW/m ²	Flame Length	23 kW/m ²	14 kW/m ²	4.7 kW/m ²
CCU-1	2.5	5.1	7.6	8.8	11.5	5.1	7.6	8.8	11.5
CCU-1	10	15.5	23.2	26.7	34.8	15.5	23.2	26.7	34.8
CCU-1	20	27.0	40.5	46.5	60.6	27.0	40.5	46.5	60.6
CCU-1	50	Pool	18.5	27.6	46.0	Pool	18.5	27.6	46.0
CCU-1	100 (flow rate limited)	Pool	18.5	27.6	46.0	Pool	18.5	27.6	46.0
CCU-2	2.5	6.72	7.4	7.65	10.11	6.72	7.4	7.65	10.11
CCU-2	10	20.38	22.3	23.20	30.63	20.38	22.3	23.20	30.63
CCU-2	20	24.67	27.0	28.09	37.09	24.67	27.0	28.09	37.09
CCU-2	50	Pool	18.5	27.59	45.96	Pool	18.5	27.59	45.96
CCU-2	100	Pool	18.5	27.59	45.96	Pool	18.5	27.59	45.96
CCU-3	2.5	4.85	5.6	6.09	7.90	4.85	5.6	6.09	7.90
CCU-3	10	9.86	11.3	12.38	16.07	9.86	11.3	12.38	16.07
CCU-3	20	9.86	11.3	12.38	16.07	9.86	11.3	12.38	16.07
CCU-6	2.5	1.0	1.5	1.5	1.84	1.0	1.5	1.5	1.84
CCU-6	10	2.9	4.2	4.4	5.34	2.9	4.2	4.4	5.34
CCU-6	20	5.1	7.4	7.7	9.40	5.1	7.4	7.7	9.40
CCU-6	50	10.6	15.4	16.0	19.53	10.6	15.4	16.0	19.53
CCU-6	100	18.4	26.8	27.8	33.90	18.4	26.8	27.8	33.90
CCU-9	Release concentration is insufficient to support combustion; however the high temperature of the gas and catalyst is a significant personal safety issue.								

6.6. Conclusion

The Reactor and Regenerator is approximately 90 m from the nearest site boundary (corner of Devon and Durham Streets). The results of the consequence analysis show that no consequences reach the site boundary. In addition, the results show that there are no increased consequence distances as a result of the project.

In the context of the consequences of releases from the unit there will be:

- no increase in offsite consequence;
- no increased consequences associated with the potential for escalation onsite; and
- a decrease in event duration.

In line with the requirement to undertake a level 3 PHA, all scenarios modelled have been carried forward to the likelihood analysis section.

7. LIKELIHOOD ANALYSIS

7.1. Introduction

The likelihood analysis is used in conjunction with the consequence analysis to determine the risk of an event. The likelihood analysis is a method for predicting the occurrence of future events based on historical data. In terms of the QRA, events may occur due to either an equipment failure, for example a leak from a flange, or following a process control failure, e.g. a tank overfill or reactor overpressure.

A leak frequency data set has been developed for loss of containment scenarios. The data set has been consolidated from recent refinery studies within Shell. This is detailed in Appendix 3 and summarised in this section. The leak frequency data set is combined with a parts count to generate the likelihood analysis.

7.2. Methodology

The frequency data and parts count as used in this PHA are detailed in Appendix 3.

The parts count was undertaken using the Shepherd equipment count option. Shell Global Solutions has undertaken a number of detailed parts counts at refineries and developed a rule set for allocation of a defined number of components (e.g. valves and flanges) to standard equipment items (e.g. a vessel).

7.3. Limitations and Assumptions

The use of generic failure data to represent a specific plant results in an inherent assumption that the plant is designed, maintained and operated as an “average” plant. Shell undertakes regular safety audits (both technical and management) to validate that the unit is operated correctly. Since Shell has a large number of these plants in operation, the assumptions in Shepherd should be an accurate reflection of the existing plant.

7.4. Conclusions

The only significant change affecting the likelihood of an event is the selective application of flanges with welded membrane seals associated with the reactor / stripper. Due to the adoption of these welded membrane flanges, the flange count was reduced by approximately 25% from 25 to 19 for the vapour space of the reactor.

8. AIR QUALITY REVIEW

DoP (Ref.1) indicates that a facility is “potentially offensive” if, “in the absence of any safeguards, the proposal would emit a polluting discharge which would cause a significant level of offence to the people, property or the environment”.

An “offensive industry” is one that causes a significant level of offence even when safeguards are implemented. The emission level considered significant is determined by the relevant environmental approval authority.

Air quality modelling has been undertaken by CH2M Hill and is reported in the project EA document (Ref 6).

9. RISK ANALYSIS AND ASSESSMENT

9.1. Introduction

The PHA has demonstrated the following on both a qualitative and quantitative basis:

- No new hazards are introduced as a result of the R&R project;
- The consequences of existing hazard events will reduce due to a reduction in inventory; and
- The likelihood of existing events will reduce as a result of the use of welded membrane seals in place of standard flanges.

Notwithstanding the above and in line with the requirement to undertake a level 3 risk assessment, the risk associated with the R&R project has been calculated and the results are shown in this section.

The analysis is presented in the following context:

1. Risk results are presented to show the potential for incidents associated with the R&R project to impact on surrounding land users. The results are presented for comparison against NSW land use planning criteria.
2. The change to the overall refinery risk profile has not been calculated. The PHA has demonstrated that both the consequence and likelihood of incidents will reduce and hence the refinery risk profile will reduce as a result of the project.

9.2. Results

The results of the risk analysis and an assessment against the NSW land use planning criteria are summarized in Table 7. Risk contour plots are provided in APPENDIX 4.

TABLE 7 COMPARISON OF RISK RESULTS AGAINST NSW RISK CRITERIA

Risk Levels (p.a.)	Effect	Limit of Exposure at the Following Locations	Results of Risk Analysis	Criteria Met?
0.5×10^{-6}	Fatality	Hospitals, child-care facilities and old age housing developments.	Contour does not extend offsite	Yes
1×10^{-6}	Fatality	Residential developments and places of continuous occupancy such as hotels and tourist resorts.	Contour does not extend offsite	Yes
5×10^{-6}	Fatality	Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres.	Contour does not extend offsite	Yes
10×10^{-6}	Fatality	Sporting complexes and active open space areas.	Contour does not extend offsite	Yes
50×10^{-6}	Fatality	Industrial. Site boundary	Contour does not extend offsite	Yes
50×10^{-6}	4.7 kW/m ²	Residential Areas (injury)	Contour does not extend offsite	Yes
50×10^{-6}	7kPa	Residential Areas (injury)	VCE not a credible scenario	Yes
50×10^{-6}	23 kW/m ²	Offsite (incident propagation)	Contour does not extend offsite	Yes
50×10^{-6}	14kPa	Offsite (incident propagation)	VCE not a credible scenario	Yes

9.2.1. Escalation Risk

The results of the consequence analysis have demonstrated that there are no incidents associated with the reactor replacement project that have the potential for offsite impact as the low pressure releases have insufficient magnitude.

The residual risk that requires assessment is the potential for incidents starting in the R&R section to escalate to other units, which may subsequently have offsite impact. Of note is the potential for a fire to escalate to equipment within the 23 kW/m² contour of a fire.

The following points are noted:

- The R&R project will result in a significant reduction in inventory. The potential magnitude of an incident in the area, and its associated potential to escalate will therefore be reduced.
- The R&R project will result in a reduction in the leak frequency due to the inclusion of flanges with welded membrane seals. Hence, the likelihood of an initiating event will be reduced.

- The R&R project includes upgrades to control and safeguarding systems. These upgrades will reduce the likelihood of an incident.
- The refinery has an integrated emergency response plan that includes:
 - Isolation of the feed to the incident and hence a reduction in event duration
 - Protection of adjacent equipment through the application of cooling water, drainage and removal of spilt inventory and passive fire protection

The frequency of incidents where the potential exists for the 23 kW/m² heat contour to extend to an adjacent area (and potentially lead to escalation) is of the order of 1x10⁻⁶ per annum. This is 50 times smaller than the NSW risk criterion for escalation leading to offsite impact at adjacent industrial developments. Hence, even assuming that:

- every fire escalated to offsite impact; and
- taking no credit for refinery emergency response to mitigate the potential escalation;

The potential for offsite impact is still well below any risk criteria.

On this basis, it is concluded that, due to the R&R upgrade:

- the risk due to escalation will reduce;
- the risk associated with escalation is below the relevant NSW DoP risk criteria; and
- the residual risk is manageable through the refinery emergency response procedures.

A recommendation has been made to complete a fire safety study in line with the requirements of the Seven Stage Planning Process. The fire safety study will, in the course of assessing fire preparedness, include an assessment of the potential for incidents to escalate.

9.2.2. Societal Risk

The consequences of an incident do not extend into dense, vulnerable populations. Therefore, the societal risk is considered insignificant.

9.2.3. Risk to the Biophysical Environment

The R&R project is located within the existing refinery complex and is not located in proximity to sensitive natural environmental areas. In addition, the following are noted:

- Accidental emissions (spills) will be captured in the refinery drainage system will be directed, to the site interceptor for recovery.

- Release of hot catalyst will have a transient impact on the local area.
- Emissions are addressed in the Environmental Assessment (Ref. 6)

Therefore, the potential effects of an accidental emission will not affect the long-term viability of the ecosystem of any sensitive natural environmental areas.

9.3. Conclusion

A risk analysis for the R&R project has been conducted in line with HIPAP No 6 and an assessment of the results made against the criteria in HIPAP No 4.

The assessment demonstrates that the project does not present a significant risk to the surrounding land uses.

It has been qualitatively demonstrated that the contribution of the releases associated with the R&R unit to the overall refinery risk profile will reduce as a result of the project. Hence, the refinery risk profile will reduce as a result of this project.

10. RISK CONTROLS

10.1. Introduction

Demonstrating that the risks meet the acceptance criteria is only one element of demonstrating that risks are being suitably managed. In order to demonstrate that the risk is being controlled the multi-level risk assessment requires a discussion of the technical controls, risk reduction measures and management measures in place.

This section sets out the risk controls under two broad headings:

- Safety in Design
- Safety in Operation

The controls were identified during the HAZID session.

10.2. Safety in Design

The R&R will be constructed to recognised Australian and International Standards. These will be supported by the Shell Design and Engineering Practice (DEP). Reference should be made to the project documentation for a complete list of standards. As stated earlier, the unit is also a copy of an existing unit from the UK, with 20 years of good operating experience. Further, the new equipment is integrated into an existing unit for which the site has 40 years of good operating experience.

Examples of applicable codes and standards are AS1170.2 and AS1170.4 for wind and earthquake design loadings.

10.3. Risk Management in Design

The design will be subject to the Shell risk management process. Risk management activities that directly relate to the NSW seven stage planning process are shown in Table 8.

TABLE 8 RISK MANAGEMENT ACTIVITIES

Activity	Status
HAZID	Completed
HAZOP of Interfaces	Completed
HAZOP of reactor/stripper	Completed By Shell Global Solutions
SIL	Completed
FSS	Planned activity
FHA	Planned activity
ERP review	N/A since ERP already addresses applicable scenarios
Constructability Safety Study	Planned activity
SMS update and review	Operating and maintenance procedures to be amended as required

10.4. Safety Systems

A summary of the existing safety systems is given in Table 9, with any changes noted. Further details are available in project documentation.

TABLE 9 PROPOSED SAFETY SYSTEMS

System	Comment
Flanged connections	Flanged connections will be minimised on the reactor by using ~25% welded membrane flanges
Process Control	The process control system already exists and is integrated with the existing refinery process control systems
Process Shutdown System	Process trips and interlocks are already on the existing unit, and so minor addition will be made to further improve existing design. An Instrumented Protective Function (IPF) review has been completed for the existing unit and will be updated for the new instrumentation. A required level of performance has been assigned to existing IPF.
Gas Detection	Gas detection is already installed on the existing complex in appropriate locations.
CCTV	CCTV is installed on existing unit and provide a means of detecting if an event has occurred
Melt tubes	Melt tubes are equipped on downstream hydrocarbon pumps to detect fires as appropriate, noting the R&R does not have any hydrocarbon pumps.
Fire Proof Skirts	The existing skirts for the reactor/stripper are fire proofed to mitigate the effects of a fire and prevent column failure in a fire. With the new design and removal of liquid hydrocarbon sources for the elevated platform, a fire safety review will be undertaken to determine if pool fire is still feasible and need to maintain the fireproofing. If deemed necessary, fireproofing will be applied.
Manual and Automated Shutdown	The existing unit is equipped with emergency automated shutdowns located within the control room, which is unchanged by this proposal. Remote battery limit valves for the feed are also available to safely isolate feed from a distance.
Emergency Relief and Blowdown	The existing unit is equipped with emergency relief system and flare system design to appropriate code. As existing system is adequate, no changes required.
Fire Water	Existing Fire water hydrants are located on the reactor/stripper structure as well as at ground level at perimeter of unit, which will be adequate for existing unit. Fire safety review will be conducted to determine any changes.
Snuffing Steam	Utility points are available to allow use of snuffing steam in case of flange leaks, allowing time for safe shutdown or other repairs to be undertaken.
Hazardous Area Classification	Ignition sources will be controlled by the application of suitable hazardous area classification standards

10.5. Safety in Operation

Shell HSSE management system covers all the refinery activities. Examples of HSSE activities that are relevant for this project are:

- Training of operators on new plant;
- Preparation, communication and control of Unit Operating Procedures; and
- Spares and maintenance of new equipment.

As the design progresses the relevant sections of the Shell HSSE management system will be triggered.

10.6. Updating the Site Safety Case

As the project progresses, the site Safety Case will be amended to integrate the changes into the overall site quantitative risk assessment (QRA). In addition to amending the QRA, the ALARP bow-ties for the R&R will also be reviewed to ensure risk is as low as reasonably practicable. The minimum criteria will be that for every threat to the safety of the unit, there are at least 3 independent preventative barriers and 2 independent detection and mitigation barriers as shown in Figure 1.

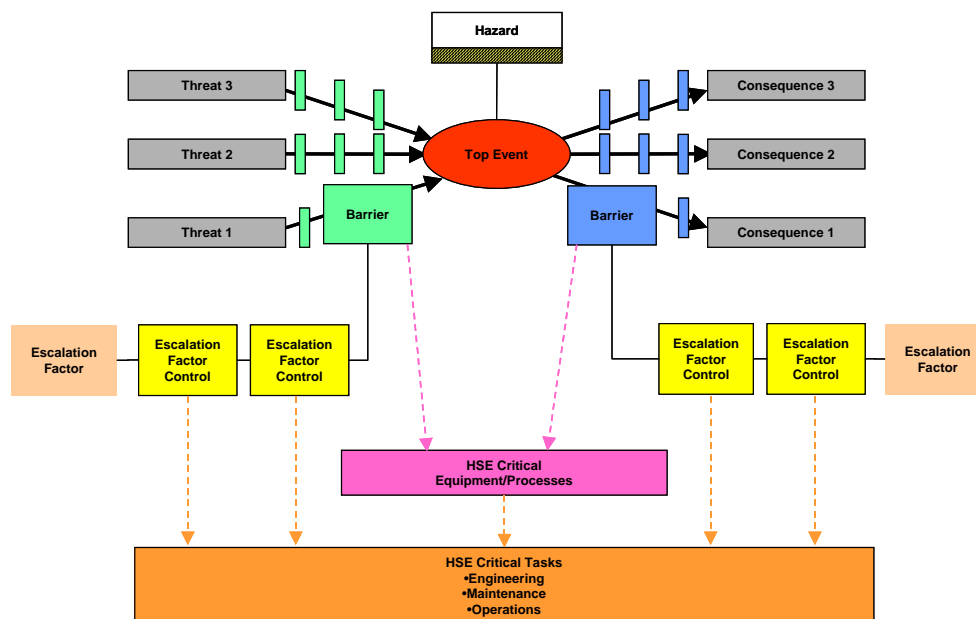


FIGURE 1 ALARP BOW-TIE DIAGRAM

APPENDIX 1. HAZID

A 1.1. Introduction

Hazard Identification (HAZID) is the first step in a risk analysis, since it provides the hazardous scenarios that are to be assessed for consequences (severity and impact) and likelihood of occurrence. HAZID is considered to be the most important step in risk assessment, since hazards that have not been identified will not be evaluated.

In anticipation of the NSW Major Hazard Facilities Legislation, SRAP facilitated HAZID workshops for the Clyde Refinery and Gore Bay Terminal during 2005. The findings of the HAZID workshops undertaken for FCCU formed the basis for this report.

A 1.2. Objectives

The main objective of the HAZID study was to identify scenarios that cover all of the potential hazards and initiating events associated with the R&R operation. Through this process, the following objectives were identified:

- Determine possible Major Accident Events (MAEs);
- Determine potential causes;
- Identify existing barriers;
- Perform a risk ranking exercise using the Shell Risk Matrix approach;
- Generate a list of MAEs to be carried forward for detailed technical analyses in the Safety Assessment and assessment under the Demonstration of Adequacy process;
- Compare the Hazard Register with previous studies for Clyde Refinery, Gore Bay Terminal, Geelong Refinery, Lara Terminal, Pinkenba Terminal, Trammere Terminal, and Stanlow Refinery;
- Compare the Hazard Register with incident histories within Shell and outside; and
- Generate the final MAE Register.

While this was conducted for the whole site, part of the analysis included the Catalytic Cracking Unit located in Process East. The R&R is an integral part of this unit.

It is noted that the hazard register was compared to similar studies for the Stanlow Refinery. This site is comparable to the Clyde refinery, given that the new reactor/stripper configuration will be a copy of the Stanlow installation. Additionally Stanlow falls under the UK COMAH regime, which places an emphasis on a risk based approach to hazard management.

A 1.3. Methodology

The core of the Hazard Identification process was a series of HAZID workshops conducted by the Safety Case Advisors. As a minimum, the following people were involved:

- Operator;
- Maintenance / Inspection;
- Process Engineer;
- Technologists
- Plant Controller; and
- Safety Case Advisor.

HAZID sessions for each area began with an introductory presentation covering the Safety Report process including how the HAZID information would be used and the methodology to be employed. Following the presentation, the team developed the scope for that session whereby the plant was broken down into units for detailed consideration.

Potential MAEs were then identified for each unit. Specific causes were then documented for every event. At this stage, the results were compared to the following:

- Previous HAZIDs completed at Clyde and Gore Bay;
- HAZID results from the following Shell MHFs:
 - Geelong Refinery (Victoria, Australia);
 - Lara Terminal (Victoria, Australia);
 - Pinkenba Terminal (Queensland, Australia);
 - Stanlow Refinery (Stanlow, UK);
 - Tranmere Oil Terminal (Tranmere, UK); and
- Incident histories from the IChemE's Accident Database and the Shell Manufacturing Fatality Database.

The HAZID study was based on a review of the appropriate sections of the Shell HAZID Checklist, which is a structured list of HSE-related hazards drawn from experience of such studies. The Checklist contains a list of guidewords and definitions, which are used as prompts for the HAZID study. The HAZID method adopted was a combination of identification, analysis and brainstorming, based on the hazards identified on the Checklist in Table 10.

TABLE 10 HAZARD CHECKLIST

Dropped object	Ignition sources
Impact (e.g. crane, stack, column, vehicle)	Backflow
Fire & explosion	Utility Failure
grass fire (e.g. started by flare)	power
fire or explosion from off-site	instrument air
Shrapnel	steam
Over-pressure	cooling water
Under-pressure / vacuum	Runaway reaction
Overfill	Human factors
Low temperature / brittle fracture	Memory limitations
High temperature	Visual acuity
Corrosion	Misunderstood instructions
Mechanical failure	Distraction
Structural failure	Fatigue
Open pathway / leak	Decision making errors
External threats	Group think
interference from unauthorised access	Rigid problem solving
interference from authorised access	
interference from off-site	

The resulting potentially hazardous scenarios were developed into a set of MAEs. The Refinery MAE list was distilled to identify those relevant to the R&R replacement.

A 1.4. Study Location and Study Team

The HAZID workshops were conducted at Shell Clyde Refinery and Gore Bay Terminal between December 2004 and September 2005. There have been no significant modifications to the plant in the time since they were completed. Separate sessions were held for each of the processing areas of the Refinery and Terminal. A multi-disciplinary team was chosen for each workshop session. The workshop teams comprised representatives from operations, maintenance, engineering and HSE. The HAZID workshop facilitator for all of the HAZID sessions was Chris Arnold (Shell Safety Case Advisor). The study team for Process East (that incorporates the R&R) is listed in Table 11.

TABLE 11 PROCESS EAST HAZID TEAM

Name	Title
Ross Walsh	Plant Controller
Dave Wynn	Shift Controller
Steve Sims	Operator
Mark Raymond	Operator
Mark McGrath	Operator
Dave Bridger	Senior Process Engineer
Emma Tan	Process Engineer
Anthony Woods	I/E Advisor
Dave Bleby	Maintenance Controller
James Liley	Technologist
Vince Humphreys	Technologist
Tony Ackland	Inspector
Alan Parnell	Senior Inspector
Allan Pennell	Safety Case Advisor
Chris Arnold	Safety Case Advisor

A 1.5. R&R Major Accident Events Carried Forward

The MAEs that relate to the R&R project are summarised in Table 2 of the main report.

APPENDIX 2. CONSEQUENCE ANALYSIS

A 2.1. Introduction

Consequence analysis involves the analysis and quantification of a potential hazardous scenario to cause injury, fatality, damage or loss. The consequence of an incident is assessed independently of the likelihood.

A 2.2. Physical Consequence Models

The following physical models were used for the study:

- Release rate models
- Dispersion
- Jet Fire
- Pool Fire

The appropriate models from the Shell FRED Version 5.0 or Shell Shepherd Desktop Version 2.0 program were selected. Details of the models are not repeated here. Reference should be made to the user manuals for details of the modelling undertaken.

Table 12 shows a matrix of the typical hazardous materials and the modelling that was undertaken.

TABLE 12 MATERIALS AND MODELLING

Model	Major Hazardous Material Groupings			
	Light Hydrocarbons (C ₁ to C ₂)	Medium Hydrocarbons (C ₃ and C ₄)	Heavy Hydrocarbons (C ₅₊) inc. refined products	Toxic Components
Release Rate	Yes	Yes	Yes	Yes
Gas Dispersion	Yes	Yes	Yes (volatile components)	Yes
Jet Fire	Yes	Yes	Yes	No
VCE	Yes	Yes	Yes (volatile components)	No
Pool Fire	No	Yes (C ₄)	Yes	No

It is noted that for the R&R project that there were no toxic hazards identified. Additionally, where releases are above the auto-ignition temperature it is assumed that immediate ignition occurs on release.

A 2.3. Effects on Offsite Personnel

The impairment criteria for off-site populations are summarised in Table 13. These criteria are based on the requirements set out by DoP.

TABLE 13 IMPAIRMENT CRITERIA

Incident	Fatality
Flammable Gas	LFL and ignition (i.e. within flash fire)
Thermal Radiation	4.7 kW/m ² (injury) 4.7 – 14 kW/m ² (50% chance of fatality) > 14 kW/m ² (100% chance of fatality)
Vapour Cloud Explosion	Within fireball (see Note below)

NOTE: For the purpose of calculating the total (location specific) risk contours in Shepherd, the effects on people (in terms of fatalities) from vapour cloud explosion overpressure are accounted for by the fireball consequence size (i.e. personnel within the flash fire are assumed to be fatalities). The Shepherd Technical Manual cites the following rationale in justifying this modelling technique:

1. “There are no validated models available [for the effects of overpressure from hydrocarbon explosions on people]. There are various Probability relationships available in the open literature, which are largely based on a variety [of] explosion incidents. These explosions are not limited to the Vapour Cloud Explosions that the Risk Tools models”
2. “It is difficult, if not impossible, to accurately model the effects of projectiles on people in a simplified modelling environment as presented by the Risk Tool”
3. “Overpressure in the Risk Tool is a result of a vapour cloud travelling into a congested area and finding a source of ignition (i.e.: VCE). It can be argued that the cloud fire will yield higher number of fatalities than the explosion; not counting overpressure helps in preventing double counting”

TABLE 14 PROCESS DATA

MAE Block No.	Description	Phase	Temperature (°C)	Pressure (bara)	Weight Flow (kg/s)	Components
CCU-1	Leak of residue feed to cracker	L	80	15	28.9	Crude Oil
CCU-2	Leak from remote cooling of HVU flash distillate	L	130	16	3.47	Diesel
CCU-3	Leak of ASO, LCO feed from V-1300	L	150.0	4.0	0.35	99.3% Diesel 0.7% HF
CCU-6	Release of reactor vapours – above auto-ignition temperature.	V	535.0	3.0	59.4	54% Gasoline 20% Diesel 26% others
CCU-9*	RELEASE OF FLUE GAS PRODUCTS FROM THE REGENERATOR SECTION	V	720	3.0	55.60	71% N ₂ , 15% CO ₂ , 10% H ₂ O, 4% CO

* Not a combustible release so considered a personal safety issue due to the high temperature. This was not modelled in the QRA.

Process block number	CCU-1	
Fuel	Long Residue (Crude Oil)	
Pressure, bara	15	
Temperature, °C	80	
Process rate, kg/s	28.90	
No. of tubular H.E.	E-301 shell-side E-335 A/B shell-side E-342 shell-side E-312 A/B shell-side	6

See the final table in this appendix for the pool fire calculations.

Leak	Hole diameter (mm)	Frequency	Mass flow rate	Immediate Ignition probability		Flame Lengths m	Distance to 14 kW/m ² m	C _{R14}	Distance to 4.7 kW/m ² m	C _{R4.7}	Distance to 23 kW/m ² m	C _{R23}
				Vapour	Liquid							
Flange	2.5	2.20E-04	0.13	0.2100	0.0096	5.1	8.8	1.73	11.46	2.25	7.64	1.50
Seal	10	3.00E-03	2.12	0.2100	0.0264	15.5	26.7	1.73	34.84	2.25	23.22	1.50
Fitting	20	1.00E-04	8.49	0.2100	0.0264	27.0	46.6	1.73	60.69	2.25	40.45	1.50
Connection	50	1.00E-05	28.90	0.2100	0.0264	Pool	27.6	2.60	45.96	4.34	18.53	1.75
Pump casing ('General leak' in Shepherd)	100	3.00E-05	28.90	0.2100	0.0264	Pool	27.6	2.60	45.96	4.34	18.53	1.75
Pipework	100	5.00E-06	28.90	0.2100	0.0264	Pool	27.6	2.60	45.96	4.34	18.53	1.75
FRED CALCULATION	36.9	-	28.90	0.2100	0.0264	44.0	75.9	1.73	98.90	2.25	65.92	1.50

Process block number	CCU-2	
Fuel	Flash distillate (diesel)	
Pressure, bara	16	
Temperature, °C	130	
Process rate, kg/s	3.47	299.8
No. of tubular H.E.	E-303	1

Leak	Hole diameter (mm)	Frequency	D5 Dist to LFL	F2 Dist to LFL	Mass flow rate	Immediate Ignition probability		Flame Lengths m	Distance to 14 kW/m ² m	C _{R14}	Distance to 4.7 kW/m ² m	C _{R4.7}	Distance to 23 kW/m ² m	C _{R23}
						Vapour	Liquid							
Flange	2.5	2.20E-04	6.3	6.3	0.13	0.2100	0.0096	6.7	7.7	1.14	10.11	1.50	7.37	1.10
Seal	10	3.00E-03	36.22	36.22	2.15	0.2100	0.0264	20.4	23.2	1.14	30.63	1.50	22.33	1.10
Fitting	20	1.00E-04	46.07	46.07	3.5	0.2100	0.0264	24.7	28.1	1.14	37.09	1.50	27.04	1.10
Connection	50	1.00E-05	46.07	46.07	3.5	0.2100	0.0264	Pool	27.6	2.6	46.0	4.3	18.53	1.75
Pump casing ('General leak' in Shepherd)	100	3.00E-05	46.07	46.07	3.5	0.2100	0.0264	Pool	27.6	2.6	46.0	4.3	18.53	1.75
Pipework	100	5.00E-06	46.07	46.07	3.5	0.2100	0.0264	Pool	27.6	2.6	46.0	4.3	18.53	1.75
FRED CALCULATION	12.7	-	46.07	46.07	3.5	0.2100	0.0264	24.7	28.1	1.14	37.09	1.50	27.04	1.10

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Process block number	CCU-3	
Fuel	99.3% diesel 0.7% HF	
Pressure, bara	4	
Temperature, °C	150	
Process rate, kg/s	0.35	
No. of vessels	V-1300 V-1301	2

Leak	Hole diameter (mm)	Frequency	Mass flow rate	Immediate Ignition probability		Flame Lengths m	Distance to 14 kW/m ² m	C _{R14}	Distance to 4.7 kW/m ² m	C _{R4.7}	Distance to 23 kW/m ² m	C _{R23}
				Vapour	Liquid							
Flange	2.5	2.20E-04	0.06	0.2100	0.0096	4.8	6.1	1.26	7.90	1.63	5.57	1.15
Seal	10	3.00E-03	0.35	0.2100	0.0096	9.9	12.4	1.26	16.07	1.63	11.33	1.15
Fitting	20	1.00E-04	0.35	0.2100	0.0096	9.9	12.4	1.26	16.07	1.63	11.33	1.15
Connection	50	1.00E-05	0.35	0.2100	0.0096	n/a - release rate not sufficient						
Pump casing ('General leak' in Shepherd)	100	3.00E-05	0.35	0.2100	0.0096							
Pipework	100	5.00E-06	0.35	0.2100	0.0096							
FRED CALCULATION	6.08	-	0.35	0.2100	0.0096	9.9	12.4	1.26	16.09	1.63	11.34	1.15

HF Modelling in FRED: Mass flowrate = 0.35 x 0.007 = 0.00245 kg/s, with process conditions as per CCU-3
 Weather 1.5F, 20°C, 70% humidity Distance to ERPG 2 (20 ppm) = unable to generate dispersion of 20 ppm.

Process block number	CCU-6	
Fuel	20% diesel 54% gasoline	
Stream	-	
Pressure, bara	3	
Temperature, °C	535	
Process rate, kg/s	59.40	
No. of vessels	R-301 (vapour space)	1

Leak	Hole diameter (mm)	Frequency	D5 Dist to LFL	F2 Dist to LFL	Mass flow rate	Immediate Ignition probability		Flame Lengths m	Distance to 14 kW/m ² m	C _{R14}	Distance to 4.7 kW/m ² m	C _{R4.7}	Distance to 23 kW/m ² m	C _{R23}
						Vapour	Liquid							
Flange	2.5	2.20E-04	0.3	0.3	0.0031	0.0096	0.0560	1.0	1.5	1.51	1.84	1.84	1.5	1.5
Seal	10	3.00E-03	1.5	1.5	0.0500	0.0096	0.0560	2.9	4.4	1.51	5.34	1.84	4.2	1.5
Fitting	20	1.00E-04	2.5	3	0.2000	0.0096	0.0560	5.1	7.7	1.51	9.40	1.84	7.4	1.5
Connection	50	1.00E-05	6.5	7.5	1.2500	0.0616	0.0560	10.6	16.0	1.51	19.53	1.84	15.4	1.5
Pump casing ('General leak' in Shepherd)	100	3.00E-05	13	14	5.0000	0.0616	0.0560	18.4	27.8	1.51	33.90	1.84	26.8	1.5
Pipework	100	5.00E-06	13	14	5.0000	0.0616	0.0560	18.4	27.8	1.51	33.90	1.84	26.8	1.5
FRED CALCULATION	100	-	13	14	5.0000	0.0616	0.0560	18.4	27.8	1.51	33.9	1.84	26.8	1.5

APPENDIX 3. LIKELIHOOD

A 3.1. Introduction

The likelihood analysis is used in conjunction with the consequence analysis to determine the risk of an event. The likelihood analysis is a method for predicting the occurrence of future events based on past data. In terms of the QRA, events may occur due to either an equipment failure, for example a leak from a flange, or following a process control failure, e.g. a tank overfill or reactor overpressure.

A leak frequency data set has been developed for loss of containment scenarios. The data set has been consolidated from recent refinery studies within Shell. The leak frequency data set is combined with the refinery parts count to generate the refinery likelihood analysis.

A 3.2. Methodology

The parts count was undertaken using the Shepherd equipment count option. Shell Global Solutions has undertaken a number of detailed parts counts at refineries and developed a rule set for allocation of a defined number of components (e.g. valves and flanges) to standard equipment items (e.g. a vessel).

A 3.3. Limitations and Assumptions

The use of generic failure data to represent a specific plant results in an inherent assumption that the plant is designed, maintained and operated as an “average” plant. Shell undertakes regular safety audits (both technical and management) to validate that the unit is operated correctly. Since Shell has a large number of these plants in operation, the assumptions in Shepherd should be an accurate reflection of the existing plant.

TABLE 15 SUMMARY OF EQUIPMENT FAILURE FREQUENCIES

Equipment Item	Equivalent Leak Size Diameter (mm)	Leak Frequency (per item-year)
Flanges and equivalent valves	2.5	2.2×10^{-4}
Instrument fitting (< 1" diameter)	20	1×10^{-4}
Connection (> 1" diameter)	50	1×10^{-5}
Pipe rupture	100 (Full bore)	5×10^{-6}
Pump Seal	10	3×10^{-3} (single seal)
		3×10^{-4} (double seal)
Pump Casing Failure	Full Bore	3×10^{-5}
Compressor Seal	10	8×10^{-4} (centrifugal)
		5.3×10^{-2} (reciprocating) (Shepherd Multiplier = 66.25)
Bellows	20	2.4×10^{-3}
	Full-bore	6×10^{-4}

TABLE 16 SHEPHERD PARTS COUNT RULE SET

Equipment Type	Leak Source Count per Equipment Item		
	Connections (> 25 mm)	Flange / Valve Equivalents	Fittings (< 25 mm)
Compressor	1	8	10
Fin-Fan Coolers	9	6	1
Furnaces	1	35	10
Pumps	1	18	9
Vessels/ Reactors (see below)	18	50	17
Shell & Tube Heat Exchangers (see below)	9	5	10
Pipe (average based on equipment count)	3	20	3

The above discussion has focused on frequency potential for leaks associated with instrument, flange and piping failures, which is used as input for developing risk contours. Not included in this analysis is potential for major reactor equipment failure as an initiating event. Such an event is not a common occurrence, with no such recorded incidents of reactors simply rupturing with no external influences. This is because such equipment are designed to the appropriate standards and using appropriate materials of construction, equipped with appropriate pressure and temperature protection, as well as second layers of instrumented safeguarding to prevent temperature/pressure excursions. Such defences include:

- Due to presence of catalyst circulating at high speeds, all piping and equipment in contact with the catalyst has erosion resistance lining to protect the pressure envelope. Inspection is carried out on this lining every 4 years, in addition to monthly visual external inspections.
- Unit is based on UK design in operation for 20 years, where sufficient inspection history (at least 5 major internal inspections) is available to demonstrate no significant damage to pressure containing equipment over this time.
- Reactor, Stripper and Regenerator is fitted with numerous temperature/pressure indicators/alarming (i.e. adequate installed redundancy) to warn of temperature/pressure excursions allowing appropriate response by operations.
- Reactor/stripper is protected from overpressure by relief valves installed on the downstream vessel, with an open system maintain between the two pieces of equipment.
- Regenerator and downstream equipment is protected from overpressure by providing an open path to the boiler stack at all times.
- Low pressure differential trips (2 out of 3 voting system) installed on main control valves between reactor and regen to prevent intermixing of air and hydrocarbons, with such trips initiating feed (hydrocarbons) to be removed from unit.
- Panel activated feed trips to allow hydrocarbons to be removed from feed remotely and instantaneously.

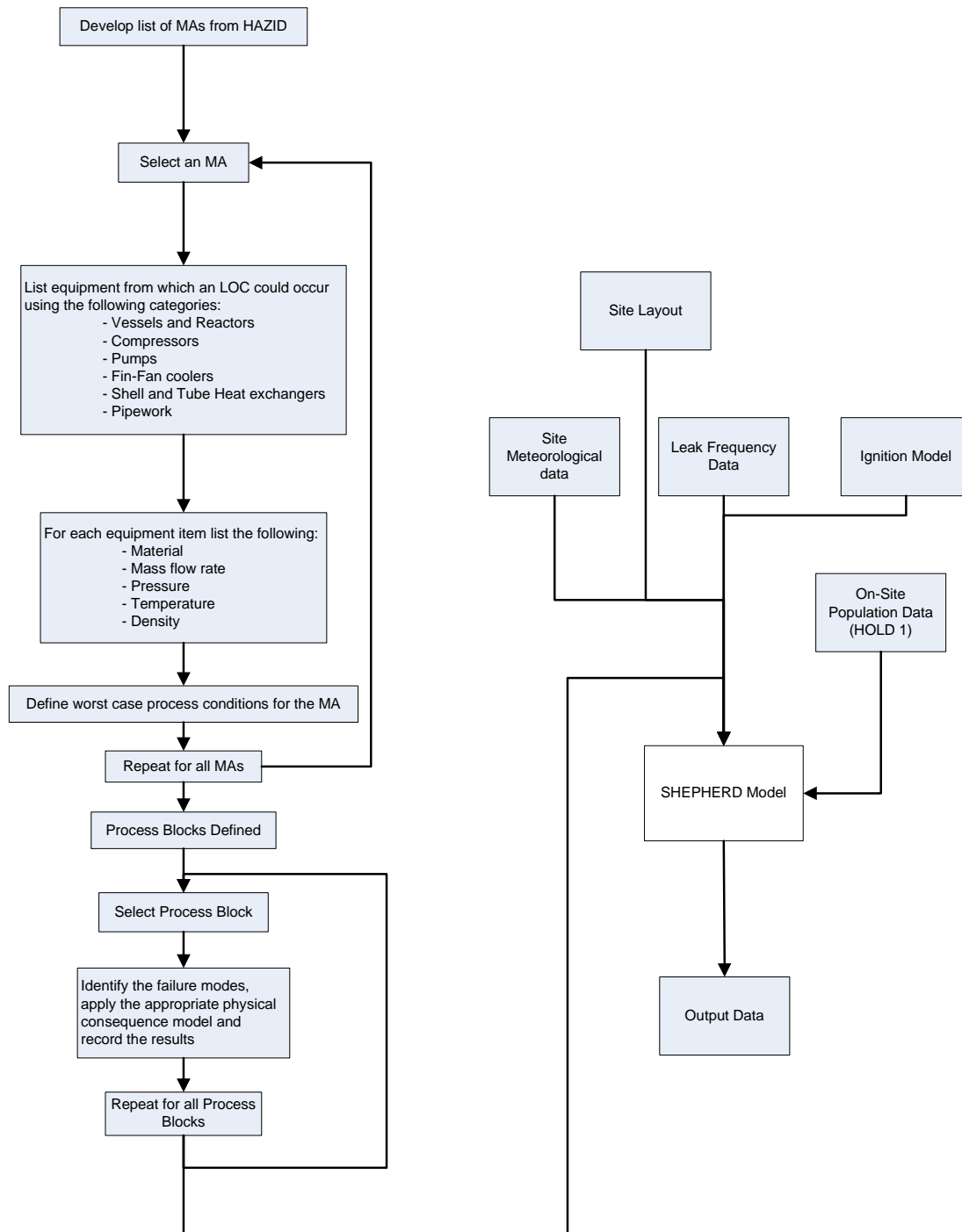
APPENDIX 4. RISK ANALYSIS

A 4.1. Introduction

The risk analysis for the site was completed in Shepherd Version 2.0. The risk analysis brings together the physical consequence model, effects models, leak frequency and parts count. The modelling also includes site specific issues such as equipment layout and prevailing weather conditions.

A step by step guide to the process is summarised in a flowchart in Figure 2.

FIGURE 2 RISK MODELLING



Modelling was undertaken in two basic modules:

- Process block development
- Shepherd risk analysis model

A 4.2. Process Block Development

Process blocks are a tool for rationalising the MAEs identified in the HAZID into Shepherd input data. A process block represents a defined process stream for a defined plant area. The development of a process block is shown on the left hand side of Figure 2. All the process block information is recorded on a spreadsheet in a format that facilitates input to the Shepherd model.

A 4.3. Shepherd Model

The Shepherd model has a number of inputs. Each is described in more detail in this section.

A 4.4. Site Layout

A scaled site layout is imported into Shepherd. The process blocks relating to MAEs are placed on the site map. The site map is also used to display the results of the risk analysis. The site map is sufficiently sized to show surrounding areas including sensitive land uses.

A 4.5. Site Meteorological Data

Shepherd uses the site wind speed and weather stability data for gas dispersion modelling. In Shepherd all modelling is done for weather stability classes / categories D and F. Weather category D with a wind speed of 5 m/s (D5) is representative of the "typical" weather category. F2 catches the longer distances, which will occur less frequently. Weather categories A and B are typical observed in hotter / tropical climates. Though not incorporated into Shepherd, they are deemed to be sufficiently well described by the D category (D will generally yield a more conservative assessment) and have thus not been explicitly included in the specification.

Shepherd calculations are based on a 12-sector wind rose; each sector representing one hour in the clock. Values of the wind speed and Pasquill class are specified by the user in each of the sectors of the wind rose for weather categories D and F, with a maximum of 3 wind speeds. In Shepherd the wind direction is defined as the being in a given 30° sector (blowing towards rather than from a sector). Note that weather data normally presents the fraction the wind is blowing from a certain direction.

Data of wind speed and probability of it being in/from a certain direction is specified by the user and is based on meteorological data (wind rose), from a nearby weather station, obtained from the Bureau of Meteorology (BoM).

The BoM does not have direct observations from Clyde. The nearest observations were taken from Olympic Park (about 4 km to the east of the refinery), where an automatic weather station (BoM site number 066195) provides observations of temperature, average wind speed and direction and standard deviation of wind direction.

The closest cloud observations were taken from an automatic ceilometer at Bankstown Airport (BoM site number 066137), about 10 km south of Clyde, which gives a cloud base measurement every 12 seconds. For times when the ceilometer was not available, manual cloud observations from Sydney Airport (site number 066037) were also obtained.

All these data are stored in ADAM, the Bureau of Meteorology's national climate data archive, and go back to at least December 1998. However, a 30-degree error in wind direction from Olympic Park occurred some time between an inspection in May 1999 and one in June 2000. For this reason, the four-year period from January 2001 to December 2004 was chosen by the BoM for the data analysis.

As summary of the wind speed and weather stability data, in the format required by Shepherd (i.e., 12-sector wind direction toward sector and D and F stability classes), is provided below:

TABLE 17 CLYDE REFINERY WEATHER DATA

Stability and Wind Speed	Probability of Wind Direction Toward (degrees true)											
	0	30	60	90	120	150	180	210	240	270	300	330
D 5	0.028	0.032	0.057	0.062	0.037	0.033	0.031	0.031	0.050	0.048	0.060	0.040
D 9	0.006	0.001	0.014	0.018	0.006	0.006	0.001	0.006	0.010	0.007	0.031	0.024
E 3	0.004	0.005	0.018	0.021	0.008	0.008	0.004	0.008	0.004	0.002	0.006	0.004
F 1.5	0.011	0.018	0.045	0.062	0.026	0.014	0.019	0.021	0.020	0.013	0.013	0.008

A 4.6. Leak Frequency Data

The development of the site leak frequency data is detailed in Appendix 3

A 4.7. Ignition Model

The immediate ignition probabilities that were used for the study were derived from data provided in Cox, Lees and Ang. A summary is provided in Table 18 for a range of leak rates.

TABLE 18 SUMMARY OF IMMEDIATE IGNITION PROBABILITIES

Release Rate (kg/s)	Immediate Ignition Probability	
	Vapour / Mixed Releases	Liquid Releases
<1 kg/s	0.0096	0.0096
1 - 50 kg/s	0.0616	0.0264
>50 kg/s	0.21	0.056

Releases which are not immediately ignited (and hence result in vapour cloud dispersion) may be ignited by ignition sources at the facility, including pilot lights, flare stacks, non-intrinsically-safe electrical equipment, vehicles and mechanical sparks.

A site ignition probability of 0.0001 per m² of the facility was adopted for this study, in order to address the potential for delayed ignition. This value was chosen based on the assumption that over the whole area of a refinery unit (~10,000 m²), e.g. the Crude Distillation Unit, the probability of ignition would be 1. This accounts for potential ignition sources such as furnaces, vehicles and electrical equipment located outside hazardous-zoned areas.

A 4.8. Shepherd Off-Site Risk Results

The Shepherd model has a number of outputs. Certain outputs are dictated by the initial set up conditions and data entry. The more relevant outputs for the QRA are:

- Frequency of incident radiation flux > 4.7 kW/m² (required for heat radiation injury contour) (4.7 kW/m² is set at a global level);
- Frequency of incident overpressure > 7 kPa (required for overpressure injury contour) (7 kPa is set at a global level);
- Frequency of toxic concentration > Level of Concern (required for toxic injury contour) (the level of concern is specified by the user for each toxic species – for this study, the ERPG-2 levels for each species are specified);
- Risk of fatality contours (for off-site QRA) (order of magnitude values are plotted i.e. 1x10⁻², 1x10⁻³ etc.); and
- F-N curves (for off-site QRA) – FN curves are frequency-fatality plots, showing the cumulative frequencies (F) of events involving N or more fatalities.

A 4.9. Limitations

The Shepherd model has been developed with inherent modelling simplifications, which allow for a complex refinery to be modelled.

For example, Shepherd allows only for a minimum and a maximum heat radiation level to be defined for calculation of fatalities. In this study, these have been taken to be 4.7 kW/m² and 14 kW/m² (see Table 6.2), in order for the model to provide both injury risk contours and fatality risk contours, respectively. However, in order to adequately address the potential for fatality from exposure to heat radiation intensities between the minimum and maximum levels, a 50% probability of fatality was conservatively assumed.

A 4.10. RESULTS OF RISK MODELING

The consequence assessment demonstrated that there were no incidents associated with the R&R section that resulted in an offsite impact. In order to show that the project has not increased the risk associated with the unit the individual risk contours are shown for both the existing and the proposed development.

FIGURE 3 INDIVIDUAL RISK FOR EXISTING R&R

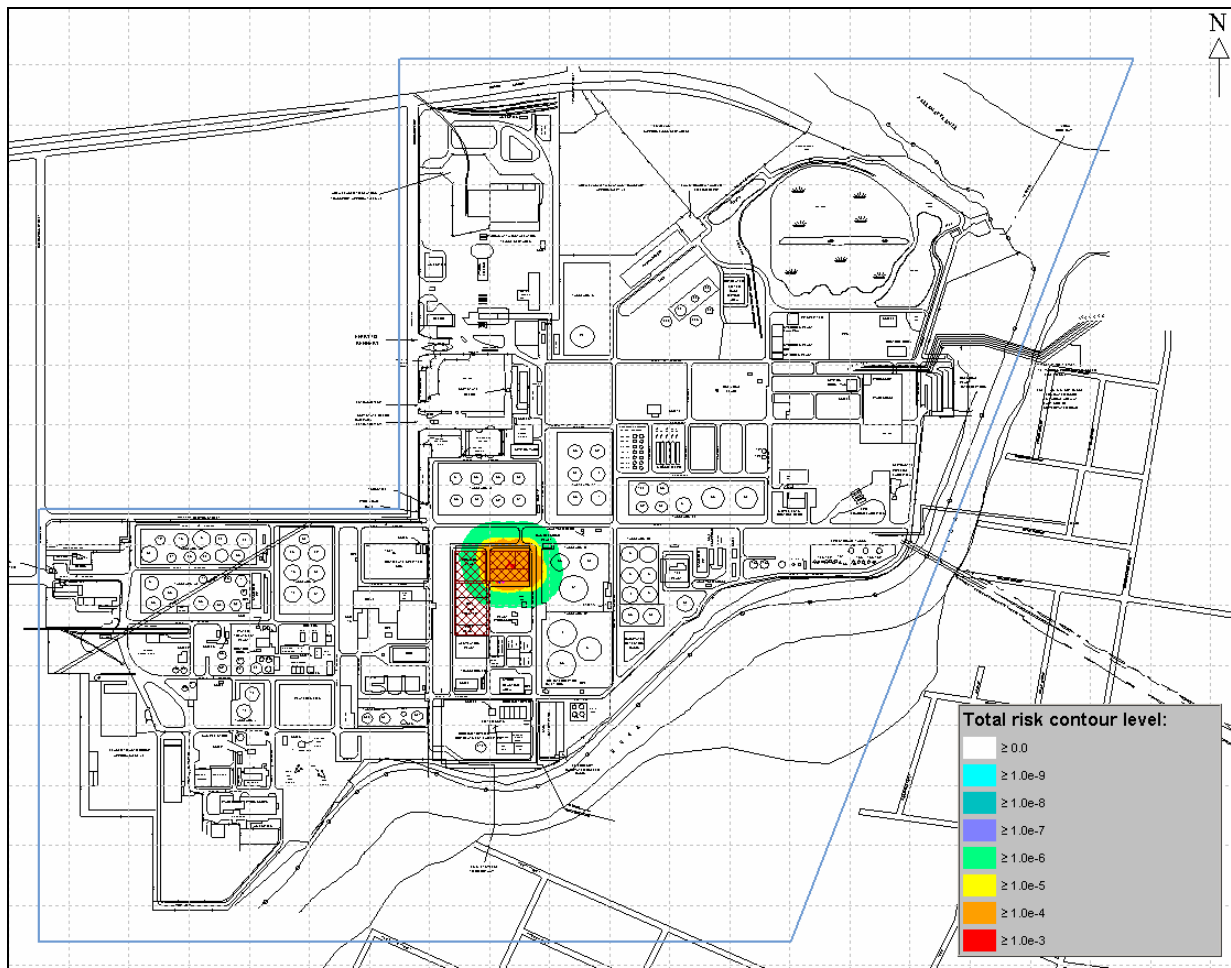


FIGURE 4 INDIVIDUAL RISK NEW R&R

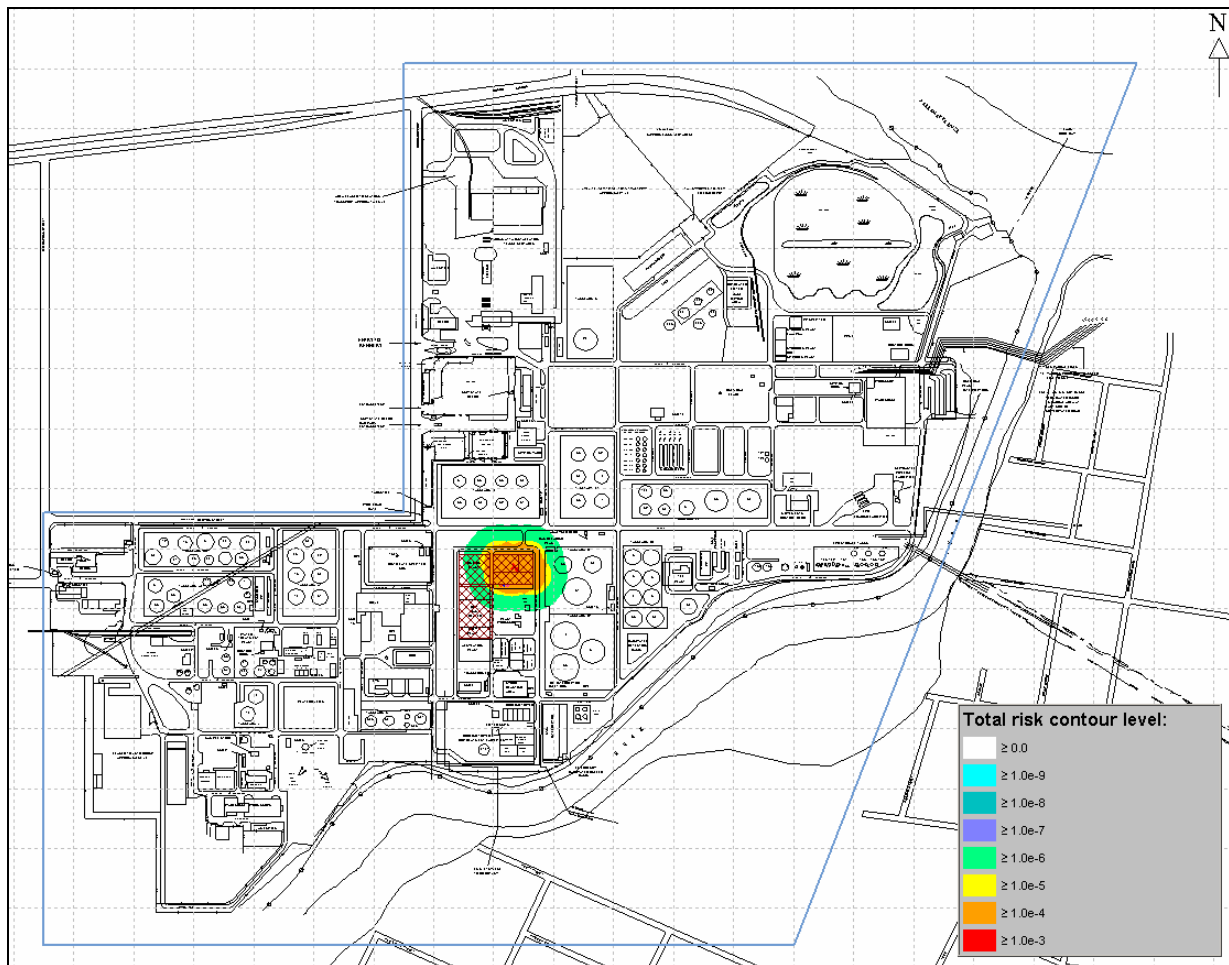


Figure 3 and Figure 4 show the risk from all potential release scenarios.

By comparing Figure 3 and Figure 4, it can be seen that there is no appreciable change in the individual risk to people associated with the R&R Rejuvenation project. Since the risk contours for the R&R are clearly within the site boundary, all associated criteria identified in table 7.1 are met.

A 4.11. Escalation

The results of the consequence analysis have demonstrated that there are no incidents associated with the reactor rejuvenation project that have the potential for offsite impact as the low pressure releases have insufficient magnitude

Hence, it is concluded that the development itself does not present a significant escalation risk and the potential for incidents in other areas of the refinery to escalate to the unit will not result in offsite impact.

The residual risk that requires assessment is the potential for incidents starting in the R&R to escalate to other units which subsequently have offsite impact. Of note is the potential for a fire to escalate due equipment within the 23kW/m² contour or within the blast wave from a catastrophic rupture.

The following points are noted:

- The R&R project will result in a significant reduction in inventory. The potential magnitude of an incident in the area, and its associated potential to escalate will therefore be reduced.
- The R&R project will result in a reduction in the leak frequency due to the selective application of flanges with welded membrane seals. Hence, the likelihood of an initiating event will be reduced.
- The R&R project includes upgrades to control and safeguarding systems. These upgrades will reduce the likelihood of an incident.
- The refinery has an integrated emergency response plan that includes:
 - Isolation of the feed to the incident and hence a reduction in event duration
 - Protection of adjacent equipment through the application of cooling water, drainage and removal of spilt inventory and passive fire protection

On the basis it is concluded that the risk due to escalation are manageable through the refinery emergency response procedures and will reduce as a result of this project.

A recommendation has been made to complete a fire safety study in line with the requirements of the Seven Stage Planning Process. The fire safety study will include an assessment of the potential for incidents to escalate.

APPENDIX 5. REFERENCES

- 1 NSW Department of Planning, *State Environmental Planning Policy No. 33 – Hazardous and Offensive Developments (SEPP 33) - Applying SEPP 33*.
- 2 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper No.6 – Guidelines for Hazard Analysis*.
- 3 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper No.2 – Fire Safety Guidelines*
- 4 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper No.7 – Construction Safety Study Guidelines*
- 5 NSW Department of Planning (1997), *Multi-Level Risk Assessment*, Revised Edition.
- 6 CH2M HILL (2006), *Environmental Assessment, Fluidised Catalytic Cracking Unit Reactor and Regenerator Rejuvenation Project*. Prepared for Shell Refining (Australia) Pty Ltd
- 7 NSW Department of Planning, *Hazardous Industry Planning Advisory Paper HIPAP No 4 – Risk Criteria for Land Use safety Planning*.