White Rose Extension Project

Wellhead Platform
Concept Safety Analysis

June 2014

Husky Energy | ARUP

Report

Project:	Business Unit:
White Rose Extension Project	**Atlantic Region**

Document Title:	Total # of Pages:
Wellhead Platform Concept Safety Analysis	**95 + Appendices**

Originating Company:	Company Document No.:	Husky Document No.:	Revision No.:
RMRI (Canada) Inc	**ARU/0383**	**WH-G-80W-X-RP-00003-001**	**E3**

Comments: This report identifies major hazards associated with the Wellhead Platform, taking into account the basic design concepts, layout and intended operations, and assesses the risks to personnel and the environment resulting from these hazards.

Company Stamp	Engineering Stamp

Revision	Date	Reason For Issue	Prepared	Checked	Lead Approval	Management Approval	Husky Acceptance
E3	04-Jun-14	Issued for Use	A. Baxter Principal	A. Pegram Technical Director	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	Derek Pearcey Engineering Manager
E3 Draft	02-Jun-14	Issued for Review	A. Baxter Principal	J. Garcia Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	
E2	14-Mar-14	Issued for Use	J. Garcia Principal	L. Chapman Managing Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	Derek Pearcey Engineering Manager
E2 Draft	07-Mar-14	Issued for Review	J. Garcia Principal	L. Chapman Managing Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	
E1	23-Nov-12	Issued for Use	L. Thame Principal	A. Pegram Managing Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	
P1	27-Jul-12	Preliminary	J. Garcia Senior	L. Thame Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	
R2	16-Jul-12	Issued for Husky Review	J. Garcia Senior	L. Thame Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	
R1	13-Jul-12	Issued for Internal Review	L. Thame Principal	A. Pegram Managing Principal	Andrew Horton Project Eng. Mgr.	John Powell Project Manager	

Revision History

Comp Rev	Husky Rev	Date	Reason for Issue	Prep	Chk	Lead	Man	HE
01	R1	13 Jul 12	Issued for Internal Review	LT	AP	APH	JP	
02	R2	16 Jul 12	Issued for Husky Review	JG	LT	APH	JP	
03	P1	27 Jul 12	Preliminary	JG	LT	APH	JP	
04	-	16 Nov 12	Preliminary for Review	LT	AP	APH	JP	
05	E1	23 Nov 12	Issued for Use	LT	AP	APH	JP	
06	E2 Draft	07 Mar 14	Issued for Review	JG	LC	APH	JP	
07	E2	14 Mar 14	Issued for Use	JG	LC	APH	JP	DP
08	E3 Draft	02 Jun 14	Issued for Review	AB	JG	APH	JP	
09	E3	04 Jun 14	Issued for Use	AB	AP	APH	JP	DP

Prime Contractor

ARUP

Arup Canada Inc.
2 Bloor Street East
Suite 2400
Toronto, ON, M4W 1A8
Canada
www.arup.com

Originating Company

RMRI

RMRI (Canada)
36 Quidi Vidi Road, St. John's
Newfoundland, A1A 1C1
Canada
http://www.rmri.ca

Table of Contents

List of Acronyms

ALARP	As Low As Reasonably Practicable
ALE	Abnormal Level Earthquake
ALIE	Abnormal Level Ice Event
API	American Petroleum Institute
BOP	Blowout Preventer
CCTV	Closed Circuit Television
CEC	Canadian Electrical Code
CGS	Concrete Gravity Structure
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CSA	Concept Safety Analysis
DDMT	Data and Decision Management Tool
DNV	Det Norske Veritas
ECM	Environmental Compliance Monitoring
EEM	Environmental Effects Monitoring
EERA	Escape, Evacuation and Rescue Assessment
ELE	Extreme Level Earthquake
EPCMP	Environmental Protection and Compliance Monitoring Plan
FEED	Front End Engineering and Design
FGS	Fire and Gas Detection System
F-N	Frequency-Number
FPSO	Floating Production, Storage and Offloading
H_2S	Hydrogen Sulphide
HMI	Human Machine Interface
HOIMS	Husky Operational Integrity Management System
HSE	(UK) Health and Safety Executive
HVAC	Heating, Ventilation and Air Conditioning
ICSS	Integrated Control and Safety System
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
IRPA	Individual Risk Per Annum
KO	Knock-Out
LFL	Lower Flammable Limit
LLWLT	Lower Low Water Large Tide
LQ	Living Quarters
MODU	Mobile Offshore Drilling Unit
OIM	Offshore Installation Manager
PAGA	Public Address General Alarm
PFP	Passive Fire Protection
PLL	Potential Loss of Life
POB	Personnel on Board
P&ID	Piping and Instrumentation Diagram
QRA	Quantitative Risk Assessment
RF	Radio Frequency
ROV	Remotely Operated Vehicle
RP	Recommended Practice
SDV	Shutdown Valve

SIL	Safety Integrity Level
SIMOPS	Simultaneous Operations
SSIV	Subsea Isolation Valve
SWRX	South White Rose Extension
TEMPSC	Totally Enclosed Motor Propelled Survival Craft
TIF	Test Independent Failure
TLS	Target Levels of Safety
TR	Temporary Refuge
UV	Ultraviolet
VEC	Valued Environmental Component
WHP	Wellhead Platform

1.0 Introduction

The White Rose Field is located in the Jeanne d'Arc Basin in approximately 120 metres of water. The White Rose Field has, to date, been developed through subsea drill centres tied back to a Floating Production, Storage and Offloading (FPSO) facility (the 'SeaRose'), located approximately 350km east of Newfoundland.

Husky Energy, and its co-venturers Suncor Energy Inc. and Nalcor Energy Inc., are proposing to further develop the White Rose Field using a Wellhead Platform (WHP), with drilling facilities, which will be tied back to the existing SeaRose FPSO.

According to Section 43 of the Newfoundland Offshore Petroleum Installations Regulations, an operator is required to submit to the Chief Safety Officer a concept safety analysis of an installation that considers all components and activities associated with each phase in the life of the production installation. The concept safety analysis must include a determination of the frequency of occurrence and potential consequences of potential accidents identified, and details of safety measures designed to protect personnel and the environment from such accidents.

This report, therefore, identifies major hazards associated with the WHP, taking into account the basic design concepts, layout and intended operations, and assesses the risks to personnel and the environment resulting from these hazards.

Section 2 provides an outline description of the WHP development project and Section 3 describes the key safety design features and systems proposed for the prevention, detection and control of potential major hazards. Sections 6 to 11 present the basis of the assessment of risk to personnel due to the identified major hazards (listed in Section 5). Section 12 presents the results of the assessment, and compares them to Husky's Target Levels of Safety (Section 4). Section 13 details sensitivity studies that have been performed, and recommendations to be considered are detailed in Section 14.

1.1 Study Objectives and Methodology

The objectives of this Concept Safety Analysis (CSA) are to:

- Identify the potential Major Hazards associated with the development concept.
- Evaluate the identified Major Hazards in terms of risk to personnel and the environment, through event tree-based Quantitative Risk Assessment (QRA).
- Compare predicted risks with Husky's Target Levels of Safety (TLS).
- Document results, findings, conclusions and recommendations.
- Fulfil the CSA requirements stipulated in Section 43 of the Offshore Petroleum Installations Regulations.

As required by the Offshore Petroleum Installations Regulations, this CSA considers all components and activities associated with each phase in the life of the WHP, including the construction, installation, operational and removal phases of the installation.

The hazard identification carried out was based on a detailed review of standard Major Hazards that have been identified as a result of many years of similar operations experience, and in particular experience on the Hibernia, Hebron, Terra Nova and White Rose projects.

As required, the risk assessment is quantitative where it can be demonstrated that input data is available in the quantity and quality necessary to demonstrate confidence in results. Where quantitative assessment methods are inappropriate, qualitative methods are employed.

The following Major Hazards are identified as requiring consideration in the quantified risk assessment:

- Loss of hydrocarbon containment (resulting in fire, explosion or unignited release).
- Blowout (resulting in fire, explosion or unignited release).
- Releases below the platform topsides.
- Subsea flowline release.
- Iceberg collision and scouring, sea ice, topsides icing.
- Ship collision.
- Helicopter transportation.
- Seismic activity.
- Structural failure due to extreme weather.
- Dropped objects.

The estimated risks are compared with Husky's TLS in order to determine whether risks are acceptable.

1.2 Review and Update

This CSA is the initial document that quantifies the risk to personnel and the environment due to operation of the installation, and is prepared and maintained during the pre-FEED and FEED stages of the White Rose Extension Project. The purpose of the CSA is to demonstrate that the WHP design is capable of meeting Husky's Target Levels of Safety and to support the WHP development application. It is intended that this Rev. E3 of the CSA will be the final revision prior to the White Rose Extension Project entering detailed design.

However, during detailed design, the WHP will be subject to a formal program of safety assessment studies. These studies will be reflected in a Quantitative Risk Assessment (QRA), which provides a more substantive assessment of risks and safety, being based on more detailed design information, than does the CSA, which the QRA will supersede. The QRA and associated studies will also be primary inputs into the Basis of Safe Operations for the WHP that will be included as part of the Safety Plan.

Husky will maintain the QRA, the associated safety studies and the Basis of Safe Operations throughout the life of the WHP, and these documents will be reviewed to reflect changes or new knowledge in operating conditions or equipment on the WHP as part of a 3 year review cycle.

In addition, where any proposed operational changes or platform, plant or equipment modifications are considered to be substantial, in that the Basis of Safe Operations is materially different to that submitted to the C-NLOPB, then Husky commit to revise the QRA and Basis of Safe Operations.

A change may be considered substantial if:

- The modification or introduction of new structures, plant, equipment or activities to the installation (or within the 500m exclusion zone) would result in the exposure of personnel to additional major accident hazards.

- Permanent or long-term (of a year's duration or more) modification of structure, plant, equipment or activity is planned that may be detrimental to the functionality, reliability, availability or survivability of safety critical elements.

- New safety systems are introduced either to manage additional hazards or to replace existing arrangements to prevent, control or mitigate major accident hazards (e.g. blast walls).

- Significant changes are to be made in the functions of the installation management or the management system.

Due regard will be paid to the cumulative effect of any series of minor changes when considering whether any change constitutes a material change and hence requires revision of the QRA and Basis of Safe Operations.

1.3 Presentation and Ongoing Use of Risk Model

The quantified risk assessment carried out for this CSA has been developed in a risk model that can be refined and updated throughout the life of the Project. To facilitate the tracking and updating of the data, the risk model is represented in RMRI's Data and Decision Management Tool (DDMT). This software tool allows quick and efficient interrogation of the risk model, ensuring that the best available data is used in ongoing decision-making on issues relating to personnel safety, the environment and the integrity of the installation.

This tool may be used during the WHP development project in order to fulfil commitments to:

- Protecting the health and safety of all individuals affected by their work, as well as the environment in which they live and operate.

- Communicating health, safety and environmental matters in an open and timely manner with all affected parties.

- Developing the culture and providing the training and resources necessary to support their commitments.

- Taking health, safety and environmental matters into account when making business decisions.

2.0 Outline Project Description

The White Rose Field (Figure 2.1) is located in the Jeanne d'Arc Basin. The White Rose Field has, to date, been developed through subsea drill centres tied back to an FPSO facility (the 'SeaRose'), located approximately 350km east of Newfoundland. Initially, production was via the Central Drill Centre (CDC) and the Southern Drill Centre (SDC). A third drill centre, the Northern Drill Centre (NDC), was developed for injection of gas that is being stored for future use. In 2010, a new drill centre (North Amethyst Drill Centre, NADC) was tied back to the Southern Drill Centre.

The Drill Centres and SeaRose FPSO are shown in Figure 2.2.

Husky Energy, and its co-venturers Suncor Energy Inc. and Nalcor Energy Inc., are proposing to further develop the White Rose Field by a Wellhead Platform (WHP), with drilling facilities, which will be tied back to the existing SeaRose FPSO vessel. A description of the proposed WHP is included in Section 2.1.

Figure 2.1: White Rose Field

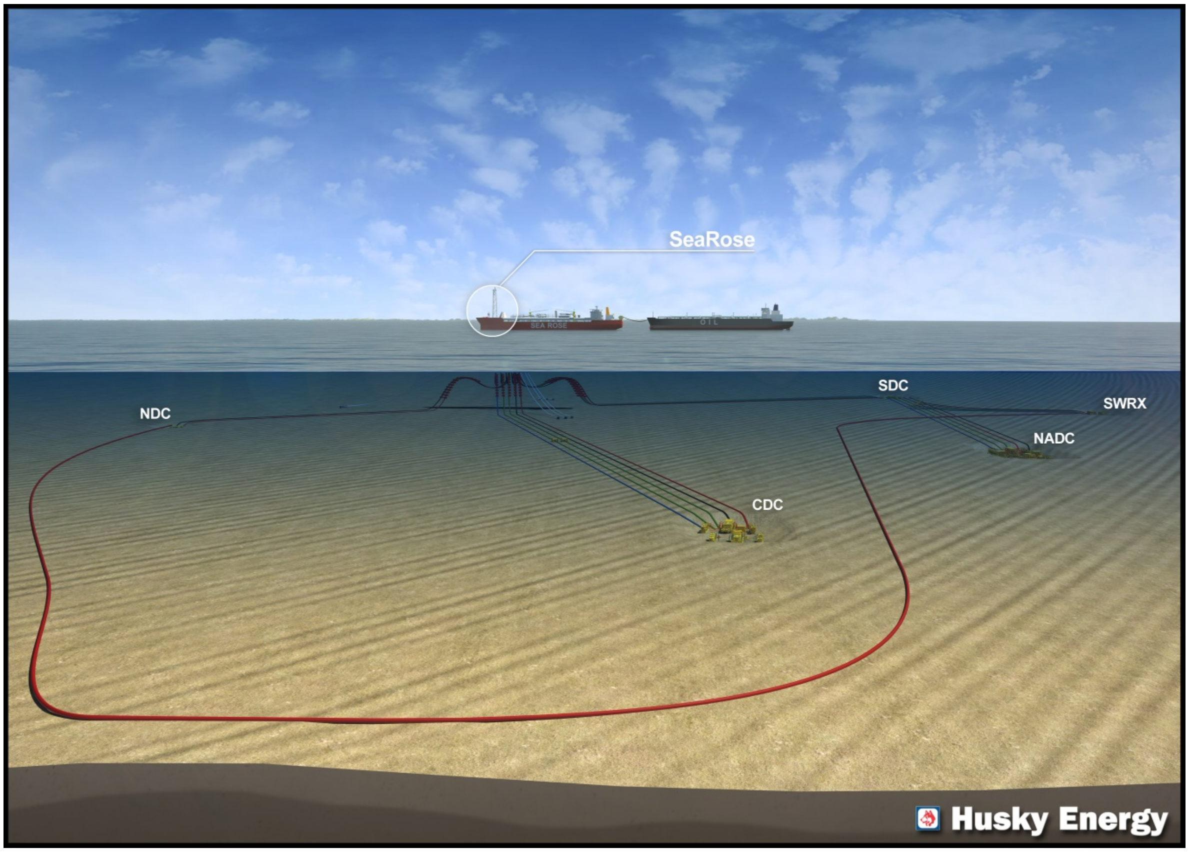


Figure 2.2: Existing White Rose Field Layout

2.1 Outline Description of the Concept Wellhead Platform

The platform description provided here is based on conceptual design and Front End Engineering and Design (FEED) studies carried out to date. The components described herein will be subject to change as the design develops during detailed design. An illustration of the WHP concept is given in Figure 2.3.

The WHP will be installed in the West White Rose area, approximately 3.5km from the SeaRose FPSO and 1.5km from the CDC.

The WHP will consist of a concrete gravity structure (CGS) with a topsides consisting of drilling facilities, wellheads and support services, such as accommodation for a maximum of 144 persons, utilities, flare boom and a helideck.

The primary function of the WHP is drilling. There will be no oil storage in the CGS. Well fluids will be transported to the SeaRose FPSO via two 10 inch subsea flowlines for processing, storage and offloading. Water will be supplied to the WHP for water injection from the SeaRose FPSO. Production and water injection flowlines will be tied in to the subsea tie-in structure on existing flowlines between CDC and the SeaRose. Gas will be supplied to the WHP from the SeaRose, via a tie-in from the South White Rose Extension (SWRX) gas injection flowline, for gas lift, gas flood and fuel gas.

The wellhead system will utilize a shared (dual) conductor system, and is planned to accommodate 38 wells in 20 well slots, with a maximum of 40 wells possible. The use of dual conductor technology offers the optimum solution for providing the required number of wells whilst reducing wellbay space requirements.

The design of the WHP will account for the risks posed by icebergs, sea ice and the harsh environmental conditions found offshore Newfoundland and Labrador. The productive life of the WHP facility is currently planned to be 25 years.

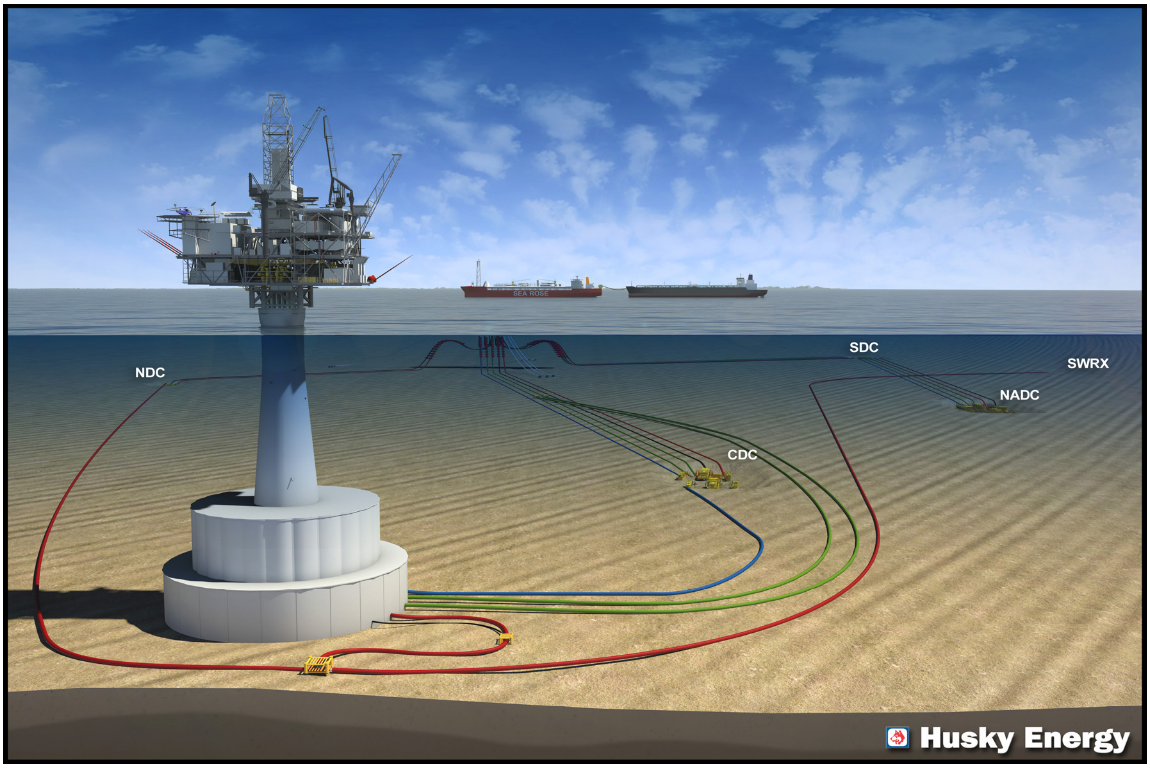


Figure 2.3: Conceptual WHP Location and Flowlines

Brief descriptions of the topsides facilities and CGS are provided in the following subsections.

2.1.1 Topsides Facilities

The topsides will be arranged over three decks (Figure 2.4):

- Cellar Deck, where the wellheads, production and test manifolds, test separator, water injection booster pumps and manifold, gas distribution system, fuel gas skid, gas lift and injection manifolds and flare KO drum will be located. The power generation packages, emergency generation package, air compressor skid, seawater filter skid, offices, a storage room and workshop will also be located on this deck, as well as facilities for storing diesel, methanol, nitrogen, potable and drilling water and chemicals.

- Middle Deck, which will include mud tanks, mud pumps, synthetic oil storage tanks and pumps, cutting injection and cementing block. Electrical wirelining and coiled tubing equipment is also provided on this deck.

- Drilling Deck, which supports the drilling rig structure and the pipe rack. The deck also includes the helicopter refueling skid, brine storage tanks and the crane pedestal.

There is also a Sub Cellar Deck, between the Cellar Deck and the top of the CGS, where the drain tanks, gas import shutdown valve (SDV), launcher/receiver and gas inlet heater are located. This deck is split into two east and west areas.

The living quarters (LQ) will be located on the west of the platform and the walls will be appropriately fire-rated (the east wall will also be appropriately blast rated). The helideck will be cantilevered off the top of the LQ.

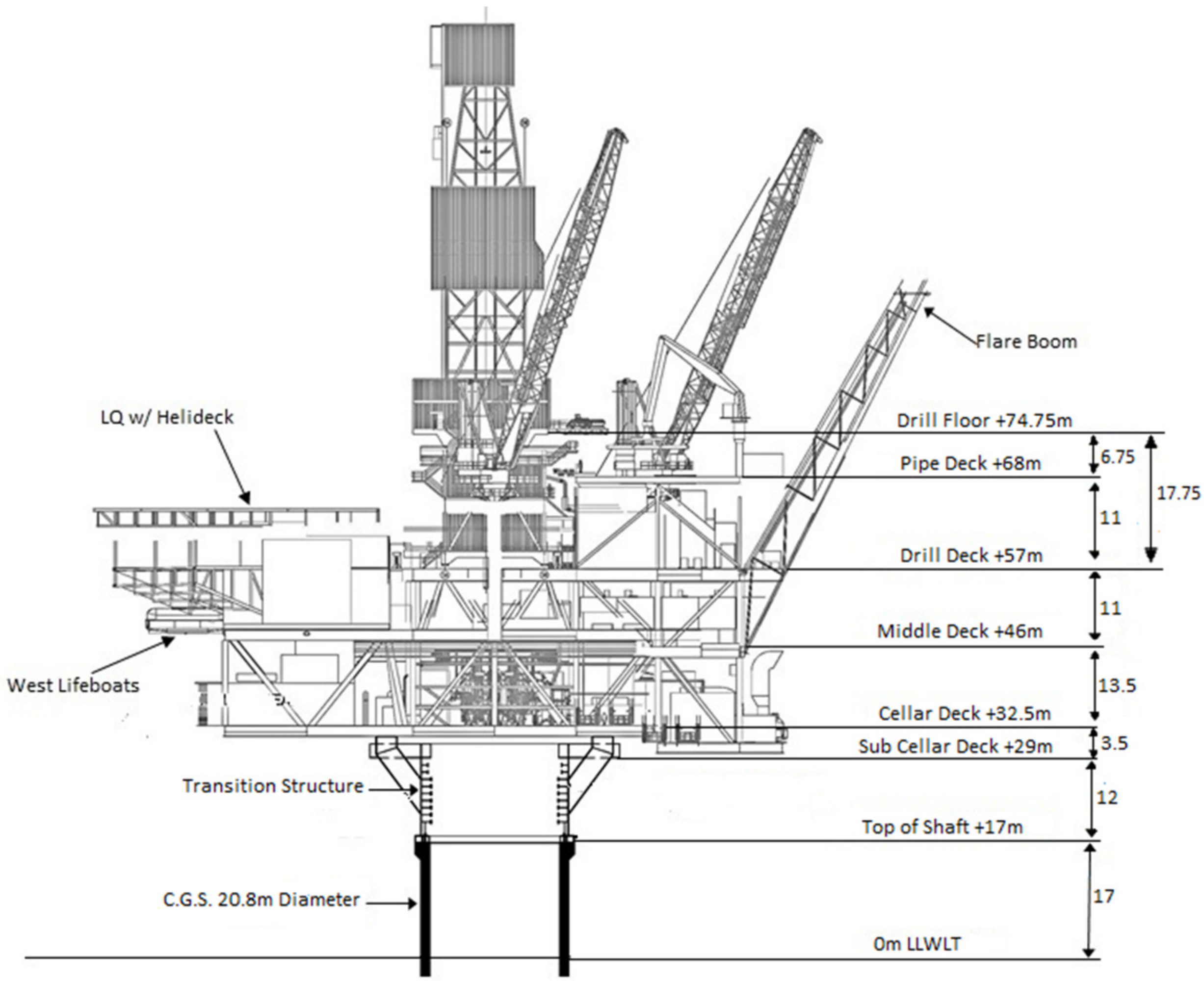


Figure 2.4: WHP Decks (Looking North)

The Living Quarters (LQ) will be designed to accommodate the maximum POB of 144 and will be laid out over five levels.

The Living Quarters will be the designated Temporary Refuge (TR) and as such will be provided with appropriate lifesaving equipment.

The primary lifeboats (three 72-man lifeboats) will be located on the west side of the LQ. An additional 72-man lifeboat will be provided at the east of the Cellar Deck.

2.1.2 Concrete Gravity Structure (CGS)

The CGS will be a concrete structure with a central column that will support the topsides approximately 32.5 metres from lower low water large tide (LLWLT) and will be designed to protect against iceberg or ship impact. A cylindrical transition structure will be used to mate the CGS to the platform topsides.

The central column of the CGS will consist of a wet shaft, flooded to sea level. It will contain well conductors, flexible risers, j-tubes, caissons and main mechanical outfitting steelwork. The shaft will not be accessible during normal operations.

3.0 Prevention, Control and Mitigation of Major Hazards

This section describes the safety design features and safety systems proposed for the prevention, detection and control of potential Major Hazards, as well as the mitigation of associated risks both to personnel and to the environment. An overview of the escape and evacuation systems is also presented.

In all cases the systems will be designed to meet or exceed appropriate codes and standards and to comply with all corporate safety and environmental policies and applicable regulations.

3.1 Facility Layout

The topsides has been designed to provide maximum separation between the wellbay and the living quarters (LQ) and helideck.

Safety considerations of the topsides layout will include the provision of:

- Separation between flammable hydrocarbons and ignition sources.
- Separation between hydrocarbon handling areas and emergency services, main safety equipment, accommodation, temporary refuge areas, means of evacuation and escape, muster points and control centres.
- Sufficient structural protection in the form of passive fire and blast protection to ensure structural integrity for the time required for orderly evacuation or escape.
- Appropriate protection on critical and pressurized equipment at risk from dropped objects from mechanical handling equipment.
- Sufficient means of escape to enable efficient and protected evacuation from all areas designated as muster and evacuation stations under foreseeable hazard conditions.
- Availability of essential services and the main safety equipment under foreseeable hazard conditions, including protecting critical systems and equipment required to function in a fire and explosion emergency.
- Safe access to systems and equipment for operational and maintenance purposes.

Specific considerations for the offshore facilities will include:

- Providing in the design for helicopter approach and take-off flight sectors that conform to Transport Canada requirements and the Civil Aviation Authority publication CAP 437 and are free of interference. This will have an influence on helideck location and platform orientation with respect to prevailing winds.
- Positioning and arranging cranes and laydown areas to facilitate safe lifts from supply boats and eliminating or reducing the potential for vessel collisions and dropped objects contacting subsea flowlines.

- Locating and orientating survival craft, launch gear and other sea evacuation or escape systems to provide the maximum practicable clearance from any part of the platform during deployment, and to avoid adverse effects of wind, waves and currents.

3.2 Classification of Hazardous Areas

Hazardous areas of the WHP in which hydrocarbon gas or vapours will, or may be, present will be classified in accordance with Section 18 of the Canadian Electrical Code (CEC) Part 1 C22.1 and API RP 505 "*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class 1, Zone 0, Zone 1, and Zone 2*".

Hazardous area classification is an important consideration in deciding the location of ventilation air inlets and outlets and location of combustion air inlets and exhausts outlets for internal combustion engines and fired units.

In classified hazardous areas, various measures will be taken to minimize the occurrence of hazards to personnel, including:

- Assurance of adequate natural ventilation or the provision of ventilation to prevent the accumulation of flammable gases or vapours.
- The control of potential ignition sources, by selection of appropriate equipment.

Electrical equipment for use in hazardous areas will be selected in compliance with API RP 14FZ – 2001 (R2007) "Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Zone 0, Zone 1 and Zone 2 Locations". In addition to API RP 14FZ, relevant Husky design specifications will be used.

3.3 Ventilation of Hazardous Areas

Hazardous areas will be ventilated to prevent the accumulation of flammable gases and vapours, to reduce the likelihood of ignition, and thereby minimize the risk from fire and explosion.

In hazardous areas where natural ventilation is not adequate, mechanically-assisted ventilation will be provided. Ventilation for hazardous areas will be in compliance with API RP 505 "*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class 1, Zone 0, Zone 1, and Zone 2*" and the Installations Regulations.

3.4 Ventilation of Non-Hazardous Areas

HVAC applications for non-hazardous areas will include pressurization systems to prevent the migration of fumes or vapours from hazardous areas to closed non-hazardous areas.

The HVAC systems will incorporate safety features designed to prevent the spread of flammable gas, fire and smoke from hazardous areas to closed non-hazardous areas. These will include:

- Fire dampers in ventilation ducts.
- Fire dampers in all main fresh air intakes.

- Fire dampers in penetrations to fire-rated assemblies.
- Location of air intakes away from potential sources of hazardous gases or vapours.
- Gas and smoke detectors protecting air intakes, all of which will generate an alarm in the control room and close intake dampers to prevent the ingress of hazardous gases or vapours.

Air handling systems will have automatic detection of system failure, with appropriate alarms to the control room.

3.5 Offshore Drainage Systems

Open and closed drain systems will be provided on the WHP. These systems are critical in protecting the safety of personnel and the environment as they are designed to collect and contain fluids (potentially containing hydrocarbons) and therefore play a role, in emergency situations, in limiting the inventory available to fuel a fire or that may spill into the sea.

The open drain systems will include non-hazardous open drain and hazardous open drain systems. These systems will be segregated to prevent migration of gas/vapours from hazardous areas to non-hazardous areas. All open drains will be individually sealed and all deluge drains in one fire area will be separated from deluge drains in all other fire areas.

The non-hazardous open drain system will collect drain water from non-hazardous areas through drip trays or tundishes and direct it to the non-hazardous open drain sump tank.

The hazardous open drain system will be designed to collect and remove washdown water, oil water from drip trays and skid pans, storm rain, and fire water (as well, in special circumstances, as hydrocarbon fluids and other contaminants) from the hazardous drilling area and process area through drip trays, drain boxes and tundishes.

Collected fluids will be directed to the hazardous open drain sump tank for separation, to avoid pollution of the environment and meet overboard disposal requirements. The open drain sump tanks will be hung from the bottom of the Sub Cellar Deck of the WHP as close to the shaft as possible.

In open areas, an upstand (curb) will run continuously around the module edges to form a bunded area, preventing the spill of liquids to lower decks or to the sea. Where escape or equipment passageways penetrate this bund a continuous drain trough will be fitted across the breach.

The closed drain system will be designed to collect drain fluid containing hydrocarbons from piping, tanks and other hydrocarbon-containing equipment. The fluids will be collected in the closed drains header and pumped into the oil export lines back to the SeaRose FPSO via the flare KO drum.

3.6 Fire and Gas Detection

All areas of the facility will be monitored by automatic fire and flammable gas detection systems appropriate to the fire or explosion risk.

The fire and gas system will be an integrated part of the WHP Integrated Control and Safety System (ICSS), and shall be SIL rated as per the IEC 61511.

Fire detectors will be installed on the offshore facility to continuously monitor spaces where the potential for fire exists. Fires will be detected and confirmed by smoke detection, flame detection or heat detection, depending on the nature of the area and the risk.

Smoke detectors (ionizing and photoelectric as appropriate), thermal detectors and manual stations will be provided in occupied buildings and machinery enclosures. Flame detection (triple IR or IR/UV combinations) will also be provided in machinery enclosures. In addition, fusible plug loops and manual pull stations that are connected to the ICSS fire and gas detection system (FGS) controller will be provided in process areas.

Packaged equipment such as turbo-machinery, galley hoods, hazardous material stores and helicopter refueling will be provided with detection and protection systems capable of local and remote alarm, release pre-alarm and local agent release.

The gas detection system will be designed to monitor gas concentrations in areas where accidental release and accumulation of flammable and/or toxic gases are possible. The basis for the location of gas detectors shall be based on a gas dispersion analysis.

The following types of gas detectors will be considered for the WHP:

- Point IR.
- Open path (line of sight) IR. These may be angled through or around the perimeter of each given area.
- Acoustic detection, in areas where high pressure gas releases are possible, for example gas system/piping areas.

The gas detection system will apply a voting philosophy that:

- Applies two detection levels for the hazardous and non-hazardous areas:
    - Hazardous areas: 20% Lower Explosive Limit (LEL) and 60% LEL.
    - Non-hazardous areas: 10% Lower Explosive Limit (LEL) and 20% LEL.
- Alerts personnel by audible and/or visual alarm upon one single detector (1ooN) indicating 20% LEL.
- Indicates confirmed gas and takes executive action (such as activating the emergency shutdown system and initiating the firewater pumps) if 2ooN detectors detect gas at 40% LEL concentration.

The fire and gas detection systems will be provided with adequate redundancy and protection to ensure, as far as is reasonably practicable, their availability in the event of a major accident.

The system will initiate audible and visual alarms within the protected buildings, at entryways to protected buildings, throughout the facilities via the Public Address/General Alarm (PAGA) system and on the Human Machine Interface (HMI). In specific cases, confirmed fire or gas detection will also automatically initiate executive actions, to control and mitigate the consequences of a fire or gas release.

A CCTV system will also be provided on the WHP. The CCTV cameras will be interfaced with the fire and gas system to enable cameras to focus on an area of interest on detection of fire or gas. The monitors in the control rooms will be able to monitor the CCTV and HMI screens.

3.7 Emergency Shutdown and Blowdown System

An emergency shutdown system (ESD) will be provided to maintain safe operating conditions compatible with production requirements. The ESD system will be an integrated part of the WHP ICSS.

Blowdown will be considered for pressurized hydrocarbon systems, to dispose of the gaseous inventory under emergency conditions in order to reduce the duration of an event and the intensity of the fire.

The principal functions of the ESD ICSS subsystem will be:

- The protection of personnel and overall safety of the platform.
- The minimization of environmental pollution.

The ESD system will be designed to comply with the relevant statutory requirements, codes and standards, and to, as far as is reasonably practicable, remain operational in an emergency. It will also be designed so that it can be initiated both manually and automatically.

The WHP ESD system will be interfaced with the SeaRose FPSO System to shutdown the import/export of hydrocarbons to either facility during emergency situations. The FPSO will however not be permitted to acknowledge or override any safety related alarm or trip on the WHP.

The topsides shutdown system logic is divided into the following levels, listed in order from the highest to the lowest based on the WHP shutdown philosophy:

- ESD Level 1 – Abandon platform.
- ESD Level 2 – WHP emergency shutdown (with immediate blowdown).
- ESD Level 3 – General WHP shutdown (with time delayed blowdown, which may be inhibited from the CCR, and immediate blowdown on confirmed wellbay fire).
- ESD Level 4 – Process shutdown (also initiated by a level 4 shutdown from the SeaRose FPSO).
- ESD Level 5 – Package shutdown (also initiated by a level 5 shutdown from the SeaRose FPSO).
- Drilling Shutdown.

Additional inter-facilities shutdown signals will be developed as the WHP design progresses.

3.8 Emergency Power

The WHP will have an emergency power generation system to allow drilling operations to be made safe and to maintain essential safety and communication systems in the event of loss of main power.

Emergency electrical power will be supplied to emergency systems, including:

- Fire and gas detection and shutdown systems.
- Emergency alarm system.
- ICSS.
- Instrument, auxiliary supply switchgear, escape lighting.
- Public address systems.
- Radio links.
- Drillers' intercom.
- Mud logging unit.
- Cement pump.
- BOP/diverter interface panel.
- Drillers' control and data acquisition systems.
- Navaids.
- Safety-related HVAC systems.
- Air compressors.

To ensure that the emergency power system will be operable during major fires on the WHP, the emergency generator system will be protected by appropriately rated firewalls.

The WHP ESD system will be designed to permit the safe shutdown of drilling operations. Some drilling equipment may have to operate in an emergency situation (such as in the event of a hydrocarbon gas release) and will need to be appropriately rated to permit safe suspension of drilling activities.

3.9 Active Fire Protection

The WHP will be provided with a combination of active fire protection and passive fire protection (PFP) selected to meet regulatory requirements and appropriate for the fire hazards that exist. This section describes the active fire protection that will be provided. Section 3.10 describes the PFP that will be provided on the WHP.

Active fire protection systems will be provided to meet the specific requirements of the Newfoundland Offshore Petroleum Installations Regulations (SOR/95-104) and referenced standards. ISO 13702 will also be considered for additional guidance as applicable.

In general, active fire protection will be arranged to ensure that a fire is prevented from spreading to other areas, and to limit damage to structures and equipment.

Details of the firewater distribution system are given in Section 3.9.1. Fire extinguishing agents and fire protection systems will be specified based on the results of fire and explosion analysis, but details of systems under consideration are given in Section 3.9.2.

3.9.1 Firewater Distribution System

The firewater (ring main) distribution system will be designed to provide an adequate supply of firewater to user points (such as deluge and sprinkler systems, monitors and hydrant/hose stations) to meet the largest credible demand for fire control and mitigation.

This will be achieved by:

- Ensuring firewater pumps are not subject to a single point failure.
- Ensuring the firewater system will deliver sufficient quantities of water at a suitable pressure.
- Ensuring that firewater drivers, firewater pumps, piping and deluge control points are adequately protected from fire and explosion damage.
- Having diverse firewater supply routes to systems and equipment.

Firewater pumps (or pump sets) are to be located within the shaft. Detailed design will evaluate the firewater system to identify potential risks to the fire water pumps and ensure that the pumps are adequately protected. There will be sufficient redundancy in the provision of pumps and drivers to ensure that firewater can be maintained in the event that a pump or driver is out of service.

The firewater pumps will be connected to the distribution system in such a way that damage in one area will not cause loss of all the firewater supply to that area.

Sea water lift pumps will be provided to maintain the pressure in the firewater distribution system.

3.9.2 Active Fire Protection Systems

The deluge systems will be automatically activated on confirmed fire detection in designated protected areas. The fire and explosion analysis will evaluate the benefits of activating such systems upon gas detection, in order to disperse vapors and reduce explosion risks.

In areas where liquid hydrocarbon fires (including condensate fires) are identified as a potential hazard, combined water spray/foam systems will be used to reduce fire intensity, cool exposed items, extinguish fires and cover spills to reduce the probability of re-ignition. Production and gas injection Christmas trees will be covered by overhead deluge spray nozzles sufficient to cover the wellbay area due to the close proximity of production Christmas tree ‘pairs’ and the potential for escalation.

Automatic sprinkler systems will be provided for the accommodation block (and other areas, as appropriate). The systems will be provided with a suitably sized freshwater source to provide the initial firewater supply. A connection will also be provided to the firewater distribution system for extended water supply if required. The use of a large capacity fire water screen or hydro-shield type nozzles may be considered for use in those area requiring additional thermal radiation protection or for gas dispersion.

Water mist systems or another approved clean agent such as inergen, will be provided in enclosures that are not normally occupied. These enclosures include turbine and generator enclosures, and certain more hazardous storage areas such as the paint stores.

Fire fighting for larger machinery spaces (i.e. drilling mud pumps) will be through a water spray and/or foam system. This may be supplemented by local water spray over key equipment/areas as a first response.

Fire monitors will be provided to supplement areas protected by water spray and/or foam, and/or provided as the primary means of active fire protection where such systems are not practical (e.g., large open areas without overhead support structure). The monitors will include the following design features:

- The nozzles will be adjustable from straight stream to full fog.
- They will have the capability of discharging both foam and water.
- Depending on location, certain monitors may be self-oscillating (certain monitors may also be identified for remote control. The provision of closed circuit television (CCTV) facilities could be used to provide feedback to the Control Points for remotely controlling monitors).

The helideck will be covered by three water/foam monitors.

The WHP will also be provided with fire hydrants connected to the firewater distribution system. The number and position of the fire hydrants will be such that water from any two hydrants, one of which is fitted with only a single length of fire hose and the other of which is fitted with one or two lengths of fire hose, can reach every part of the installation where a fire may occur. Fire hydrants will be capable of being connected to a foam source (e.g., foam carts).

3.10 Passive Fire and Blast Protection

PFP will be provided for offshore topsides primary structures and hydrocarbon vessels that contain significant quantities of hydrocarbons, to prevent fires escalating through structural collapse or vessel failure. Specifically to manage the potential for escalation within the wellhead area, the production and gas injection Christmas trees are to be provided with insulating fire blankets.

The selection of PFP will account for the:

- Required period of protection.
- Characteristics of the type of fire that may occur.
- Limiting temperature for the integrity of the structural elements or equipment.

Fire-rated and, where necessary, blast-rated divisions will be installed to:

- Segregate hazardous and non-hazardous areas.
- Subdivide areas to prevent the spread of fire, to reduce the overall area that might be subjected to a fire.

The external walls of the TR will be fire and blast-rated. In addition, two fire/blast-rated walls, running north to south of the platform, will be provided on the Cellar Deck and the Middle Deck to segregate the hazardous areas.

The fire and blast ratings of these partitions will be confirmed during detailed design, but they will, as a minimum, meet all regulatory requirements and will be specified and constructed in order to minimize the potential for escalation of events and in particular for impairment of the TR.

PFP may also be used to protect piping, emergency shutdown valves and enclosures. This possibility will be investigated at a later stage of the project.

3.11 Telecommunication and Alarm Systems

The telecommunications system will be designed in order to facilitate safe and efficient operation of the WHP, as well as informing and entertaining personnel on the WHP. The WHP telecommunications system will provide primary and backup voice and data communication capability between the WHP and the SeaRose FPSO, vessels, aircraft, shore facilities and nearby installations on a 24 hour basis.

The system will be designed so that the performance of the systems/subsystems essential to the safety of the platform and personnel will remain operational during an emergency situation.

Radio systems will be designed so as to limit the radio frequency (RF) radiation to an acceptable safe level. This is to ensure that personnel are not exposed to harmful radiation and that under gas escape conditions RF power radiated in hazardous areas is kept well below the threshold to avoid any possibility of sparks and ignition.

Where required by the availability criteria, systems will be duplicated such that failure of any one area will not render the system inoperable. The systems will be designed to allow maintenance activity on any one of the redundant units whilst the system remains in service, without endangering service personnel or the safe operation of the equipment.

Essential control equipment for communications systems will be located in designated safe areas. This will enable communications to be maintained in the event of a hazard. As appropriate, non-essential equipment and supplies may be isolated to eliminate ignition sources during certain ESD situations. Where necessary to meet operational requirements for use in hazardous areas, telecommunications equipment will be appropriately Ex rated, intrinsically safe, or housed in an explosion proof enclosure.

A Public Address and General Alarm (PAGA) System will be provided to support voice communications between the various operating areas and the Central Control Room (CCR). The PAGA system will allow personnel to broadcast voice messages and emergency tones/alarms throughout the WHP, and provide an interface accessible by personnel on the SeaRose to allow for remote communication. In an emergency, the PAGA system will be used to broadcast one of a selection of alarm tones to indicate the nature of the emergency, and to issue instructions to all areas where personnel may be located. Alarm signals will be attenuated during the transmission of emergency speech messages. Visual indications of alarms, through beacons or other lighting devices, will be provided in all high noise areas.

Speakers, handsets and visual alarm notification devices will be strategically located throughout the facilities and in sufficient number and kind to provide warning to personnel in the area. The notification devices in the process area shall be suitable for locations in electrically classified hazardous areas.

3.12 Escape Routes

Every work area will be provided with at least two well-marked separate escape routes that are situated as far apart as is practicable. Escape routes will be sheltered, as required, based on the results of the EERA.

Escape routes will direct personnel to the Temporary Refuge and to the means of evacuation or escape from the platform. Escape routes will take as direct a route as possible, from the immediate hazard to an area of shelter.

Main escape routes will be:

- Of sufficient height and width, meeting or exceeding regulatory requirements (Newfoundland Offshore Petroleum Installations Regulations) and in line with industry best practice (ISO 13702 Clause 14).
- Readily accessible and permanently unobstructed.
- Clearly marked and rapidly identifiable by everyone at the facility.
- Adequately illuminated by escape lighting independent of the normal power supply.

3.13 Temporary Refuge

The prime function of the Temporary Refuge (TR) is to protect all personnel for a pre-determined time during an emergency. The TR will be designed to protect and shelter personnel from accidental events for sufficient time to organize and execute a safe evacuation.

The TR will contain facilities that allow the incident to be investigated, emergency response procedures to be initiated and pre-evacuation planning to be undertaken.

It will therefore provide:

- Shelter for personnel and control points, particularly from fire, smoke, unburned and toxic gases, explosion and thermal radiation.
- Sufficient control facilities to facilitate the evaluation of an incident and, where possible, allow personnel to bring it under control.
- Sufficient means of communication between individuals at the installation and those at other installations (SeaRose FPSO), on vessels, aircraft and on shore.

The TR will be located and orientated with regards to the predominant wind direction, in order to minimize the likelihood of the infiltration of a gas release or smoke into the TR and to minimize the presence of gas or smoke at the evacuation routes and escape embarkation areas. The TR will also be positively pressurized to prevent ingress of smoke and gas.

3.14 Evacuation and Rescue Systems

The following means of evacuation and escape are provided (listed in descending order of preference):

- Helicopter.
- Lifeboats (Totally-Enclosed Motor-Propelled Survival Craft, or TEMPSC).
- Escape to sea via life rafts.

There will be sufficient provision of lifeboats to provide for a minimum of 200% of the maximum POB during normal operations. The average weight of offshore personnel, as defined by the Canada-Newfoundland Offshore Petroleum Board (C-NLOPB), is 100 kg per person (including immersion suit) and will be factored into evaluating the capacity of evacuation systems.

Lifeboats will be distributed between the primary muster station and a secondary muster station at the production end of the platform according to the Newfoundland Offshore Petroleum Installations Regulations. The current arrangement locates three 72-man craft at the west end of the WHP in the vicinity of the TR and one 72-man at the alternative muster station at the east side of the WHP.

In addition, inflatable life rafts will be provided, with a total capacity sufficient for a minimum of 100% of the maximum platform POB. There will be a minimum of 50% capacity on both the East and West side of the platform, which, based on the preliminary findings of the EERA, is considered to be adequate.

3.15 Lifesaving Equipment

Provision of the following lifesaving equipment will be considered:

- Immersion suits (for marine abandonment).
- Lifejackets, smoke hoods and other personal protective devices.
- Lifebuoys (including appropriate launching and signalling devices).
- First aid and rescue equipment.
- Eyewash stations and safety showers.
- Breathing apparatus sets and emergency air supplies.
- Marine communication and signalling devices.
- Personnel transfer baskets.

All safety equipment will meet international marine requirements and Canadian regulations.

3.16 Operating and Maintenance Procedures

Operating and maintenance procedures exist for the SeaRose FPSO. Where appropriate, the existing SeaRose procedures shall be amended to include the WHP or new WHP procedures will be developed.

In developing the new and amended procedures the following will be considered:

- Maintenance Procedures - a phase-specific, operations-integrity plan detailing maintenance and inspection procedures. Operating parameters will ensure all systems and equipment do not exceed design specifications or environmental limits. Maintenance programs will ensure the safe operation and optimum reliability of equipment. Safety critical elements (SCEs, systems and measures that perform a critical function in terms of prevention, detection, control or mitigation of Major Hazards, as well as measures provided to ensure effective escape, evacuation and rescue in the event of such hazards) will be identified and Performance Standards developed that will provide the basis for assuring/verifying the suitability and condition of the SCEs and specify the maintenance and inspection activities required in order to ensure that they are available to perform the function required of them during a Major Accident Event.

- Drilling, Production and Marine Procedures - a phase-specific integrity plan detailing the procedures associated with drilling, production and marine supply activities, including environmental concerns, mitigation procedures and roles, responsibilities and authority will be implemented. In developing drilling procedures, particular consideration will be given to the risks associated with dual conductor technology and it is anticipated that specific measures to be implemented will include, for example:

    - Developing a detailed directional plan for each well in the trajectory planning phase to ensure that all wellbores can be safely drilled within safe limits of wellbore proximity.

    - Setting the conductor in a preferred direction by first drilling a pilot hole, in order to provide more precise directional control and placement.

    - Close monitoring of the wellbore whilst drilling, with frequent directional surveys (gyro), to ensure that the directional plan is followed and that a safe distance from other wellbores is maintained.

- Emergency Procedures - procedures to cover all aspects of the combined WHP/SeaRose production operations, and these procedures will reflect and incorporate Husky's existing Emergency Response Plan.

- Facility-Specific Alert and Emergency Response Procedures - facility-specific contingency plans incorporating procedures necessary during operation and maintenance will be implemented. These will take into account the simultaneous operations (SIMOPS) of the two assets, WHP and SeaRose FPSO.

- Environmental Protection and Monitoring Procedures - both environmental effects monitoring (EEM) and environmental compliance monitoring (ECM) will be conducted.

All effluents from the new WHP facilities will be treated, where necessary, and monitored to safeguard the environment.

- Joint Operations Manual - the existing manual will be updated to address the interface between the WHP and SeaRose FPSO.
- Simultaneous Operations procedures - to address the interface between the WHP, SeaRose FPSO and MODU operations.

3.17 Contingency Plans

Husky has existing contingency plans for drilling and other exploration activities, which include ice management, oil spill response and emergency response. These plans will be further developed and expanded to reflect drilling, production and operational concerns associated with the introduction of the new WHP facilities into the White Rose Field.

4.0 Target Levels of Safety

The selection of clear design goals aimed at protecting personnel and the environment is fundamental to the design of offshore facilities. These design goals are known as Target Levels of Safety (TLS).

TLS provide a benchmark against which the results of the QRA can be assessed. Tolerability of risk to personnel is generally judged based on three risk 'regions', the boundaries of which are defined by the TLS:

- An upper region (intolerable region), which defines risk levels that are unacceptable, so that further risk control measures must be taken.
- A lower region (broadly acceptable or 'negligible' region), which defines risk levels that are generally tolerable and there is no need for consideration of further safety measures.
- Between these upper and lower regions, an intermediate (ALARP) region where the risk may be tolerable, but it must be demonstrated that risk is 'As Low As Reasonably Practicable' (ALARP), that is, that no further credible risk reduction measures could be implemented cost-effectively.

Husky have developed a Quantitative Safety Risk Criteria document (Ref. 1) that outlines their criteria for assessing the tolerability of risk for their workforce and contractors. Sections 4.1 and 4.2 summarize the individual risk criteria and societal risk criteria given in this document respectively.

For environmental risks, a benchmark against which estimated frequencies of spills to sea of differing sizes resulting from topsides releases can be compared is presented separately in Section 4.3.

4.1 Individual Risk Criteria

Risks to personnel will be measured in terms of Individual Risk (IR), which is a measure of the annual risk to an individual.

The target levels for risks to individuals on the WHP will be (Ref. 1):

- **Intolerable** IR > 5×10^{-4} per year.
- **ALARP** IR < 5×10^{-4} per year, but > 1×10^{-6} per year.
- **Negligible** IR < 1×10^{-6} per year.

If risks can be shown to be below the 'negligible' level, no further action is required.

If risks are not negligible, it will first be necessary to show that risks are below the intolerable level, and then to demonstrate that risks have been reduced to a level that is ALARP.

4.2 Societal Risk Criteria

Societal risk is a measure of the likelihood of multiple fatality accidents, and can be expressed as the frequency of accidents involving fatalities above a specified level.

The most common representation of societal risk is in the form of an F-N (Frequency-Number) curve. An F-N curve is a plot of the frequency distribution of multiple fatality accidents, where F is the cumulative frequency of all events leading to N or more fatalities.

Husky's societal risk criteria are expressed in terms of F-N curves (Figure 4.1). The criteria from Figure 4.1 are also summarized in Table 4.1.

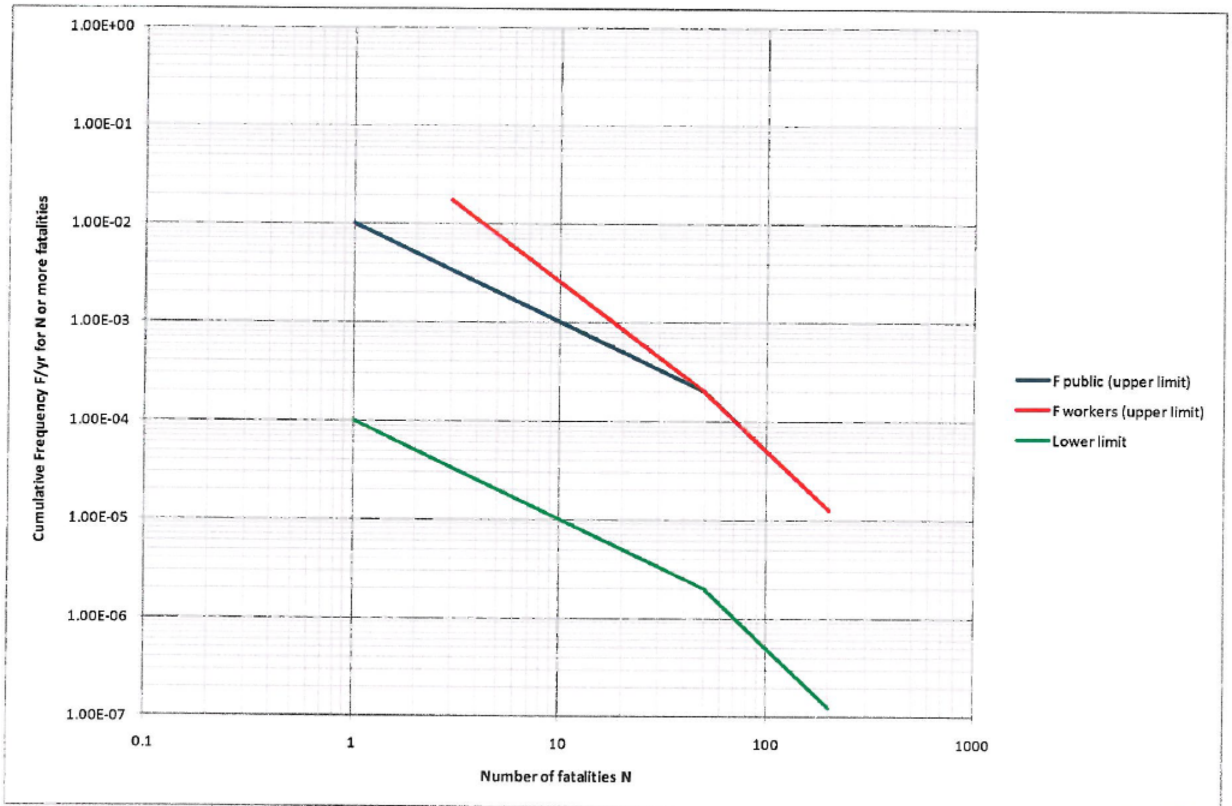


Figure 4.1: Husky Societal Risk Criteria

Level	Frequency of ≥ N Fatalities (per year)		
	N = 10	N = 50	N = 100
Intolerable:	≥ 2.6 x 10^{-3}	≥ 2.0 x 10^{-4}	≥ 5.0 x 10^{-5}
ALARP:	< 2.6 x 10^{-3}, but ≥ 1.0 x 10^{-5}	< 2.0 x 10^{-4}, but ≥ 2.0 x 10^{-6}	< 5.0 x 10^{-5}, but ≥ 5.0 x 10^{-7}
Negligible:	< 1.0 x 10^{-5}	< 2.0 x 10^{-6}	< 5.0 x 10^{-7}

Table 4.1: Societal Risk Criterion Thresholds

4.3 Environmental Risk Criteria

The WHP Environmental Assessment (EA, Ref. 2 and Ref. 3) considers the potential environmental impact of incidents and provides qualitative targets for environmental effects.

The EA includes a determination of historical frequencies of occurrence of environmental incidents resulting from topsides hydrocarbon releases by volume of oil spilled into the sea. Historical data from Ref. 3 is presented in Table 4.2.

Volume of Oil Spilled into Sea	Historical Frequency (per well-year)
0 to 49 bbls	0.70
50 to 999 bbls	4.8×10^{-4}
> 1,000bbls	1.5×10^{-5}
> 10,000bbls	5.5×10^{-6}

Table 4.2: Historical Spill Frequencies Resulting from Platform Topsides Releases

Husky will use the historical data from Ref. 3 presented in Table 4.2 as a benchmark against which to compare the results of the CSA and operational performance going forward.

Husky will continue to work with the regulator and industry to further define and develop environmental data collection methods, standards for measuring environmental performance and the criteria for measuring environmental effects within the White Rose Field.

5.0 Identification of Major Hazards

Hazard identification forms the basis of any risk assessment. If the hazards are not adequately identified, the risk assessment will be incomplete. To identify possible causes of accidents or precursors that may lead to accidental events, it is necessary to use information derived from industry experience. It is also necessary to ensure that small hazards are not overlooked. Only after due consideration of the consequences of the hazard and its potential for escalation should small hazards be discounted.

Whilst all potential accidents should be considered, the focus, in terms of identifying those hazards that it is appropriate to assess quantitatively, is on identifying Major Hazards. In this context, Major Hazards are commonly accepted as being fire and explosion events, and other accidental events that have the potential to result in multiple fatalities, either in the immediate area of the event or because they have the potential to escalate and result in fatalities outside the immediate area. Events that have the potential to impair the integrity of the TR are also considered to be Major Hazards. Other accidental events are categorized as occupational hazards. These hazards affect one or a small number of personnel, for example trips, falls or electrocution.

It is clearly necessary to recognize occupational hazards, and to reduce the frequency and mitigate the consequences of such events. However it is not, in general, appropriate to assess these hazards quantitatively, particularly at the concept stage of a project, when information is inevitably limited. Measures in place for the monitoring, control and mitigation of occupational hazards and accidental events include:

- A comprehensive, auditable Safety Management System.
- Hazard identification and assessment studies, to be undertaken prior to commencing short-term work or introducing modifications to procedures or processes.
- Rigorous tracking procedures, to ensure that recommendations from such hazard identification and assessment studies are implemented as required.
- Provision of appropriate training to all personnel.
- Comprehensive incident reporting procedures and monitoring of incident records, providing feedback to update procedures, as required.

All stages of the Project have been considered during the hazard identification, including construction onshore, marine installation, hook-up and commissioning, pipe-laying, and drilling and production.

The subsea infrastructure of the WHP will be designed to minimize the need for diver intervention after installation and provide maximum clearance for ROV operations during inspection and maintenance of equipment. Hazards identified that are specific to the construction and installation stages of the Project are, in general, categorized as occupational hazards but there is also the potential for Major Hazards associated with installation and integration activities such as CGS construction in drydock, CGS floatout, CGS/topsides mating, installation and tie-back of flowlines. However, due to the infrequent (if not unique) nature of these activities, industry data is sparse and therefore insufficiently complete to allow an adequate and meaningful assessment of the associated risks until planning for these events is at a more defined stage. These activities will be of limited duration, will have clearly defined scope and will be the subject of thorough consideration and assessment prior to commencement to ensure identification and appropriate mitigation of all risks. In addition, as required by legislative authorities and by Husky, a Construction and Commissioning Safety Plan will be prepared covering all aspects of construction and commissioning, in accordance with the recommendations of the C-NLOPB. Risks associated with these stages of the project are therefore not considered further here.

At the end of the production life of the WHP, the WHP will be decommissioned and abandoned by first abandoning the wells in accordance with standard oil field practices, then decommissioning the topsides, followed by decommissioning and abandonment of the CGS. All infrastructure will be abandoned in accordance with the relevant regulations. The topsides will be removed from the CGS in the manner evaluated to be most effective at the time of decommissioning. The WHP will not be abandoned and disposed of offshore, nor converted to another use on site. Again, these activities will be of limited duration, will have clearly defined scope and will be the subject of thorough consideration and assessment prior to commencement to ensure identification and appropriate mitigation of all risks. Hazards specific to these decommissioning activities are, therefore, not considered further here.

5.1 Potential Major Hazards Identified and Assessed

Hazards identified are recorded in a Register of Identified Hazards (Ref. 4), produced as part of the CSA. The hazards register also identifies those that have been ‘screened out’ based on a preliminary assessment (i.e. demonstration that either the likelihood of occurrence is low or the potential consequences are not significant) and will therefore not be carried forward for detailed risk assessment. Where appropriate, the relevant prevention, detection, control and mitigation measures that ensure such hazards do not present a significant risk to personnel are identified. This primarily relates to non-hydrocarbon fire and explosion events, such as a fire in living quarters and control room, which are discounted from further assessment based on the consequences and limited potential for escalation due to the active and passive fire protection measures to be implemented.

Based on the findings from Ref. 4, the following Major Hazards are identified as requiring consideration in the quantified risk assessment:

- Loss of Hydrocarbon Containment, resulting in:
    - Fire and smoke.
    - Explosion.
    - Unignited release.
- Blowout.
- Releases below the platform topsides.
- Subsea flowline release.
- Iceberg collision and scouring, sea ice, topsides icing.
- Ship collision.

- Helicopter transportation.
- Seismic activity.
- Structural failure due to extreme weather.
- Dropped objects.

Descriptions of each of these Major Hazards are given in Sections 7 to 11. Each hazard is described in terms of:

- Potential causes.
- Safeguards to prevent occurrence.
- Consequences and potential for escalation.
- Mitigation measures in place to minimize consequences.
- Impairment of main safety systems.

6.0 Basis of Hazard Assessment and Risk Assessment

The major hazards identified for the installation are listed in Section 5.1. The risk assessment for each of these major hazards is summarized in Sections 7 through to 11.

In the risk assessment outlined in the following sections, judgements have been made to estimate the likely number of statistical fatalities arising from each of the hazards considered, as well as the volume of oil likely to be spilled into the sea. To ensure a conservative analysis, pessimistic judgements have been made where there is uncertainty in the data used, ensuring that worst case scenarios are considered in the assessment. In each case, the basis of the risk analysis is stated.

Fatalities are classified as:

- **Immediate Fatalities.** These are fatalities local to an event. For example, for ignited loss of containment events, immediate fatalities are those caused by the immediate thermal or overpressure effects of the ignited release in the area in which the release occurs.

- **Escape and Escalation Fatalities.** These are fatalities that occur outside the immediate area of an event either because an event escalates to affect personnel in adjacent areas or whilst personnel are escaping to the TR.

- **Precautionary Evacuation Fatalities.** It is recognized in the risk assessment that the Offshore Installation Manager (OIM) would not necessarily wait for the TR to be impaired before ordering an evacuation of the installation. Under certain circumstances, the OIM may order an evacuation by lifeboat as a precautionary measure. Precautionary evacuation fatalities include fatalities due to failure of the evacuation systems, fatalities while escaping to sea and fatalities whilst rescuing personnel from lifeboats or survivors from the sea.

- **TR Impairment Fatalities.** These are fatalities that occur as a result of impairment of the installation's TR. They also include any fatalities that occur during an evacuation of the installation in the event that the TR is impaired.

In addition, as discussed above, the volume of oil likely to be spilled into the sea is also estimated for each hazardous event considered.

6.1 Personnel Distribution

The anticipated average personnel levels in each area of the WHP are shown in Table 6.1. This average personnel distribution takes into account the fact that personnel will work twelve hour shifts (and will spend the remaining twelve hours out of the twenty-four in the living quarters) and that most areas of the platform will have reduced manning levels at night.

Platform Level/Area	Average Manning
Shaft	0
Sub Cellar Deck	0
Cellar Deck	
North	0.45
East	1.78
South	0.70
West	1.45
Central	1.25
Middle Deck	
North	5.45
East	10.28
South	3.97
West	1.55
Central	1.83
Drilling Deck	4.89
Drilling Rig	12.38
Higher Levels	
Pipe Rack	2.75
Helideck	0.05
Crane Cab	1.55
Living Quarters	93.67
INSTALLATION TOTAL	**144**

Table 6.1: Personnel Distribution

6.2 Platform Layout

Because of the stage of the Project, some key aspects of the design, including the rating of fire and blast divisions, have not yet been finalized. For the purposes of this assessment, it is assumed that the ratings of fire walls are sufficient to prevent escalation of a fire to an adjacent area within the time required for personnel to escape that area.

Further analysis will be required at detailed design stage, when more information is available on other aspects of the Project, in order to ensure that the final design is practicable and affords a high level of protection for personnel.

The selected design will, of course, as a minimum, meet prescriptive regulatory requirements and be such that risks can be demonstrated to be As Low As Reasonably Practicable (ALARP).

6.3 Evaluation of Risks to Personnel

In this assessment, risks to personnel are estimated in terms of:

- Potential Loss of Life (PLL): the average number of fatalities per year on the installation resulting from that hazard. For each hazard identified, PLL is calculated as:

  PLL = Hazard Frequency (per year) x Potential Fatalities

- Average individual risk per annum (IRPA): defined as the average annual risk to an individual on the installation and calculated as:

  $$\text{IRPA} = \frac{\text{PLL}}{\text{POB}} \text{ x Exposure}$$

- Societal risk: expressed as the frequency of accidents involving fatalities above a specified level. Societal risk is a measure of the likelihood of multiple fatality accidents.

6.4 Evaluation of Risks to the Environment

In this assessment, environmental risks are considered by estimating annual frequencies of releases of oil into the sea exceeding:

- 10,000 bbls
- 1,000 bbls
- 50 bbls
- 0 bbls

The exceedance frequencies are determined based on the hazard frequencies (per year) and the estimated volumes of oil spilled into the sea for each identified hazardous outcome.

7.0 Process Loss of Containment Events

Loss of hydrocarbon containment can result in several possible outcomes (for example, a fire, an explosion or an unignited, potentially toxic, release). This is because the actual outcome depends on other events that may or may not occur following the initial release. Event Tree Analysis is therefore used to identify the potential outcomes of a hydrocarbon release and to quantify the risk associated with the outcomes. A representative loss of hydrocarbon containment event tree is shown in Appendix 1. In the event trees, the following branch events are considered:

- Non-explosive ignition.
- Fire or gas detection.
- Inventory isolation.
- Deluge operation.
- Explosive ignition.
- Explosion overpressure.

The event tree branches enable the following factors to be taken into account:

- Whether ignition occurs and the timing of an ignition (relative to the time of release).
- Any benefit provided by the facility's safety systems, which are described in Section 3.

If a release ignites rapidly, a jet fire or pool fire may result. Alternatively, a gas cloud may accumulate before ignition, resulting in an explosion or flash fire.

The risk to personnel, in terms of Potential Loss of Life (PLL), from each event tree outcome is the product of the frequency of that outcome and its consequence (in terms of statistical fatalities).

The contribution to environmental risk from an outcome is evaluated by assigning the frequency of its occurrence to the appropriate consequence category, in terms of volume of oil spilled into the sea.

Each outcome frequency is derived by estimating:

- The frequency of the initiating event (the release event).
- The probability of each of the events represented by the event tree branches leading to that outcome.

The consequence of an outcome is determined by:

- Modelling the initial physical conditions produced by the fire event, explosion or unignited release. This physical consequence modelling does not take into account the safety design features and safety systems described in Section 3, designed to prevent, detect and control potential hazards.

- Assessing the impact of those conditions on personnel, in terms of potential statistical fatalities.
- Estimating the volume of oil spilled into the sea.

7.1 Isolatable Inventories and Release Events

The process stream on the WHP is provided with Shutdown Valves (SDVs) at selected locations. In the event of an emergency shutdown, these SDVs close to isolate individual sections of the total process inventory. This reduces the amount of hydrocarbon that can be released and is available to fuel a fire.

The isolatable sections on the WHP have been identified based on the Piping and Instrumentation Diagrams (P&IDs). In some cases, the isolatable sections have been further subdivided to allow different operating conditions or fluid type within one isolatable section to be taken into account in the event tree modelling. The resulting release events are identified in Table 7.1.

7.2 Hydrocarbon Release Frequencies

7.2.1 Event Leak Frequencies

Ref. 5 provides leak frequency data collected between 1992 and May 2012 for various individual items of equipment (for example, vessels and pipework) and for typical representative process systems.

The release frequency for each event in Table 7.1 is estimated from Ref. 5 leak frequency data. Where possible, the leak frequency given in Ref. 5 for a representative system similar to the WHP equipment was chosen as the basis of the leak frequency for the event.

For some release events, the above method could not be used, as none of the representative systems were considered to be sufficiently similar to the WHP equipment. In such cases, release frequencies were estimated from leak frequencies given in Ref. 5 for individual items of process equipment. To account for piping, flanges, valves and instrument tappings, the equipment frequencies were increased by 50% for use in the risk assessment.

It is recommended that consideration be given to undertaking a parts count, based on piping and instrumentation drawings, at detailed design stage in order to refine the leak frequency estimates and more accurately reflect the equipment associated with each inventory.

The leak frequency for the production and test manifolds, and gas lift manifold, will depend on the number of wells in operation. Based on the nominal well count, it is assumed that there are 19 production wells and 2 gas injection wells in operation for the purposes of this assessment.

Release Event	Type of Equipment (Ref. 5)	Frequency Per Year
Production Wellheads	Wellhead	1.32×10^{-1}
Production and Test Flowlines	Piping	1.70×10^{-1}
Production and Test Manifolds	Manifold	4.19×10^{-2}
Test Separation System	Heater, Horizontal Separator	4.60×10^{-2}
Multiphase Flow Meters	Multiphase Flow Meter	7.19×10^{-2}
Oil Export	Piping	7.87×10^{-3}
Flare KO Drum Pump (Condensate)	Reciprocating Pump	1.34×10^{-2}
Subtotal Liquid		**0.483**
Gas Import and Distribution System	-	5.99×10^{-3}
Gas Injection Wellheads	Wellhead	2.76×10^{-2}
Gas Injection Flowlines	Piping	7.87×10^{-3}
Gas Injection Manifold	Manifold	1.20×10^{-2}
Gas Lift Flowlines	Piping	7.47×10^{-2}
Gas Lift Manifold	Manifold	1.20×10^{-2}
Flare KO Drum (Gas)	Horizontal KO Drum	1.97×10^{-2}
Fuel Gas Inlet Heater	Heat Exchanger, Shell & Tube HC in Tube	9.93×10^{-3}
Fuel Gas KO Drum	Vertical Knockout Drum	3.66×10^{-3}
Fuel Gas Super-Heater	Heat Exchanger, Shell & Tube HC in tube	9.93×10^{-3}
Gas Turbines	Gas Turbine	5.81×10^{-2}
Subtotal Gas		**0.241**
WHP Total		**0.724**

Table 7.1: Release Events in the Production Area on the Cellar Deck

7.2.2 Selection of Representative Hole Sizes

A major factor influencing the characteristics of a release is the hole size. In conjunction with inventory conditions such as pressure, hole size affects the initial hydrocarbon mass release rate and hence, if the release is ignited, the size of the resulting fire. Hole size and release rate are also factors in determining release duration.

In reality, a continuum of hole sizes is possible. In order to rationalize hydrocarbon risk assessment, it is industry practice to select three distinct hole sizes (described as ‘small’, ‘medium’ and ‘large’) to be representative of the range of possible hole sizes.

The representative hole sizes used in this assessment are presented in Table 7.2 (Ref. 6). The hole size distribution is estimated based on data from Ref. 5 and a generic parts count of a production installation.

Hole Size	Hole Size Range (mm)	Representative Diameter (mm)	Hole Size Distribution
Small	< 20	10	90.47%
Medium	20 – 80	50	6.98%
Large	> 80	100	2.55%

Table 7.2: Representative Hole Sizes and Distribution

Therefore, for each of the release events identified in Table 7.1, three event trees are actually used in the risk assessment, one for each of the small, medium and large hole sizes. A proportion of the total leak frequency for each release event is allocated to the event tree for each representative hole size according to the distribution shown in Table 7.2.

7.3 Ignition Probability

An ignition probability is calculated for each release event based on the initial mass release rate, using the UKOOA ignition model (Ref. 7). The UKOOA ignition model assesses the probability of ignition of hydrocarbon releases for use in QRAs by combining established data and methods on gas build up, gas dispersion, area and ignition source characteristics, etc. The model estimates the volume or area of flammable gas or liquid in a given plant area, and then combines this with suitable ignition source densities to calculate the overall ignition probability.

The model includes data on ignition of both gas and oil releases, as well as on the probability of explosion in the case of gas releases. Representative ignition and explosion probabilities are given in Tables 7.3 and 7.4, respectively.

Release Rate	Ignition Probability	
	Gas	Oil
Minor (<1kg/s)	0.0038	0.0021
Major (1-50kg/s)	0.0240	0.0070
Massive (>50kg/s)	0.0400	0.0175

Table 7.3: Representative Ignition Probabilities (Ref. 7)

Release Rate	Explosion Probability[1]
Minor (<1kg/s)	0.04
Major (1-50kg/s)	0.12
Massive (>50kg/s)	0.3

(1) For gas release, given that ignition occurs

Table 7.4: Representative Explosion Probabilities (Ref. 7)

Mass release rates are estimated for each release event using DNV's consequence modelling software package, PHAST, based on hole size and stream composition, temperature and pressure. Stream data used in the consequence modelling and results from PHAST are presented in Appendix 2.

The liquid inventories contain a significant proportion of lighter hydrocarbons. Therefore, in order to estimate the overall ignition probabilities for these releases, the process gas ignition model from Ref. 7 is conservatively used as, for a given mass release rate, the probability of ignition for a gas release is generally higher than that for an oil release. In order to estimate the explosion ignition probabilities for these releases, an 'equivalent' gas mass release rate is calculated, based on the liquid mass release rate and the 'flash fraction'.

In the event trees (see Appendix 1), the first branch represents 'non-explosive' ignition. Non-explosive ignition events are represented as fire events, because sufficient time is unlikely to elapse to allow a gas/air mixture to accumulate and cause an explosion. The probability of 'non-explosive' ignition is calculated as the total ignition probability minus the probability of an explosion (the product of the 'explosion probability' and the total ignition probability).

The probability of explosive ignition required in the event trees (fifth branch) is the probability of delayed ignition given that non-explosive ignition did not occur.

Due to the low release rate of small process releases, it is considered that there is limited potential for a significant cloud of gas to build up prior to ignition, even if ignition is not immediate. It is therefore assumed that 'delayed' ignition of a small process release would result in a flash fire, as opposed to an explosion with significant overpressure. Since the impact area of a jet fire that may follow an initial flash fire is, in almost all cases, larger than the gas cloud size, it is standard practice to estimate fatalities for flash fires based on the size of the subsequent jet fire. Therefore, for the purposes of this assessment, all small process releases are modelled as 'non-explosive' ignition events resulting in a jet fire.

7.4 Fire and Gas Detection Probability

Fire and gas detection probabilities are estimated based on historical failure data for fire and gas detectors (Ref. 8 and Ref. 9). These probabilities account for the probability that a gas release will be out of range of a detector or a fire will be obscured from a detector (the Test Independent Failure (TIF) probability), as well as the probability that the detector will fail to operate on demand.

The fire and gas detection probabilities calculated, based on the Ref. 8 and Ref. 9 data, for use in the event tree risk assessment are shown in Table 7.5. In each case, probabilities are calculated for small and large releases, and the probability for medium releases is assumed to be the average of these two.

Representative Hole Size	Detection Probability	
	Gas	Fire
Small (7mm)	0.9	0.75
Medium (33mm)	0.95	0.87
Large (76mm)	0.99	0.99

Table 7.5: Fire and Gas Detection Probabilities

Any attempt to link detection probability to release rate (rather than hole size) is considered spurious accuracy because of the quality of the historical data available on TIF probabilities, which is quoted only as a range between 0.0003 and 0.5 for fire detectors and between 0.0003 and 0.1 for gas detectors.

7.5 Inventory Isolation Probability

Each event tree represents a release from a specific isolatable section (inventory) of the production system. The probability of the inventory being isolated on an emergency shutdown is determined by:

- The number of SDVs that must close.
- The probability that each SDV will operate successfully on demand.

Ref. 9 gives failure rate data for SDVs. Although the regulations require monthly testing, a three month test interval is conservatively assumed in calculating a probability of failure on demand for an SDV of 0.01, based on the Ref. 9 data. Therefore, the probability that a single valve operates on demand is 1 – 0.01 = 0.99.

For the purposes of this CSA, it is assumed that a process inventory (other than wellheads, flowlines and manifold inventories) is successfully isolated if two SDVs operate successfully. Therefore, the probability of successful isolation of a typical process inventory is $0.99^2 = 0.98$.

There are a number of valves associated with each well that can provide isolation (Upper Master Valve, the Wing Valve and the Downhole Safety Valve). Failure to shut in a well requires failures of all of these valves. This is accounted for in calculating the isolation probabilities for the wellheads and flowlines.

When calculating the isolation probabilities for manifold inventories, the probability that the wellhead is successfully isolated is accounted for as well as the number of flowlines and therefore the number of valves that must close to successfully isolate the flowlines downstream.

It is expected that an assessment of the number of valves that would have to operate successfully to ensure isolation of each inventory would be undertaken for the detailed QRA to be performed at design stage.

For some release events the effects of blowdown on the consequence of a release are not particularly significant and, therefore, the benefits of blowdown are not accounted for in this risk assessment. The effects of blowdown for relevant release events should be reviewed at the detailed design stage and, where appropriate, credit should be taken of the benefit it provides.

7.6 Deluge Probability

The event tree risk assessment is based on the assumption that deluge will be initiated on successful fire detection, but not on gas detection. It is, however, recognized that the potential for deluge to be activated on gas detection will be considered further during detailed design.

The probability that the deluge system does not operate on demand is assumed, in the risk assessment, to be 0.015. This is based on reliability data for modern deluge systems quoted in Ref. 6.

7.7 Explosion Overpressure Probability

The explosion overpressure branches provided in the process loss of containment event tree structure in Appendix 1 enable each explosive ignition event to be represented by four possible outcomes, where each outcome is representative of an explosion within a specific range of overpressure. This is necessary because the consequence of an explosion depends on the overpressure produced.

There are several explosion overpressure ‘thresholds’ of interest with respect to the risk assessment:

- Threshold 1 (T1): 0.2 barg. This is the explosion overpressure above which all personnel in the area in which the explosion occurs are considered, in the risk assessment, to be fatally injured by the explosion.

- Threshold 2 (T2): 1.0 barg. This is the overpressure above which it is considered that bulkheads and partitions (e.g. decks) may fail, resulting in escalation of the effects of the explosion to other platform areas.

- Threshold 3 (T3): 2 barg. This is the overpressure above which it is assumed that structural steel in the affected area may fail, leading to impairment of the platform structure in the vicinity of the explosion.

The four overpressure ranges defined by the three overpressure thresholds are therefore:

- Explosion overpressure is between 0 and 0.2 barg.

- Explosion overpressure is between 0.2 barg and 1 barg.

- Explosion overpressure is between 1 barg and 2 barg.

- Explosion overpressure is greater than 2 barg.

The probability that an explosion in an area exceeds each of the thresholds is determined from explosion overpressure exceedance ‘curves’. These ‘curves’ are generated assuming a linear relationship between the exceedance probability and overpressure, and accounting for an assumed worst case overpressure. Based on explosion modelling performed using DNV’s consequence modelling software package, PHAST, the worst case maximum overpressure on Cellar Deck, central is calculated to be 2.03 barg and the maximum overpressure on Cellar Deck, east is calculated to be 1.01 barg. The explosion overpressure branch probabilities used in the event trees are estimated based on the exceedance probabilities and are given in Table 7.6. For the purposes of this assessment, it is considered that if deluge activates, it reduces the maximum explosion overpressure by 50%. It should be noted that, as discussed in Section 7.6, the event tree risk assessment is based on the assumption that deluge will not be initiated on gas detection (and therefore, the overpressure reduction assumed has no impact on the assessment results).

Overpressure Range	Cellar Deck, Central		Cellar Deck, East	
	Probability (Deluge)	Probability (No Deluge)	Probability (Deluge)	Probability (No Deluge)
< 0.2 Barg	0.197	0.099	0.396	0.198
0.2 Barg to 1.0 Barg	0.788	0.394	0.604	0.792
1.0 Barg to 2.0 Barg	0.015	0.493	0	0.010
> 2.0 Barg	0	0.014	0	0

Table 7.6: Overpressure Probabilities

7.8 Consequence Assessment

As discussed in Section 6, fatalities are classified as immediate fatalities, escape/escalation fatalities, precautionary evacuation fatalities and TR impairment fatalities. For this assessment of loss of containment events, the following types of fatalities are discussed, in Sections 7.8.1 to 7.8.5:

- Immediate fatalities due to non-explosive ignition (fires).
- Immediate fatalities due to explosive ignition (explosions).
- Escalation fatalities.
- Escape fatalities.
- TR impairment fatalities.
- Precautionary evacuation fatalities.

Section 7.8.6 discusses the potential impact on the environment in terms of the volume of oil that may spill into the sea in the event of a process loss of containment event.

7.8.1 Immediate Fatalities due to Non-Explosive Ignition (Fires)

A jet fire is likely to result if a gas release ignites rapidly. A flash fire occurs when a cloud of gas burns without generating any significant overpressure. The duration of the flash fire is likely to be relatively short, but it may stabilize as a continuing jet fire from the leak source. The size of the gas cloud may be calculated using gas dispersion models, but Ref. 6 indicates that, with the exception of passive releases in low wind speeds, the gas cloud size is smaller than the effect zone from a jet fire. As a result, many studies model only the ensuing jet fire. Since the impact area of the jet fire that may follow an initial flash fire is, in almost all cases, larger than the gas cloud size, this approach results in a conservative estimate of fatalities and is adopted in this assessment.

Thermal radiation from a hydrocarbon fire is a significant hazard to personnel. The degree of injury caused by thermal radiation is related to the intensity of the thermal radiation and the exposure time.

Ref. 6 discusses typical thermal radiation criteria for use in offshore risk assessment:

- 12.5kW/m^2 is taken as the limiting radiation intensity for escape actions lasting a few seconds. At this level, the pain threshold is reached in about 4 seconds, and second degree burns on exposed skin in about 40 seconds.
- 37.5kW/m^2 is taken as the criterion for immediate fatality. At this level, the pain threshold is virtually instantaneous and second degree burns occur on exposed skin in about 8 seconds.
- Between 12.5 and 37.5kW/m^2 personnel are assumed to be able to use escape routes, provided that this allows them to leave the area within a few seconds, but they may suffer second degree burn injuries.

Personnel exposed initially to heat radiation less than 37.5kW/m^2 may be seriously or even fatally injured if their escape from the effects of the radiation is not rapid. For radiation of 25kW/m^2, pain is virtually instantaneous, second degree burns occur within approximately 12 seconds, third degree burns after approximately 30 seconds and '50% lethality' very soon after (Ref. 6).

It is considered, in this risk assessment, that all personnel within the 25kW/m^2 heat flux contour around a fire are fatally injured. The area bounded by this contour is referred to as the 'Fatality Area', and outside this contour it is assumed that personnel are able to escape the immediate vicinity of the fire.

The 25kW/m^2 heat flux contour represents a larger area than that corresponding to the 37.5kW/m^2 heat flux stated as the criterion for 'immediate fatality' above. The 25kW/m^2 heat flux contour is used to conservatively account for the fact that personnel outside the 37.5kW/m^2 heat flux may still be sufficiently injured that they cannot effectively escape within 'a few seconds', as stipulated above.

The consequences of event tree outcomes that represent non-explosive ignition events are therefore modelled, using DNV's consequence modelling software package, PHAST, as follows:

- A mass release rate is determined, based on representative inventory conditions identified for the release location.
- From the mass release rate, jet fire dimensions and the resulting 'Fatality Area' are determined.

Immediate fatalities from jet fires are calculated as:

Fatalities = Fatality Area x Population Density

If the Fatality Area for a release is greater than the area of the section of deck in which the release occurs, the number of personnel in the area is taken as an upper bound on the number of immediate fatalities.

Population Density is a characteristic of the area of the platform in which the release event occurs. It is calculated as:

$$\text{Population Density} = \frac{\text{Number of Personnel in Release Location}}{\text{Area of Release Location}}$$

The assumed number of personnel in each area of the platform is detailed in Table 6.1.

Details on the number of fatalities estimated for each identified release event are given in Appendix 3.

7.8.2 Immediate Fatalities due to Explosions

If ignition of a hydrocarbon release is delayed, a gas/air mixture may accumulate prior to ignition and an explosion could result.

Ref. 10 gives fatality probabilities, reproduced in Table 7.7, for the effects of explosion overpressure on personnel.

Explosion Overpressure (Bar)	Fatality Probability
0 to 0.07	0
0.07 to 0.21	0.1
0.21 to 0.34	0.25
0.34 to 0.48	0.7
> 0.48	0.95

Table 7.7: Effect of Overpressure on Fatality Probability

Ref. 6, however, suggests that, irrespective of the overpressure produced, personnel that are caught in a burning gas cloud are likely to be fatally injured from thermal effects. For a large gas cloud that ignites after filling an area, this suggests that all personnel in that area will be fatally injured.

However, not all explosions will result from a gas cloud that fills an area. In fact, for many smaller releases the gas cloud will occupy only a small proportion of the volume of an area at the time of ignition.

To take account of both the thermal effects and overpressure produced by an explosion, the rule set in Table 7.8 is, therefore, used to estimate immediate fatalities for explosion events.

Explosion Overpressure	Fatality Probability	
	Not Detected	Detected
<0.2 Bar	0.5	0.25
>0.2 Bar	1.0	0.5

Table 7.8: Explosion Immediate Fatality Rule-Set

For releases that are successfully detected, it is assumed that there is a probability of 0.5 that personnel escape from the area before ignition occurs.

The rule set gives the probability of fatality to be applied to each person in the platform area affected by the explosion.

Details on the number of explosion fatalities estimated for each identified release event are given in Appendix 4.

7.8.3 Escalation Fatalities

Fatalities could occur, outside the immediate area of an event, if the event rapidly escalates due to impairment of walls or decks.

It is assumed that fire walls provided will be appropriately rated in order to minimize escalation to other process inventories and to ensure sufficient protection for personnel in the TR. As a result, no escalation fatalities are accounted for in fire (non-explosive ignition) scenarios resulting from process loss of containment events.

Explosion events may, however, have the potential to escalate to adjacent areas, if the blast overpressure is sufficient to breach boundaries (module walls and/or decks). For the purposes of this assessment, it is assumed that a blast overpressure greater than 1 bar would be sufficient to breach boundaries.

The rule set in Table 7.9 is used to estimate fatalities resulting from explosions that escalate to adjacent areas. For releases that are successfully detected, it is assumed that there is a probability of 0.5 that personnel leave the area before ignition occurs.

Overpressure Range	Fatality Probability in Adjacent Areas	
	Not Detected	Detected
< 0.2 Bar	0	0
0.2 Bar to 1.0 Bar	0	0
1.0 Bar to 2.0 Bar	0.5	0.25
> 2.0 Bar	1.0	0.5

Table 7.9: Explosion Escalation Fatality Rule Set

Details of the number of explosion fatalities estimated for each identified release event are given in Appendix 4.

7.8.4 Escape Fatalities

The risk assessment accounts for escape fatalities in a scenario for which it is considered that both routes from an area may become impassable. For example, a sufficiently large fire in an area could impair the escape routes at the side of the platform adjacent to the event by heat/flames. Then, if the wind direction is towards the other side of the platform, escape routes at that side could be affected by smoke.

Every work area will be provided with at least two well-marked separate escape routes that are situated as far apart as is practicable. It is therefore assumed that there will be escape routes in the east-west direction on the north and south sides of each level of the platform, with approximately 40 metres separation.

Escape routes will direct personnel to the Temporary Refuge and to the means of evacuation or escape from the platform, and all escape routes and associated stairwells will be appropriately protected from the effects of fire and explosion.

Taking into account the likely location of and redundancy in escape routes, it is considered unlikely that both escape routes from any area will be impaired by a fire, explosion or toxic gas release event. This risk assessment does not therefore account for any escape fatalities. However, as the design of the WHP is still at a relatively early stage, details of escape routes have not yet been finalized. It will be necessary, at detailed design stage, to review the above qualitative assessment in a detailed escape, evacuation and rescue study, and to revise the risk assessment accordingly.

7.8.5 Precautionary Evacuation and TR Impairment Fatalities

In most hazardous loss of containment scenarios, personnel who muster will remain in the TR until the event is under control. In extreme scenarios, however, the integrity of the TR may be threatened. In some cases, the TR and/or lifeboat evacuation systems may become impaired.

This section considers risk to personnel from TR/evacuation system impairment due to the following mechanisms:

- Structural impairment.
- Smoke ingress.
- Gas ingress (flammable gas leading to potential for an explosion within the TR).
- High temperature.
- External explosions.

For each mechanism, events that could cause impairment (if they occur coincident with other unfavourable conditions) are identified.

Event tree analysis is then used to identify the hazardous TR conditions that could result from the impairment mechanism. For example:

- A threat to TR integrity, leading to a precautionary lifeboat evacuation.
- Impairment of TR and/or evacuation systems, leading to an emergency evacuation.

An estimate is made of the potential fatalities for each hazardous TR condition identified. Statistical fatality rates are then determined for each identified potential TR impairment event. The fatality rates are determined from the event trees, accounting for the likelihood of a potential impairment event resulting in a hazardous TR condition and the fatality estimate associated with that condition.

This analysis provides only an indication of the risk to personnel from TR impairment conditions. In the absence of details of the final TR design and detailed smoke, gas and flame modelling studies, simplifying assumptions have been made. It is recommended that detailed studies should be performed at detailed design stage.

7.8.5.1 Structural Impairment

The PFP provided for the structural steel and bulkheads will protect the platform structure in the event of a large jet fire or pool fire.

In the case of a jet fire, the blowdown systems will reduce inventory pressure and terminate jet fires. Even if a blowdown valve in an isolated inventory fails to open, a large jet fire would diminish rapidly due to the effect of the isolated inventory being released through the hole.

For a liquid release to persist, the release rate would have to be small and so the resultant fire should be able to be controlled and extinguished by the automatic or, if necessary, manual fire-fighting systems.

The protection provided by the PFP allows ample time for personnel to muster in the TR and for both automatic and manual fire fighting action.

However, if a large release occurs from the production flowlines, manifold or wellheads, or a medium or large release occurs from the gas lift/injection flowlines, manifolds or wellheads, and, upon ESD, a well fails to shut in, a long duration release could occur. If such a release ignites, the resulting fire could eventually impair the platform structure or bulkheads.

For the purposes of this concept stage assessment, it is conservatively assumed that these releases could potentially impair the platform structure and, therefore, the TR.

In such a situation, it is considered that an OIM will not wait for structural impairment to occur before considering an evacuation of the platform. Rather, when an assessment of the situation indicates that a well has failed to shut-in and could possibly continue to fuel a fire for many hours, the OIM will initiate a precautionary evacuation.

In this situation, ‘precautionary evacuation fatalities’ are accounted for. It is assumed that a lifeboat evacuation will be undertaken, and a fatality rate of 4.4% is applied. This has been estimated based on lifeboat failure rates in Ref. 11 and Ref. 12 and fatality rates from Ref. 6. A specific fatality rate has been estimated considering different weather conditions with an average value estimated based on specific weather data for the area (Ref. 13).

7.8.5.2 Smoke Ingress

Smoke is generated by any burning hydrocarbon but, in general, significant quantities of smoke are only generated by long duration liquid fires. Therefore, it is assumed that any unisolated ignited medium or large produced oil release will result in a large long duration fire, which, if coincident with unfavourable conditions, could impair the TR.

For the TR to be affected by smoke, the following conditions would have to occur, coincident with a long duration fire:

- Wind blows smoke from the fire towards the TR.
- Smoke reaches TR at high concentration.
- Smoke enters the TR (for example, via the HVAC inlet or any other penetrations such as doors).

Any decision to evacuate the platform will be at the discretion of the OIM. If smoke enters the TR, the OIM will not necessarily wait until the concentration reaches impairment levels before considering an evacuation of the platform.

It is assumed therefore that if smoke begins to ingress into the TR and the lifeboat evacuation systems are <u>not</u> impaired by smoke, the OIM will order a ‘precautionary’ evacuation. That is, the OIM will tactically decide to evacuate by lifeboat whilst they are available, to protect personnel from the possibility of further smoke ingress and the possibility of subsequent coincident impairment of both TR and evacuation systems.

However, if the evacuation systems are impaired by smoke, it is assumed that personnel remain in the TR. That is, to wait either for the event to be brought under control or for wind conditions to improve. Should impairment conditions subsequently be reached in the TR, however, the OIM would have to order an 'emergency evacuation' of the installation under smoke impairment conditions.

Event trees (see Appendix 5) are used to account for the likelihood of the coincident conditions that must occur for the TR to be affected by smoke from a long duration fire. Details of the event tree analysis and the statistical fatalities assigned to each of the scenarios detailed above are given in Appendix 6. Statistical fatality rates are determined for:

- Precautionary evacuation of the TR, as a result of smoke ingress.
- Smoke impairment of the TR and/or the lifeboats.

7.8.5.3 Gas Ingress

If gas from a large long duration release reaches the TR at a flammable concentration, it could ingress into the TR and result in the potential for an explosion within the TR.

In general, gas releases from the process systems will be transient events, even in the case of an SDV failure. This is particularly true in the case of large gas releases.

However, it is considered that if a medium or large release occurs from the gas lift/injection flowlines, manifolds or wellheads and, upon ESD, a well fails to shut in, a long duration gas release could occur.

It is also considered that if a large release occurs from the production wellheads, manifolds or flowlines and, upon ESD, a well fails to shut in, a long duration 2-phase release could occur.

Therefore, it is considered that any unignited unisolated release from these areas, coincident with unfavourable conditions, could impair the TR.

For the TR to be affected by gas, the following coincident conditions would have to occur:

- Wind blows gas from the release towards the TR.
- Gas reaches the TR at high concentration.
- Gas enters the TR (for example, via the HVAC inlet or any other penetrations such as doors).

Any decision to evacuate the platform will be at the discretion of the OIM. If gas enters the TR, the OIM will not wait until the concentration reaches LFL levels before considering an evacuation of the platform.

Because the potential impairment event involves failure of a well to shut-in, and is therefore unlikely to be transient, it is assumed that the OIM will order a 'precautionary' evacuation. That is, the OIM will tactically decide to evacuate by lifeboat, to protect personnel from the possibility of further gas ingress and the possibility of a subsequent explosion within the TR. In this situation a precautionary evacuation fatality rate of 4.4% is considered.

Event trees (see Appendix 7) are used to account for the likelihood of the coincident conditions that must occur for the TR to be affected by gas from a large long duration release. Details of the event tree analysis and the statistical fatalities assigned to each of the scenarios detailed above are given in Appendix 6.

7.8.5.4 High Temperature

The TR (located on the west of the WHP) will be protected by an appropriate fire and blast-rated wall. All process release events identified are located on the Cellar Deck, central or Cellar Deck, east, whilst the TR is located at Middle Deck level and above. There is also a fire/blast wall separating the hazardous inventories on the central area of the platform from the utilities on Cellar Deck, west. This wall extends up to the Drilling Deck level.

Based on this discussion, the potential for heat impairment of the TR, due to direct fire impingement from process releases, is considered to be negligible. The potential for TR impairment from structural failure due to fires is considered in Section 7.8.5.1.

7.8.5.5 External Explosion

Based on the discussion in Section 7.8.5.4, it is also considered that the potential for structural impairment of the TR, due to external explosion resulting from a process release, is considered to be negligible.

7.8.6 Impact on the Environment

As discussed in Section 6.4, environmental risk is considered in this assessment by considering the expected frequencies of spills of oil, of various specified sizes, into the sea. The potential environmental impact of incidents (i.e. the impact of a spill on valued ecosystem components) is discussed in the EA (Ref. 2 and Ref. 3).

For process liquid release events, the volume of oil that could be released is estimated based on the initial release rate, the proportion of the inventory fluids that are liquid hydrocarbons (at atmospheric conditions) and the time required for the release to be detected and isolated.

If a release is detected by the platform detection system, and the emergency shutdown system is activated, the SDVs close, isolating the release. This reduces the volume of oil that can be released. Prompt manual intervention could also result in a release being isolated quickly. The probability of successful manual intervention is taken to be 0.9.

The release durations considered in the assessment account for the time for a release to be detected by the platform detection systems and the time for the isolation valves to close. If a release is not detected by the automatic detection system or by personnel in the vicinity, it is assumed, for the purposes of this assessment, that it would eventually be detected by the process control systems or by personnel on the platform.

Details of release durations, and the corresponding volumes of oil released, for topsides release events are given in Appendix 8.

The hazardous open drains will be designed to handle the maximum expected volume of oil released in the event of an isolated hydrocarbon spill. However, if the deluge system is activated the capacity of the drains would be exceeded. It is considered that, unless the deluge system is activated, the drains would be greater than 90% effective in containing isolated topsides releases. Therefore, the probability that oil is spilled into the sea in the event of an isolated release where deluge is not activated is taken to be 10%. For release events where the deluge system is activated or isolation fails, it is conservatively considered that all of the oil released subsequently enters the sea.

7.9 Risk Summary

Table 7.10 presents the PLL associated with process loss of containment for each release event. A summary of the environmental risk associated with process loss of containment is presented in Table 7.11. (In both tables, cases where there is no associated risk are represented by a dash.)

Release Event	PLL				Total
	Fatality Classification				
	Immediate	Escape/ Escalation	Precautionary Evacuation	TR Impairment	
Production Wellheads	3.5×10^{-3}	2.0×10^{-4}	2.9×10^{-4}	1.9×10^{-5}	4.0×10^{-3}
Production/Test Flowlines	4.6×10^{-3}	2.6×10^{-4}	4.3×10^{-4}	2.7×10^{-5}	5.3×10^{-3}
Production/Test Manifolds	1.1×10^{-3}	6.4×10^{-5}	1.5×10^{-4}	8.8×10^{-6}	1.3×10^{-3}
Test Separation System	1.2×10^{-3}	7.0×10^{-5}	5.7×10^{-6}	7.9×10^{-6}	1.3×10^{-3}
Multiphase Flow Meter	1.9×10^{-3}	1.1×10^{-4}	8.9×10^{-6}	1.2×10^{-5}	2.1×10^{-3}
Oil Export	2.1×10^{-4}	1.2×10^{-5}	9.7×10^{-7}	1.3×10^{-6}	2.3×10^{-4}
Flare KO Drum Pump	2.5×10^{-4}	4.0×10^{-7}	1.6×10^{-6}	2.3×10^{-6}	2.5×10^{-4}
Gas Import and Distribution	1.4×10^{-4}	1.3×10^{-5}	4.2×10^{-8}	-	1.6×10^{-4}
Gas Injection Wellheads	6.6×10^{-4}	6.1×10^{-5}	9.3×10^{-5}	-	8.1×10^{-4}
Gas Injection Flowlines	1.9×10^{-4}	1.7×10^{-5}	3.1×10^{-5}	-	2.3×10^{-4}
Gas Injection Manifold	2.9×10^{-4}	2.6×10^{-5}	4.9×10^{-5}	-	3.6×10^{-4}
Gas Lift Flowlines	1.8×10^{-3}	1.6×10^{-4}	2.9×10^{-4}	-	2.2×10^{-3}
Gas Lift Manifold	2.9×10^{-4}	2.6×10^{-5}	7.1×10^{-5}	-	3.8×10^{-4}
Flare KO Drum	3.2×10^{-5}	1.4×10^{-7}	-	-	3.2×10^{-5}
Fuel Gas Inlet Heater	1.3×10^{-4}	4.1×10^{-7}	-	-	1.3×10^{-4}
Fuel Gas KO Drum (Gas)	6.0×10^{-6}	2.7×10^{-8}	-	-	6.0×10^{-6}
Fuel Gas Super-Heater	1.6×10^{-5}	7.3×10^{-8}	-	-	1.6×10^{-5}
Gas Turbines	9.5×10^{-5}	4.3×10^{-7}	-	-	9.5×10^{-5}
TOTAL	1.6×10^{-2}	1.0×10^{-3}	1.4×10^{-3}	7.9×10^{-5}	1.8×10^{-2}

Table 7.10: Risk Summary, PLL (Process Loss of Containment)

Release Event	Frequency of Oil Spill into the Sea (per Year)			
	All Spills	>50bbls	>1,000bbls	>10,000bbls
Production Wellheads	1.6×10^{-2}	1.7×10^{-3}	4.0×10^{-6}	-
Production/Test Flowlines	2.1×10^{-2}	2.4×10^{-3}	9.5×10^{-6}	-
Production/Test Manifolds	5.2×10^{-3}	7.2×10^{-4}	6.0×10^{-6}	-
Test Separation System	5.6×10^{-3}	6.7×10^{-4}	3.5×10^{-6}	-
Multiphase Flow Meter	8.8×10^{-3}	1.1×10^{-3}	5.5×10^{-6}	-
Oil Export	1.6×10^{-3}	2.0×10^{-4}	1.0×10^{-6}	-
Flare KO Drum Pump	9.7×10^{-4}	1.2×10^{-4}	6.0×10^{-7}	-
Gas Releases	-	-	-	-
TOTAL	5.9×10^{-2}	6.8×10^{-3}	3.0×10^{-5}	-

Table 7.11: Environmental Risk Summary (Process Loss of Containment)

8.0 Blowouts

The WHP is to be provided with a drilling rig package, which includes an integrated single drilling rig capable of undertaking drilling and well intervention activities. The drilling rig package will comprise a Drilling Equipment Set (DES) and drill floor with derrick on the topsides.

This section therefore considers the potential for blowouts during drilling and well intervention activities, as well as during production.

The risk to personnel from blowouts is assessed using the same event tree structure as is used to assess the risk due to loss of containment events (see Appendix 1).

The basis of the blowout risk assessment is outlined below.

8.1 Blowout Location and Frequency

The blowout frequency depends on the drilling and well activities being carried out and on the number of wells in production.

Ref. 14 provides historical data on the frequency of blowout events for ‘offshore operations of North Sea standard’, which is deemed to be appropriate for the operating environment and drilling standards in the Atlantic region. Table 8.1 provides blowout frequency based on data from Ref. 14.

Well Activity	**Blowout Frequency**	
Development Drilling:		
Oil Wells	4.8×10^{-5}	per well drilled
Shallow Gas	4.7×10^{-4}	per well drilled
Total	5.18×10^{-4}	per well drilled
Completion	5.4×10^{-5}	per well completed
Production, Oil	2.6×10^{-6}	per well year
Water Injection	2.4×10^{-6}	per well year
Gas Injection	1.8×10^{-5}	per well year
Workover	1.8×10^{-4}	per workover
Wirelining	3.6×10^{-6}	per wireline job
Coiled Tubing	7.8×10^{-5}	per operation

Table 8.1: Blowout Frequency Data

From Ref. 15, it is anticipated that there will be:

- 19 oil production wells.
- 15 water injection wells.
- 2 gas injection wells.

- 2 cuttings re-injection wells.

It is considered unlikely that a blowout from a water injection well would result in a release of hydrocarbons. However, blowouts from water injection wells during production are conservatively considered in the assessment. The drilling of these wells is also accounted for in the number of wells assumed to be drilled per year. The cuttings re-injection wells are considered to present a negligible risk to personnel and are therefore not accounted for in the assessment.

For the purposes of this assessment, it is conservatively assumed that all the oil production wells, gas injection wells and water injection wells are in operation. It is further assumed that:

- 5 wells are drilled per year.
- 2 wirelining and 2 coiled tubing activities are undertaken per year.
- 1 workover is undertaken every 5 years.

It is acknowledged that the 5 wells drilled per year will be achievable earlier in the WHP platform life, when the number of wells in production is lower. Taking into account the anticipated field life, it is estimated in the WHP Environmental Assessment (Ref. 2 and Ref. 3) that a total of 60 wells will be drilled (this is an average of less than 3 wells per year, over the current platform design life of 25 years). A total of 300 production well years is also estimated in the Environmental Assessment, which results in an average number of wells in production per year significantly lower than the maximum of 19 considered in this assessment.

The estimated blowout frequencies, by well activity, are given in Table 8.2, based on the assumptions discussed above and the Ref. 14 blowout frequency data given in Table 8.1. If the WHP is located where there is no danger of shallow gas, a reduced development drilling frequency could be used for the risk assessment.

As discussed in Section 2.1, dual conductor technology will be used to reduce the wellbay space required for the planned wells. Although dual conductor technology requires wells to be drilled in close proximity, the historical drilling blowout frequencies given in Table 8.1 are considered directly applicable in estimating blowout frequencies for the WHP on the basis that:

- Dual conductor technology is commonly used in the oil and gas industry, and has been implemented successfully over many years.
- The decision to adopt dual conductor technology was made during the pre-FEED stage of the project and was taken into account in the basis of design for the WHP and during development of the drilling plan.
- Procedural measures are in place to minimize specific risks associated with drilling wells using dual conductor technology, as outlined in Section 3.16.

Well Activity	Blowout Frequency (per well-year)	Number of Wells	Blowout Frequency (per year of operation)
Development Drilling	5.18×10^{-4}	5	2.59×10^{-3}
Completion	5.4×10^{-5}	5	2.70×10^{-4}
Production, Oil	2.6×10^{-6}	19	4.94×10^{-5}
Water Injection	2.4×10^{-6}	15	3.60×10^{-5}
Gas Injection	1.8×10^{-5}	2	3.60×10^{-5}
Workover	1.8×10^{-4}	0.2	3.60×10^{-5}
Wirelining	3.6×10^{-6}	2	7.02×10^{-6}
Coiled Tubing	7.8×10^{-5}	2	1.56×10^{-4}
Total			$\mathbf{3.18 \times 10^{-3}}$

Table 8.2: Estimated Blowout Frequencies for Wellhead Platform

Historical data indicates that:

- The majority of blowouts during production, wirelining and completion occur at the wellhead.
- The majority of blowouts during workovers and drilling occur at the Drill floor.
- A minority of blowouts occur subsea.

It is not considered that a subsea blowout has the potential to impact the CGS (and therefore personnel on the platform) because, even if the blowout occurs below the platform, the multiple barriers in place (tubing, casing, conductors, cement etc.) will prevent ingress of gas into the shaft.

Therefore, for the purposes of this risk assessment, the combined total frequency of all production, injection, wirelining, coiled tubing and completion blowouts is taken as representative of the blowout frequency in the wellhead area on the Cellar Deck. Similarly, the combined total frequency of all workover and drilling blowouts is taken as representative of the blowout frequency at the Drill Floor of the drilling rig.

The total blowout frequencies, estimated on this basis, are given in Table 8.3.

Location	Blowout Frequency (per year)
Wellhead Area (Cellar Deck)	5.55×10^{-4}
Drill Floor of Drilling Rig	2.63×10^{-3}
Total	$\mathbf{3.18 \times 10^{-3}}$

Table 8.3: Blowout Frequencies by Location

8.2 Ignition Probability

Ignition probabilities are calculated using the UKOOA ignition model (Ref. 7), as described in Section 7.3.

The model calculates ignition probabilities based on mass release rate, with a maximum ignition probability for a blowout of 0.1 and a maximum explosion probability, given ignition, of 0.3.

These maximum ignition probabilities are used for the purposes of this assessment.

8.3 Fire and Gas Detection Probability

For blowouts, the detection probability is assumed to be similar to that for a large process release (i.e. 0.99, see Table 7.5).

8.4 Isolation Probability

A blowout is, by definition, an uncontrolled release of fluids from a well. Therefore, the probability of isolating the release is 0.

8.5 Deluge Probability

The overall on-demand failure probability for deluge is 0.015, see Section 7.6.

8.6 Explosion Overpressure Probability

As discussed in Section 7.7, four overpressure ranges are considered in the risk assessment:

- Explosion overpressure between 0 and 0.2 bar.
- Explosion overpressure between 0.2 bar and 1 bar.
- Explosion overpressure between 1 bar and 2 bar.
- Explosion overpressure greater than 2 bar.

Also from Section 7.7, based on explosion modelling performed using DNV's consequence modelling software package, PHAST, the worst case maximum overpressure in the Wellhead/Manifold Area is taken to be 1.01 bar. Based on the discussion in Section 7.7, the explosion overpressure branch probabilities used in the assessment of blowouts in the Wellhead Area are given in Table 8.4.

Overpressure Range	**Probability (Deluge)**	**Probability (No Deluge)**
< 0.2 Bar	0.197	0.099
0.2 Bar to 1.0 Bar	0.788	0.394
1.0 Bar to 2.0 Bar	0.015	0.493
> 2.0 Bar	0	0.014

Table 8.4: Overpressure Probabilities

Due to the open elevated position of the drilling rig, it is considered that, in the event of an explosion, the overpressure generated would not be sufficient to affect personnel in areas other than the Drill Floor. Therefore, the event tree for Drill Floor blowouts does not distinguish between explosions of different overpressure in the event of a delayed ignition.

8.7 Consequence Assessment

The approach to estimation of consequences for blowout events, in terms of risk to personnel, is similar to that applied for process loss of hydrocarbon containment events (in Section 7.8).

The environmental risks associated with blowouts have been reviewed against the assessment of environmental risks in the EA (Ref. 2 and Ref. 3) and have been demonstrated to be consistent. Environmental risks associated with blowouts are therefore not considered further in this assessment.

8.7.1 Immediate Fatalities for Blowouts in the Wellhead Area on the Cellar Deck

8.7.1.1 Non-Explosive Ignition (Fires)

The immediate fatalities resulting from an ignited blowout in the wellbay area of the Cellar Deck are taken to be the same as those for a large process release (100% fatalities in the wellbay area, see Appendix 3).

8.7.1.2 Explosions

Based on the rule set presented in Section 7.8.2, it is assumed that, in the event of an explosion of overpressure less than 0.2 bar, 50% of personnel in the area when ignition occurs are fatally injured. For overpressures of 0.2 bar or greater, 100% of personnel in the area when ignition occurs are assumed to be fatally injured.

However, in the event of a delayed ignition following a blowout in the wellbay area of the Cellar Deck, it is assumed that personnel will be aware of the incident and that there is a 50% chance that they will escape from the area before ignition occurs.

8.7.2 Immediate Fatalities for Blowouts at the Drill Floor of the Drilling Rig

8.7.2.1 Non-Explosive Ignition (Fires)

It is assumed that there are, on average, 12.38 personnel on the drilling rig (see Section 6.1). During well activities (such as drilling into a reservoir) a 'well kick' will, in general, occur, which gives forewarning of the potential blowout situation. This may give time for a precautionary down-manning of the immediate area, with only essential personnel remaining to attempt to control the situation. However, in order to present a conservative assessment, and to account for recent industry experience, it is assumed that all personnel on the drilling rig at the time that an ignited blowout occurs will be fatally injured.

8.7.2.2 Explosions

As discussed in Section 8.6, the Drill Floor is a very open area, with low congestion and low confinement. It is considered that, in the event of an explosive ignition on the Drill Floor, the overpressure generated would not be sufficient to result in fatalities in other areas of the platform or to cause significant structural damage.

On this basis, the risks to personnel due to any ignited blowout on the Drill Floor are estimated as discussed in Section 8.7.2.1 in which it is assumed that there will be 100% immediate fatalities on the Drill Floor. As for process loss of containment events, it is assumed that there is a probability of 0.5 that personnel escape from the area before explosive ignition occurs.

8.7.3 Escalation Fatalities due to Impairment of Fire and Blast Walls

As for process loss of containment events in Section 7.8.3, no escalation fatalities are accounted for in fire (non-explosive ignition) scenarios.

In addition, as discussed in Section 8.7.3, it is considered that an explosion on the Drill Floor would not affect personnel in other areas or cause significant structural damage to the platform.

It is however considered that a delayed ignition blowout event in the wellhead area of the Cellar Deck has the potential to escalate to adjacent areas and result in fatalities. The rule set described for process releases (Section 7.8.3) is used to estimate escalation fatalities resulting from delayed ignition of a blowout in the wellhead area.

8.7.4 Escape Fatalities

As discussed in Section 7.8.4, the risk assessment does not account for any escape fatalities.

8.7.5 Precautionary Evacuation and TR Impairment Fatalities

8.7.5.1 Precautionary Evacuation

As blowouts are uncontrolled release of well fluids, ignited blowouts (either in the wellhead area of the Cellar Deck or on the Drill Floor of the drilling rig) could result in long duration fires that could eventually impair the platform structure. Unignited blowouts could result in TR gas impairment and internal explosion if gas enters the TR.

In fact, because of the severity of the consequences of a blowout, it is assumed that the OIM may initiate a precautionary evacuation, irrespective of whether the blowout ignites, if the weather conditions are reasonable. Therefore, for all blowouts, ‘precautionary evacuation’ fatalities are accounted for.

For ignited blowouts, it is assumed that a lifeboat evacuation will be undertaken, and a fatality rate of 4.4% is applied, as discussed in Section 7.8.5.

For unignited blowouts, it is assumed that the OIM would not initiate a precautionary evacuation in severe weather conditions. A TEMPSC evacuation fatality rate of 1.2% is therefore applied, which is estimated as described above for ignited blowouts.

Additional risks associated with remaining on the installation during severe weather are discussed in Section 8.7.5.3 which considers that, in the event of an unignited blowout, gas ingress may threaten the integrity of the TR.

8.7.5.2 Smoke Ingress

The basis of the risk assessment for ignited blowouts is that personnel will muster in the TR and the OIM will initiate a precautionary evacuation.

If, however, smoke from an ignited blowout impairs the evacuation systems, it is assumed that personnel will remain in the TR. That is, to wait either for the event to be brought under control or for wind conditions to improve. Should impairment conditions subsequently be reached in the TR, however, the OIM would have to order an 'emergency evacuation' of the installation under smoke impairment conditions.

The elevation of the Drill Floor of the drilling rig is approximately 29 meters higher than the elevation of the Middle Deck, where the primary TEMPSC are located. In the event of an ignited blowout on the Drill Floor, it is assumed that heat from the fire would generate buoyant products, which would tend to carry smoke upwards and away from the TEMPSC. It is therefore assumed that the TEMPSC would not be impaired as a result of smoke from an ignited blowout on the Drill Floor.

The statistical fatalities for smoke impairment of the TR and evacuation systems as a result of an ignited blowout in the wellhead area of the Cellar Deck is calculated based on the method discussed in Section 7.8.5.2 and Appendix 6.

8.7.5.3 Gas Ingress

The likelihood of rapid ingress of gas into the TR due to the HVAC system failing to shutdown is not considered in the risk assessment (Appendix 6). It is assumed, however, that gas could enter slowly through various other TR penetrations, such as doors.

The basis of the risk assessment for blowouts is that when a blowout occurs, the OIM will initiate a precautionary evacuation if the weather conditions are not severe. In these circumstances, because the risk assessment considers only slow ingress of gas into the TR, personnel will have evacuated the platform before gas ingress and explosion impair the integrity of the TR.

However, in severe weather conditions, it is assumed that the OIM would not initiate an evacuation unless the integrity of the TR were threatened. A high evacuation fatality rate of 50% is assumed in the event that an evacuation in severe weather is required due to gas ingress into the TR.

8.7.5.4 High Temperature

As discussed for process releases (Section 7.8.5.4), the potential for heat impairment of the TR, due to direct fire impingement, is not considered to be significant, due to the fire and blast-rated divisions provided.

8.7.5.5 External Explosion

As discussed for process releases (Section 7.8.5.5), the potential for impairment of the TR due to external explosion is not considered to be significant.

8.8 Risk Summary

Table 8.5 presents the PLL associated with blowouts. As discussed in Section 8.7, the environmental risks associated with blowouts have been reviewed against the assessment of environmental risks in the EA (Ref. 2 and Ref. 3) and have been demonstrated to be consistent. Environmental risks associated with blowouts are therefore not considered further in this assessment.

Blowout Location	PLL				Total
	Fatality Classification				
	Immediate	Escape/ Escalation	Precautionary Evacuation	TR Impairment	
Cellar Deck	1.1×10^{-4}	3.1×10^{-5}	1.1×10^{-3}	3.5×10^{-4}	1.6×10^{-3}
Drill Floor	2.8×10^{-3}	-	5.0×10^{-3}	1.5×10^{-3}	9.3×10^{-3}
TOTAL	2.9×10^{-3}	3.1×10^{-5}	6.1×10^{-3}	1.9×10^{-3}	1.1×10^{-2}

Table 8.5: Risk Summary, PLL (Blowouts)

9.0 Releases Below the Platform Topsides

The central column of the CGS consists of a wet shaft, which is flooded up to sea level. As discussed in Section 2.1.2, a cylindrical transition structure will be used to mate the CGS to the platform topsides. The following subsections discuss hydrocarbon releases below the Cellar Deck level (both within and above the shaft).

9.1 Releases in the Shaft

The shaft will contain well conductors, flexible risers, j-tubes, caissons and main mechanical outfitting steelwork. The shaft will be open to the transition structure. Openings will be provided in the shaft to allow seawater to flow in and out.

There is the potential for a hydrocarbon release within the shaft (or below the Cellar Deck) from the well conductors, the export risers or the gas import riser. The Cellar Deck will be plated and fire rated and therefore a fire on this level will not have the potential to impact the CGS.

A release of well fluid could result in a rapid accumulation of gas in the void, above sea level, within the shaft. The conductors consist of several concentric casings and production tubing, and the annuli between the casings are regularly monitored for pressure. The likelihood of a rapid accumulation of gas within the shaft as a result of a release from the conductors is considered to be small.

Risers will be designed in accordance with established codes and standards and will have defined operational parameters in order to minimize the potential for releases. The gas import riser SDV will be located on the Sub Cellar Deck and the export production riser SDV will be located on the Cellar Deck and, as the risers will be fully welded up to the SDV (i.e. there will be no valves, flanges, fixtures or fittings within the shaft or transition structure), the likelihood of a release within the shaft is low.

The shaft will therefore be classified as a non-hazardous area (with no specific ventilation requirements) on the basis that it meets the requirements of API RP 505 for non-hazardous areas (i.e. that *"flammable substances are contained in all-welded closed piping systems without valves, flanges or similar devices"* and that flammable gas is present for less than 1 hour per year).

Although the likelihood is low, if ignition within the shaft were to occur, it could result in either a jet fire, a pool fire or an explosion.

The protected environment within the shaft will mitigate the risks of environmental and accidental loading and the shaft walls will provide protection from wave loading, ice loading and boat and wreck impact.

High pressure gas risers will be of flexible design and routed within a J-tube. These will be designed for 440 bar (but operating pressures will be significantly lower). Due to the high pressure, a large release could potentially result in overpressurization of the shaft, resulting in structural failure and subsequent loss of the facility. Ref. 16 estimates the frequency of shaft collapse accounting for a number of factors such as whether monitoring can detect an incipient problem before riser failure occurs, the type of riser failure, whether catastrophic failure of the riser also results in sudden catastrophic failure etc. The worst case frequency of collapse for the four design options (50 bar capacity wet and dry J-tubes and 10 bar capacity wet and dry J-tubes) considered in Ref. 16 was approximately 1×10^{-7} per year.

A release in the shaft from the production export risers could also present an environmental risk. However, the release frequency is very low and, depending on the volume of oil spilled, it could be contained within the shaft in the event of a release. Therefore, the environmental risk resulting from releases in the shaft is considered negligible compared to the environmental risk for other hazards.

Although the potential for ignition in the normally inaccessible shaft is low, and the potential for a hydrocarbon release is also low, ongoing studies are being undertaken to assess the potential for explosions in the CGS. These studies will identify measures to prevent and mitigate the fire and explosion risk within the shaft.

Based on the above discussions, and taking into account that studies are ongoing to ensure that the fire and explosion risk within the shaft is low, this hazard is not quantified in this assessment. However, the likelihood and consequences of releases within the shaft should be reviewed at detailed design to ensure that risks are ALARP.

9.2 Releases within the Transition Structure

The Cellar Deck will be plated and fire rated and any penetration will be sealed with equivalent fire rating. A fire on the Cellar Deck will therefore not have the potential to impact the transition structure or the CGS.

However, a hydrocarbon release that occurs below the Cellar Deck may result in a jet fire that impinges on the transition structure. A large release from the production riser may also result in a pool fire on the sea surface that is large enough to affect the transition structure. Studies are ongoing to assess the risk of a fire or explosion below the Cellar Deck impacting the transition structure. These studies will discuss PFP and blast rating requirements of the transition structure and the Cellar Deck floor, and will identify measures to prevent and mitigate the fire and explosion risk.

Therefore, this hazard is not quantified in this assessment. However, the likelihood and consequences of releases within the transition structure should be reviewed at detailed design to ensure that risks to personnel are ALARP. Due to the very low likelihood of a release, the environmental risk is considered negligible compared to the environmental risk for other hazards.

10.0 Subsea Flowline Releases

The potential risk associated with releases within the shaft is discussed in Section 9. This section discusses the potential risk to the environment and personnel on the WHP associated with subsea flowline releases outside the shaft.

The export production flowlines contain a significant proportion of gas. Therefore, in the event of a release from these flowlines, or from the gas supply flowline, gas may reach the WHP in flammable concentrations and ignite resulting in a flash fire or explosion. In addition, a release from the production flowlines could result in an oil spill or a sea fire in the vicinity of the WHP. A release at any point in the production flowline may present a risk to the environment. However, only releases within the 500 platform safety zone are considered to present a risk to personnel on the WHP. Therefore, all releases from the production export flowlines (up to the tie-in with the CDC flowlines) are considered in this assessment, but releases from the gas import flowline outside the 500m exclusion zone are not considered on the basis that they present negligible risk to personnel or to the environment.

A representative subsea flowline release event tree is shown in Appendix 9. In the event trees, the following branches are considered:

- Gas reaches WHP topsides in flammable concentrations.
- Gas detection.
- Isolation.
- Ignition.

10.1 Frequency Assessment

The flowline release frequency assessment for the WHP is based on the following:

- Two 10" production export flowlines (3km in length) that transfer fluids to the SeaRose FPSO.
- One 6" gas import flowline (7km in length).

The frequency assessment in the following subsections is based on data in Ref. 13 for releases from steel flowlines. The detailed design QRA should review these assumptions to ensure that it reflects the final design of the flowlines (e.g. material, diameter, etc.).

10.1.1 Release Frequencies

Ref. 17 presents data on subsea flowline releases due to:

- Anchoring and impact failures, which depend primarily on the section of the flowline (safety zone or mid-line) and the diameter of the flowline.
- Corrosion and material defects, which depend primarily on flowline length.

Release frequencies for flowlines are estimated based on the sum of the release frequencies for the above two components and the release frequency associated with fittings and valves.

The total leak frequencies are then apportioned to four representative hole sizes (see Section 10.1.2).

10.1.1.1 Anchoring and Impact Failures

From Ref. 17, the anchoring and impact failure frequencies for steel flowlines within the safety zone are:

- 3.34×10^{-4} per flowline year for steel flowlines with a diameter less than 10".
- 3.71×10^{-4} per flowline year for steel flowlines with a diameter of 10" or greater.

Also from Ref. 17, the anchoring and impact failure frequency for steel flowlines with a diameter less than 10" outside the safety zone is 1.64×10^{-5} per flowline year.

10.1.1.2 Corrosion and Material Defects

The frequencies given in Ref. 17 for loss of containment from steel flowlines due to corrosion and material defects are:

- 4.16×10^{-5} per km year for steel flowlines with a length greater than 5km.
- 9.28×10^{-4} per km year for steel flowlines with a length between 2 and 5km.

10.1.1.3 Release Frequency Associated with Fittings

The frequencies of leaks from fittings are estimated based on historical data in the Ref. 5 database and a parts count of the fittings.

A subsea isolation valve (SSIV) will be provided on the gas import flowline. Therefore, one SDV and two flanges are accounted for in calculating the frequency of gas import flowline releases.

No fittings are accounted for in calculating the frequency of releases from the production export flowlines.

10.1.2 Hole Size Distribution

The hole size distribution for subsea flowlines is estimated using loss of containment data for risers/flowlines in Ref. 17. Based on this data, the hole size distribution for releases from flowlines (excluding fittings) is as presented in Table 10.1.

Hole Size	Distribution
Small (<20mm)	56.92%
Medium (20-80mm)	13.85%
Large (>80mm)	9.23%
Fullbore Rupture	20.00%

Table 10.1: Representative Hole Size Distribution

The hole size distributions for releases from fittings are based on those given in Ref. 5 database.

10.1.3 Frequencies

Based on Sections 10.1.1 and 10.1.2, the estimated annual frequencies of flowline releases within the safety zone are given in Table 10.2.

Hole Size	Gas Import Flowline	Production Export Flowlines Within 500m Zone	Production Export Flowlines Outside 500m Zone
Small	2.53×10^{-3}	9.51×10^{-4}	2.35×10^{-3}
Medium	4.27×10^{-4}	2.31×10^{-4}	5.70×10^{-4}
Large	3.72×10^{-5}	1.54×10^{-4}	3.80×10^{-4}
Fullbore	7.10×10^{-5}	3.34×10^{-4}	8.24×10^{-4}
Total	$\mathbf{3.07 \times 10^{-3}}$	$\mathbf{1.67 \times 10^{-3}}$	$\mathbf{4.12 \times 10^{-3}}$

Table 10.2: Subsea Flowline Release Frequencies

10.2 Probability that Gas Reaches Platform in Flammable Concentrations

For releases within the 500m exclusion zone, the probabilities that gas from the gas import or production flowlines reaches the topsides in flammable concentration are assumed to be as given in Table 10.3. Releases from the production export flowlines outside the 500m exclusion zone are considered unlikely to result in gas reaching the platform topsides. As discussed in Section 10, releases from the gas import flowline outside the 500m exclusion zone are not considered in this assessment.

Hole Size	Gas Import Flowline	Production Export Flowlines
Small	0	0
Medium	0.1	0
Large	0.15	0.1
Fullbore	0.20	0.15

Table 10.3: Probabilities that Flammable Gas Reaches the Platform

10.3 Detection Probability

The gas detection probabilities calculated for process loss of containment events (Section 7.4) are also assumed for subsea flowline release events that reach the platform in flammable concentrations. The probabilities are given in Table 10.4.

Hole Size	Gas Detection
Small	0.90
Medium	0.95
Large/Fullbore	0.99

Table 10.4: Fire and Gas Detection Probabilities

10.4 Isolation Probability

As discussed in Section 10.1.1.3, an SSIV will be provided on the gas import flowline. Therefore, gas flowline releases are considered to be successfully isolated if this SSIV operates successfully, as well as the riser SDV on the WHP (if the release is between the valves). The probability of the SSIV operating successfully is assumed to be the same as that for an SDV (Section 7.5) and therefore the probability of successful isolation is estimated as 0.98.

The production flowlines will be tied in to the subsea tie-in structure on existing flowlines between CDC and the SeaRose FPSO.

There are no SSIVs on the production export flowlines, but the flowlines can be isolated by activation of the riser SDV on the WHP and the CDC valves. The probability that the export production flowlines are successfully isolated is also estimated as 0.98.

10.5 Ignition Probability

In the event that gas (as a result of a release from the gas import flowline or a production flowline) reaches the topsides in flammable concentrations, the probability of ignition is taken to be 0.1, based on the 'Engulf – blowout/riser' release type within the UKOOA look-up model.

It is also conservatively assumed that the probability of ignition of a pool on the sea surface, as a result of a release from a production flowline, is 0.1.

10.6 Consequence Assessment

10.6.1 Immediate Fatalities

It is assumed that ignition of gas releases that reach the platform in flammable concentrations would occur on the central area of Cellar Deck and that all personnel in this area would be fatally injured. For releases that are successfully detected, a 50% reduction factor is applied.

No immediate fatalities are accounted for in the event of a sea fire or if the release is unignited.

10.6.2 Escalation Fatalities

It is assumed that appropriate fire-rated divisions will be provided in order to minimize escalation and to ensure sufficient protection for personnel in the TR. In addition, a flash fire (or explosion followed by a flash fire) resulting from an ignited subsea flowline release would be a transient event of limited duration. No escalation fatalities are therefore accounted for.

10.6.3 Escape Fatalities

As discussed in Section 7.8.4, the risk assessment does not account for any escape fatalities.

10.6.4 Precautionary Evacuation and TR Impairment Fatalities

It is considered that unignited unisolated medium, large and fullbore releases from the gas import flowline that reach the WHP in flammable concentrations, coincident with unfavourable conditions, could impair the TR due to gas ingress. Similarly, it is considered that unignited large or fullbore releases from the production flowlines within the 500m exclusion zone could impair the TR due to gas ingress. Releases outside the 500m exclusion zone are not considered to have the potential to impair the TR due to gas ingress.

As discussed in Section 7.8.5.3, if gas enters the TR, it is likely that the OIM will not wait until the concentration reaches LFL before considering an evacuation of the platform. It is therefore assumed that the OIM will order a ‘precautionary’ evacuation. That is, the OIM will tactically decide to evacuate by lifeboat if the weather conditions are appropriate, to protect personnel from the possibility of further gas ingress and subsequent explosion within the TR. Precautionary evacuation fatality rates and TR impairment (due to gas ingress) fatality rates are calculated as discussed in Section 7.8.5.3.

It is also considered that, in the event of an ignited large or fullbore release from a production flowline within the 500m exclusion zone, a sustained sea fire generating significant levels of smoke could result. It is therefore assumed that there is the potential for smoke impairment of the TR due to such a sea fire, if it reaches the WHP and occurs coincident with unfavourable conditions. It is assumed that the OIM would not initiate a precautionary evacuation in the event of a sea fire and therefore persons would remain in the TR unless the TR were impaired. In the event that the TR is impaired, it is assumed that personnel would evacuate and a fatality rate of 50% is assumed to reflect the fact that it would be an emergency evacuation under impairment conditions. Conservatively, no account is taken of isolation of the export flowlines when determining the potential for impairment to occur.

10.6.5 Impact on the Environment

As for topsides release events (Section 7.8.6), the volume of oil that could be spilled in the event of a production export flowline release event is estimated based on the initial release rate, the proportion of the fluids released that are liquid hydrocarbons and the time required for the release to be detected and isolated.

A release may be detected by the platform detection system, if flammable gas reaches the topsides, but, for the purposes of this assessment, it is considered unlikely that small or medium subsea releases would be detected by the platform gas detection system.

Medium, large and fullbore releases may also be detected by the process control systems due to the reduction in pressure in the export flowline, which would raise a low alarm or a low-low trip alarm. Due to the comparatively low release rate, small releases are unlikely to trip process alarms, and hence may remain undetected. However, due to the discrepancy in the export and import logs the release is likely to be identified in the daily production meeting.

If a release ignites, the sea surface pool fire may also be noticed by personnel on the platform.

As discussed in Section 2.1, the production flowlines will be tied in to the subsea tie-in structure on existing flowlines between CDC and the SeaRose FPSO. For a release from a production flowline to be isolated, the SDVs at the WHP and the CDC are required to close, but the volume of oil isolated within the flowline may continue to be released after the SDVs close. There are also valves at the tie-in, but as these are not SDVs (and hence are not quick closing), some oil from the existing flowlines would also continue to feed the release until the tie-in valves close. Therefore, the total volume of oil assumed to be released accounts for the volume of oil released prior to isolation, the volume of oil in the production export flowline after isolation plus a proportion of the volume of oil in the connecting flowlines.

Further details of release durations, and the corresponding volumes of oil released, for subsea flowline release events are given in Appendix 8.

10.7 Risk Summary

Table 10.5 presents the PLL associated with subsea flowline releases. A summary of the environmental risk associated with subsea flowline releases is presented in Table 10.6.

Subsea Flowline	PLL				Total
	Fatality Classification				
	Immediate	Escape/ Escalation	Precautionary Evacuation	TR Impairment	
Gas Import Flowline	7.8×10^{-6}	-	1.2×10^{-6}	-	9.0×10^{-6}
Export Flowline	7.9×10^{-6}	-	2.2×10^{-5}	2.3×10^{-5}	5.3×10^{-5}
Total	1.6×10^{-5}	-	2.4×10^{-5}	2.3×10^{-5}	6.3×10^{-5}

Table 10.5: Risk Summary, PLL (Subsea Flowline Releases)

Release Event	Frequency of Oil Spills (per Year)			
	All Spills	>50bbls	>1,000bbls	>10,000bbls
Gas Import Flowline	-	-	-	-
Export Flowline	5.8×10^{-3}	5.8×10^{-3}	4.6×10^{-3}	-
TOTAL	5.8×10^{-3}	5.8×10^{-3}	4.6×10^{-3}	-

Table 10.6: Environmental Risk Summary (Subsea Flowline Releases)

11.0 Other Hazards

Ref. 4 also identifies the following non-hydrocarbon hazards, which are discussed in the following sections:

- Iceberg collision with the installation, sea ice and ice loading.
- Ship collision with the installation.
- Helicopter accidents, during transportation of platform personnel to and from the installation.
- Seismic activity, leading to structural damage and/or damage to equipment.
- Extreme weather leading to structural failure.
- Dropped objects.

11.1 Iceberg Collision and Scouring, Sea Ice, Topsides Icing

The design of the WHP and associated subsea facilities accounts for the risks associated with icebergs, ice scour and sea ice and ice accretion (discussed in the following subsections).

11.1.1 Iceberg Collision

Icebergs originating from the glaciers in Greenland and Ellesmere Island drift south through the White Rose area. These icebergs vary in size, but can potentially reach a maximum of 5,900,000 tonnes and therefore present a major hazard to the WHP.

The CAN/CSA-ISO 19906 standard (Ref. 18) provides guidance on the design, analysis and assessment of arctic and cold region offshore structures in order to achieve appropriate structural reliability levels. A number of design studies to ensure that the project fully complies with all requirements are ongoing, in particular a probabilistic assessment of iceberg loading exceeding the platform design, as well as a topsides risk assessment to determine the required deck elevation to minimize potential damage from iceberg impact (Ref. 20 and Ref. 21).

In the event of a significant iceberg threat to the WHP, the philosophy will be to shut in the wells, depressurize the topsides and initiate a controlled down-manning prior to iceberg impact.

The WHP will be designed to meet CAN/CSA-ISO 19906 (Ref. 18) Level 2 (L2) exposure classification for ice loading on the structure, whilst exposure level 1 (L1) will form the basis of design for all other events. Exposure level 2 is determined by the Life Safety Category (S2) and the Consequence Category (C2).

The Ref. 18 design and operational requirements for Life Safety Category (S2), which applies to a normally manned facility, and how the WHP will meet them, are discussed below:

- Ability to reliably forecast a design environmental event and weather is not likely to inhibit down-manning: As described by ISO 19906, the design environmental event relating to ice is the ALIE (Abnormal Level Ice Event). Husky currently has comprehensive methods of early ice detection and will take a conservative approach to the identification of ALIE ice by considering iceberg water line length, mass, volume and speed.

- Planned down-manning ahead of a design environmental event: Husky has an Ice Management Plan that outlines the ice management policies and procedures developed to support offshore operations. This plan will be revised to meet the needs of the WHP, which is a permanent fixed structure. The Ice Management Plan will detail the down-manning plan ahead of a design environmental event.

- Sufficient time and resources to safely down-man: The revised Ice Management Plan will include defined T-Times. The T-Time is the total time required to secure the facility and down-man personnel. T-Time calculations will include the following inputs to ensure there is sufficient time for down-manning:

    - The operational status of the facility will determine the time required to shutdown, secure wells, drain and purge the WHP facility.

    - Weather forecasting will ensure sufficient time for down-manning after the operational phase is completed.

    - Historical weather statistics for a particular time of year will also be utilized to ensure sufficient time is allotted for down-manning after the operational phase is completed. The preferred means of down-manning will be via helicopter with transfer to a supply vessel providing an alternative means of down-manning.

The Ref. 18 design and operational requirements, and how the WHP will meet them, for Consequence Category (C2) are discussed below:

- Production can be shut-in during a design event: This is inherent in the design of the wells.

- Wells that can flow have Subsurface Isolation Valves: The WHP wells will have Subsurface Isolation Valves.

- Oil storage limited to process inventory and surge tanks for transfer: The WHP will not have oil storage or processing and oil will be transferred to the SeaRose FPSO for processing, storage and offloading. Therefore, the oil inventory on the WHP is limited.

- Subsea flowlines have limited hydrocarbon release potential: The design and material of the WHP flowlines will ensure that the potential for a hydrocarbon release is limited.

On this basis, the Life Safety (S2) and Consequence Category (C2) requirements of ISO 19906 Code will be met through both engineering design and operational policies and procedures such as Husky's Ice Management Program. By meeting these requirements, the WHP structure can be designated as exposure class L2 for ice loading.

As outlined in the Class 2 Exposure Level Submission (Ref. 19), the basis for L2 classification is that the platform is not used for oil storage and that abnormal icebergs can be successfully detected in sufficient time to enable the platform to be shut-down, risers flushed, and personnel evacuated safely prior to iceberg impact with a probability of 90%. (As success for shut-down is considered independent from the success of down-manning, the probability of success of each should be at least 95%.) In practice, this means the WHP is designed for iceberg impact events with an annual probability of occurrence of 1×10^{-3} and a target annual failure probability of 1×10^{-4}.

A quantitative assessment has been undertaken (Ref. 22) to demonstrate that the probability of successfully shutting-in and evacuating the platform is in line with the criteria specified for L2 classification.

Based on the iceberg season (taken to be April through to July), the assessment (Ref. 22) considers:

- Husky's ice detection and management system, isolation and shut-in procedures, and evacuation arrangements and facilities for the WHP. This includes both the physical means provided and the procedural measures in place to respond to an iceberg threat, for example:
  - Detection and tracking of significant icebergs on the Grand Banks using aerial surveillance, radars and attendant vessels.
  - Deflection of the iceberg by towing or pushing the iceberg or by using water cannons.
- The effectiveness of ice detection and management procedures in order to determine the frequency of iceberg events that present a threat to the WHP and the likelihood of subsequent collision with the WHP, using event tree analysis.
- The overall probability of successfully shutting-in and down-manning the platform in the event of an iceberg threat for the two modes of WHP operation, production and drilling. This is largely achieved through the implementation of T-Time calculations that dictate the time frames required to cease operations, secure wells, and prepare the installation for abandonment.
- The probability of personnel being safely and successfully down-manned from the WHP in the event of an iceberg on a potential collision course. Overall success rates are estimated based on availability of the following means:
  - Helicopter (preferred means).
  - Marine transfer using personnel transfer devices (FROG) (preferred alternative).

Overall, Ref. 22 concludes that the means and procedures in place to manage iceberg threats (to be outlined in the WHP Ice Management Plan) ensure that the risk to personnel, the environment and the asset is low and that shutdown and down-manning can be achieved successfully when required with a probability greater than 90%. In particular, the success rate for down-manning of non-essential personnel, which could be undertaken as a precaution on a more frequent basis, is estimated to be greater than 99.5%.

However, it should be noted that this down-manning assessment is still being further analyzed by Husky to optimize down-manning and is subject to ongoing review by the

C-NLOPB, particularly in relation to ice monitoring and effectiveness of ice management measures, operational T-Time calculations and the time required to safely down-man the platform.

On the basis that the WHP is designed to withstand a 1 in 1,000 year iceberg collision and that the platform would be evacuated prior to iceberg impact, the risk to personnel directly associated with an iceberg collision is considered negligible. There may be a residual risk associated with the down-manning/evacuation of personnel, but as the impairment event frequency is low, and the down-manning assessment is still being revised, risks to personnel associated with iceberg collision are not quantified in this assessment. It is recommended that a quantified assessment of risks to personnel as a result of iceberg collision is included in the detailed design QRA once issues regarding the L2 classification are closed out.

Shutting down drilling and production operations, closing all isolation valves (including subsurface, wellhead and riser isolation valves) and flushing the production flowlines, minimizes any potential environmental impact, and hence the potential for an oil spill due to iceberg collision is not considered further in this assessment.

11.1.2 Iceberg Scour

Well fluids will be exported to the SeaRose FPSO via two production flowlines and gas will be imported via a gas import flowline. These flowlines could be exposed to iceberg scour, resulting in a breach and subsequent hydrocarbon release.

However, as discussed in Section 11.1.1, a controlled down-manning of the platform would be initiated in the event of a significant iceberg threat. In addition, the production flowlines would be isolated and flushed with sea water to minimize any potential environmental impact.

It is not therefore considered that hydrocarbon releases due to iceberg scouring represent a risk to personnel on the WHP or to the environment.

11.1.3 Sea Ice

Sea ice can occur in the White Rose area, particularly during the spring months. Sea ice can create loads on the CGS (see Section 11.1.4). Sea ice can also affect the movement of standby vessels and supply vessels, and, in an emergency, the launching of lifeboats and liferafts.

However all vessels contracted by Husky that perform standby activities comply to DNV ice class ICE-1C and are therefore suitably ice-strengthened to permit their use in most sea ice conditions. The standby vessels should therefore be capable of performing their duty in an emergency even if sea ice is present.

11.1.4 Ice Accretion

The WHP is located in an area where ice accretion may occur, with the possibility of ice accumulation on decks, superstructure and process equipment from freezing sea spray and atmospheric precipitation, resulting in ice loading.

The topsides is located approximately 30 metres above sea level, therefore freezing sea spray is not considered to affect the WHP topsides.

For the purposes of this assessment, it is assumed that the topsides and superstructure will be appropriately designed for anticipated ice thickness and density levels. This assumption should be reviewed at detailed design stage.

In addition, winterization procedures will be established in order to ensure that ice loading is limited to acceptable limits for the facility.

Based on this discussion, it is not considered that ice loading leading to structural damage is a significant risk to personnel or to the environment.

11.2 Ship Collision

Risk from ship collision falls into two categories: risk due to impact from passing vessel and risk due to impact from infield vessels. Infield vessels are those that have a specific function associated with the platform, such as supply and standby vessels.

Each of these is discussed in the following subsections, based on a study of possible vessel collisions with the WHP (Ref. 23).

11.2.1 Infield Vessels

Infield vessel collisions with offshore installations occur more frequently than passing ship collisions, with little or no warning. The main causes of an infield (or authorized) vessel colliding with an installation are likely to be loss of power, and therefore steering, or pilot error, neither of which should result in a high energy collision.

Ref. 23 estimates an infield vessel impact frequency of 4.20×10^{-2} per year, which is based on UK incident data for ship/installation collisions and taking into account the frequency of visits and types of vessels that will operate in the vicinity of the WHP. From Ref. 23, 99% of these collisions have a predicted impact energy below 20MJ, and the frequency of a collision with an impact energy above 35MJ is estimated to be considerably lower than 1×10^{-6} per year.

Studies are ongoing to determine the ability of the CGS to withstand powered vessel collisions. However, given the low frequencies estimated in Ref. 23, the risk to personnel on the WHP due to collisions from infield vessels is considered to be negligible and is not discussed further in this assessment.

Although there is potential for a vessel collision to result in localised damage to the shaft, there are no hydrocarbons in the wall of the shaft and the shaft is not used for storage of hydrocarbons. Therefore, breaching of the shaft wall will not result in a release. In addition, there are no conductor frames situated in the potential vessel impact zone and hence an infield vessel collision is also unlikely to result in damage to a conductor.

Therefore, there is considered to be negligible risk associated with infield vessel collision with the CGS resulting in a release of hydrocarbons.

11.2.2 Passing Vessels

Ref. 23 estimates collision frequencies for passing powered vessels, passing drifting vessels, shuttle tankers associated with the SeaRose FPSO operations and drilling MODUs operating in the White Rose field. These are discussed in the following subsections.

11.2.2.1 Passing Powered Vessels

Collisions between passing vessels and offshore installations are relatively infrequent, but, if they do occur, have the potential to be high energy resulting in significant structural damage to an installation or damage to process equipment.

Ref. 23 estimates the frequency of passing ship collisions with the WHP as 3.8 x 10^{-6} per year, based on shipping data from the White Rose area. Ref. 23 also estimates that the vast majority of these collisions will be high energy, with an impact energy greater than 100MJ.

For the purposes of this assessment, it is assumed that a high energy passing vessel impact will cause significant damage to the platform. In such situations, it is therefore assumed in the risk assessment that an emergency evacuation by lifeboat would be initiated. An emergency evacuation fatality rate of 8.8%, i.e. twice the weather averaged precautionary evacuation fatality rate, is assigned. This takes account of the fact that the evacuation is not being undertaken in normal circumstances. In addition, damage to the platform may adversely affect the launch capability of the TEMPSCs.

Although a passing powered vessel collision could result in significant damage to the shaft and to the topsides, the environmental risk is considered to be very low compared to the environmental risk associated with other hazards due to the fact that:

- A high energy passing powered vessel collision is a very low frequency event.
- Any large passing vessels that are on a collision course with the platform are likely to be detected, allowing for the platform to be shutdown and hence minimizing the potential size of a release.

11.2.2.2 Passing Drifting Vessels

In the event of a passing vessel losing power and drifting towards the WHP, there is potential for a collision, which given the low collision speed is likely to result in a low energy impact.

Ref. 23 estimates a frequency of drifting vessel collisions with the WHP of 1.6 x 10^{-7} per year. Due to the low frequency, the fact that an infield vessel may be able to assist a drifting vessel (not accounted for in the frequency assessment in Ref. 23) and the fact that drifting vessel collisions are likely to result in low impact energies, the risks to personnel on the WHP and to the environment due to passing drifting vessel collisions are considered negligible.

11.2.2.3 Shuttle Tankers

Shuttle tankers visit the SeaRose FPSO when offloading, which is located approximately 3.5km to the East of the WHP. Ref. 23 estimates the annual frequency of collisions from shuttle tankers associated with the SeaRose FPSO offloading operations.

It is assumed during passage to and from the FPSO, the tankers will follow procedures prescribing a safe minimum passing distance from the WHP. It is further assumed that when shuttle tankers are waiting within the White Rose field, they will do so at a safe distance and not up-weather of the platform. Therefore, a collision with a shuttle tanker is only likely to occur in the event of a drifting (as a result of engine failure and dependent on wind direction) or drive-off event (due to DP (Dynamic Positioning) failures, human error, etc.).

Due to the distance between the FPSO and the Wellhead Platform (WHP), Ref. 23 concludes that the shuttle tanker collision risk with the WHP is low and a collision frequency of less than 1 x 10^{-6} is estimated, with the majority of these collisions having low impact energies (less than 20MJ). The risks to personnel on the WHP and to the environment from shuttle tanker collisions are therefore considered to be negligible and are not discussed further in this assessment.

11.2.2.4 MODU

There will be drilling MODUs operating in the subsea drill centers within the White Rose Field that have the potential for a collision in the event of a MODU drifting or dragging anchor towards the WHP, for example, in the event of mooring line failure.

Ref. 23 estimates a collision frequency of 2.5×10^{-5} per year for a MODU operating at the Central Drill Centre (which is closest to the WHP at a distance of 1.5km). Based on the distances between the drilling locations and the WHP meaning there is a good prospect of the MODU being recovered prior to collision. Collisions with a drifting MODU are likely to be low energy and the risks to personnel on the WHP and to the environment are therefore considered negligible.

11.2.3 Risk Summary

The PLL for ship collision events is 4.8×10^{-5}, which is attributable to passing powered vessel collision resulting in significant damage to the platform.

The risk to the environment associated with ship collision is considered to be negligible compared to that for other hazards and is not quantified in this assessment.

11.3 Helicopter Transportation

Helicopter accidents during take-off and landing and in-flight are considered, and the risk assessment takes account of:

- The likelihood of a helicopter accident (per flying hour and per take-off/landing).
- The probability that an accident is a ‘fatality accident’.
- The probability of each individual onboard being fatally injured in the event of a fatality accident.

The maximum environmental impact in the event of a helicopter crash is limited to the volume of the helicopter fuel tank, and therefore environmental risk associated with helicopter transportation is not considered further in this assessment.

Helicopter accident data is provided in Ref. 24 for three regions:

- North Sea.
- Gulf of Mexico.
- Rest of the world.

Ref. 24 suggests that North Sea data is most representative of operations in Atlantic Canada, in terms of helicopter type/age, maintenance, pilot training and weather conditions. For the purposes of this assessment, North Sea data related to heavy-lift twin engine helicopters is used, as this is considered the most relevant for White Rose helicopter operations.

11.3.1 WHP Helicopter Operations

It is assumed that there will be 230 return flights per year between the heliport and the WHP. Of these, it is assumed that 110 will be direct and 120 will stop at another installation en route.

It is also assumed that:

- Each flight to, or from, the WHP will take 1.75 hours.
- If the flight stops at another installation, it will increase the flight duration by 0.5 hours.
- An average of 13 persons will be transferred on each flight.

11.3.2 Helicopter Transport Risk, In-Flight

Ref. 24 indicates an in-flight ('cruise') helicopter accident frequency of 6.39×10^{-6} per flying hour. The in-flight accident frequency is calculated to be:

$$6.39 \times 10^{-6} \times (2 \times 110 \times 1.75 + 2 \times 120 \times 2.25) = 5.91 \times 10^{-3} \text{ per year.}$$

For in-flight accidents, it is assumed, based on Ref.24, that the probability that any accident is a fatality accident is 0.42 and that the probability of fatal injury for each individual in the accident is 0.79. Therefore, the overall fatality rate for an in-flight accident is 0.33. Accounting for the numbers of persons being transferred on each flight, the PLL due to in-flight helicopter accidents is:

$$5.91 \times 10^{-3} \times 0.33 \times 13 = 2.54 \times 10^{-2} \text{ per year.}$$

With respect to the helicopter crew, the PLL is 3.90×10^{-3} per year.

The Individual Risk Per Annum (IRPA) is estimated taking into account that an individual will undertake an average of 17.3 one-way flights per year (based on a 3 week offshore/onshore rotation). The IRPA due to in-flight helicopter accidents is therefore:

$$6.39 \times 10^{-6} \times 17.3 \times ((120/230) \times 2.25 + (110/230) \times 1.75)) \times 0.33 = 7.34 \times 10^{-5}.$$

11.3.3 Helicopter Crash Frequency, Take-Off and Landing

Ref. 24 indicates a departure/arrival helicopter accident rate of 1.42×10^{-6} per flight stage. Therefore, take-off/landing accident frequency is calculated to be:

$$1.42 \times 10^{-6} \times (2 \times (230 + 120)) = 9.94 \times 10^{-4} \text{ per year.}$$

For accidents during take-off and landing, it is assumed, based on Ref. 24, that the probability that any accident is a fatality accident is 0.44 and that the probability of fatal injury for each individual in the accident is 0.29. Therefore, the overall fatality rate for an accident on take-off or landing is 0.13. Accounting for the numbers of persons being transferred on the flights, the PLL due to take-off/landings helicopter accidents is:

$$9.94 \times 10^{-4} \times 0.13 \times 13 = 1.68 \times 10^{-3} \text{ per year.}$$

With respect to the helicopter crew, the PLL is 2.58×10^{-4} per year.

As discussed in Section 11.3.2, the Individual Risk Per Annum (IRPA) is estimated taking into account that an individual will undertake an average of 17.3 one-way flights per year. The IRPA due to take-off/landings helicopter accidents is therefore:

$$1.42 \times 10^{-6} \times 17.3\ (2 \times (120/230) + (110/230)) \times 0.13 = 4.86 \times 10^{-6}.$$

11.3.4 Risk Summary

Table 11.1 presents the PLL associated with helicopter transportation accidents. Fatalities in the event of a helicopter crash are classified as immediate fatalities.

Flight Stage	PLL
During Flight	2.5×10^{-2}
During Take-off/Landing	1.7×10^{-3}
TOTAL	2.7×10^{-2}

Table 11.1: Risk Summary, PLL (Helicopter Transportation)

As discussed, the environmental impact in the event of a helicopter crash is limited to the volume of the helicopter fuel tank, and the environmental risk is therefore considered negligible compared to that for other hazards.

11.4 Seismic Activity

The Grand Banks is classified as an area of relatively low seismic activity. However, in 1929 an earthquake of magnitude 7.2 occurred approximately 650 km from the White Rose field. This earthquake resulted in a large tsunami (seismic sea-wave) which drowned 28 people.

Ref. 25 contains requirements for defining seismic design procedures and criteria for offshore structures. Based on Ref. 25, a comprehensive probabilistic seismic hazard assessment (Ref. 26) has been undertaken that estimates a return period for the bedrock ground motion of 725 years for the Extreme Level Earthquake (ELE) and a return period of 3,190 years for the Abnormal Level Earthquake (ALE).

Under an ELE event, the structure and topsides should sustain little or no damage. However, an ALE could result in structural stresses exceeding yield. For the purposes of this assessment, it is considered that, in 10% of ALE events, significant damage to the platform and the TR will occur and an emergency evacuation will be required. An evacuation fatality rate of 8.8% is assigned, twice the precautionary evacuation fatality rate discussed in Section 7.8.5, to account for the fact that the evacuation may take place under TR impairment conditions and that the evacuation systems may also have been impaired.

In the remaining 90% of cases, it is assumed that the integrity of the TR is threatened (rather than impaired). In such a scenario, it is considered that the OIM will not wait for TR impairment conditions to arise but will initiate an evacuation under controlled conditions as a precautionary measure, to safeguard personnel against sudden escalation of a potentially severe event. A weather-averaged precautionary evacuation fatality rate of 4.4% is assumed (see Section 7.8.5).

Damage to the topsides in the event of structural failure could present an environmental risk if hydrocarbons are released. As a seismic event could occur with no warning, there is potential for damage to the hydrocarbon containing equipment to occur with the platform still operational. There is also potential for damage to result in a well failing to shut-in, although the likelihood of this occurring is minimized by the redundancy in the well isolation system and the provision of Subsurface Isolation Valves. For the purposes of this assessment, the following is considered in the event of an ALE event resulting in significant damage to the platform:

- In 25% of cases, it is assumed that the damage to the platform will not be sufficient to result in any hydrocarbons being released.
- It is conservatively assumed that there is a 5% chance of having a spill of greater than 10,000bbls, on the basis that there is potential for a well to fail to shut-in.
- In the remaining 70% of cases, it is assumed that a hydrocarbon release occurs, but that the volume of hydrocarbons released will be limited to that contained within the topsides inventory or flowlines (taken to be between 50bbls and 1,000bbls).

It is assumed that any oil released will enter the sea.

As discussed above, as a result of an ELE event, the structure and topsides should sustain little or no damage and the potential for hydrocarbons to be released is therefore not considered here.

The event tree assessment of risk to platform personnel and the environment for seismic activities is shown in Appendix 10.

Table 11.2 presents the PLL associated with seismic activity. A summary of the environmental risk associated with seismic activity is presented in Table 11.3.

Fatality Classification	PLL
Precautionary Evacuation	1.8×10^{-3}
TR Impairment	4.0×10^{-4}
TOTAL	2.2×10^{-3}

Table 11.2: Risk Summary, PLL (Seismic Activity)

	All Spills	>50bbls	>1,000bbls	>10,000bbls
Frequency of Oil Spill into Sea (per Year)	2.3×10^{-5}	2.3×10^{-5}	1.6×10^{-6}	1.6×10^{-6}

Table 11.3: Environmental Risk Summary (Seismic Activity)

11.5 Structural Failure due to Extreme Weather

It is assumed that the platform will be designed to withstand appropriate wind and wave forces likely to be experienced during its design life, as defined in Ref. 15. The structure will be assessed under a number of design actions and action combinations in accordance with the relevant design codes. Extreme and abnormal level events will be based on annual probability of exceedance of 10^{-2} and 10^{-4}, respectively.

Under an extreme event, the structure and topsides should sustain little or no damage. However, an abnormal event could result in stresses exceeding yield. For the purposes of this assessment, it is considered that, in 10% of abnormal level events, significant damage to the platform and the TR will occur and an emergency evacuation will be required.

The platform will have extreme weather warning/contingency plans. For example, given advanced warning, if extraordinarily severe weather is anticipated the platform could be shutdown and personnel transferred to a place of safety. For the purposes of this assessment, it is considered that, in 90% of cases, an abnormal event will be forecast with sufficient warning for personnel to be transferred to a place of safety before it occurs.

In the event that sufficient warning does not exist then a high fatality rate (50%) is considered to account for the fact that the evacuation may take place under TR impairment conditions, that the evacuation systems may also have been impaired and that the sea conditions are likely to significantly affect rescue operations.

In the remaining 90% of cases, it is assumed that the integrity of the TR is threatened (rather than impaired). In such a scenario, it is considered that the OIM will not wait for TR impairment conditions to arise but will initiate an evacuation to safeguard personnel against sudden escalation of a potentially severe event. A weather-averaged precautionary evacuation fatality rate of 4.4% is assumed (see Section 7.8.5).

Damage to the topsides in the event of structural failure could present an environmental risk if hydrocarbons are released. However, the frequency of extreme weather resulting in structural failure is low and such extreme weather conditions are unlikely to develop rapidly, allowing time for the platform to be completely shutdown and the wells shut in before any structural failure occurs. Therefore, the environmental risk resulting from structural failure due to extreme weather is considered negligible compared to the environmental risk for other hazards.

The event tree assessment of risk to platform personnel for structural failure is shown in Appendix 11.

Table 11.4 presents the PLL associated with extreme weather.

Fatality Classification	**PLL**
Precautionary Evacuation	5.7×10^{-5}
TR Impairment	7.2×10^{-5}
TOTAL	1.3×10^{-4}

Table 11.4: Risk Summary, PLL (Structural Failure due to Extreme Weather)

11.6 Dropped Objects

The major hazard associated with dropped objects, which may occur due to human error or mechanical failure, is the potential for loss of hydrocarbon containment following impact on process equipment.

Dropped object events leading to loss of hydrocarbon containment are implicitly accounted for in the historical leak frequencies derived from hydrocarbon release databases and accounted for in the hydrocarbon release risk assessment (see Sections 7, 8 and 10).

In addition, it is assumed that the following measures will be in place to prevent a dropped object event resulting in a hydrocarbon release:

- Procedures to ensure that lifting devices are appropriately operated and maintained.
- Procedures to restrict lifts over equipment containing hydrocarbons.
- Appropriate procedures to restrict lifting heights where necessary.
- Decks over which lifting will occur designed to withstand most credible dropped load events.
- Appropriate protection provided for pressurized and critical equipment over which lifting may occur.
- Appropriate protection provided for flowlines and umbilicals/cables close to the WHP.

Therefore, risks to personnel or the environment associated with dropped objects are not explicitly quantified in this risk assessment.

However, there are a number of dropped object studies being undertaken, including studies relating to an assessment of the dropped object risks associated with drilling, impacts on topsides hydrocarbon equipment, impact on subsea flowlines and manual handling.

It is recommended that these studies should be revised as necessary at detailed design stage in order to ensure that the proposed procedures are adequate and:

- Either confirm the above assumption that the risk due to dropped objects need not be explicitly quantified.
- Or identify events that should be considered in the design-stage QRA.

12.0 Risk Summary and Conclusions

12.1 Potential Loss of Life

The Potential Loss of Life (PLL) for a hazard is the average number of fatalities per year on the installation resulting from that hazard. For each hazard identified, PLL is calculated as:

PLL = Hazard Frequency (per year) x Potential Fatalities

Table 12.1 summarizes the risk assessment by presenting the PLL for each major hazard, assessed as described in the previous sections.

Hazard	PLL				Total
	Fatality Classification				
	Immediate	Escape/ Escalation	Precautionary Evacuation	TR Impairment	
Process Loss of Containment	0.016	0.001	0.0014	0.000079	0.018
Blowouts	0.0029	0.000031	0.0061	0.0019	0.011
Releases Below the Platform Topsides[1]	-	-	-	-	-
Subsea Flowline Releases	0.000016	-	0.000024	0.000023	0.000063
Ice Hazards[1]	-	-	-	-	-
Ship Collision	-	-	-	0.000048	0.000048
Helicopter Transportation	0.027	-	-	-	0.027
Seismic Activity	-	-	0.0018	0.0004	0.0022
Structural Failure due to Extreme Weather	-	-	0.000057	0.000072	0.00013
Dropped Objects[1]	-	-	-	-	-
TOTAL	0.046	0.001	0.0094	0.0025	0.058

1: Risk to personnel not quantified. However, the likelihood and consequences should be reviewed at detailed design stage to ensure that risks are ALARP.

Table 12.1: Risk Summary, PLL

12.2 Individual Risk per Annum

To assess the risk to each individual on the installation, it is necessary to normalize the PLL calculation to account for the distribution of risk over the entire population of the installation. This can be achieved by calculating an average individual risk per annum (IRPA), which is defined as the average annual risk to an individual on the installation. It can be calculated as:

$$IRPA = \frac{PLL}{POB} \text{ x Exposure}$$

where 'exposure' is the proportion of the year that an individual would spend at the installation. This is taken to be 0.5 (based on a 3 week offshore/ 3 week onshore rotation).

For helicopter risks, the IRPA is estimated as discussed in Section 11.3.

Table 12.2 presents the average IRPA for platform personnel calculated for each major hazard assessed.

Hazard	Average IRPA				Total
	Fatality Classification				
	Immediate	Escape/ Escalation	Precautionary Evacuation	TR Impairment	
Process Loss of Containment	5.6×10^{-5}	3.5×10^{-6}	4.9×10^{-6}	2.7×10^{-7}	6.5×10^{-5}
Blowouts	1.0×10^{-5}	1.1×10^{-7}	2.1×10^{-5}	6.6×10^{-6}	3.8×10^{-5}
Releases Below the Platform Topsides[1]	-	-	-	-	-
Subsea Flowline Releases	5.6×10^{-8}	-	8.3×10^{-8}	8.0×10^{-8}	2.2×10^{-7}
Ice Hazards[1]	-	-	-	-	-
Ship Collision	-	-	-	1.7×10^{-7}	1.7×10^{-7}
Helicopter Transportation	7.8×10^{-5}	-	-	-	7.8×10^{-5}
Seismic Activity	-	-	6.3×10^{-6}	1.4×10^{-6}	7.7×10^{-6}
Structural Failure due to Extreme Weather	-	-	2.0×10^{-7}	2.5×10^{-7}	4.5×10^{-7}
Dropped Objects[1]	-	-	-	-	-
TOTAL	1.4×10^{-4}	3.6×10^{-6}	3.2×10^{-5}	8.8×10^{-6}	1.9×10^{-4}

1: Risk to personnel not quantified. However, the likelihood and consequences should be reviewed at detailed design stage to ensure that risks are ALARP.

Table 12.2: Risk Summary, IRPA

Individual risk figures are calculated taking into account:

- The proportion of time individuals spend in each location, based on the personnel distributions given in Table 6.1.
- The predicted frequency of hazardous events to which individuals are exposed in each location.
- The impact of those hazardous events, in terms of predicted fatality rates.

12.3 Societal Risk

Societal risk is a measure of the likelihood of multiple fatality accidents, and can be expressed as the frequency of accidents involving fatalities above a specified level.

The most common representation of societal risk is in the form of an F-N (Frequency-Number) curve. An F-N curve is a plot of the frequency distribution of multiple fatality accidents, where F is the cumulative frequency of all events leading to N or more fatalities.

Figure 12.1 shows the F-N curve estimated for the assessment and compares the curve to Husky's societal risk criteria in Section 4.2.

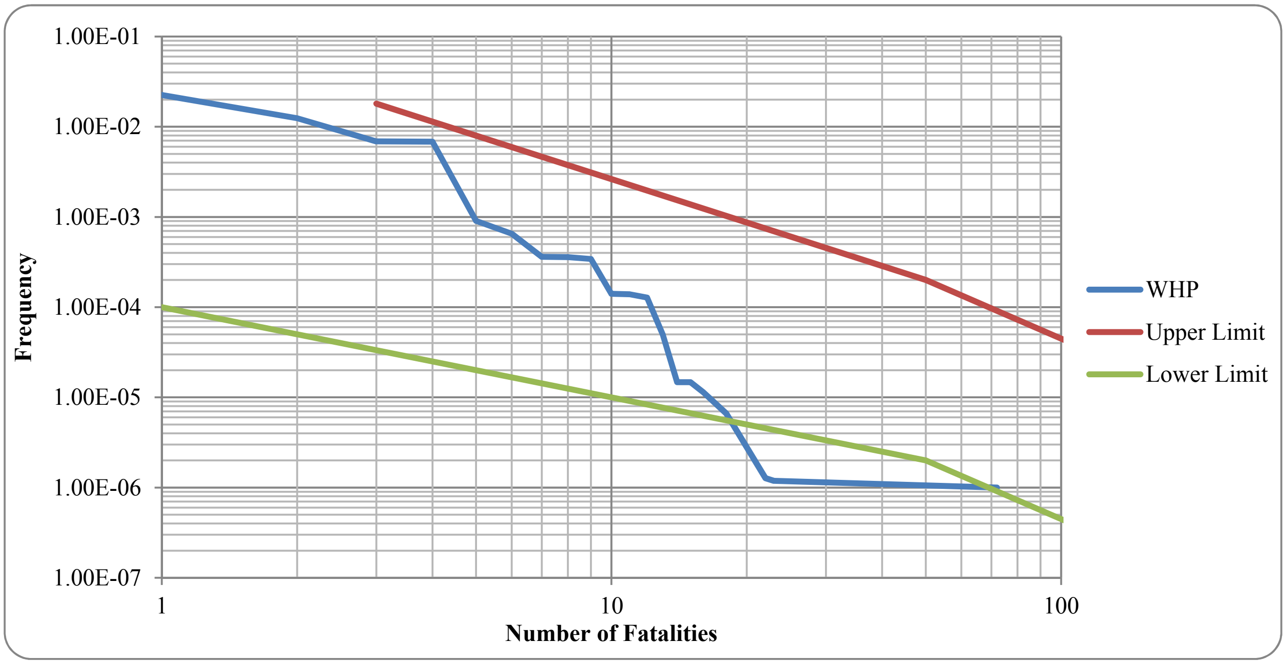


Figure 12.1: F-N Curve

12.4 Environmental Risks

Table 12.3 presents, annual exceedance frequencies for volumes of oil spilled into the sea based on the assessment of environmental risks associated with the major hazards discussed in Sections 7 to 11.

	Frequency of Oil Spilled into the Sea (per Year)			
Hazard	**All Spills**	**>50bbls**	**>1,000bbls**	**>10,000bbls**
Process Loss of Containment	5.9×10^{-2}	6.8×10^{-3}	3.0×10^{-5}	-
Blowouts[1]	-	-	-	-
Releases Below the Platform Topsides[2]	-	-	-	
Subsea Flowline Releases	5.8×10^{-3}	5.8×10^{-3}	4.6×10^{-3}	-
Ice Hazards[3]	-	-	-	-
Ship Collision[2]	-	-	-	-
Helicopter Transportation[2]	-	-	-	-
Seismic Activity	2.3×10^{-5}	2.3×10^{-5}	1.6×10^{-6}	1.6×10^{-6}
Structural Failure due to Extreme Weather[2]	-	-	-	-
Dropped Objects[3]	-	-	-	-
TOTAL	6.5×10^{-2}	1.3×10^{-2}	4.6×10^{-3}	1.6×10^{-6}

1: The environmental risks associated with blowouts have been reviewed against the assessment of environmental risks in the EA (Ref. 2 and Ref. 3) and have been demonstrated to be consistent. Environmental risks associated with blowouts are therefore not quantified in this assessment.

2: Risk to the environment considered to be negligible compared to that for other hazards.

3: Risk to the environment not quantified. However, the likelihood and consequences should be reviewed at detailed design stage to ensure that risks are ALARP.

Table 12.3: Environmental Risk Summary

The environmental effects from activities associated with the WHP project have been assessed in the Environmental Assessment (Ref. 2 and 3) submitted as part of Husky's Development Plan, in order to consider the potential impact on Valued Environmental Components (VECs), such as:

- Air quality.
- Fish and fish habitat.
- Commercial fisheries.
- Marine birds.
- Marine mammals and sea turtles.
- Species at risk (marine fish, mammals, birds and reptiles).

- Sensitive areas.

The potential impact on VECs is evaluated based on consideration of a number of subject variables, including:

- Likelihood of occurrence of the accident, malfunction or unplanned event.
- Size of an oil spill.
- Duration of spill.
- Geographical extent of spill.
- Consequences of the accident, malfunction or unplanned event.
- Ability of the VEC to return to pre-spill levels.

The environmental assessment is based on specific modelling undertaken for the White Rose Field and included air quality dispersion, underwater noise, dredging, drill cuttings deposition, synthetic-based mud whole mud spill trajectory and near shore and offshore oil spill trajectories.

In general, the conclusion for each VEC identified and assessed within the assessment is that implementation of the proposed mitigation measures should mean any environmental effects will not be significant during the construction, installation, operation and maintenance phases of the WHP. Marine birds (including those species at risk) could potentially be exposed to significant residual adverse environmental effects in the event of a large or prolonged oil spill, the likelihood of which is considered to be low due to the design and maintenance of hydrocarbon containing equipment/piping, pollution prevention measures and emergency response procedures to be put in place.

Regulatory requirements for environmental protection will be used to develop a WHP Environmental Protection and Compliance Monitoring Plan (EPCMP). All monitoring results will be analyzed to ensure that compliance limits are met and environmental exceedances are avoided. Husky conducts periodic reviews of compliance information in order to determine priorities for improvement initiatives.

The Husky White Rose Environmental Effects Monitoring (EEM) program will also be revised to include monitoring of the effects associated with operation of the WHP. The EEM is intended to provide the primary means by which to determine and quantify project-induced change in the surrounding environment and currently includes a fish habitat compensation monitoring program, marine mammal and sea turtle observation program and, in the event of a spill, marine bird effects monitoring.

12.5 Conclusions

Review of Table 12.1 indicates that the largest contributors to risk to personnel on the White Rose WHP are:

- Helicopter transportation (accounting for approximately 47% of overall platform risk, in terms of PLL).

- Process loss of containment events resulting in immediate fatalities (approximately 28% of overall platform risk).
- Blowout events resulting in evacuation fatalities (approximately 10% of overall platform risk).

A review of the adequacy of potential risk reduction measures to prevent, mitigate and safeguard against these main risk contributors should be undertaken at detailed design stage, in order to ensure that risks are ALARP.

The risk from blowouts will decrease significantly once the frequency of drilling activities decreases, as the blowout risk associated with drilling activities is greater than that associated with well activities carried out on production wells.

Comparison of the Individual Risk levels in Table 12.2 with the Husky Target Levels of Safety (presented in Section 4.1) concludes that risks are below the intolerable IR criterion threshold of 5×10^{-4} per year, and within the 'ALARP' region defined by the criteria.

Comparison of the societal risk levels in Figure 12.1 with the Husky Target Levels of Safety (presented in Section 4.2) concludes that all frequencies are below the upper limit defined by the criteria.

From Figure 12.1, it can be seen that the frequencies of hazards resulting in 3 or 4 fatalities approach the intolerable threshold. The main contributors to these frequencies are:

- Fatal in-flight helicopter accidents.
- Unisolated ignited process releases.

To comply with the Target Levels of Safety, it will also be necessary to show, for hazards that are assessed as being in the ALARP region, that all practicable means of risk reduction have been employed to ensure that the risk is demonstrably ALARP. To achieve, this cost benefit studies may be required at detailed design stage to ensure that appropriate measures of risk reduction are incorporated into the final design.

It is concluded that there are no areas for concern that could prevent demonstration that risks have been reduced to a level that is ALARP at the detailed design stage. Further detailed studies will, however, be required at detailed design stage, to confirm or refine the assumptions that have been made in this Concept Safety Analysis.

As discussed in Section 4.3, the spill frequencies for topsides releases that result in a spill of oil into the sea estimated in the WHP EA are used in this assessment as a benchmark against which the CSA results on environmental impacts can be compared. The data presented in the EA is based on historical data from Newfoundland and Labrador operations and from the Gulf of Mexico (US data).

Table 12.4 presents frequencies for platform topsides releases that result in oil spilled into the sea based on the frequencies from the EA presented in Section 4.3 and taking into account the 19 production wells considered in this assessment (Section 8). Table 12.4 also presents the corresponding frequencies estimated in this assessment for topsides releases on the WHP (taken from Table 12.3) to allow comparison.

Volume of Oil Spilled into Sea	**Historical Exceedance Frequency per Year (Benchmark)**	**WHP Exceedance Frequency per year (CSA Results)**
All	13	5.9×10^{-2}
> 50 bbls	9.4×10^{-3}	6.8×10^{-3}
> 1,000 bbls	2.9×10^{-4}	3.0×10^{-5}
> 10,000 bbls	1.0×10^{-4}	-

Table 12.4: Environmental Risk Comparison Against Benchmark (Process Loss of Containment)

It can be seen, from comparison of the frequencies in Table 12.4, that the total frequency of oil spilled into the sea estimated in the CSA is lower than that considered in the EA (Ref. 2 and Ref. 3) for all spill sizes.

13.0 Sensitivity Analysis

Risk assessment is essentially a predictive process. As for any predictive process, the results are subject to uncertainty, especially when undertaken early in the Project life cycle.

Where there is reliable published data or models (such as Ref. 7 and Ref. 9), this data has been used with limited or no conservative bias applied.

However, where significant uncertainty exists in the data used to estimate frequency or consequence, a conservative bias is has been applied. To address this, sensitivity studies were previously undertaken (Rev. E1 of this CSA) for a number of these assumptions to ensure that the information used was robust and appropriate at that stage of the Project. Specifically studies were performed considering the effect of varying the isolation probabilities and lifeboat precautionary evacuation fatality rates.

The results of those studies showed that whilst varying the isolation probabilities had a negligible effect on risk, changing the precautionary evacuation fatality rate did have a significant effect on the overall risk levels. Therefore, this revision of the CSA accounts for a refined precautionary evacuation fatality rate, as described in Section 7.8.5.

No additional sensitivity studies have been undertaken in this latest revision of the CSA. Where it has still been necessary to make a number of assumptions within the CSA, recommendations are made to refine the assessment in the QRA to be undertaken at detailed design (refer to Section 14).

14.0 Recommendations

Where uncertainty exists in the risk analysis, conservative assumptions (that is, assumptions that over-estimate the risk, rather than under-estimate the risk) have been made. Several recommendations have therefore been made in this report advising that these assumptions should be reviewed and revised at detailed design stage, when more detailed information is available, to facilitate a more robust and representative assessment.

This section therefore summarizes the recommendations made in this report, all of which Husky has committed to addressing during detailed design.

1. The dropped object studies that are currently being undertaken should be revised as necessary, to either confirm the assumptions made in this assessment or identify specific dropped object events that should be explicitly considered in the detailed design stage QRA (Section 5.1).

2. Consideration should be given to performing a parts count, based on piping and instrumentation drawings, in order to refine leak frequency estimates (Section 7.2).

3. An assessment of the number of valves that would have to operate successfully to ensure isolation and blowdown (where relevant) of each inventory should be undertaken for the detailed QRA, once Piping and Instrumentation Diagrams are finalized (Section 7.5).

4. Detailed smoke, gas and flame modelling studies, and escape, evacuation and rescue, including TR impairment, studies should be performed (Section 7.8.5).

5. Consideration should be given to developing a detailed model to quantitatively assess the effectiveness of the ice monitoring and management procedures, in order to confirm the conclusion that risks associated with iceberg impact are negligible (Section 11.1.1).

6. The assessment of risk due to ship collision should be refined, if necessary, following completion of ongoing studies to determine the ability of the CGS to withstand powered vessel collisions (Section 11.2).

7. A review of the adequacy of potential risk reduction measures to prevent, mitigate and safeguard against the scenarios identified in Section 12.5 as major risk contributors should be undertaken.

In addition, all assumptions made in the assessment should be reviewed, in developing the detailed QRA for the project, in order to ensure that they remain valid and appropriate.

Two of the recommendations made in Revision E1 of this CSA are no longer included as they have been implemented (Recommendation 4 in Revision E1 related to determining an appropriate precautionary evacuation fatality rate (see Section 13) and Recommendation 8 related to ice-strengthening of support and standby vessels (see Section 11.1.3).

15.0 References

1. Quantitative Safety Risk Criteria, Husky Energy Document No. 53495880, Rev. 1, January 2011.
2. White Rose Extension Project Environmental Assessment, Husky Energy Document No. WH-HSE-RP-0001, 2012.
3. Consolidated Response to Review Comments on the White Rose Extension Project Environmental Assessment and Addendum, Husky Energy Document No. WH-DWH-RP-0031, Rev. 1, 2013.
4. Register of Identified Hazards, RMRI Ref. No. ARU/0383, Technical Document 001, Rev. 3, May 2014.
5. The Hydrocarbon Releases (HCR) System Database, HSE, Data from 1992 to 2012.
6. A Guide to Quantitative Risk Assessment for Offshore Installations, CMPT, CMPT Publications 99/100, 1999.
7. Ignition Probability Review, Model Development and Look-up Correlations, Energy Institute, January 2006.
8. Quantitative Risk Assessment Datasheet Directory, E&P Forum, Report 11.8/250, 1996.
9. OREDA 2009, Offshore Reliability Data, Prepared by Sintef, 2009.
10. The Effects of Explosions in the Process Industries, Institute of Chemical Engineers, 1989.
11. TEMPSC Structural Design Basis Determination, Part 3 – Event Levels and Safety Margins, UK HSE Research Report 2000, 2004.
12. Performance Assessment of Davit-Launched Lifeboats, OMAE2008-57734, 2008.
13. Annual Environmental Data Summary White Rose 2008-2012, Husky Energy.
14. OGP Risk Assessment Data Directory, Blowout Frequencies, Report No. 434 – 2, International Association of Oil and Gas Producers, March 2010.
15. Wellhead Platform Basis of Design, White Rose Extension Project, Husky Document No. WH-G-99W-G-SP-00002-001, Rev. E1, October 2013.
16. Assessment of Riser Design on the White Rose Wellhead Platform, White Rose Extension Project, Husky Document No. WH-G-80W-X-RP-00008-001, Rev. B1, Husky Energy, October 2013.
17. PARLOC 2001: The Update of Loss of Containment Data for Offshore Pipelines, Published by Energy Institute, London, 5th Edition, July 2003.
18. CAN/CSA-ISO 19906:11 Petroleum and Natural Gas Industries – Arctic Offshore Structure.
19. Wellhead Platform: Husky Energy Wellhead Platform Class L2 Exposure Level Submission – C-NLOPB, Husky Document No: WH-B-87W-G-RP-00001-001, Rev. E1, September 2013.
20. Ice Design Basis, White Rose Extension Project, Husky Energy, Document No. WH-B-87W-S-PY-00005-001, Rev. B1, November 2013.

21. Iceberg Design Loads and Topsides Risk Assessment, White Rose Extension Project, Husky Energy, Document No. WH-B-87W-S-CA-00001-001, Rev. P3, April 2013.
22. WHP Quantitative Assessment Study for L2 Classification, Wellhead Platform, Husky Energy, Document No. WH-HSE-RP-0019, Rev. E1, October 2013.
23. Collision Risk Assessment White Rose Field Wellhead Platform, Anatec Ltd, Ref: A3289-ATK0RA-1, Rev. 03, February 2014.
24. An Analysis of Helicopter Accident Statistics, Husky Energy Document No. WR-HSE-RP-1158, Rev. 02, 2009.
25. CAN/CSA-Z19901-2-07ISO: 19901-2 (2004). Petroleum and Natural Gas Industries-Specific requirements for Offshore Structures- Part 2: Seismic design procedures and criteria. International Standards.
26. Probabilistic Seismic Hazard Analysis, White Rose Extension Project, Husky Energy Doc. No. WH-G-00W-X-RP-00004-001, Rev. B2, January 2014.
27. Wellhead Platform Pre-FEED General Parameters, White Rose Extension Project, Husky Energy Doc. No. DG-A-99-G-SP-00002-001 Rev. E1, April 2012.
28. Heat and Material Balance, White Rose Production Expansion – Wellhead Platform, Drawing No. P12-007 4010-4012, Rev. A, June 2012.

Appendices

Appendix 1: Representative Process Loss of Containment Event Tree

Appendix 2: PHAST Jet Fire Modelling

Appendix 3: Immediate Fatalities Due to Fires

Appendix 4: Explosion Fatalities

Appendix 5: Representative Smoke Ingress Event Tree

Appendix 6: Smoke and Gas Impairment of TR/Evacuation Systems

Appendix 7: Gas Ingress Event Tree

Appendix 8: Volume of Oil Released

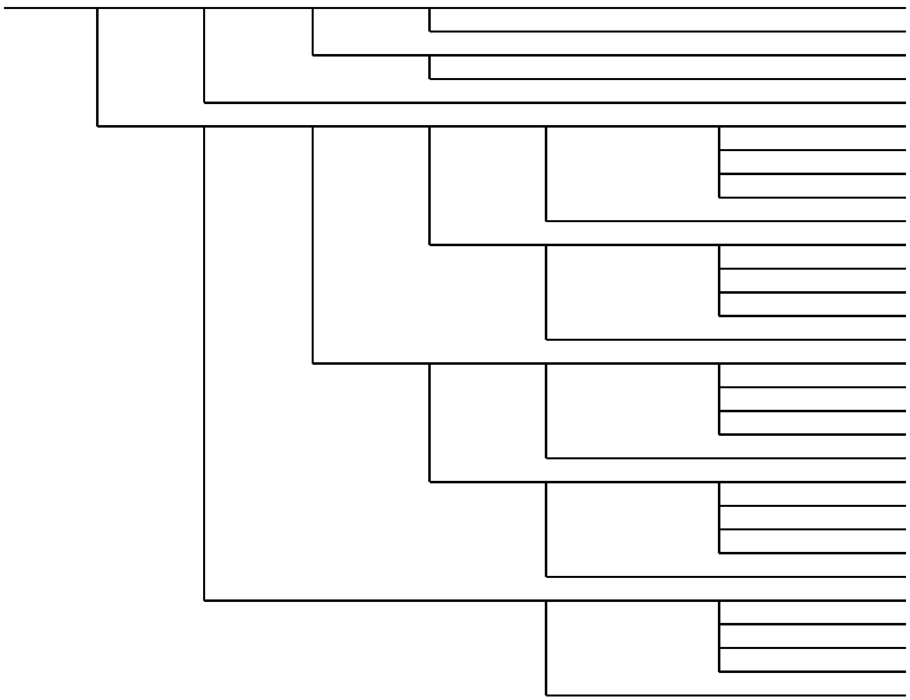
Appendix 9: Representative Subsea Flowline Release Event Tree

Appendix 10: Seismic Activity Event Tree

Appendix 11: Structural Failure Event Tree

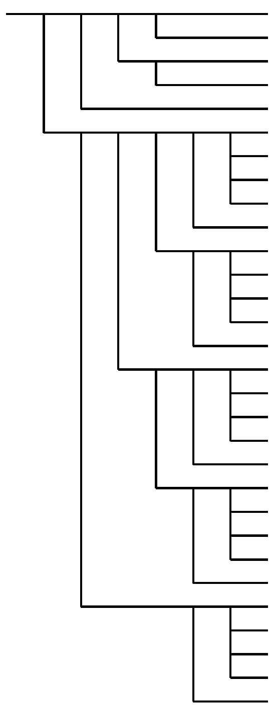
Appendix 1: Representative Process Loss of Containment Event Tree

Event Tree Probabilities						ID	Event Frequency	PLL Contribution	Fatalities				Pollution > 1 bbl
Non-Explosive Ignition	Fire/Gas Detection	Isolation	Deluge	Explosive Ignition	Explosion Overpressure				Immediate Fatalities	Escape and Escalation Fatalities	Precautionary Evacuation Fatalities	TR Impairment Fatalities	



Hazard :	Inventory :	Hole Size :		Project :
LOC (Production)	Production and test manifold	Large		White Rose WHP CSA

R M R I



ID	Pollution > 50 bbl	Pollution > 1,000 bbl	Pollution > 10,000 bbl
(E1)	1	0	0
(E2)	0.1	0	0
(E3)	1	0.1	0
(E4)	0.19	0.1	0
(E5)	0.19	0.1	0
(E6)	1	0	0
(E7)	1	0	0
(E8)	1	0	0
(E9)	1	0	0
(E10)	1	0	0
(E11)	0.1	0	0
(E12)	0.1	0	0
(E13)	0.1	0	0
(E14)	0.1	0	0
(E15)	0.1	0	0
(E16)	1	0.1	0
(E17)	1	0.1	0
(E18)	1	0.1	0
(E19)	1	0.1	0
(E20)	1	0.1	0
(E21)	0.19	0.1	0
(E22)	0.19	0.1	0
(E23)	0.19	0.1	0
(E24)	0.19	0.1	0
(E25)	0.19	0.1	0
(E26)	0.19	0.1	0
(E27)	0.19	0.1	0
(E28)	0.19	0.1	0
(E29)	0.19	0.1	0
(E30)	0.19	0.1	0

Hazard :	Inventory :	Hole Size :		Project :
LOC (Production)	Production and test manifold	Large		White Rose WHP CSA

Appendix 2: PHAST Jet Fire Modelling

A2.1 Process Release Event Jet Fire Modelling

In the event of a hydrocarbon release, the process conditions (temperature and pressure etc.) of the section where the release occurs and the composition of the fluid released affect the physical consequences (mass release rate, ignition probability, flame dimensions etc.) of the release.

Compositions for production fluid and imported gas are given in the Husky Wellhead Platform Pre-FEED General Parameters document (Ref. 27). The process conditions, including pressure, temperature, mass flow rate and gas volume fraction, for each piece of equipment are given in heat and material balance sheets (Ref. 28).

Based on fluid composition and process conditions, DNV's consequence modelling software, PHAST, is used to determine the mass release rate and, if ignited, the dimensions of the 25kW/m^2 radiation contour, which is taken as the thermal radiation level at which personnel are considered to be immediate fatalities.

The fluid compositions and process conditions assumed during pre-FEED are still considered valid and the pre-FEED jet fire modelling has therefore not been modified in this 2014 update.

Process conditions and fluid compositions for the release events considered in this assessment are discussed in Section A2.1.1 and Section A2.1.2 respectively. Results of the consequence modelling are given in Section A2.1.3.

A2.1.1 Process Conditions

Table A2.1 provides process conditions (pressure, temperature) for each release event considered in the assessment.

Release Event	Pressure (MPag)	Temperature (°C)	Fluid Type
Production Wellheads	6	81	Production
Production and Test Flowlines	6	81	Production
Production and Test Manifolds	6	81	Production
Test Heater and Test Separator	6	95	Production
Multiphase Flow Meter	6	95	Production
Oil Export	6	83	Production
Flare KO Drum Pump (Liquid)	(1)	(1)	Condensate
Gas Import and Distribution System	25	12	Gas
Gas Injection Wellheads	25	12	Gas
Gas Injection Flowlines	25	12	Gas
Gas Injection Manifold	25	12	Gas
Gas Lift Flowlines	25	12	Gas
Gas Lift Manifold	25	12	Gas
Flare KO Drum (Gas)	(2)	(2)	Gas
Fuel Gas Inlet Heater	18	4	Gas
Fuel Gas KO Drum	1	18	Gas
Fuel Gas Super-Heater	1	18	Gas
Gas Turbines	1	40	Gas

[1] Conditions not given in Ref. 28. For the purposes of this assessment, pressure and temperature are conservatively taken to be the same as the export system.
[2] Conditions not given in Ref. 28. For the purposes of this assessment, pressure and temperature are conservatively taken to be the same as the fuel gas KO drum.

Table A2.1: Process Hydrocarbon Release Event Process Conditions

For the purposes of consequence modelling, release events with similar process conditions are grouped as presented in Table A2.2, and representative process conditions assigned to each group. The release rate calculations, and therefore consequence modelling, are not as sensitive to temperature as to pressure. The representative temperatures assigned to each group in Table A2.2 are based on the lowest temperature in the group, because the release rate is inversely proportional to the temperature.

Group	Release Events	Pressure (MPag)	Temperature (°C)	Fluid Type
G-1	Multiphase and Condensate Release Events	6	81	Production
G-2	Gas Import and Distribution System, Gas Lift and Injection Manifolds and Flowlines, Gas Injection Wellheads	25	12	Gas
G-3	Fuel Gas Inlet Heater	18	4	Gas
G-4	Fuel Gas and Flare KO Drums, Fuel Gas Super-Heater, Gas Turbines	1	18	Gas

Table A2.2: Representative Groups

A2.1.2 Fluid Composition

Representative compositions for multiphase and gas releases are presented in Tables A2.3 and A2.4, respectively.

Component	Mass Fraction
Nitrogen	0.00077
CO_2	0.00451
H_2S	0
Methane	0.04933
Ethane	0.00659
Propane	0.00594
Butane	0.01027
Pentane	0.00567
Hexane	0.00347
Heptane	0.59501
Naphthenes[1]	0.00959
Aromatics[2]	0.01010
Water	0.30000
Total	1

[1]M-Xylene taken as representative component
[2]Styrene taken as representative component

Table A2.3: Production Fluids Mass Composition

Component	Mole Fraction
CO	0.0001
H_2	0
Oxygen	0.0028
Nitrogen	0.0136
CO_2	0.0208
H_2S	0
Methane	0.8509
Ethane	0.0554
Propane	0.0318
Butane	0.0151
Pentane	0.0056
Hexane	0.0021
Heptane	0.0011
Octane	0.0007
Total	1

Table A2.4: Gas Molar Composition

A2.1.3 PHAST Output

Mass release rates, flame lengths and the area affected by 25kW/m^2 thermal radiation region for each consequence group, generated by PHAST, are given in Table A2.5.

Group	Hole Size	Initial Mass Release Rate (kg/s)	Flame Length (m)	25 kW/m^2 Area (m^2)
G-1	Small	3.99	17	425
	Medium	99.8	69	8,370
	Large	399	124	30,100
G-2	Small	4.45	18	350
	Medium	111	77	7,190
	Large	445	140	26,200
G-3	Small	3.42	17	280
	Medium	85.5	69	5,770
	Large	342	126	21,000
G-4	Small	0.14	5	5.36
	Medium	3.60	22	193
	Large	14.4	40	943

Table A2.5: Mass Release Rates and Thermal Radiation Dimensions

Appendix 3: Immediate Fatalities Due to Fires

A3.1 Estimation of Fire Fatalities

As described in Section 7.8.1, immediate fatalities from jet fires are calculated as:

Fatalities = Fatality Area x Population Density

where Population Density is a characteristic of the area of the platform in which the release event occurs. It is calculated as:

$$\text{Population Density} = \frac{\text{Number of Personnel in Release Location}}{\text{Area of Release Location}}$$

All process loss of containment release events are located in the wellhead/manifold area in the central area of the Cellar Deck, except for the fuel gas system, gas turbines and the flare KO drum, which are located on Cellar Deck, east. The area of the Cellar Deck, central is calculated to be $840m^2$ and the area of the Cellar Deck, east is calculated to be $920m^2$.

Table A3.1 shows, for each release event and release size:

- The fatality area, based on jet fire modelling and thermal radiation threshold of $25kW/m^2$ (see Appendix 2).

- The fatality rate, which is derived as:

$$\text{Fatality Rate} = \frac{\text{Fatality Area}}{\text{Cellar Deck Area}}$$

- The number of fatalities on the relevant area of the Cellar Deck, which is estimated based on the fatality rate and the number of personnel in that area of the Cellar Deck (taken from Table 6.1). Each release event is assumed to cause immediate fatalities only in the area in which the release occurs.

Release Event	Hole Size	Fatality Area (m^2)	Cellar Deck, Central		Cellar Deck, East	
			Fatality Rate	Fatalities	Fatality Rate	Fatalities
Multiphase and Condensate Release Events	Small	425	0.51	1.224	0.46	0.8188
	Medium	8,370	1.00	2.4	1.00	1.78
	Large	30,100	1.00	2.4	1.00	1.78
Gas Import and Distribution System, Gas Lift and Injection Manifolds and Flowlines, Gas Injection Wellheads	Small	350	0.42	1.008	-	-
	Medium	7,190	1.00	2.4	-	-
	Large	26,200	1.00	2.4	-	-
Fuel Gas Inlet Heater	Small	280	-	-	0.3	0.534
	Medium	5,770	-	-	1	1.78
	Large	21,000	-	-	1	1.78
Fuel Gas and Flare KO Drum, Fuel Gas Super-Heater, Gas Turbines	Small	5.36	-	-	<0.01	0.01032
	Medium	193	-	-	0.21	0.3738
	Large	943	-	-	1	1.78

Table A3.1: Jet Fire Immediate Fatality Estimates

Appendix 4: Explosion Fatalities

A4.1 Estimation of Explosion Fatalities

As discussed in Sections 7.8.2 and 7.8.3, the rule set in Table A4.1 is used to estimate fatalities resulting from explosions, accounting for the effects of explosion overpressure on personnel and also for the effects of the size of a gas cloud on the overpressure generated. As discussed in Section 7.8.2, if a release is detected, the fatality rates are reduced by 50% to account for the possibility that some personnel could escape before an ignition occurs.

Overpressure Range	Immediate Area		Adjacent Areas	
	Not Detected	Detected	Not Detected	Detected
< 0.2 Bar	0.5	0.25	0	0
0.2 Bar to 1.0 Bar	1	0.5	0	0
1.0 Bar to 2.0 Bar	1	0.5	0.5	0.25
> 2.0 Bar	1	0.5	1	0.5

Table A4.1: Explosion Fatality Rule Set

Table A4.2 and A4.3 show, for detected and undetected releases, respectively:

- The number of fatalities in the immediate area, estimated based on the fatality percentage and the number of personnel in the area of the platform in which the release occurs (taken from Table 6.1).

- The number of fatalities in adjacent areas, estimated taking account the fatality rates in Table A4.1 and the number of personnel in adjacent areas (taken from Table 6.1). For explosions that occur in the wellhead/manifold (central) area of Cellar Deck, Cellar Deck west, Cellar Deck east and Middle Deck central are taken as the adjacent areas. For explosions that occur on the Cellar Deck east, the Cellar Deck central and the Middle Deck east are taken as the adjacent areas.

Overpressure Range	Explosions on Cellar Deck, Central			Explosions on Cellar Deck, East		
	Fatalities in Immediate Area	Fatalities in Adjacent Areas	Total Fatalities	Fatalities in Immediate Area	Fatalities in Adjacent Areas	Total Fatalities
< 0.2 Bar	1.2	0	1.2	0.89	0	0.89
0.2 Bar to 1.0 Bar	2.4	0	2.4	1.78	0	1.78
1.0 Bar to 2.0 Bar	2.4	7.1	9.5	1.78	7.255	9.035
> 2.0 Bar	2.4	14.2	16.6	1.78	14.51	16.29

Table A4.2: Explosion Fatalities, Undetected Releases

Overpressure Range	Explosions on Cellar Deck, Central			Explosions on Cellar Deck, East		
	Fatalities in Immediate Area	Fatalities in Adjacent Areas	Total Fatalities	Fatalities in Immediate Area	Fatalities in Adjacent Areas	Total Fatalities
< 0.2 Bar	0.6	0	0.6	0.445	0	0.445
0.2 Bar to 1.0 Bar	1.2	0	1.2	0.89	0	0.89
1.0 Bar to 2.0 Bar	1.2	3.55	4.75	0.89	3.628	4.518
> 2.0 Bar	1.2	7.1	8.3	0.89	7.255	8.145

Table A4.3: Explosion Fatalities, Detected Releases

Appendix 5: Representative Smoke Ingress Event Tree

R M R I	Event Tree Probabilities				ID	Event Frequency	Precautionary Evacuation Fatality Rate	TR (Smoke) Impairment Fatality Rate
	Wind in TR Direction	Smoke Enters TR	Lifeboats Impaired	TR Impaired				
IF: 1.0	a) Yes: 0.3	a) Yes: 0.2	a) Yes: 0.2	a) Yes: 0.5	(E1)	6.00E-03	0	0.5
				b) No: 0.5	(E2)	6.00E-03	0	0
			b) No: 0.8		(E3)	0.048	0.05	0
		b) No: 0.8			(E4)	0.24	0	0
	b) No: 0.7				(E5)	0.7	0	0

Hazard :
Smoke Ingress

Project :
White Rose WHP CSA

Appendix 6: Smoke and Gas Impairment of TR/Evacuation Systems

A6.1 Smoke Ingress

Smoke is generated by any burning hydrocarbon but, in general, significant quantities of smoke are only generated by long-duration liquid fires. Therefore, it is assumed that any unisolated ignited medium or large liquid release will result in a large long-duration fire which, if coincident with unfavourable conditions, could impair the TR.

It is assumed that if smoke begins to ingress the TR and the lifeboat evacuation system are not impaired by smoke, the OIM will order a ‘precautionary’ evacuation. However, if the evacuation systems are impaired by smoke, personnel would remain in the TR. Should impairment conditions subsequently be reached in the TR however, the OIM would have to order an ‘emergency evacuation’ of the installation under smoke impairment conditions.

Section 7.8.5.1 considers that in the event of a medium and large ignited release that is not isolated from the wells (i.e. medium and large unisolated releases from the wellheads, manifolds and flowlines), the OIM would immediately evacuate the platform as a precautionary measure (without waiting to see if smoke starts ingressing into the TR), because these events have the potential to result in significant structural damage to the platform. If the TEMPSC are impaired due to smoke, it is assumed that personnel remain in the TR and that, as discussed above, the OIM would order an ‘emergency evacuation’ under impairment conditions if the TR were subsequently impaired.

A6.1.1 Smoke Impairment Event Tree

For the TR to be affected by smoke, the following conditions would have to occur, coincident with a long-duration fire:

- Wind blows smoke towards the TR.
- Smoke reaches TR at high concentration.
- Smoke enters the TR (for example, via the HVAC inlet or any other penetrations such as doors).

The event tree used to account for the likelihood of the coincident conditions that must occur for the TR to be affected by smoke from a long duration fire is shown in Appendix 5. The event tree branch events are:

1. Smoke travels towards the TR.
2. Smoke reaches the TR in high concentration and enters the TR.
3. Smoke impairs the evacuation systems.
4. Smoke impairment conditions are reached inside the TR.

The event tree identifies five possible outcomes. These outcomes represent four ‘TR Conditions’, see Table A6.1.

Condition No.	TR Condition
1	No smoke hazard in the TR (Outcomes E4 and E5)
2	Smoke reaches the TR and begins to ingress into the TR, but does not impair the lifeboats (Outcome E3)
3	Smoke reaches the TR, begins to ingress, and also impairs the lifeboat evacuation systems (Outcome E2)
4	Smoke impairment conditions are also reached in the TR (Outcome E1)

Table A6.1: Smoke Impairment Event Tree, TR Conditions

Any decision to evacuate the platform will be at the discretion of the OIM. If smoke enters the TR, the OIM will not necessarily wait until the concentration reaches impairment levels before considering an evacuation of the platform.

It is assumed that if smoke begins to ingress the TR and the lifeboat evacuation system are not impaired by smoke, the OIM will order a ‘precautionary’ evacuation. That is, the OIM will tactically decide to evacuate by lifeboat whilst they are available, to protect personnel from the possibility of further smoke ingress and the possibility of subsequent coincident impairment of both TR and evacuation systems.

However, if the evacuation systems are impaired by smoke when smoke begins to ingress the TR, it is assumed that personnel remain in the TR. That is, to wait either for the event to be brought under control or for wind conditions to improve. Should impairment conditions subsequently be reached in the TR however, the OIM would have to order an ‘emergency evacuation’ of the installation under smoke impairment conditions.

A6.1.2 Event Tree Branch Probabilities

The branch probabilities used in the smoke impairment event trees are shown in Table A6.2. These probabilities are subjectively estimated, based on experience of undertaking studies for similar installations. It may be necessary, at detailed design stage, to review these probabilities in a detailed TR impairment analysis and revise the risk assessment accordingly.

Branch	‘Yes’ Probability
1	0.3
2	0.2
3	0.2
4	0.5

Table A6.2: Branch Probabilities for Smoke Impairment Event Trees

<u>Branch 1: Smoke Travels Towards the TR</u>

Smoke will only travel towards the TR if wind direction is from the fire towards the TR. The probability is conservatively taken to be 0.3 based on weather data for the area.

Branch 2: Smoke Reaches the TR in High Concentration and Enters the TR

If smoke from a fire blows towards the TR, the distance it has to travel would result in dilution. Heat from the fire would generate buoyant products, which would tend to carry smoke above the TR.

If smoke, nevertheless, does reach the TR in high concentration, it could enter the TR via the HVAC intakes or any other penetrations such as doors. Smoke could ingress rapidly if drawn in through the HVAC intakes, or would ingress only slowly through the various other TR penetrations.

However, if smoke is detected at the HVAC intakes, the HVAC system shuts down and the dampers close, to prevent rapid ingress. The likelihood of rapid smoke ingress due to the HVAC system failing to shut down is not considered here. It is assumed that the HVAC inlets will be located in a sheltered area of the platform and that the reliability of the smoke detectors and dampers will be addressed during detailed design. Smoke could enter the TR slowly through the various other TR penetrations, but a modern TR design should ensure that this is unlikely.

Based on this discussion, the probability that smoke from a liquid fire reaches the TR in 'high' concentration and enters the TR is considered to be low (0.2).

Branch 3: Smoke Impairs the Evacuation Systems

The lifeboats are sheltered from all potential fire events by the TR and are located at the lowest (Cellar Deck) level. Therefore, the probability of evacuation systems being impaired by smoke when smoke reaches to the TR in high concentration is conservatively assumed to be 0.2.

Branch 4: Smoke Impairment Conditions are Reached Inside the TR

If the evacuation systems are impaired by smoke and smoke enters the TR, it is assumed that personnel will remain in the TR. Should impairment conditions subsequently be reached in the TR, the OIM would have to order an 'emergency evacuation' of the installation under smoke impairment conditions.

A modern TR design should ensure that smoke impairment is unlikely. However, in order to ensure a conservative analysis, the probability that smoke reaches a concentration that constitutes impairment conditions is assumed to be 0.5.

A6.1.3 Fatality Rates

The smoke impairment event tree (Appendix 5) identifies four possible 'TR Conditions' (see Table A6.1). The fatality rates assigned, in the event tree analysis, for each TR Condition are shown in Table A6.3 (and in Appendix 5).

Condition No.	TR Condition	Lifeboat Evacuation Fatality Rate	Smoke Impairment Fatality Rate
1	No smoke hazard in the vicinity of the TR	5%[1]	-
2	Smoke ingress into the TR, but does not impair the lifeboats	5%	-
3	Smoke ingress into the TR and lifeboat impairment. Personnel remain in TR.	-	-
4	Smoke impairment conditions are also reached in the TR	-	50%

[1] Applied only to medium and large ignited releases not isolated from the wells.

Table A6.3: Smoke Impairment Event Tree Fatality Rates

Condition 1:

As there is no smoke hazard, in the majority of cases no fatalities are assigned.

However, as discussed, in the event of a medium and large ignited release that is not isolated from the wells (i.e. medium and large unisolated releases from the wellheads, manifolds and flowlines), it is considered that the OIM would immediately evacuate the platform as a precautionary measure (5% fatality rate assumed).

Condition 2:

This refers to an outcome where smoke enters the TR (but does not reach impairment concentration) and the evacuation systems are unimpaired. The OIM will not necessarily wait until the concentration reaches impairment levels before considering an evacuation of the platform. Therefore, for this situation, 'precautionary evacuation fatalities' are accounted for. It is assumed that a lifeboat evacuation will be undertaken, and a weather-averaged fatality rate of 5% is applied.

Condition 3:

If, however, the evacuation systems are impaired by smoke, the OIM would not be able to initiate a precautionary evacuation. Personnel would remain in the TR. No fatalities are assigned (unless impairment conditions are reached in the TR, see below).

Condition 4:

If both the TR and the evacuation systems are impaired by smoke, a 50% fatality rate is assumed for emergency evacuation under smoke impairment conditions. This is based on the fact that personnel may still be able to use the evacuation systems by wearing smoke hoods. There is also the possibility of escape to sea using the escape chutes.

A6.1.4 Statistical Fatalities

Accounting for the probability of occurrence (Section A6.1.2 and Appendix 7) and associated fatality rates (Section A6.1.3), statistical fatalities are determined for:

- Precautionary evacuation of the TR, as a result of smoke ingress.

- Smoke impairment of the TR and/or the lifeboats.
- Precautionary evacuation of the TR for releases not isolated from the wells.

When applying these statistical fatalities to the loss of containment event tree outcomes, those personnel that have been fatally injured in the immediate effects of the fire are accounted for.

A6.2 Gas Ingress

If gas from a long-duration release reaches the TR at LFL concentration, it could ingress into the TR and result in the potential for an explosion within the TR.

In general, gas releases will be transient events, even in the case of an SDV failure. This is particularly true in the case of large gas releases.

However, if, for example, a release occurs from the production or gas lift flowlines or manifolds in the wellhead/manifold area and, upon ESD, a well fails to shut in, a long duration gas or 2-phase release could result. A large long duration release such as this, if it occurs coincident with unfavourable conditions, could result in impairment of the TR.

A6.2.1 Gas Impairment Event Tree

For the TR to be affected by gas, the following coincident conditions would have to occur:

- Wind blows gas from the release towards the TR.
- Gas reaches the TR at high concentration.
- Gas enters the TR (for example, via the HVAC inlet or any other penetrations such as doors).

The event tree used to account for the likelihood of the coincident conditions that must occur for the TR to be affected by gas from a large long duration release is shown in Appendix 7. The event tree branch events are:

1. Gas travels towards the TR.
2. Gas reaches the TR at high concentration and enters the TR.

The event tree identifies three possible outcomes. These outcomes represent two 'TR Conditions', see Table A6.4.

Condition No.	TR Condition
1	No gas hazard at the TR (Outcomes E2 and E3)
2	Gas reaches the TR and begins to ingress into the TR (Outcome E1)

Table A6.4: Gas Impairment Event Tree, TR Conditions

Any decision to evacuate the platform will be at the discretion of the OIM. If gas enters the TR, the OIM will not wait until the concentration reaches LFL levels before considering an evacuation of the platform.

Because the potential impairment events are long duration events, it is assumed that the OIM will order a 'precautionary' evacuation. That is, the OIM will tactically decide to evacuate by lifeboat, to protect personnel from the possibility of further gas ingress and the possibility of a subsequent explosion within the TR.

A6.2.2 Event Tree Branch Probabilities

The branch probabilities used in the gas impairment event trees are shown in Table A6.5. These probabilities are subjectively estimated, based on experience of undertaking studies for similar installations. It may be necessary, at detailed design stage, to review these probabilities in a detailed TR impairment analysis and revise the risk assessment accordingly.

Branch	Condition	Yes Probability
1	Wind Blows Towards TR	0.3
2	Gas Enters TR at High Concentration	0.2

Table A6.5: Branch Probabilities for Gas Impairment Event Trees

Branch 1: Gas Travels Towards the TR

Gas will only travel towards the TR if wind direction is from the release location towards the TR. The probability is taken to be 0.3, as discussed in Section A6.1.2.

Branch 2: Gas Reaches the TR in High Concentration and Enters the TR

If gas reaches the TR in high concentration, it could enter the TR via the HVAC intakes or any other penetrations, such as doors. Gas could ingress rapidly if drawn in through the HVAC intakes or ingress slowly through the various other TR penetrations.

However, if gas is detected at the HVAC intakes, the HVAC system will shut down and the dampers will close, to prevent rapid ingress. The likelihood of rapid gas ingress due to the HVAC system failing to shut down is not considered here. It is assumed that the HVAC inlets will be located in a sheltered area of the platform and that the reliability of the gas detectors and dampers will be addressed during detailed design stage. Gas could enter the TR slowly through the various other TR penetrations, but a modern TR design should ensure that this is unlikely.

Therefore, the probability that gas reaches the TR in high concentration and enters the TR is considered to be low (0.2).

A6.2.3 Fatality Rates

The gas impairment event tree (Appendix 7) identifies two possible 'TR Conditions' (see Table A6.4). The fatality rates assigned, in the event tree analysis, for each TR Condition are discussed below.

Condition 1:

No hazard and therefore no fatalities are assigned.

Condition 2:

This refers to an outcome where gas enters the TR. The OIM will not wait until the gas concentration reaches LFL levels before considering an evacuation of the platform. Therefore, for this situation, 'precautionary evacuation fatalities' are accounted for. It is assumed that a lifeboat evacuation will be undertaken, and a weather-averaged fatality rate of 5% is applied.

A6.2.4 Statistical Fatalities

Based on the event tree (branch probability and fatality) data described above (and shown in Appendix 7), the number of statistical fatalities for potential gas impairment events is estimated as 0.39, accounting for the full complement of platform personnel mustering and evacuating from the TR.

Appendix 7: Gas Ingress Event Tree

Event Tree Probabilities: Wind in TR Direction	Event Tree Probabilities: Gas Enters TR	ID	Event Frequency	Precautionary Evacuation Fatality Rate	TR (Gas) Impairment Fatality Rate
IF: 1.0 — a) Yes: 0.3	a) Yes: 0.2	(E1)	0.06	0.05	0
	b) No: 0.8	(E2)	0.24	0	0
b) No: 0.7		(E3)	0.7	0	0

Hazard :
Gas Ingress

Project :
White Rose WHP CSA

Appendix 8: Volume of Oil Released

A8.1 Oil Spill Sizes

A8.1.1 Process Liquid Releases

A process liquid release on the WHP may be detected by the automatic detection system or by personnel in the vicinity of the release. Once detected, the emergency shutdown system is activated, restricting the volume of oil released. If the release is not detected by the automatic detection system or by personnel in the vicinity, it is assumed, for the purposes of this assessment, that it would eventually be detected by the process control systems or by personnel on the platform.

The release durations considered account for the time for the release to be detected, either by the platform detection systems or by personnel, and the time for the isolation valves to close. The durations take into account that larger releases are unlikely to remain unnoticed.

Table A8.1 presents the duration of the topsides release events for liquid inventories considered in this assessment (refer to Section 7.2.1). In line with the above discussions, two scenarios are considered:

- Rapid detection and isolation: A release is detected by the automatic detection system or by personnel in the vicinity of the release and the emergency shutdown system is activated.
- Delayed isolation: A release is eventually detected by the process control systems or by personnel on the platform.

The times in Table A8.1 are believed to represent a realistic, but still conservative, assessment.

Table A8.2 presents the corresponding volume of oil released.

Hole Size	Release Duration (minutes)	
	Rapid Detection and Isolation	Delayed Isolation
Small	2	120
Medium	1	20
Large	1	20

Table A8.1: Release Duration, Process Liquid Releases

Hole Size	Mass Release Rate (kg/s)	Size of Release (bbls)	
		Rapid Detection and Isolation	Delayed Isolation
Small	3.99	< 50	50 to 1,000
Medium	99.8	< 50	50 to 1,000
Large	399	50 to 1,000	1,000 to 10,000

Table A8.2: Volume of Oil Released, Process Liquid Releases

As discussed in Section 7.8.6, the hazardous open drains will be designed to handle the maximum expected volume of oil released in the event of an isolated hydrocarbon spill.

However, if the deluge system is activated the capacity of the drains would be exceeded. It is considered that, unless the deluge system is activated, the drains would be greater than 90% effective in containing isolated topsides releases. Therefore, the probability that oil is spilled into the sea in the event of an isolated release where deluge is not activated is taken to be 10%. For release events where the deluge system is activated or isolation fails, it is conservatively considered that all of the oil released subsequently spills into the sea.

A8.1.1 Subsea Flowline Releases

If a subsea flowline release results in flammable gas reaching the platform topsides, it may be detected by the platform detection system. If a release is detected, the emergency shutdown system is activated, restricting the volume of oil released. However, it is considered unlikely that small or medium releases would actually be detected by the platform gas detection system. For large and fullbore subsea releases, the time until isolation accounts for the release reaching the sea surface and for gas to subsequently reach the platform.

Medium, large and fullbore releases may also be detected by the process control systems due to the reduction in pressure in the export flowline, which would raise a low alarm or a low-low trip alarm. Accounting for the time for personnel to react to the alarm, the time for manual isolation is taken to be 10 minutes if a release is detected but not isolated automatically.

Due to the comparatively low release rate, small releases are unlikely to trip any process alarms, and hence may go undetected for a number of hours. However, due to the discrepancy in the export and import logs the release is likely to be identified in the daily production meeting. It is therefore assumed that the release would be isolated within 36 hours.

If a release ignites, it is assumed that ignition occurs, and the release detected and isolated, within an hour.

The subsea flowline release durations estimated in this assessment account for the time for the release to be detected, either by the platform detection systems or by personnel, and, where necessary, the time for personnel to react to an alarm.

Table A8.3 presents the duration of the production export flowline release events considered in this assessment

Hole Size	Release Duration (minutes)		
	ESD Successful[1]	Ignited Releases (Unless ESD is Successful)	All Other Releases
Small	N/A[1]	60	2,160 (36hrs)
Medium	N/A[1]	10	10
Large/Fullbore	2	10	10

1: It is considered unlikely that small or medium releases would actually be detected by the platform gas detection system.

Table A8.3: Release Duration, Production Export Flowline Releases

Based on the release durations in Table A8.3, Table A8.4 presents the corresponding volume of oil spilled.

As discussed in Section 10.6.5, the production flowlines will be tied in to the subsea tie-in structure on existing flowlines between CDC and the SeaRose FPSO. For a release from a production flowline to be isolated, the SDVs at the WHP and the CDC are required to close, but the volume of oil isolated within the flowline may continue to be released after the SDVs close. There are also valves at the tie-in, but as these are not SDVs (and hence are not quick closing, taking up to 22 minutes to close), some oil from the existing flowlines would also continue to feed the release until the tie-in valves close. Therefore, the total volume of oil assumed to be released accounts for the volume of oil released prior to isolation, the volume of oil in the production export flowline after isolation plus, subjectively, 25% of the volume of oil in the two connecting flowlines.

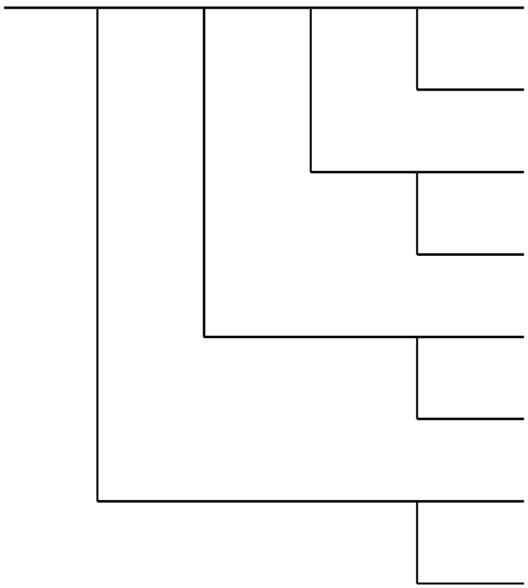
Hole Size	Mass Release Rate (kg/s)	Size of Release (bbls)		
		ESD Successful	Ignited Releases (Unless ESD is Successful)	All Other Releases
Small	3.99	N/A[1]	50 to 1,000	1,000 to 10,000
Medium	99.8	N/A[1]	50 to 1,000	50 to 1,000
Large/Fullbore	399	50 to 1,000	1,000 to 10,000	1,000 to 10,000

1: It is considered unlikely that small or medium releases would actually be detected by the platform gas detection system.

Table A8.4: Volume of Oil Released, Production Export Flowline Releases

Appendix 9: Representative Subsea Flowline Release Event Tree

Event Tree Probabilities				ID	Event Frequency	PLL Contribution	Fatalities				Pollution > 1 bbl	Pollution > 50 bbl	Pollution > 1,000 bbl	Pollution > 10,000 bbl
Gas Reaches the Installation	Gas Detection	Isolation	Ignition				Immediate Fatalities	Escape and Escalation Fatalities	Precautionary Evacuation Fatalities	TR Impairment Fatalities				



Hazard : LOC (Subsea Pipeline)	Inventory : Export Pipelines <500m	Hole Size : Fullbore		Project : White Rose WHP CSA

Appendix 10: Seismic Activity Event Tree

RMRI	Event / Level of Damage	ID	Event Frequency	PLL Contribution	Fatalities: Immediate Fatalities	Fatalities: Escape and Escalation Fatalities	Fatalities: Precautionary Evacuation Fatalities	Fatalities: TR Impairment Fatalities	Pollution > 1 bbl	Pollution > 50 bbl	Pollution > 1,000 bbl	Pollution > 10,000 bbl
IF: 3.13E-04	Yes: 0.1	(E1)	3.13E-05	3.97E-04	0	0	0	12.672	0.75	0.75	0.05	0.05
	No: 0.9	(E2)	2.82E-04	1.78E-03	0	0	6.336	0	0	0	0	0
				2.18E-03								

Hazard :
Seismic Activity

Project :
White Rose WHP CSA

Appendix 11: Structural Failure Event Tree

Event Tree Probabilities			ID	Event Frequency	PLL Contribution	Fatalities				Pollution > 1 bbl	Pollution > 50 bbl	Pollution > 1,000 bbl	Pollution > 10,000 bbl
	Demannig of Platform	Level of Damage				Immediate Fatalities	Escape and Escalation Fatalities	Precautionary Evacuation Fatalities	TR Impairment Fatalities				
IF: 1.00E-04	Yes: 0.9		(E1)	9.00E-05	0	0	0	0	0	0	0	0	0
	No: 0.1	Yes: 0.1	(E2)	1.00E-06	7.20E-05	0	0	0	72	0	0	0	0
		No: 0.9	(E3)	9.00E-06	5.70E-05	0	0	6.336	0	0	0	0	0
					1.29E-04								

Hazard : Structural Failure	Project : White Rose WHP CSA