WHITE ROSE OILFIELD DEVELOPMENT APPLICATION

VOLUME 5
PRELIMINARY SAFETY PLAN
AND
CONCEPT SAFETY ANALYSIS

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED (AS OPERATOR)
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

January 2001

This Development Application is submitted by Husky Oil Operations Limited (as Operator) on behalf of itself and its co-venturer Petro-Canada, who are the project proponents. The Application is comprised of a Project Summary and five volumes.

- Project Summary
- Volume 1 – Canada-Newfoundland Benefits Plan
- Volume 2 – Development Plan
- Volume 3 – Environmental Impact Statement (Comprehensive Study Part One (issued October 2000))
- Volume 4 – Socio-Economic Impact Statement (Comprehensive Study Part Two (issued October 2000))
- Volume 5 – Safety Plan and Concept Safety Analysis

This is Volume 5 – the Safety Plan and Concept Safety Analysis. The following Part II documents have also been prepared in support of Volume 5 of the Development Application:

JWEL (Jacques Whitford Environment Limited). 2000. White Rose Oilfield Development Public Consultation Report. Part II Document prepared for Husky Oil Operations Limited, St. John's, NF.

WHITE ROSE OILFIELD
DEVELOPMENT APPLICATION

VOLUME 5
PART ONE
PRELIMINARY SAFETY PLAN

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED (AS OPERATOR)
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

January 2001

TABLE OF CONTENTS

LIST OF TABLES

Page No.

LIST OF FIGURES

Page No.

1 INTRODUCTION

1.1 Requirement for a Safety Plan

In the responsible conduct of its business, Husky Oil Operations Limited (Husky Oil) is committed to ensuring that the safety of its personnel is not compromised. Safety transcends exploration, drilling, production, and corporate image in importance, and will not be sacrificed for the sake of expediency. Husky Oil is also committed in its obligation to diligently minimize any adverse effects to the environment, as a result of the Company's activities.

As the Operator for the White Rose Oilfield Development project (the Project), Husky Oil is accountable for the safety of all personnel, facilities, and equipment associated with the exploitation and development of the field. To achieve this objective, a comprehensive Safety Plan will be in place to address all activities associated with the design, construction, installation, commissioning, drilling, production, transportation, decommissioning and abandonment phases of the Project. This preliminary safety plan outlines key factors to be incorporated into the final plan prior to production operations commencing.

The Safety Plan is a vital part of an extensive Loss Control Management System and is integrated into Husky Oil's Health, Safety, and Environment (HS&E) framework. This framework encompasses all activities associated with health, safety, environment, reliability, hazard management, risk assessment and loss prevention, as it relates to personnel (that is, Company and Contractors), the asset, production, and the environment.

The Project Safety Plan is built on the foundation of continuous improvement and maturation of the Project's safety culture. An underlying assumption of the plan is that compliance with all safety legislation is an absolute minimum requirement. In many cases, the Company's programs currently in place actually exceed these minimum requirements.

The White Rose oilfield development project will be very similar to the current Hibernia and Terra Nova projects. Husky Oil will further develop its HS&E management system, taking into consideration programs in place for the Hibernia and Terra Nova projects, making improvements wherever possible and ensuring that every effort is made to use only proven technology. For example, integrated Ice Management, Oil Spill Response and environmental monitoring plans will be in place for White Rose and will be in concert with other operators.

The Safety Plan, or specific components of the plan, will be modified as necessary to reflect continuous improvement and any changes in facilities, management systems, or organizational structure. The Safety Plan will also include measures to respond to operating and industry experience, as well as regulatory developments, as it evolves throughout the life of the Project.

As a component of the Development Application (DA) for White Rose, Husky Oil has prepared a Concept Safety Analysis (CSA) (Volume 5, Part Two) that focuses on the assessment of risks for the viable options being considered to develop the field.

As is to be expected with a concept risk assessment, assumptions have to be made. The assumptions are based on similar existing projects and many of the findings resulting from the CSA are dependent on those assumptions being fulfilled in the detailed design of the White Rose facilities.

Each of the viable proposed concepts are analyzed, with the frequencies and consequences associated with the major hazards quantified wherever possible. A more in-depth analysis is completed for the ship-shaped steel floating production storage and offloading (FPSO) facility, which has been initially selected by Husky Oil as the preferred option. Major hazards considered in the risk assessment, as applicable for each option, include:

- process and non-process loss of hydrocarbon containment (fire and explosion) (above sea);
- subsea loss of hydrocarbon containment (fire and explosion);
- blowout;
- ship impact;
- iceberg impact;
- dropped object;
- helicopter operations;
- fishing gear impact;
- structural failure;
- mooring failure; and
- seismic activity.

Consequential outcomes of the above major hazards, for each of options being proposed, are described in terms of fatalities and environmental damage. Fatalities are further sub-divided in terms of immediate fatalities, escape and escalation fatalities, and evacuation and rescue fatalities. It should be noted that escape and escalation fatalities are defined as those which occur outside the immediate area in which the event occurs, such as, while personnel are escaping to, or mustering within, the Temporary Safe Refuge (TSR). Evacuation and rescue fatalities are defined as those which occur while personnel are evacuating the installation.

Major environmental damage reflects the potential for a major oil spill and reflects an estimate of the amount of oil entering the sea. It is made only for event sequences that have the potential to result in a significant size spill (for example, loss of containment to subsea facilities, loss of containment of crude storage, and major and/or unisolated process loss of containment).

A fundamental aspect of the concept and design phases of the Project is the selection of clear goals to ensure the safety of personnel and the environment. Consequently, another requirement identified and included in the CSA is the setting of the Target Levels of Safety (TLS) that must be adhered to by the Project.

The TLS stipulated contains both risk and impairment-based criteria. The risk-based criteria can be further sub-divided into:

- individual risk (IR);
- group risk; or
- environmental risk.

The impairment-based criteria stipulated are applied to the following installation safety functions:

- primary structure of the installation;
- TSR;
- escape routes; and
- availability of evacuation systems.

Of the above, IR is the primary overriding criterion and must be met in the final design. It should be noted, according to Section 2.1.1 of the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) Safety Plan Guidelines (C-NOPB 1995) that:

> *"Risk to individuals can emanate from "major accidents" which affect the entire, or large portions of the installation or from what may be termed "routine occupational exposures" which only have the potential to affect single, or small numbers of, individuals. It is expected that the risk from "major accidents" to both the installation as a whole and to individuals be quantified. It is not expected that risk to individuals from each "routine occupational exposure" be quantified. The method of assessment of risk to individuals from these exposures is left to the discretion of the operator."*

The measures outlined in this preliminary Safety Plan are activities Husky Oil will use to minimize the risks from major accidents as well as from "routine occupational exposures".

Statistical risk to an individual can be calculated from the frequency of an undesired event, multiplied by the probability that the individual is exposed to the hazard associated with the undesired event, multiplied by the probability that the hazard causes fatal injury. The various risks to which the individual is exposed as a result of carrying out his or her duties can be summed to give the total risk to the individual. This aids targeting and implementing the most effective risk prevention and mitigation measures. The TLS for IR is summarized below in Table 1.1-1.

Table 1.1-1 Target Levels of Safety for Individual Risk

Level	Individual Risk	Description
Intolerable	IR > 10^{-3}	Unacceptable, risk control measures must be taken
As Low As Reasonably Practicable (ALARP)	10^{-3} > IR > 10^{-6}	It must be demonstrated that all practical means of risk reductions have been employed to ensure that the risk is as low as reasonably practicable
Negligible	IR < 10^{-6}	No need to consider further safety measures (For example an IR of 10^{-6} means that there is a 0.000001 probability of fatality per year for an individual on the installation)

All accidents, as a result of major hazards, that might have a significant effect on IR have been taken into account. The calculation of risk for any particular individual in the CSA takes into account that any given individual is normally working offshore 50 percent of the time.

The remaining secondary criteria (that is, group and environmental risk) are provided to allow the assessment of the design when personnel levels are uncertain, or when the overall risk assessment is at a preliminary stage. Such criteria are to be used as guidance only.

Impairment-based criteria are used during the concept and design phases to distinguish between possible hazardous events which have the potential to cause high-fatality accidents, and those which do not.

Recommendations and conclusions from the CSA will be considered and appropriately implemented into the Safety Plan. In addition to the CSA, Husky Oil, in order to provide a basis to demonstrate safe operation, will appropriately conduct various individual studies as the Project develops. Typical studies that Husky Oil will initiate will include:

- hazard identification;
- fire hazard analysis;
- explosion hazard analysis;
- dropped object;
- marine systems failure;
- review of integrity of emergency systems;
- escape, evacuation, and rescue assessment;
- review of integrity of TSR;
- analysis of other major identified hazards; and
- updates to the quantified risk assessment of major hazards.

The remaining sections of this Safety Plan will outline the aspects of Husky Oil's management of the White Rose oilfield which will be in place to ensure that risk has been reduced to a level considered to be as low as reasonably practicable (ALARP).

Items discussed include the following:

- safety management policies and procedures;
- facilities and equipment;
- operations and maintenance procedures;
- training and qualifications;
- command structure; and
- contingency planning.

This document generally follows the approach outlined in the C-NOPB's "Safety Plan Guidelines" (C-NOPB 1995).

It should be noted that the Safety Plan can only be developed to a level of detail that corresponds to the current level of project design and development of management systems. Accordingly, this plan is referred to as the Preliminary Safety Plan. The Project Safety Plan will undergo further refinements, as additional information becomes available. Key milestones influencing the Project Safety Plan will include changes required as a result of the impact of final system design on the CSA as well as other hazard and operability studies and risk assessments which are carried out as part of the final system design.

1.2 Issues Scoping and Stakeholder Consultation

Husky Oil conducted an extensive issues scoping and stakeholder information/consultation program in preparing the DA for the White Rose oilfield development. This program met the requirements of the Canadian Environmental Assessment Act, C-NOPB Development Application Guidelines (1988) and the *Atlantic Accord Acts*. A detailed report of the issues scoping and stakeholder consultation program is provided in the Part II Document to this DA, titled White Rose Oilfield Development Public Consultation Report (JWEL 2000). The program involved:

- reviewing relevant legislation and guidelines;
- reviewing the scoping document issued by C-NOPB, Department of Fisheries and Oceans (DFO), Environment Canada and Industry Canada;
- reviewing documents prepared for the Terra Nova and Hibernia oilfield developments;
- reviewing issues raised during the Terra Nova Development environmental assessment review process;

- consulting community, business, women's and non-governmental organizations, and the general public (key informant workshops, open houses and meetings/presentations);
- holding meetings with government departments and agencies;
- conducting media briefings and preparing press releases;
- tracking articles/stories from media sources;
- distributing project information (two mail distributions);
- establishing a project information telephone number (724-7244 and 1-877-724-7244);
- setting up a project-specific web site (www.huskywhiterose.com);
- documenting issues and concerns, and following up when necessary; and
- using professional judgement based on the particular characteristics of the White Rose oilfield development.

The main message heard throughout the scoping/consultation program was that the majority of participants were supportive of the development and interested in seeing it proceed. There was also a strong interest in ensuring that the project proceed in an environmentally, socially and economically responsible manner.

A number of general items that apply to all aspects of the project were noted throughout the consultation program. They are:

- learn from the Hibernia and Terra Nova experience;
- ensure ongoing, two-way communication with stakeholders;
- ensure project information is accurate, timely and appropriate; and
- do not raise false expectations in relation to benefits from the project.

Items raised throughout the scoping/consultation program have been incorporated in project planning and are reflected in the DA. A comprehensive list of items heard from stakeholders throughout the scoping/consultation program is provided in JWEL (2000). Items specific to each component of the DA are highlighted in the relevant DA documents. Specific comments received about health and safety, and accidental events are listed in Table 1.2-1, with the locations noted as to where they are addressed in this document.

Table 1.2-1 Comments about Health, Safety and Accidental Events

Comments	Where Addressed
Accidental Events	
Concern about the potential for a blowout, oil spill (all volumes) or chemical spill at the site or during transportation, and resulting effects of such accidents.	Part Two, Chapter 5
Ability to effectively respond to oil spills resulting from the operation.	Part One, Chapter 7
Emergency response plans for all accidents, including risk-based determination of response needs, types and location of response equipment, and time to deploy equipment.	Part One, Chapter 7 Part Two, Chapters 4, 7
Chronic oil pollution on the Grand Banks (e.g. drilling fluids and well-head leaks), cumulative effects and perceived lack of enforcement by regulatory agencies.	Part One, Section 7.8
Criteria, ability and time required to disconnect and move the facility in an emergency.	Part Two, Chapter 7, Sections 9.5.2, 10.3
Health and Safety	
Need for rigorous safety standards, and procedures for monitoring and enforcing safety requirements.	Part One, Chapter 2
Ability to operate in severe weather conditions.	Part Two, Chapter 8
Need for appropriate and effective safety and evacuation equipment and procedures.	Part One, Chapters 3, 4
Need to optimize the location of accommodations on the production facility relative to the production/processing activity.	Part Two, Sections 3.3, 10.6
Effects of electromagnetic emissions from radio equipment on personnel safety and mitigation measures for emissions.	Comprehensive Study Part One, Section 8.8.3.6
Air emissions and any implications for the health and safety of workers that may be exposed to them.	Comprehensive Study Part One, Section 8.8.3.1 Appendix 4.A
Need for employee and family assistance/support programs.	Comprehensive Study Part Two, Section 5.4
Need for a complaint reporting system.	Part One, Section 2.3

2 SAFETY MANAGEMENT POLICIES & PROCEDURES

2.1 General Safety Policy Statement

Husky Oil has developed and implemented a HS&E Policy that guides the company in all aspects of its business. This policy, plus the programs and procedures which support it, assists Husky Oil to be both responsible and duly diligent in its stewardship of health, safety, and environment. The Husky Oil Policy is endorsed by the CEO of the Corporation and by the East Coast Operations Manager; it is included as Figure 2.1-1.

A key document, which supports the HS&E Policy statement, is Husky Oil's East Coast Operations "Health, Safety and Environmental (HS&E) Loss Control Management Performance Standards" (Husky Oil 1998a). The stated purpose of that document is "to establish specific Health, Safety, and Environmental Loss Control standards for the Husky Oil East Coast Operations". Furthermore, the document intention is that adherence to these standards will assist in meeting the following objectives:

- keep employees (Husky Oil and contractor) free from harm;
- ensure that project facilities and operations are run in a manner that demonstrates Husky Oil's commitment to HS&E stewardship to its employees, neighbours, regulators and the general public;
- manage risk to protect Husky Oil from loss;
- manage the effects of Husky Oil's operations on the environment and the liabilities associated with those impacts;
- ensure clarity of expectations and appropriate consistency in the company's HS&E loss control program; and
- facilitate consistent company wide application of The Husky Oil Loss Control Management Program.

The following sections outline some of the key elements of the HS&E Loss Control Management system.

Figure 2.1-1 Health, Safety and Environment Policy

HEALTH, SAFETY AND ENVIRONMENT POLICY

We insist on a high level of concern for our employees, contractors, communities, customers and the environment. In conjunction with our business objectives we are striving to be one of the leading edge corporations in Health, Safety and Environmental stewardship and believe we can achieve this goal by managing our business under the following principles and values:

LEADERSHIP

High quality Health, Safety and Environmental stewardship is one of our corporate priorities and achieving this requires leadership, commitment and dedication of resources. We will include Health, Safety and Environmental objectives as part of our work and annual strategic plans.

RESPONSIBILITY

Health, Safety and Environmental protection is the responsibility of all employees and contractors. We will promote Health, Safety and Environmental awareness and respond promptly to and work diligently with all our stakeholders.

ACCOUNTABILITY

We are accountable for our performance and it will be measured against the Company's Health, Safety and Environmental Management Performance Standards. Safety and Environmental audits will be conducted on a regular basis to monitor compliance with the Standards, assess performance and identify areas where improvements are needed.

IMPROVEMENT

We will conduct our business activities with a progressive approach towards Health, Safety and Environmental protection and will monitor and if necessary, improve the performance of our operations. Improvements will be attained through planning, training and appropriate action.

Husky Oil

C.E.O.
HUSKY OIL LTD.

C.P. Baley
MANAGER

2.2 Functional/Departmental Responsibility for Health and Safety

Both Husky Oil and Contractor personnel involved in the Husky Oil East Coast Operations will participate in, and contribute to, the Project HS&E Loss Control Management system.

The Project Managers, FPSO/mobile offshore drilling unit (MODU) Offshore Installation Managers (OIMs) and Support Vessel Masters shall ensure that all shorebase and vessel management personnel will have specific HS&E Loss Control Management responsibilities clearly defined in their job outlines or descriptions, including any regulatory requirements involved in these responsibilities. In particular, the OIMs overriding authority to make decisions with respect to HS&E Loss Control Management issues shall be clearly identified. HS&E Loss Control Management responsibilities shall be included in employees' objectives and shall be evaluated as part of the annual performance appraisal. Copies of relevant documents concerning HS&E Loss Control Management responsibilities shall be provided to employees as appropriate.

2.2.1 Managers

Project managers will have primary responsibility for verifying/ensuring that the requirements of the HS&E Loss Control Management system are implemented and maintained. This would include development, implementation, review and revision of Project HS&E Loss Control Management performance objectives. On a periodic basis, they will be responsible to:

- participate in the establishment of annual HS&E objectives for the Project and/or the Shorebase, FPSO, MODU, Support Vessels and their applicable departments;
- on a scheduled basis, attend and participate in regular HS&E meetings;
- perform HS&E Loss Control Management inspections of facility departments;
- ensure that an audit and report on compliance with all of the elements of the HS&E Loss Control Management Performance Standard is completed annually and recommend modifications when appropriate to enhance compliance;
- review quarterly HS&E performance indicators (for example, statistics) in relation to established objectives and discuss HS&E performance/issues as appropriate at management meetings;
- ensure that a member of the Project, FPSO, MODU or Support Vessel management team participates in the monthly facility HS&E Committee Meeting; and
- review with facility management any necessary changes or deviations to the established Loss Control Management system

2.2.2 Supervisors

As part of their HS&E responsibilities, Supervisors will:

- participate in the establishment of annual HS&E Loss Control Management objectives;
- participate in the annual review of the HS&E Loss Control Management System as outlined above;
- carry out HS&E Loss Control Management inspections of their areas of responsibility ensuring that findings are documented and followed up;
- ensure their departments/areas hold HS&E meetings and that employees receive prompt feedback to the questions/suggestions; and
- require that all proposed equipment modifications are reviewed to ensure continued compliance with regulations and HS&E requirements.

2.2.3 Line Employees

All line employees will have clearly defined individual HS&E responsibilities to carry out under the Project HS&E Loss Control Management system.

2.2.4 Loss Control Program Support

Husky Oil and its major Contractors will formally allocate appropriate resources to support Project Managers, OIMs, and Support Vessel Masters in the safe performance of their duties. All shorebased and offshore facilities will have designated resources to assist with HS&E Loss Control Management issues. This responsibility could be divided among more than one position or could be combined with other responsibilities assigned to one position.

Written management performance standards for the HS&E/Loss Control Management program will be prepared and updated on an as required basis.

Specific Loss Control Management procedures will be implemented, as appropriate, to comply with Operator/Contractor corporate-wide standards and regulations. Project HS&E Policies and Procedures Manuals (both corporate and facility-specific) outlining standards, policies and procedures and offering guidance will be maintained and updated on an annual basis.

All shorebased and offshore facilities will have HS&E committees which are representative of all personnel at the worksite and function according to legislated requirements and individual company policy.

2.3 Employee Rights

2.3.1 The Right to Know

All employees of Husky Oil and Contractor(s) have a right to know of any working conditions that may in any way pose a hazard to health and safety. This awareness is fostered by Husky Oil through a variety of measures such as:

- an initial orientation, as outlined in Section 2.7.2 of this Preliminary Safety Plan, including hazard awareness and reporting;
- health hazard identification, and communication of that information. Supervisors will require that all employees are properly informed and knowledgeable about the potential occupational health and industrial hygiene hazards related to their work, including the handling of hazardous materials to which they could be exposed;
- supervisors will require group HS&E meetings to be held to discuss HS&E related topics;
- crew HS&E Meetings will be held monthly (or more frequently as dictated by crew change requirements) with individual shifts and department personnel including both Husky Oil and regular Contractor staff;
- joint Health Safety and Environmental Committees will be established on board vessels as required by regulation and meetings will be held at least monthly; and
- recommendations raised at the HS&E meetings will be recorded and addressed by designated personnel and action will be followed up and tracked on an ongoing basis.

2.3.2 The Right to Participate

The right of employees and contractors to participate in identification and management of HS&E issues is fostered by Husky Oil as follows:

- all shorebased and offshore facilities will have HS&E committees which are representative of all personnel at the worksite and function according to legislated requirements and individual company policy;
- management personnel will encourage employees to raise HS&E Loss Control Management concerns to their supervisors or team leaders either openly or in confidence at any time or at scheduled HS&E meetings, where concerns raised will be dealt with and recorded; and
- recommendations raised at meetings will be recorded and addressed by designated personnel and action will be reported at the next meeting.

2.3.3 The Right to Refuse Dangerous Work

Husky Oil and contractor personnel will be informed of their right to refuse to do any work that they feel, based on reasonable grounds, is dangerous to their health and safety or to the health and safety of other persons at the worksite. Personnel shall also be informed of the procedures to be followed if such a situation were to occur.

2.4 Individual Responsibility for Health and Safety

Husky Oil and contractor employees are encouraged by various measures specified throughout the Husky Oil HS&E Loss Control Management Performance Standards to assume personal responsibility for the health and safety of themselves and for their colleagues on the facility. This standard also states explicitly that observing and recognizing compliance with rules, policy and procedures is a responsibility of each employee.

2.5 Quality Assurance

Husky Oil will require specific quality assurance systems, across the whole development. This will be applicable to all major contractors and suppliers in the conduct of their activities associated with the project. As well, Husky Oil will ensure that the conduct of all project tasks, and the quality of installation, are in accordance with applicable Canadian and Newfoundland offshore regulations.

Before going into production operation, Husky Oil will obtain the requisite Certificates of Fitness, and Letters of Compliance. An independent certifying agency will be engaged to monitor the project throughout its development phase and to confirm that the complete installation has been designed, constructed and installed in compliance with regulations.

Husky Oil has developed HS&E Loss Control Management Performance Standards for its East Coast Operations, which mirror company standards across the country while recognizing the unique nature of the marine environment. The Loss Control Management Performance Standards are based on internationally recognized systems including the International Safety Rating System, the International Marine Safety Rating System, the International Safety Management (ISM) Code and the Det Norske Veritas (DNV) Safety and Environmental Protection Rules.

The relationship between Husky Oil and its major contractors, particularly in the case of the installation, needs to be seamless. A key element in achieving that seamless relationship is the demonstrated compatibility of the HS&E Loss Control Management system of the Company with that of its contractor(s). Husky Oil requires that its major contractors document how their Loss Control Management systems equate to that of Husky Oil, and how identified gaps are to be rectified, in order to achieve complete consistency. Husky Oil then conducts regular structured audits against the contractors systems.

2.6 Accident Investigation Procedures and Analysis

All accidents/incidents and near miss incidents resulting in personal injury/occupational illness, environmental releases, equipment damage or failure, fire, lost equipment, or criminal acts will be reported, investigated, and followed up by the Project Managers, OIMs or Support Vessel Master and the applicable area Supervisors. Investigation reviews for serious incidents will be conducted in a systematic fashion using established techniques (for example, Root Cause Analysis) and critical information will be documented and communicated to stakeholders. Reports will be completed thoroughly and in a timely manner as dictated by severity. The incident investigation system will include the following components:

- a review of events surrounding the incident with personnel directly involved;
- a description of what occurred;
- identification of substandard acts or conditions leading to the incident and the basic underlying causes;
- identification of corrective actions, assignment of responsibility to implement these actions as well as a system to ensure follow up of the implementation of the corrective actions;
- identification of required internal and external distribution of investigation reports to ensure that personnel who require the reports for operational or regulatory requirements receive the information on a timely basis; and
- investigation/reporting procedures to address Workers Compensation as well as cargo, subcontractor and third party claims (for example, damage to fishing equipment).

2.6.1 Accident Statistics and Analysis

At the end of each quarter, an overall Project report (Incident Summary) providing the cumulative annual accident/incident statistics will be published and communicated to employees. A copy of the report will be directed to Husky Oil’s Corporate Manager of Risk, Health, Safety and Environment and Business Unit Leader or Lead Officer. Major incidents will be reviewed at local management meetings.

Records of accident/incident investigation reports are maintained and will be readily accessible in an active file.

2.7 Organisational Rules

2.7.1 General Health, Safety and Environment Policies

At all facilities the HS&E Coordinators will require that Husky Oil's general HS&E policy is:

- posted in suitable locations where it is visible to all;
- contained in rule booklets, policy and procedure manuals, etc.; and
- referred to in all major training programs.

2.7.2 Rules Development, Communication and Evaluation

Project HS&E rules, policies and standards will be developed and maintained on an ongoing basis in consultation with the shorebased and offshore facilities. Management will be responsible for ensuring that these policies and procedures are reviewed, and updated as required. Where appropriate, site or vessel-specific HS&E rules and procedures will be developed to supplement corporate-wide rules, policies and procedures.

A systematic approach will be used to identify requirements for specialized work rules. This will typically involve reviewing regulatory requirements, hazard assessments, incident report analysis or lists of occupations and the critical tasks for those occupations. Required specialized work rules will be prepared by the Supervisors and local HS&E program Coordinators as appropriate.

The requirements for work permits will be clearly indicated, including a description of the process to determine the need for permits, formal issuing and approval system, permit life requirements, permit training process, and permit retention requirements. Permits are required for:

- confined space entry;
- work within hazardous atmospheres (breathing apparatus work);
- personnel transfer between vessels/MODU;
- hot work/work generating ignition source (for example, welding);
- suspension of safety functions or equipment;
- energy source lock-out/tag-out;
- working at heights or over the ship's side;
- work with hazardous material including radioactive sources/explosives;
- carrying out of simultaneous operations;
- working under water (diving);
- heavy lifts; and
- transfer of well control.

A specific area dedicated to posting HS&E material will be maintained in locations readily accessible to all employees at shorebase, FPSO, MODU, or support vessels. Current information concerning HS&E Loss Control Management, including rules, policies, and programs, will be posted to facilitate communication to all employees.

Individual HS&E rules will be reviewed on an ongoing basis and updated as conditions warrant. All employees will receive an initial orientation, upon arrival at all offshore facilities, which will include an explanation of the following HS&E information:

- key policies/principles;
- general HS&E rules;
- emergency response procedures and responsibilities (for example, evacuation plans and drills);
- instructions essential for safe MODU/ship operations;
- work procedures (for example, use of work permits) and potential effects of departure from them;
- Loss Control Management objectives and the employees' role in achieving them;
- hazard awareness and reporting;
- shipboard drug and alcohol policy and the process for monitoring compliance to the policy;
- legal/legislative conditions and employees' roles in meeting them (including approval, or permit requirements); and
- environmental sensitivities and programs (for example, environmental awareness, waste management, discharge requirements).

Where necessary, employees will be tested, either orally or in writing, for understanding and knowledge of key rules following the initial instruction. Employees will be given a thorough review of key rules for their area at least once a year during safety meetings and a record will be kept of these reviews in HS&E Committee meeting minutes.

Transferred employees will receive updated training in rules and procedures specific to their new assignment prior to commencing regular duties.

All employees with specific HS&E responsibilities will be fully aware, trained and monitored through the facility performance management process in the execution of those responsibilities.

Commendation and re-training or discipline for compliance or non-compliance of rules will be administered consistent with shorebase, FPSO, MODU, or support vessel policies. Records relating to compliance or non-compliance of rules will be used to evaluate the effectiveness of methods used to review rules with employees. Observing and recognizing compliance with rules, policies and procedures is a responsibility of each employee.

Existing general and specialized rules, policies and procedures will be reviewed and updated at least on an annual basis, or as needs dictate. Distribution lists for this Loss Control Management material will also be reviewed. The findings and recommendations, with respect to policies and procedures, will be incorporated into the annual review of the overall Loss Control Management system.

An evaluation of the compliance with major rule requirements, in particular, safe work permits, will be carried out following any major or high potential incidents and at least on an annual basis.

2.7.3 Statutory and Classification Certificates and Standards

Husky Oil will operate within a framework of laws, standards, procedures and instructions. Safe operations will be achieved by complying with the law, selecting and meeting the right standards, applying the correct procedures and by following the right instructions. A system will be in place to identify and monitor regulatory and class society certification and licensing requirements such as load line certificates, radio equipment certificates, lifting equipment certificates and safety equipment certificates. The system should include a process to ensure that:

- all required certification requirements are met and certificates maintained;
- required survey/audit deadlines are met;
- identified deficiencies are corrected to the satisfaction of the certifying authority or Class Society; and
- communication requirements related to correction of deficiencies are defined and met.

2.8 Contractors

Husky Oil will ensure that all contractors are capable of achieving acceptable standards. Contractor performance will be monitored throughout the duration of the contract. Loss Control Management considerations will be incorporated into the subcontractor selection and management process. Selection will be based in part on their HS&E program.

2.9 Purchasing

A system will be developed and implemented to ensure that all equipment and materials brought on to the offshore facilities are controlled throughout the procurement cycle to ensure that they do not introduce any unacceptable risks to personnel on the installation.

2.10 Hiring and Placement

Husky Oil's staffing philosophy will be consistent with both the intent and the spirit of the *Atlantic Accord Legislation*. A systematic approach will be used to recruit personnel which addresses staffing requirements, qualification/experience requirements and language requirements.

Employee development will be conducted on an ongoing basis through a combination of training, coaching and specific job assignments.

Pre-employment medical examinations are carried out as stipulated in company policy.

Competency assessments of employees will be undertaken on a regular basis to establish their theoretical and practical knowledge levels and to determine their ability to effectively perform their duties. Where staffing agents are used, a verification process will be used to ensure the agent complies with Company requirements and language considerations and that checks are used to determine the validity of crew qualifications, licenses and certificates.

2.11 Safety Audits

Systematic safety audits will be conducted on a regular basis, within a prescribed frequency. Audits will evaluate the implementation of project Loss Control Management systems as well as physical conditions (as outlined in Section 4.7 of this Preliminary Safety Plan).

2.12 Health and Hygiene Control

Occupational health and hygiene hazards related to all aspects of vessel operations will be identified and evaluated on an ongoing basis.

Where potential hazards have been identified, surveys will be conducted to evaluate exposure levels to health and hygiene hazards. Regular monitoring to measure hazardous exposures will be done as necessary to ensure hazards are being controlled at safe levels.

A Health Surveillance Program will be introduced which includes:

- personnel medicals as required;
- medical fitness verification prior to returning to work after a prolonged illness or injury;
- medical monitoring as dictated by health hazard exposures; and
- drug and alcohol testing as required under Husky Oil's Alcohol and Drug Policy.

A medical support program will be in place at all times which includes the presence of appropriate medical teams in place at all offshore facilities, on-call physician and medivac support on a 24-hour basis and well equipped on-site medical facilities. Husky Oil has established Employee Assistance Program in place for employees to provide medical and mental health support as required.

3 FACILITIES AND EQUIPMENT

3.1 Description of Facilities

3.1.1 Facilities Included

The Safety Plan will address existing and future facilities and operations (such as, drilling units, production wells, production facilities, support vessels, aircraft and shorebase).

3.1.2 Oil Reservoir and Production Wells

The White Rose field is located approximately 350 km east of Newfoundland on the eastern edge of the Jeanne d'Arc Basin. Water depth at this location is approximately 120 m.

Ultimately, there will be up to 10 to 14 production wells associated with the Project. To maximize oil production, reservoir pressure will be maintained by injecting water into up to an additional six to eight strategically placed wells. It is also planned to inject surplus gas into the reservoir for gas conservation and, if necessary, to assist in pressure maintenance. It is currently assumed that the facilities will have a 20-year design life.

A typical subsea arrangement consists of templates, manifolds, flowlines, umbilicals, and risers. The main method of iceberg scour protection will be dredged glory holes, with the possibility of using a caisson system at strategic locations to optimize field layout.

The preliminary subsea layout for the Project can be described as follows:

- two to three drill centres in a north-south alignment to allow complete access to the South White Rose oil pool;
- gas injection, water injection and oil production capabilities required at various drill centres;
- a possible one to three additional well centres, depending on depletion plan requirements for the area, and well trajectory design considerations;
- templates used to minimize glory hole size, (templates are single service, either production/gas lift or water or gas injection);
- flowlines used for all intrafield lines and risers;
- well testing carried out via a dedicated test line;
- round trip pigging facilities for wax removal and line displacement of production fluids; and
- conventional electro-hydraulic control systems.

3.1.3 Drilling Unit

The drilling unit will typically be an anchored steel-hulled semi-submersible MODU. Its staffing complement will typically be approximately 70 to 100 persons.

3.1.4 Support Vessels

Two to three support vessels will be used for resupply and standby requirements. Vessel complements typically range from 10 to 12 persons.

3.1.5 Supply Base

An existing supply base will be used to provide logistics support to the operation.

3.1.6 Helicopter Support

Personnel will be transported to and from the field by helicopter. Helicopter support is provided by a flight centre at the St. John's Airport. Current aircraft used are Aerospatial Super Pumas, each having a carrying capacity of approximately 9 to 10 passengers and two crew members.

3.1.7 Production Unit

The following is an overview description of the production facility. Additional information is included in the attached CSA (Volume 5, Part Two).

The preferred production unit is a steel-hulled FPSO. Its oil production rate is estimated at 12,000 to 18,000 m^3 (75,000 to 100,000 barrels per day). It will have a storage capacity of approximately 110,000 to 135,000 m^3 (700,000 to 850,000 barrels).

The FPSO will contain a turret and emergency shutdown systems, which allows the FPSO to disconnect and move off location under its own power to address operational or emergency situations.

There will be approximately 50 to 60 personnel on board the FPSO at any one time, with approximately 50 being permanent crew and the remainder being temporary specialist personnel.

The FPSO is expected to include the following typical systems:

- separation, including manifolds and two-stage separation;
- oil handling – treating, metering, pumping, pigging, storage;
- gas handling – compression, dehydration, metering, and injection;

- water handling – treatment, disposal, injection;
- oil offloading;
- chemical additives – storage, injection;
- heating and cooling;
- potable water;
- air – compression, drying, distribution;
- nitrogen – gas and liquid distribution;
- power – generation and lighting distribution;
- fuel – gas, diesel, aircraft;
- vents;
- flares;
- drains;
- communications;
- sewage;
- living quarters;
- fire protection, fire pumps, water distribution, deluge, sprinklers, carbon dioxide, fire and gas detection;
- controls – process control, emergency shutdown; and
- ventilation.

3.2 Certification of Fitness

A current Certificate of Fitness for the FPSO and MODU will be maintained at all times while the facilities are in operation.

3.3 Prevention, Control and Mitigation of Major Hazards

3.3.1 Hazard Prevention and Detection

3.3.1.1 Production Facility Layout

Design criteria for the installation will be used to provide the required separation between the living quarters and the main sources of hydrocarbons, namely the process module and the turret. The areas between will act as a buffer zone to minimize any potential impact of hydrocarbon incidents on the living quarters.

The equipment layout will account for potential releases of flammable gases or liquids and potential ignition sources. The potential for overpressures will be minimized by providing vent paths for any potential explosions.

The configuration will provide for minimum evacuation times and minimum exposure to hazards, ensuring personnel will be able to leave the installation under all credible contingencies.

A minimum of two alternate routes will be provided for escaping from most locations on the installation, ensuring that at least one escape route is passable at all times.

3.3.1.2 Hazardous Area Classification and Minimisation of Ignition Sources

The installation will incorporate a Hazardous Area Classification System designed in accordance with the America Petroleum Institute (API) Recommended Practice (API RP 500) or equivalent. Areas on the installation will be classified in the following categories:

- Hazardous Class 1 Division 1: a hazardous area in which a flammable atmosphere is likely to occur in normal operation.
- Hazardous Class 1 Division 2: a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it does occur, will only exist for a short period.
- Unclassified: an area where the occurrence of a flammable atmosphere is so infrequent as to be deemed insignificant.

One of the main potential sources of ignition is electrical equipment. Where electrical apparatus is to be used in a hazardous area, it will be classed appropriately for the area and will be selected to withstand the environmental conditions to which it will be exposed.

3.3.1.3 Heating, Ventilation and Air Conditioning

The installation design will include multiple independent heating, ventilation and air conditioning (HVAC) systems which will satisfy both area classification requirements. The separation of the systems will minimize the possibility of back flow of gas into non-hazardous areas through the air intakes and will provide for a selective emergency shutdown strategy.

HVAC inlets will be located in non-hazardous locations and will be fitted with both smoke and gas detection, which will serve as trigger points for action related to the emergency shutdown system.

3.3.1.4 Fire and Gas Detection

A fire and gas detection system (FGS) will monitor the installation for fire, smoke and flammable gases. Upon detection, personnel will be automatically alerted both audibly and visually via local alarms and at the FGS panel in the central control room (CCR).

Upon confirmed fire or gas, the FGS will automatically activate the active fire protection systems and the emergency notification systems. The FGS will also shut down the ventilation systems and initiate operational shutdowns.

The detection devices will be selected according to the types of vapours and fires which would be anticipated in each area of the installation. They will be positioned to facilitate early activation and provide maximum protection.

3.3.1.5 Wellhead Control and Shutdown

The oilfield reservoirs will be capable of being isolated from the process areas by separate and independently controlled valves for each well. Typically these include a Surface Controlled Subsurface Safety Valve (SCSSV) and the upper master gate and wing valves at each wellhead.

The valves will be hydraulically operated and will be fail-safe, that is, if the control signal or power is lost the valves will fail in the closed position.

Riser emergency shutdown valves (ESDVs) are also provided to protect process areas from flowline inventories.

3.3.1.6 Process Isolation

Effective process isolation will limit the volume of inventory released in an incident, which in turn prevents escalation of a potential hazard. Upon detection of a hazardous condition emergency shutdown will be initiated isolating sections of the process, which will minimize the available inventory of hydrocarbons. This will limit the duration and consequence of a hydrocarbon release.

3.3.1.7 Blowout Preventer Systems

Blowout preventer (BOP) systems provide a means of preventing an uncontrolled release of well fluids during a drilling or workover operation.

Each BOP is equipped with a series of rams and an annular preventer designed to seal off the annular space around the drill pipe. The rams are closed by hydraulic pressure and the design of the BOP uses the pressure of the well fluid to keep the rams closed.

3.3.1.8 Marine Systems

The installation will be designed to ensure that all marine systems, such as ballast control, propulsion, engines, etc, can be safely operated during an emergency situation. Systems will be in place to ensure that ballast control can be achieved both automatically and manually.

3.3.1.9 Physical Environment Data Collection

Husky Oil currently has in place a physical environment data collection program consisting of a number of components. The program is in support of Husky Oil's drilling operations, and a similar program will be in effect to support the White Rose production facility operations. The program includes a physical oceanographic component, a Marine Weather Observation (MANMAR) component, a Supplementary Aviation Weather Reporting Station (SAWRS) component, a rig response component and a site-specific marine weather and sea state forecast component.

All components are such that the C-NOPB "Guidelines Respecting Physical Environmental Programs During Drilling and Production Activities on Frontier Lands" are satisfied. The physical oceanographic component consists of moored current meters at several depths, a current meter for real time current profiling, a waverider for measuring waves, and a water level recorder to record tidal elevations when necessary. Separate reports are issued for current data and for wave data.

Both the MANMAR and SAWRS observation components will be taken on-board the FPSO and MODU. Both are used in the preparation of the site specific operational forecasts, and the former is also distributed to the Atmospheric Environment Service of Environment Canada for regional weather forecasting, while the latter is transmitted directly to the Helicopter Contractor for flight support operations.

Observations include:

- date and time;
- type of observation;
- sky conditions;
- visibility;
- weather conditions;
- dry bulb air temperature;
- dew point;
- wind speed and direction;
- wind character;
- altimeter and mean sea lever barometric pressures;
- comments on weather conditions;

- sea temperature;
- maximum combined seas;
- maximum trough to crest wave;
- significant wave height;
- average wave period;
- height and period of wind driven wave;
- height, period, and direction of primary non-wind driven wave component; and
- height, period, and direction of secondary non-wind driven wave component.

The rig response component of the program includes the heave, pitch, and roll experienced by the facility. The information for these three components is combined into an operational log which is used by the onboard drilling and marine personnel.

The ice observation component of the program encompasses both pack ice and icebergs. The observations of this component will include:

- date and time;
- descriptions of ice in terms of type, size and shape;
- the geographic position;
- the course of drift; and
- the calculated closest point of approach (CPA) to the facility and the time to CPA (or TCPA).

Ice observation data is then interpreted into the Ice Management Plan to assist in tactical decision making. In the event of a tow, further observations will be made and recorded and will include:

- vessel call sign;
- bollard pull of tow;
- tow direction; and
- any relevant factors such as rolling or breaking up.

Third party information using satellite and aircraft surveillance techniques will also be used for predicting ice conditions.

The weather forecasting component of the program in support of Husky Oil's drilling operations typically consists of:

- two site-specific forecasts per day at twelve-hour intervals;
- two six-hour updates;
- a continuous weather watch, including routine ongoing quality assurance/quality control (QA/QC) procedures for evaluation and verification of forecasts;

- site-specific weather forecasts consisting of short-term site-specific forecast issued in six-hour time steps for 54 hours, followed by a long-range forecast in twelve-hour time steps for an additional three days;
- updated forecasts on a three-hour basis or more frequently if required during emergency or storm situations;
- issuance of weather warnings whenever appropriate;
- weather briefing in Husky Oil's office in St. John's when required;
- telephone briefing and weather related discussions at any time;
- maintenance of an effective data communications systems to ensure timely receipt and issuance of environmental data and forecasts. Back-up by an on-site electrical generator to ensure continuous operation during power interruptions; and
- preparation of forecast verification reports on completion of each drilling program that meets Husky Oil's needs and satisfies C-NOPB guidelines.

A sample forecast, as produced in tabular form, is illustrated in Figure 3.3-1.

3.3.2 Hazard Control Systems

The offshore facilities will incorporate facilities and systems to control and monitor hazardous areas during both normal operation and potential hazardous situations.

The following control systems will be used:

- **Distributed Control System (DCS)**: This is the primary means for controlling and monitoring the installation.
- **Emergency Control System (ECS)**: Designed to initiate specific actions after receiving outputs from the FGS. The main functions of this system are to minimize the consequences of a fire or hydrocarbon release and provide a safe and orderly shutdown of the installation. An emergency shutdown may be initiated manually from designated pushbuttons or automatically via the FGS.
- **Process Shutdown System (PSD)**: This system will be an integral part of the DCS and will initiate a controlled process shutdown in the event of process upset.
- **Vessel Control System (VCS)**: For controlling all marine systems within the vessel (such as, ballast, cargo transfer).

The various control systems will all be operated from the central control room located in the process building on the FPSO.

Figure 3.3-1 Weather Forecast Form

Oceans LTD.

MARINE WEATHER SITE FORECAST

Sample Forecast Husky Oil Operations Ltd. offshore Newfoundland, issued by OCEANS Ltd., St. John's
Monday July 14 1997 at 1630 NDT , valid until 2130 NDT Wednesday
with a long range forecast for the following three days.

WARNINGS IN EFFECT: NIL

SYNOPSIS

A 1000 MB LOW PRESSURE CENTER LOCATED NEAR SABLE ISLAND AT FORECAST TIME WILL TRACK NORTHEASTWARD PASSING TO THE NORTH OF THE PLATFORM LATE TUESDAY AFTERNOON. THEREAFTER, THE LOW WILL CONTINUE NORTHEASTWARD INTO THE NORTH CENTRAL NORTH ATLANTIC. LIGHT SOUTHERLY WINDS THIS EVENING WILL INCREASE TO STRONG SOUTHEAST WINDS SHORTLY AFTER DAWN TUESDAY THEN VEER INTO THE SOUTHWEST BY EVENING. A COLD FRONT SWINGING EASTWARD AROUND THE LOW WILL CROSS THE FORECAST WATERS LATE TUESDAY EVENING . STRONG WEST TO NORTHWEST WINDS ARE FORECAST BEHIND THE COLD FRONT ON WEDNESDAY.

VALID DATE / TIME

DAY / DATE	MON JUL 14	TUE JUL 15	TUE JUL 15	TUE JUL 15	TUE JUL 15	WED JUL 16	WED JUL 16	WED JUL 16	WED JUL 16
TIME (NDT / UTC)	2130/00Z	0330/06Z	0930/12Z	1530/18Z	2130/00Z	0330/06Z	0930/12Z	1530/18Z	2130/00Z
WIND AT									
DIRECTION (true)	180	160	150	190	240	270	330	340	330
MEAN SPEED (kt)	10	15	25	22	25	20	28	30	25
MAX SPEED (kt)	12	20	30	25	30	25	34	38	30
WIND WAVES									
SIG HEIGHT (m)	0.5	0.7	2.2	1.5	1.8	1.3	2.2	3.3	3.0
PERIOD (s)	3	3	5	4	5	4	5	7	7
PRIMARY / SECONDARY SWELL									
DIRECTION (true)	200	200	200/180	180	180	180	NIL	NIL	NIL
HEIGHT (m)	1.5	1.0	1.0/1.5	1.8	1.5	1.2	0.0	0.0	0.0
PERIOD (s)	9	9	9/7	7	8	8	-	-	-
COMBINED SEA									
SIG HEIGHT (m)	1.6	1.2	2.8	2.3	2.3	1.8	2.2	3.3	3.0
MAX HEIGHT (m)	3.0	2.0	5.0	4.0	4.0	3.0	4.0	5.5	5.0
TEMPERATURE (C)	11	11	12	14	13	12	11	11	9
MSL PRESSURE (hPa)	1006.2	1004.0	1001.6	999.6	998.4	1000.1	1003.2	1006.1	1008.3
SKY COVER	OBSC	OBSC	OBSC	OBSC	OVC VRBL OBSC	OVC VRBL OBSC	OVC/BKN	OVC/BKN	BKN
WEATHER	L-FOG OCNL R-FOG	L-FOG OCNL R-FOG	R-L-FOG OCNL RFOG	R-L-FOG	FOG/MIST OCNL RW-MIS	FOG VRBL RW-MIST	OCNL RW-MIST	OCNL RW-MIST	NIL
VISIBILITY (nm)	1/8 - 1/2	1/8 - 1/2	1/8 - 1/2	1/8 - 1/2	1/4 - 1/2 VRBL 1 - 5	1/4 - 1/2 VRBL 1 - 5	6+ OCNL 2 - 5	6+ OCNL 2 - 5	6+

LONG RANGE FORECAST

VALID DAY / DATE	THU JUL 17	THU JUL 17	FRI JUL 18	FRI JUL 18	SAT JUL 19	SAT JUL 19
VALID PERIOD	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
WIND DIRECTION (t)	WESTERLY	W TO SW	SOUTHWESTERLY	SOUTHERLY	S TO SW	S TO SW
WIND SPEED (kt)	10 - 15	10 - 15	10 - 20	15 - 20	20 - 25	20 - 25
COMB WAVE HGT(m)	2 - 3	2 - 3	3 - 4	3 - 4	4 - 5	4 - 5
VISIBILITY	FAIR TO GOOD	FAIR TO GOOD	POOR	POOR	POOR	POOR

Next Regular Forecast issued: SAMPLE ONLY Prepared by: NC Forecast number H A 140797 . 16
Phone: (709) 753 2482 Fax: (709) 753 5972

3.3.3 Hazard Mitigating Systems

3.3.3.1 Active Fire Protection Systems

The installation will be provided with the necessary level and type of active fire protection (AFP) systems to assist in the recovery from fire, by applying a reliable and effective distribution of firewater and foam. The following AFP systems are planned to be used:

- **Deluge**: Primarily used in hydrocarbon areas where gas or liquid fires could occur. Deluge limits escalation of a fire by reducing the effect of the fire on equipment and structures. It provides a means of applying foam to assist in extinguishing hydrocarbon pool fires. It also provides protective water barriers to assist personnel during escape and evacuation.
- **Sprinkler**: Provided as the primary means of AFP in all accommodation areas, laboratories and workshops.
- **Fire Hydrants**: Provided on all areas of the installation for general fire fighting purposes.
- **Firewater Monitors**: Primarily used for the helideck. Firewater monitors use a dedicated foam supply and can be manually or automatically operated.
- **Hose Reels**: Provided in accommodation, utility and other areas.
- **Water Fog Systems**: For vessel machinery spaces.

The above systems will be supplemented with hand-held, portable or wheeled-type fire extinguishers strategically located around the installation and in the accommodation areas.

3.3.3.2 Passive Fire Protection

The installation design will be based on a passive fire containment principle. High-risk areas will be separated from adjacent areas by partitions designed to control the spread of fire.

Passive fire protection (PFP) systems are capable of providing an approved fire barrier and structural stability in the event that there is an absence or failure of any AFP system.

During a hydrocarbon fire, PFP systems provide stability for the primary and load bearing structure for a period of time sufficient to allow fire-fighting to proceed in a controlled manner and for personnel to evacuate the installation should this be deemed necessary.

3.3.3.3 Explosion Protection

In the event of an explosion, the installation will be designed to minimize pressure build-up in confined areas. This ensures that explosion overpressure does not impair the function of the primary structural members or the fire divisions. Rated blast walls will be used in specific areas to minimize the potential for an explosion in an area to impact nearby areas.

3.3.3.4 Blowdown and Flare System

The installation design will incorporate a blowdown system to minimize the risk of equipment rupturing and to reduce the quantity of inventory that may feed a fire or gas cloud.

The installation flare system will provide a safe and efficient way of collecting and disposing of hydrocarbons associated with the following:

- discharge from the safety valves during pressure relief conditions;
- partial or total installation depressurization scenarios; and
- disposal of hydrocarbons from process systems.

3.3.3.5 Power Generation

Power generation systems will provide electricity to the installation. Apart from normal power generation the installation will have an essential power supply which will serve emergency loads, such as firewater supply, in the event that main generation, is lost. In addition to this, an uninterruptible power supply (UPS) will be provided to power critical loads that must remain in service after a total loss of normal and essential power supply.

3.3.3.6 Communications

The installation will incorporate both internal and external communication systems to provide for effective, efficient and reliable communications links between the installation helicopters, attendant vessels and on-shore facilities. In the event of an emergency, they provide a means of communicating with lifeboats and assisting such agencies as the Canadian Coast Guard.

3.3.3.7 Temporary Safe Refuge

The installation will incorporate a TSR which serves as a “safe haven” where personnel can safely muster during emergency. The TSR will provide a resource base for emergency actions, the installation communications center and a means of getting to and using the evacuation systems. Access routes to the TSR provide a safe path from any area on the installation during the initial stages of an incident.

The TSR will incorporate the following features:

- in accordance with the TLS the installation design will provide a stable structure for the TSR and the evacuation systems for a minimum period of two hours. Performance standards to which the TSR and associated facilities are designed will be established to identify the minimum period that the facilities will remain capable of functioning in conditions of fire, explosion, toxic fumes and other hazards;
- protection against smoke and gas ingress;
- protection against loss of breathable atmosphere;
- protection against heat/temperature build-up;
- reliable power supplies;
- lighting and visibility systems;
- communication systems;
- command structure; and
- facilities to handle medical and rescue emergencies.

3.3.3.8 Evacuation, Escape and Rescue Systems

Two safe escape routes will be provided from all work areas to increase the likelihood that at least one route will remain accessible during any given condition. These routes will be clearly marked and lead to the TSR, where the muster areas will be located, and to the embarkation areas for the evacuation system.

Evacuation systems, such as Totally Enclosed Motor Propelled Survival Craft (TEMPSC) will be provided in sufficient quantity, and at strategic locations, to cater for 200 percent of the normal persons on board (POB). Secondary and tertiary escape systems will also be provided to satisfy regulatory requirements.

A Multifunctional Platform Support Vessel (MFPSV) on standby duty will be used for rescuing personnel who have escaped to the sea. The vessel will provide hospital space and food provisions.

The MFPSV will have a fast rescue craft that can be used for retrieving personnel who have left the installation and transferring them to the MFPSV.

3.4 Life Supporting and Life Saving Equipment

3.4.1 Lifebuoys

The installation will incorporate an adequate supply of lifebuoys distributed in such a way as to enable one lifebuoy to be visible from any point of the outside walkways on the installation.

Each lifebuoy will be supplied with a suitable tail line and self-actuating buoyant light. Each lifebuoy and its associated equipment will be designed to comply with current regulatory requirements.

3.4.2 Lifejackets

The installation will be provided, as a minimum, with the following allocation of lifejackets:

- 100 percent of maximum POB located within the TSR; and
- a minimum of 50 percent of maximum POB located outside the TSR.

Each lifejacket will be designed to comply with the current regulatory requirements. They will be of automatic inflating design and be provided with a strobe light to make the wearer more conspicuous to rescuers.

The location of all lifejackets will be clearly marked and will be easily accessible. Those located outside the TSR will be stowed in cabinets.

3.4.3 Survival Suits

These suits may be either the suits issued to personnel at the heliport for use while flying, or they may be separate suits issued at the installation. On arrival at the installation, each person will keep his or her survival suit in an emergency survival pack, as outlined in Section 3.5 of this Preliminary Safety Plan, contained within his or her cabin.

Additional suits to accommodate an additional 100 percent of the maximum POB will be located outside the TSR in storage cabinets located adjacent to the TEMPSC's.

3.5 Emergency Survival Packs

In each cabin there will be an emergency survival pack or "grab bag" for each person. The following equipment will be contained in each bag:

- heat resistant gloves;
- a flashlight; and
- survival suit.

In addition to the above, each cabin will contain two smoke hoods and a fluorescent snap nightstick for use in an emergency. For more information on personal protective equipment (PPE), refer to Section 4.8 of this Preliminary Safety Plan.

4 OPERATIONS AND MAINTENANCE PROCEDURES

4.1 Operations/Maintenance Manuals

Operating and maintenance procedure manuals will be used in all aspects of support of the White Rose Project. The manuals will be implemented specifically for the Project and will incorporate all regulatory requirements. These manuals will be a vital tool in the promotion of safe and efficient operations. Personnel will be trained in the use of the appropriate manuals and in associated procedures.

4.2 Production Monitoring and Control Systems

System manuals will be provided that will contain design rationale and operating parameters that will form the basis for the operating manuals for all primary, sub and ancillary systems.

4.3 Simultaneous Operations and Procedures

A simultaneous operations and procedure manual will be provided to address all aspects of simultaneous operations involving the FPSO and MODUs working over drill centres. This manual will be designed to enhance safety on both facilities at all times.

4.4 Work Permit System

A system of work permits will be in place for the installation. The system is described in more detail in Section 2.7.2 of this Preliminary Safety Plan.

4.5 Planned Maintenance System

The maintenance system is an integral part of the safety system in that it must provide assurances of the physical integrity of the individual components of the production system. A reliability centred maintenance (RCM) concept will be employed to ensure that equipment achieves required reliability levels. Reliability will be a function of criticality.

An inventory of critical parts, products, equipment and systems will be identified, established and maintained at each FPSO, MODU, support vessel and shorebase facility in order to fulfil parts and maintenance requirements and associated record keeping. Suppliers of critical materials will be identified based on their ability to meet required specifications. Critical parts are those whose failure are most likely to result in a major loss to people, property and/or the environment. Critical systems include ballasting systems, standby equipment (for example, emergency generators, emergency steering, main engine manoeuvring controls) and inactive equipment (for example, lifeboat launching systems, mooring and anchoring equipment).

Critical equipment and systems will be inspected on a regular basis in accordance with the vessel's regular inspection program.

Critical safety systems, monitoring instruments, and other equipment will be inspected, calibrated, and repaired as per manufacturer's specifications and applicable Husky Oil and contractor standards by maintenance personnel or other designated contractors.

Shorebased and offshore facilities will maintain and keep appropriate records regarding planned maintenance programs, including elements such as corrosion protection, leak detection and winterization programs, materials handling equipment and lifting gear.

4.6 Management of Change

A system will be developed and implemented to manage all process, engineering, procedural and organizational changes in a timely and effective manner. Relevant engineering regulations, codes, classification rules and industry standards will be reviewed on an ongoing basis to ensure compliance. A review system is in place to incorporate Loss Control Management considerations into design, construction and commissioning of vessel modifications or repairs.

Systematic processes will be used to identify hazards and assess risks associated with new, or changes to existing, work processes and procedures prior to the procedures being used and to ensure appropriate weight control procedures are employed.

Loss Control Management requirements are used as part of the acquisition criteria for spot charters or additional vessels. Vessels are inspected by qualified personnel prior to acquisition.

4.6.1 Non-Standard Modes of Operation

Procedures and guidelines will be developed as part of the overall Safety Management System to ensure that operational limits are not breached. An approval system will be implemented to ensure that process variables and unusual operating conditions are subject to appropriate control. Limitations imposed by the physical restrictions of the facilities will be established during the design stage of the project.

4.7 Planned Inspections

4.7.1 Health, Safety And Environment Inspections

All shorebased and offshore facilities are required to carry out inspections on a regular basis to identify conditions and practices which have the potential to cause health, safety or environmental problems, and have documentation, regarding these inspections which specify the following:

- those personnel responsible for conducting the inspections;
- frequency of the inspections;
- checklists to be used;
- written reporting, distribution, record keeping and follow up procedures; and
- responsibility/ confirmation to ensure that remedial actions are carried out in a timely manner along with analyses of the reports.

This documentation shall be updated on a yearly basis or when significant changes occur.

The inspection program design includes, but is not limited to, a consideration of the following general areas as they apply to the FPSO, MODU, supply vessels and shorebase facilities (dock, warehouse, offices):

- bridge;
- vessel offices;
- radio room;
- deck areas;
- engine room;
- living areas;
- galley;
- messes;
- drilling facilities/process areas and equipment;
- emissions monitoring and control equipment;
- effluent streams monitoring, treatment/control equipment;
- waste handling and storage facilities;
- maintenance/work shops;
- stores areas;
- bulk product containment/storage areas;
- fuel storage areas;
- loading and unloading areas;
- ballast control areas;
- relevant off-site areas;
- spill response and control equipment;
- fire and emergency equipment;
- all product and chemical transfer points;
- contractor work sites;
- leak detection systems; and
- corrosion detection systems.

4.7.2 Regular Health, Safety and Environment Inspections

Regular inspections will be conducted as follows:

- Monthly planned inspections of fire and emergency equipment by the applicable area Supervisor or designate, as set down on an approved check list.
- On a monthly basis, designated personnel will carry out HS&E inspections, using checklists, of a pre-determined section of their work area, and will identify and correct deficiencies. Significant findings from inspections will be reported at HS&E group/committee meetings.
- Supervisors will carry out formal scheduled HS&E inspections of their areas annually using checklists, and will follow up and correct deficiencies on a timely basis.

Copies of inspection reports will be forwarded to the appropriate Supervisors for follow-up actions. Inspection and follow-up reports will be maintained on file as necessary. Records of deficiency reports will also be maintained on shore.

Management and other appropriate personnel will be kept regularly informed of results of planned inspections, along with the details of remedial actions taken or reasons for delays to address high hazard (priority) items.

4.8 Personal Protective Equipment

4.8.1 Personal Protective Equipment Information

Requirements and needs for PPE will be identified on an ongoing basis by Husky Oil and Contractors. Needs will be based on:

- regulations, Class Society requirements;
- HS&E Committee recommendations/employee consultation and input;
- job analysis and history;
- accident incident investigations;
- accepted industry standards; and
- work permits.

PPE standards, requirements and procedures will be written down and communicated through:

- policy and rule booklets;
- site-specific job procedures and Safe Work Permits or plans;
- material safety data sheets;
- training programs;

- special bulletins; and
- posted warning signs.

4.8.2 Protective Equipment Availability And Maintenance

As a means to control occupational hazards at the worksite, Supervisors will be responsible for ensuring that PPE is available and used as appropriate by all personnel. Proper facilities and expertise will be provided for maintaining, cleaning and storage of PPE. All employees (Husky Oil and Contractor) will be instructed in the need for, proper use, limitations, cleaning and maintenance of applicable PPE prior to commencing job assignments. Records will be maintained of the instruction.

Employees will be required to check and monitor the condition of PPE as part of their regular routine and standard practice. Substandard equipment shall be taken out of service. The condition and use of employees PPE will be maintained on a random basis to ensure it is being maintained and remains in serviceable condition.

To meet legislative requirements, Supervisors and/or Program Coordinators will ensure that records are kept on testing, repair, replacement, usage, inspection and issuance of applicable PPE (for example, breathing apparatus).

The shorebased and offshore facility’s disciplinary and commendation procedures concerning PPE requirements and use will be discussed with all employees so that enforcement will be consistent throughout the shorebase, FPSO, MODU, and support vessels.

4.9 Hazardous/Dangerous Goods

Husky Oil will ensure that all requirements for both provincial and federal Transportation of Dangerous Goods and Workplace Hazardous Materials Information System (WHMIS) regulations and legislation are met. All requirements of both provincial and federal legislation and regulations respecting the handling, storage, use and disposal of hazardous materials will be met.

An Offshore Chemical Management System (OCMS) will be developed and implemented to ensure that HS&E considerations are taken into account prior to the introduction of any chemicals to the site. Material Safety Data Sheets (MSDS) will be readily available to all employees and user systems put in place.

5 TRAINING AND QUALIFICATIONS

5.1 Organizational Structure

Husky Oil will manage the operation on behalf of itself and its co-venturer, Petro-Canada, from the Husky Oil office in St. John's. The operation will include an integrated team of trained personnel from both owners, supplemented by contractor's personnel. A preliminary overview of the onshore operation is outlined in Tables 5.1-1 and 5.1-2 and Figures 5.1-1 and 5.1-2.

Table 5.1-1 Functions of On-shore Personnel

Responsibility	Number of Persons	Function
Management	1	Operations Management
Drilling and Completions	3-4	Drilling Supervision Drilling Engineering Completions Engineering
Technical Services	15-16	Facilities Engineering Reservoir Engineering Geology Geophysics Petroleum Engineering Petrophysics Telecommunications Computer Services Maintenance Engineering Subsea Engineering Instrumentation and Controls
Logistics	11-12	Procurement Materials Transportation Crane Operation Radio Operation Yard Labour
Business Services	7-8	General Accounting Invoice Processing Production Accounting
Administration	5-6	Office Management Human Resources Public Relations Secretarial Services Reception Telephone
Loss Prevention	3-5	Loss Management Quality Assurance Quality Control Security
Total	45-52	

Table 5.1-2 Functions of FPSO Offshore Personnel

Responsibility	Number of Persons	Function
Management	1	Offshore Installation Manager
Loss Management	2	Loss Prevention Advice Environment Advice Medical Services
Production	6-7	Supervision Control Room Operators Production Operations
Marine	6-7	Marine Supervisors Marine Operations
Maintenance	14-15	Supervision Instrument Maintenance Mechanical Maintenance Electrical Maintenance Telecommunication Maintenance Maintenance Scheduling
Services	16-18	Supervision Helideck Loading Deck Crew Supervision Deck Crew Operations Crane Operations Radio Operations Ice and Weather Surveillance Catering and Accommodations Services
Total	45-50	

Figure 5.1-1 On-shore Organization

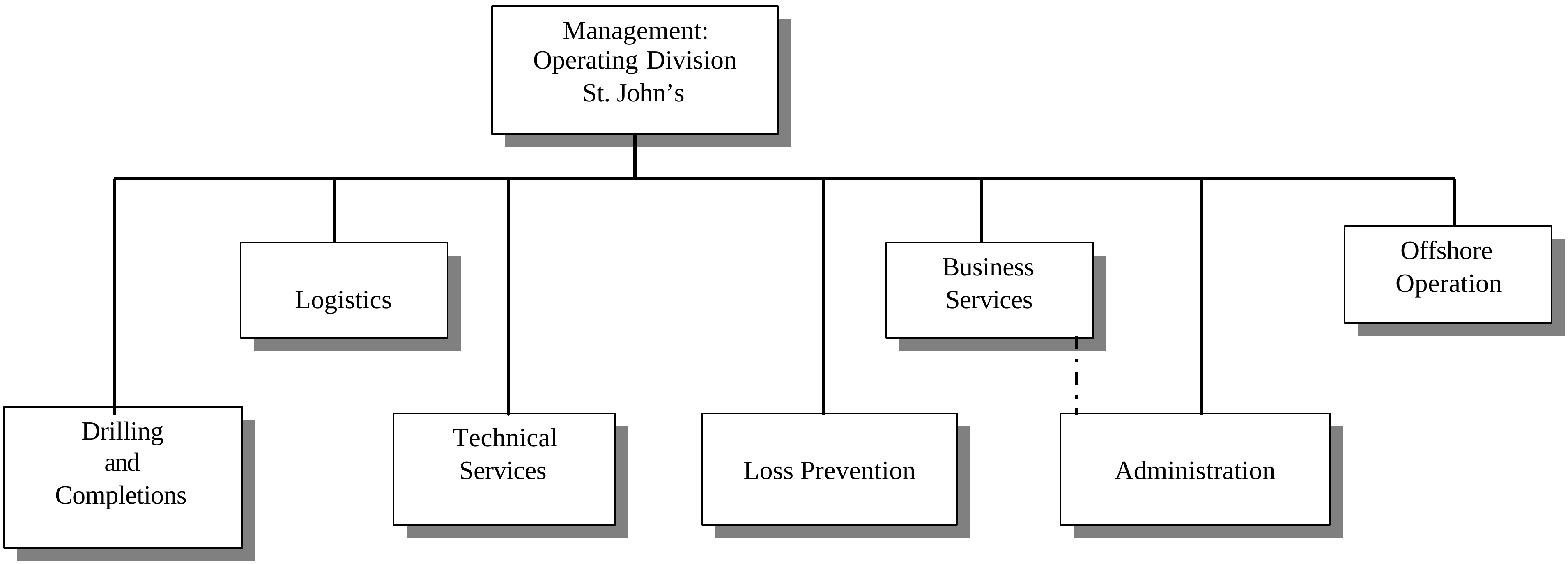
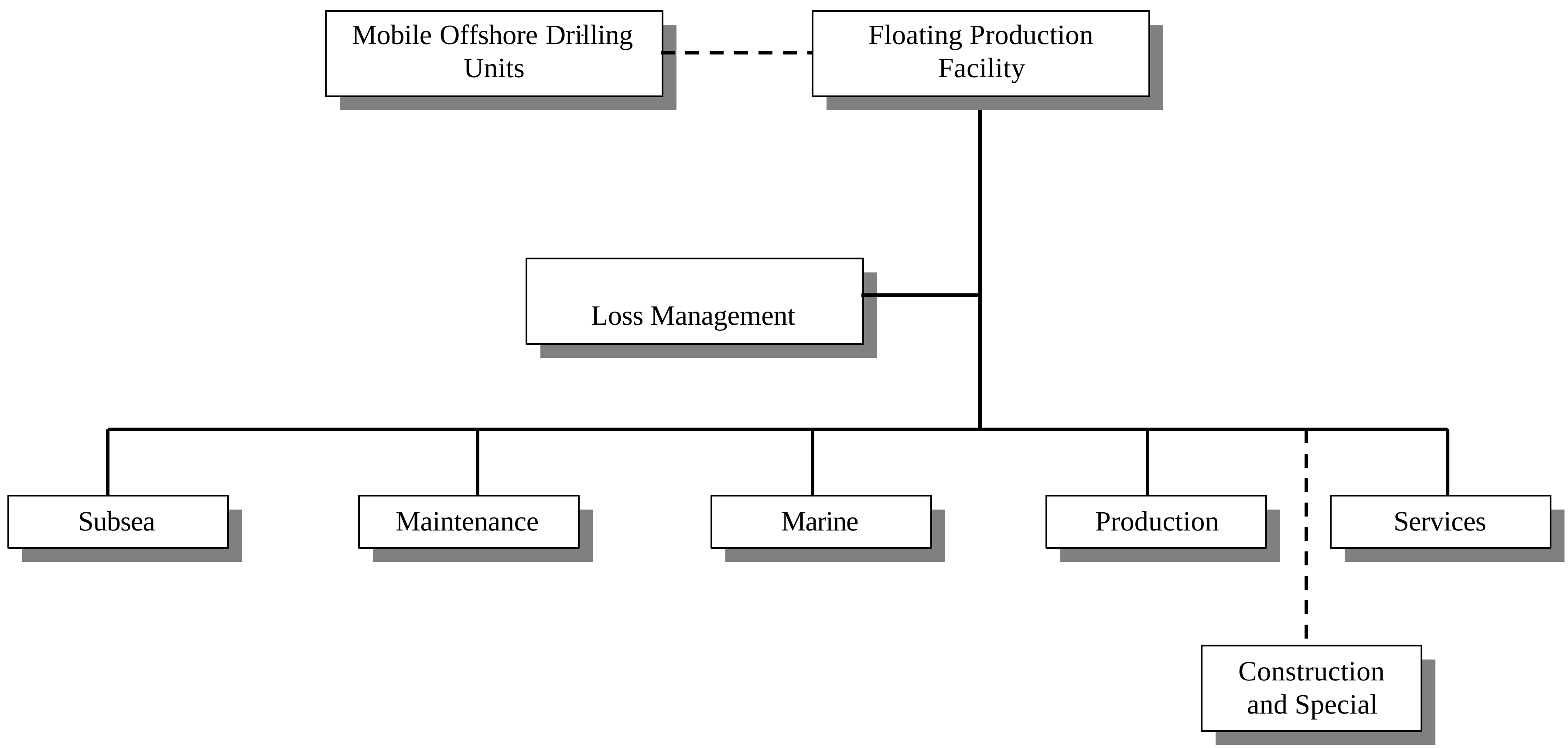


Figure 5.1-2 Offshore Organization



5.2 Entry Level Qualifications

As outlined in Section 2.10 of this Preliminary Safety Plan, Husky Oil's staffing philosophy will adopt a systematic approach in the recruiting of personnel which, among other factors, will address entry level qualifications.

5.3 Job Orientation and Follow-up

As outlined in Section 2.7.2 of this Preliminary Safety Plan, all employees will receive an initial orientation upon arrival at all offshore facilities, including an explanation of key HS&E policies, principles and rules. Where necessary, employees will be tested for understanding and knowledge of key rules following the instruction.

5.4 Operating Maintenance Procedures and Practices

As outlined in Chapter 4 of this Preliminary Safety Plan, operating and maintenance procedure manuals will be used in support of all aspects of the Project. These manuals will be a vital tool in the promotion of safe and efficient operations and personnel will be trained in the use of the appropriate manuals and in the associated procedures.

5.5 Safety and Emergency Preparedness/Response Training

Individuals and work groups will be assigned specific offshore responsibilities for safety and emergency response preparedness. Specialized training will be provided prior to going offshore to ensure that personnel are sufficiently competent to perform effectively in these areas. The training will include the following:

- helideck teams;
- lifeboat coxwains;
- advanced first aid;
- man overboard;
- transportation of dangerous goods;
- medical escort;
- fire teams; and
- on scene incident command.

In addition, a command structure will be established to handle all offshore emergencies. Personnel assigned to the offshore command teams will receive specialized training in the following areas:

- command skills;
- search and rescue methods;
- stress management;
- oil spill management; and
- fire management.

The emergency command team will participate in regular team exercises to develop their skills and to foster effective teamwork amongst team members.

5.6 Ongoing Competency of Personnel

Husky Oil will implement a system for documenting all employee qualification and training records. These records will identify the date that training occurred, topics covered and the methodology applied to verify that the employee understood the training. The system will also flag when refresher training is required.

Where certified safety training is specifically required by regulation or by Husky Oil policy, copies of the relevant certificates will be held on file.

The company will consider the use of a centralized training and qualifications register or database to provide a current summary of all employees. This system would expedite internal and regulatory audits of employee competence levels.

5.7 Simulator Training

In addition to the use of traditional training programs, Husky Oil will consider the use of a simulator that can realistically reproduce operating and emergency conditions on the installation. The simulator would provide particular benefit in training central control room personnel in process control, well control, ballast control and start-up/shutdown operations. As appropriate, existing simulators in place for the Hibernia and Terra Nova programs will be used.

5.8 Training Documentation and Compliance Auditing

Audits to ensure essential training requirements are met will be conducted on a scheduled basis as part of the HS&E auditing program. Contractors will be required to demonstrate their compliance with essential training prior to any person going offshore. Training audits of Contractors will also be conducted.

5.8.1 Training Needs Identification

Supervisors, and/or HS&E Coordinators will identify training needs for all positions based on applicable regulations, employee job functions, training requirements for next professional level, reviews of the Loss Control Management system and reviews of accident/incident investigation reports. Training requirements will be set down in an annual training requirements (budget) summary.

Supervisors will conduct a formal training needs analysis for all new or reassigned employees, with particular emphasis on personnel performing potentially dangerous work such as handling hazardous materials or working in specific hazardous environments.

5.8.2 Training Aids

To provide training consistency and thoroughness, as well as to facilitate flexibility in the use of trainers, designated personnel will ensure that effective training aids such as written lesson plans, audio visual aids or computer based training will be used where possible.

5.8.3 Records And Compliance

The Project Manager, OIMs, and Support Vessel Master or designated personnel will ensure that training needs as outlined in the shorebase, FPSO, MODU, or support vessel training plan are met.

For those courses where testing is mandatory, designated personnel will ensure that employees are tested for knowledge and proficiency, with results recorded on file as required.

Records will be maintained of training for all employees and will be used to assess compliance with training plans.

The Project Managers, MODU OIM, and Support Vessel Master or designated personnel will ensure that training records are maintained and updated to reflect training received by employees on an ongoing basis.

5.9 Management Training and Qualifications

5.9.1 Management Personnel

Loss Control Management leadership training (shorebased and shipboard) needs will be identified based on regulatory requirements, Husky Oil's Loss Control Management system, and individual performance objectives. Shorebased and offshore management personnel (such as, first line Supervisors and higher) will receive HS&E Loss Control Management training on a scheduled basis to facilitate their effectiveness in carrying out their loss control responsibilities.

6 COMMAND STRUCTURE

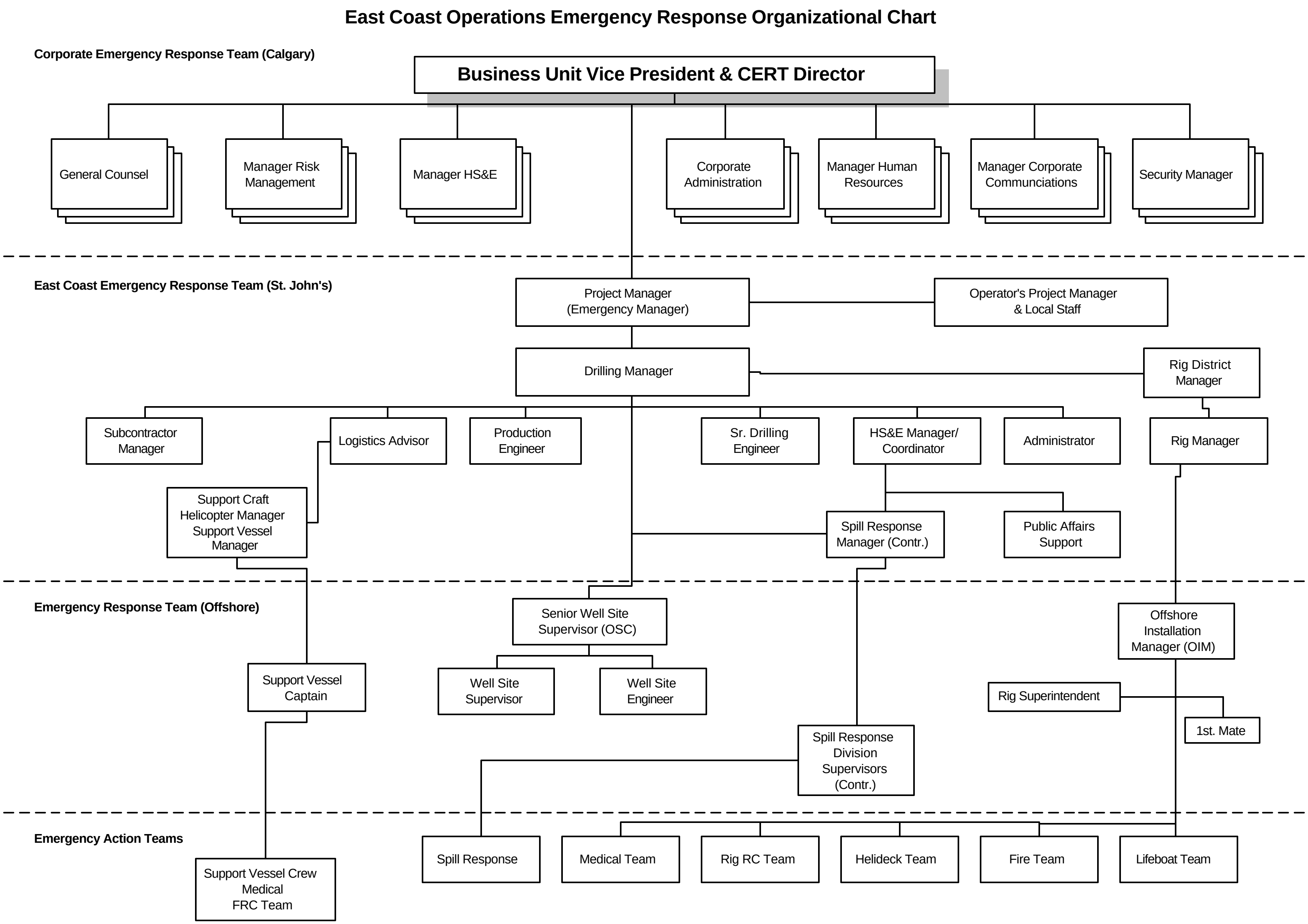
The final organizational structure for the Project has not yet been established, and will be developed and incorporated into this Preliminary Safety Plan at the appropriate time in the overall project realization. The command structure will indicate clearly the on-shore management structure as well as the command structure in place at the FPSO and MODU. Duties, responsibilities and authorities of all management personnel will be defined for both normal operating conditions and emergency situations. This will include lines of reporting and information flow, and lines of authority, and it will extend not only to Husky Oil's personnel but also to its contractor(s) personnel. Also, the interfaces with the corporate office, support craft and installation personnel will be identified. A succession plan will be identified in the event of key Managerial incapacitation during an emergency.

Husky Oil currently has in place a fully developed organizational structure for its East Coast Operations Emergency Response Plan, which is applicable to the Company's exploration program. This structure will of necessity be modified, as it focuses entirely upon the current exploratory drilling activities. In addition, it will need to reflect the organization that will govern the FPSO. Nonetheless, it can be anticipated that a significant portion of the final structure will be similar, if not identical, to the existing organization.

The Emergency Response Plan structure encompasses not only the command organization governing activities in the offshore environment, but also the on-shore command organization in St. John's, as well as the corporate command structure based in Calgary, Alberta. In addition to the Husky Oil internal organization, the structure may include the contract/operator of the offshore installation. While there will be clearly defined demarcations of responsibilities between the Husky Oil internal organization and that of the installation partner, from a functional point of view the overall organizational command structure will be seamless.

The current Husky Oil East Coast Operations Emergency Response Organization is represented in Figure 6.1. This is presented at this time as a representative command organization only, on the possible understanding that the organization may be customized as the Project develops, to align as closely as to the routine operating organization.

Figure 6.1 East Coast Operations Emergency Response Organizational Chart



6.1 Offshore Installation Manager

The OIM is the person in charge of the floating production facility and is responsible for coordinating all activities in the field. Their responsibilities will include:

- health, safety and welfare of all personnel working on the installation and for the protection of the environment;
- maintenance of order and discipline;
- emergency procedures, written instructions and the Permit to Work (PTW) system; and
- application of corporate procedures on the installation.

Activities under the OIM's jurisdiction are performed in accordance with company policy. Key HS&E responsibilities will include:

- developing HS&E awareness in the workforce, for both Husky Oil and Contractor personnel, through the enforcement of safety standards, the creation and implementation of relevant programs and active encouragement of workforce involvement in HS&E management;
- applying the PTW system to control and coordinate work on and around the installation;
- developing and maintaining emergency response capability;
- control of hazardous materials;
- monitoring and analyzing safety performance and communicating results;
- achieving the installation waste management objectives; and
- maintaining the integrity of the installation.

If an emergency affects, or threatens to effect, the integrity of the installation, and is not being contained, the OIM will initiate precautionary evacuation procedures for all personnel not involved in attempts to control the emergency. An immediate decision to totally evacuate the installation will be made by the OIM should it be apparent that the emergency is beyond control (for example, major structural failure). If a situation arises whereby it is necessary to disconnect the vessel, the responsibility for the vessel will then be assumed by the marine lead.

Within the terms of the above responsibilities, all departments on the installation will report to the OIM. These include production and marine operations personnel, contractors, well services, installation services, and safety and facilities management.

7 CONTINGENCY PLANNING

7.1 Scope of Planning

Prior to commencement of production operations, Husky Oil will develop contingency plans that will serve as the guides for the company's response to any emergency encountered during the White Rose production and will file them with the appropriate authorities. Plans will be developed to address emergencies that could potentially be encountered based on operations-specific hazard/risk analysis. The plans will outline the necessary personnel, equipment, and logistics support along with procedures to implement initial actions to respond to an emergency incident in a safe, prompt, coordinated manner. The plans will be distributed to designated personnel who will be responsible for emergency response actions. The content of the plans will contain sufficient detail to enable personnel to respond in a coordinated and effective manner.

7.1.1 Geographic Area Covered by Planning

Emergency response planning for White Rose production operations will focus on the area immediately adjacent to the location of the potential emergency which in most cases is the production site or satellite drill sites. This area will be defined as the safety zone established around the production site to ensure collision avoidance with ocean-going vessels. This is the area that will be under the jurisdiction of the *Atlantic Accord Implementation Act* and administered by the C-NOPB.

The safety zone will be recognized by Transport Canada, who will publish a description of this area for the information of all ocean-going traffic. Based on the precedent set by Terra Nova, Husky will apply for a 5-nautical mile (9.5 km) safety zone and an additional 5 nautical mile cautionary zone around the FPSO production location.

7.1.2 Husky Oil Corporate Policy

Husky Oil maintains a strong commitment to health, safety and environmental stewardship. The company conducts its business activities with a progressive approach and is committed to monitoring and improving its performance. Central to this commitment is a corporate HS&E Management System, which governs all aspects of loss control management.

7.1.3 Husky Oil Corporate Contingency Planning

As part of the corporate HS&E Management System, Husky Oil has developed a company-wide approach to contingency planning. All Husky Oil facilities, both in western Canada and offshore operations, are equipped with emergency response plans and procedures that share common format and approaches. Each plan reflects conditions and is risk specific to each facility but is similar enough to plans for other facilities that it may be quickly implemented by any trained Husky Oil personnel.

Husky Oil will use the same philosophy and approach that it uses throughout the company when developing contingency plans for the proposed White Rose offshore oilfield development. In addition to environmental protection plans (including environmental compliance, monitoring and environmental effects monitoring programs) to be developed specifically for all phases of White Rose production operations, Husky Oil will update and modify its existing offshore ice management and emergency response plans for use in production operations. Specifically, general emergency response procedures that have been developed for delineation drilling in 1999 will be updated and expanded for use during production operations. Facility-specific alert and emergency response procedures and vessel-specific contingency plans will also be developed to cover the details of local response procedures.

7.1.4 Emergencies Covered by White Rose Contingency Planning

An emergency will be defined as any unexpected occurrence resulting or having the potential to result in:

- death or serious injury/illness requiring hospitalization;
- an environmental effect posing serious threat to on-scene personnel, third-party personnel, marine life or wildlife; or
- major or substantial damage to operator or contractor property.

Several types of emergencies will be covered by White Rose contingency plans. The response to any of the following incidents will require immediate notification and action:

- accidental injury;
- explosion or fire;
- loss of well control;
- hydrocarbon or chemical spills;
- loss of or damage to aircraft supporting production operations;
- loss of or damage to support or standby vessels;
- loss or disablement of the FPSO or MODU, including ballast control or stability problems;
- major damage to equipment not caused by any of the above (for example, materials handling, equipment failure, or operator error);
- imminent threat to operations posed by weather, sea ice, or icebergs;
- collision or threat of collision with an ocean-going vessel;
- diving incidents;
- threatened or actual damage to subsea pipelines or well centre hardware; and
- security-related incidents such as extortion, bomb threat, or criminal or terrorist acts.

7.1.5 Proposed Contingency Plan Development

Because of the complexity of the White Rose development, contingency planning will be addressed in a number of inter-related documents, each of which will cover a specific aspect of production operations. An overview of the individual documents that, collectively, will dictate all emergency response operations is presented in Table 7.1-1. The plan names used in Table 7.1-1 are generic. The structure and naming of each plan will be finalized during the development of the White Rose production program.

Figure 7.1-1 Overview of Contingency Plans to be Developed for the White Rose Project

Plan	Description
HS&E Loss Control Management System	• a series of policies and procedures requiring activities to be carried out so as to prevent the occurrence of emergency incidents.
Offshore Emergency Response Procedures	• directs on-site actions at the White Rose site (including production operations at the FPSO and production drilling at the MODU); • provides very specific actions for supervisory and technical response personnel for a number of potential emergencies; • provides a link between all offshore facilities (FPSO, MODU, and support vessels); and • communication to area operators and regulatory first responders.
Alert and Emergency Response Plan	• integrates overall response actions; • directs actions of shore-based Emergency Response Team; • provides general management procedures for any emergency; • allows for increasing shore and corporate responsibility as an incident escalates; • provides the link between offshore actions (coordinated by FPSO Offshore Installation Manager (OIM)) and corporate emergency teams; and • communication to area operators and regulatory responders.
Collision Avoidance Plan	• a specific plan for ! identifying all potential collision situations involving the FPSO or MODU, ! communications with the threatening vessel, and ! prompt relocation of the offshore platform in the event that the threatening vessel does not change course; • includes an expanded multi-level traffic control area regulated by the FPSO; and • developed specifically for offshore use and directly related to the Offshore Emergency Response Procedures.
Ice Management Plan	• a plan that describes the procedures for ! monitoring the movement of icebergs that might pose a threat to drilling and production activities, and ! determining the need for specific countermeasure operations, including iceberg deflection or moving the platform off location; • the plan provides a link between all ice management operations offshore and on-shore; and • the plan provides a link between Husky Oil and other operators.
Oil Spill Response Plan	• procedures developed specifically for the response to oil spills originating from the White Rose production site; • covers situation where Husky Oil is the responsible party; • applies for both C-NOPB and *Canada Shipping Act* jurisdictions;

Plan	Description
	• covers ! specific actions to be taken by platform and support vessel personnel, ! management or coordination actions taken by shore-based company and contractor personnel, and ! specific strategies for the response to anticipated oil spill scenario situations; • the plan provides a link between all spill response operations offshore and on-shore; • details procedures for spill response management (ISC-based) when an incident escalates above Stage 1; • the plan provides a link between Husky Oil and other operators; and • directly related to the FPSO or MODU SOPEP, Offshore Emergency Response Plan, and the Alert and Emergency Response Plan.
Ship's Oil Pollution Emergency Plans (SOPEP)	• individual oil spill response plans developed for each of the vessels contracted by Husky Oil for offshore production-related activities; • will apply when vessel is not at the production and is under the jurisdiction of the *Canada Shipping Act*; and • vessel operator and not Husky Oil will be the responsible party.
Family Support Plan	• a plan to assist family members and friends of offshore personnel during an emergency situation; • description of the operation of a family information service and a family support centre; • protocols for contacting family members in a constructive and proactive manner; and • guidelines for volunteer family responders in how to deal with concerned relatives and friends.
Emergency Communications Plan	• a comprehensive guide to all communications with affected individuals, the public, and the media during an emergency response; • description of the operation of a media response centre; • news release and statement templates; • sample media questions and answers; • media information packages; and • directly linked to Corporate Plan.
Action Plans and Standard Operating Procedures	• set procedures for specific technical activities undertaken by Emergency Action Teams.
Corporate Emergency Notification Procedures	• Overall Husky Corporate Response Plan and Procedures outlining senior management and specialized corporate support department response to an emergency.

7.1.6 Plan Description

Because of the similarity in the response to different emergencies and construction of all Husky Oil contingency plans, the White Rose plan structures will be generic. Emergency response plans will outline management and operational procedures only. Procedures for the technical response to many of the above emergencies (medical, fire fighting, well control, ice management, spill response, equipment repairs, etc.) will be outlined in specific manuals and Standard Operating Procedures (SOPs) intended for the training and direction of designated Emergency Action Teams (EAT).

Most emergencies, however serious, will be of short duration and require a concentrated response involving a limited amount of resources. The exception will be the response to a major oil spill, which may require the mobilization of considerable equipment, vessel, and personnel for an extended period of time. Because of the complexity of oil spill response preparations and because of the environmental implications of a major oil spill, this review of White Rose contingency planning will include a detailed section on oil spill response management and countermeasures.

7.2 Plan Format

All Husky Oil contingency planning follows a standard format. This consistency allows any Husky Oil emergency response personnel to become quickly assimilated into an emergency response at any company facility. As a result, Husky Oil has the basis for continuous improvement of its corporate response capability and a complement of trained responders who can be employed as required in an emergency response at any company facility.

7.2.1 General Layout

The plan will be controlled in its distribution to company employees, contract personnel and regulatory agencies. Each copy will be numbered and assigned to a designated user. Each page is clearly labelled to indicate the revision date and chapter and page numbers. The plan will be produced in 8.5” x 11” format and bound in a 3-ring binder for ease in updating. The plan will be divided into logical sections and appendices separated by colour-coded tabs for quick access.

7.2.2 Division of Content

The content of the main portion of the plan will be based on a standard outline (Table 7.2-1). Procedures for specific emergencies will be presented in dedicated appendices.

Table 7.2-1 Overview Content for White Rose Project Contingency Plans.

Section	Description
Introduction	C Purpose and scope of plan C Geographic coverage C Definition of emergencies covered
Action Plan	C Conditions leading to emergencies C Stages of alert and response C Roles and responsibilities C Notification procedures C Specific response activities
Emergency Telephone List	C Emergency services groups C Company personnel C Contractors and suppliers C Government contacts
Area Considerations	C Location maps C Facility and vessel diagrams C Sensitive areas near the emergency scene
Emergency Support	C Medical services C Logistics support resources C Media guidelines C Family support C Communication systems
Emergency Preparedness	C Plan maintenance C Personnel training C Exercises
External Assistance	C Mutual Aid arrangements C Canadian Coast Guard assistance C Well relief resources C C-NOPB Emergency Response Plan

7.3 Classification of Emergencies

The level of response to an emergency at White Rose will be dictated by the scale of the incident. Husky Oil uses a tiered approach to response ("principle of graduated response") that relies upon increasing levels of resources from a larger pool as the scope of an emergency escalates. There are four stages of emergency in Husky Oil's response process, including an alert stage which acknowledges threatening circumstances that may precede an actual emergency.

7.3.1 Alert Stage

An alert stage will be declared when any condition exists or is forecast which does not require immediate emergency response but has the likely potential to escalate into a defined emergency situation. Examples include forecast heavy weather or approaching icebergs that have the potential to become emergency situations.

7.3.2 Emergency Stages

7.3.2.1 Stage 1 Emergency

The OIM will declare a Stage 1 Emergency when a situation is confirmed that will affect one area of the site or facility. At this stage, there is no immediate hazard to the public or environment and there is no immediate danger of uncontrolled escalation.

The emergency may not be trivial and could include loss of life. The key feature of a Stage 1 Emergency is that the effect is limited and identified and that the conditions that led to declaration of an emergency have either passed or have been controlled so that no further escalation is anticipated.

Actions include internal and regulatory notification and response by on-scene personnel, with logistical support, as required, from shore. Until the emergency has been declared over, responders will take the necessary steps to prepare for a possible Stage 2 Emergency.

7.3.2.2 Stage 2 Emergency

In a Stage 2 Emergency, the related effect is broader than just a confined portion of the site or facility. The situation has the potential to result in serious off-site effects and there is some hazard to the public or the environment. A key feature is the potential for uncontrolled escalation.

Primary activities focus on ongoing response and containment. At Stage 2, additional personnel or equipment may be needed from shore or from other operators offshore, to support the on-site resources.

7.3.2.3 Stage 3 Emergency

A Stage 3 Emergency is considered to be a major emergency in which operating control has been lost and the integrity of the facility is threatened. The situation is escalating and uncontrolled and definite, and serious hazard to the public or environment exists.

The primary activities include ongoing response and containment, mobilization of external resources, and implementation of public information initiatives.

7.3.3 Post-Emergency Stages

Once the conditions that led to the emergency have passed, Husky Oil will take measures to terminate the response in an orderly and responsible fashion. Some of the actions that are prescribed during this stage of an emergency response will include:

- advise all company and contract personnel, government agencies, and the public of the termination of response operations;
- initiate incident debriefing, reporting, and investigation;
- ensure integrity of all equipment before returning to production operations;
- monitor needs for critical incident stress debriefing for response personnel;
- implement longer term effects monitoring program, if required;
- review response actions and modify Emergency Response Plan (ERP), as required; and
- complete all financial issues relating to the response.

7.4 Emergency Response Management

7.4.1 Management System Processes

The White Rose emergency response structure will be based on the organization of action-oriented teams structured for the rapid and efficient response to emergencies. Organization will be specific to each operating location but within the context of a corporate system. Response organization will be comprised of four levels:

- Corporate Emergency Response Team (CERT);
- East Coast Emergency Response Team (ECERT);
- Offshore Emergency Response Team (OERT); and
- Offshore EAT including
  - Technical Operations Team,
  - Medical Team,
  - Fire Team,
  - Helideck Team,
  - Lifeboat Team,
  - Fast Rescue Craft Team, and
  - Spill Response Team.

This structure relies on a strong response team offshore which is in command of trained action teams to implement specific actions. Offshore personnel will be supported and complemented by regional and corporate teams in the event that the incident escalates.

Management will rely upon close interaction between team members. As most decisions must be made quickly, management team members will work very closely together. All communications will be as efficient as possible. The focus at this stage will be directed towards dealing with the emergency.

Documentation will be efficient, relying on status boards and pre-formatted self-carbon note pads. Reporting will be done upon completion of the response and be based upon the documentation generated during the response by the responders themselves.

7.4.2 Response Organizational Structure

Most emergencies covered by this plan will take place offshore at or near the White Rose production field. In most cases, regardless of the level of the emergency, the OIM on the FPSO or MODU will act as On-Scene Commander (OSC) and be in command and control of response operations. Exceptions would be:

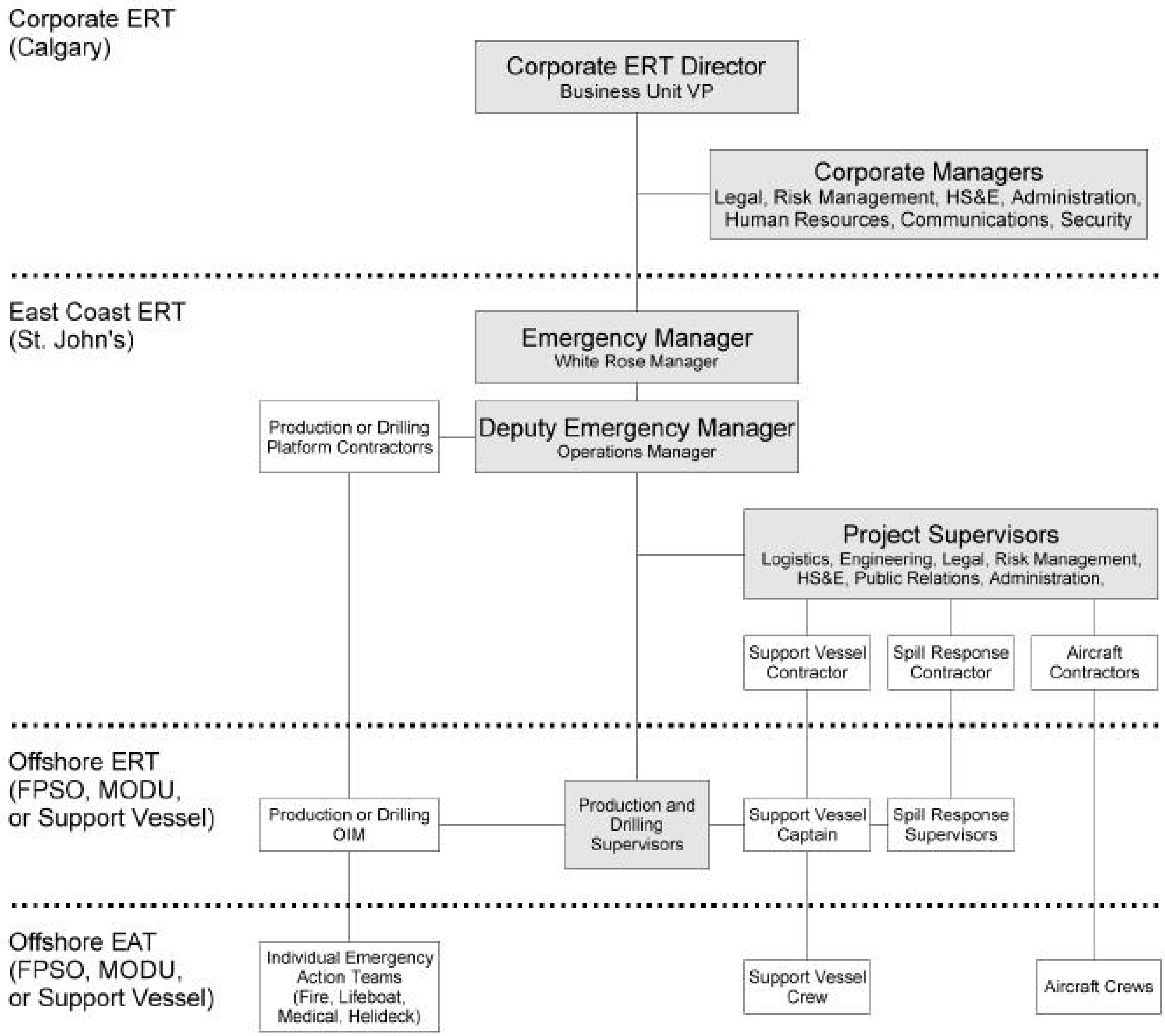
- loss of the FPSO or MODU (OSC would shift to another platform or standby vessel);
- Search and Rescue (SAR) Operations, in which case the Rescue Coordination Centre (RCC) (Halifax) or Marine Rescue Sub Centre (MSRC) Canadian Coast Guard (St. John's) will take command; and
- major oil spill, during which incident command will be based in St. John's.

Even in cases where command is not based offshore, the OERT will coordinate all offshore operations and be a principal point of contact for all other responders.

7.4.2.1 General Emergencies

The main role of the shore-based ECERT (Figure 7.4-1) is to provide support for operations taking place offshore and for developing larger scale response plans. Support could be provided in a number of different ways, including logistics, materials, technical advice, regulatory liaison, family notification, and media or public relations. In major emergencies, support offered by the CERT will generally consist of public relations, insurance issues, legal advice, risk assessment, and impacts to corporate business created by the emergency. In major emergencies, operational management will usually remain with the on-shore or off-shore ERTs.

Figure 7.4-1 General Organization For White Rose Emergency Response Management

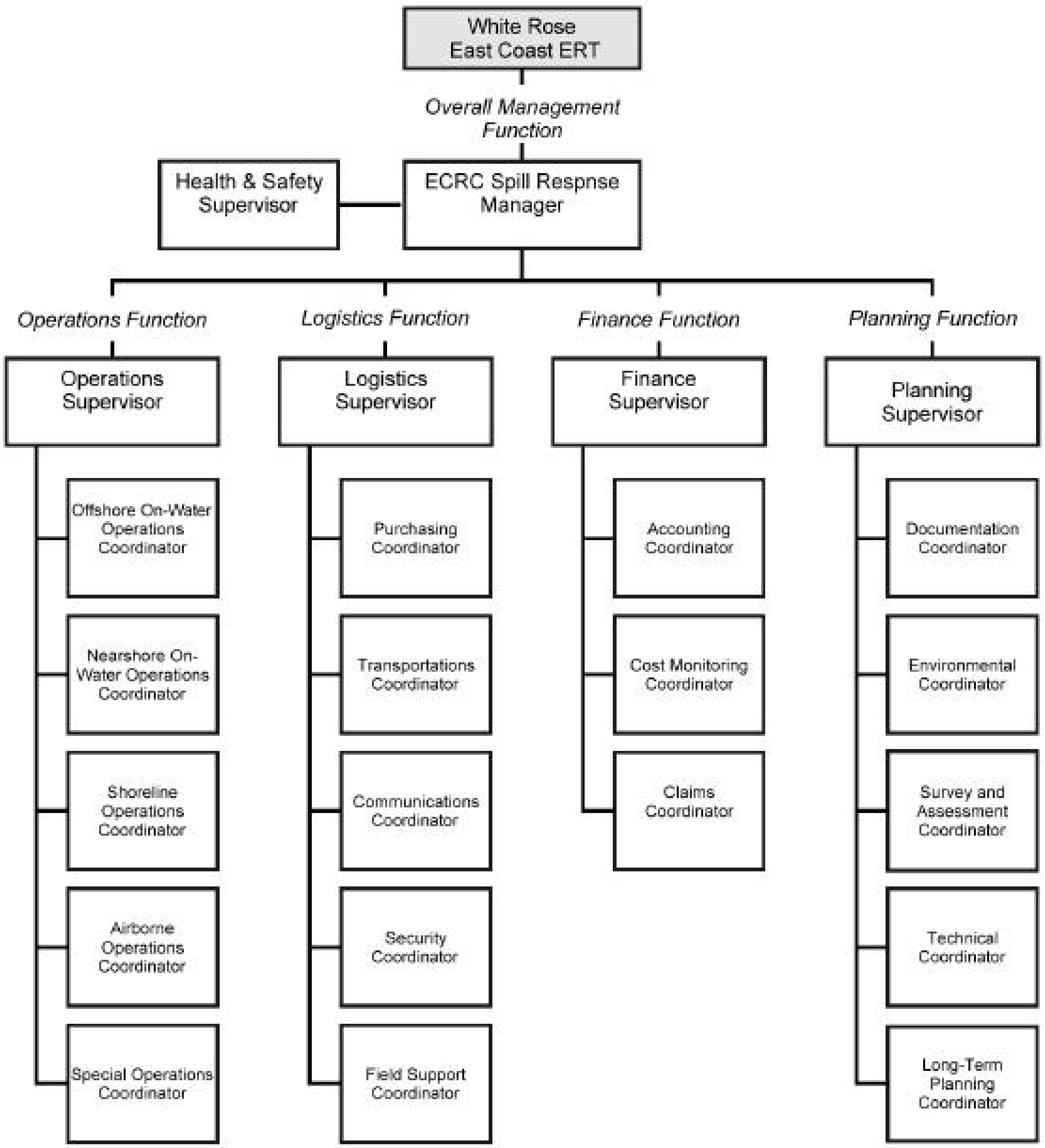


7.4.2.2 Oil Spill Response

In the event of a major oil spill, the operational component of the response will be managed by using a unified management approach such as the Incident Command System (ICS). The ICS emergency response management structure has been widely adopted by emergency response agencies throughout North America as a means of sustaining a long term response effort by adopting a function-based approach that allows personnel to rotate through positions over an extended period.

The Eastern Canada Response Corporation (ECRC) Spill Management System is ICS-based. Hibernia Management and Development Company (HMDC) and Terra Nova are also developing ICS-based oil spill response procedures. The fully activated ECRC ICS management structure is outlined here in Figure 7.4-2.

Figure 7.4-2 ECRC Incident Command System-Based Oil Spill Response Management Structure (Expanded for major oil spill)



7.4.3 Response Centres

An Offshore On-Scene Command Post will be staffed on the FPSO or MODU within minutes of the declaration of an emergency. This site will be the headquarters for the OERT and all off-platform communications. This centre will be supported by the Central Control Room, which will be the primary point of contact for all personnel on the platform. In the event the platform must be abandoned, the command post will shift to the remaining platform or, if necessary, to the standby vessel.

On-shore emergency response activities will be directed from an Emergency Response Centre within the Husky Oil office in St. John's. This site will be staffed by the ECERT. Depending upon the circumstances of the emergency, the Emergency Response Centre will be supported by a communications contractor, a Media Centre, and Public Inquiry Centre (family support centres). In the case where the emergency is a major oil spill, the Emergency Response Centre will be supported by a dedicated Oil Spill Response Centre.

Oil spill response operations will be managed on shore from a dedicated Response Centre shared with Terra Nova and HMDC and located at Pier 12 in St. John's. The Response Centre will be kept in a state of readiness at all times and be outfitted with complete telephone, fax, and data communications and all spill management maps and posters. All reference and reporting materials will be available at the Response Centre. All spill response training and exercise practices for company and contract personnel will take place in the Response Centre.

7.4.4 Use of Response Contractors

In general, White Rose emergency response management personnel will be drawn from in-house resources and include both Husky Oil and major contractor staff. In the event of an oil spill, however, the incident may require considerable resources over an extended period. In such a case, it will be necessary to use the services of additional personnel to assist in the coordination of response operations. In such a case, Husky Oil would use ECRC in a spill response management role. ECRC could be used in one of two ways:

- ECRC could act as a stand-alone response management entity answering to the ECERT. In this case, ECRC personnel would probably be based at its Mount Pearl response depot; or
- Husky Oil and ECRC personnel could be integrated into a single team working from the Husky Oil Response Centre. Common grounding between the Husky Oil spill response plan and ECRC in ICS management will allow for such an integration to be efficient.

7.5 Roles and Responsibilities

7.5.1 Roles During an Oil Spill Incident

The response management structure used by Husky Oil during an oil spill incident defines the functional roles for all supervisory personnel. These functions include Command, Operations, Planning, Logistics, and Finance. Additional functions that might be required as the scale of the emergency escalates are shown in Figure 7.4-2. The specific tasks that individuals will be assigned will be determined over time as a result of the evolution of the incident and consultation between functional groups. The Unified Management Approach process ensures that the level of response is always reasonable and necessary through:

- established and communicated objectives;
- integrated field operations, tactical planning, and logistics support through situation analysis;
- longer term planning and operational preparation based on prediction of future situations; and
- information exchange through continuous interaction of supervisory personnel, scheduled review meetings, routine written reports, and daily proposed action plans.

7.5.2 Roles During Non-Oil Spill Incidents

In all other emergencies, which are generally short term by nature, the emphasis will be more on rapid response to very specific scenarios. In many cases, the conditions of the emergency can be anticipated so that action plans can be prepared in advance. General responsibilities for White Rose emergency response personnel in non-oil spill incidents are shown in Table 7.5-1. More detailed versions of this table and specific task summaries for individual team members will be developed in specific plans.

Table 7.5-1 General Response Actions for Non Oil Spill Incidents

Level	Corporate ERT	On-shore ERT	Offshore ERT (OIM)
Alert	– No formal notification	– Notified by OIM – Alert ERT, review actions	– Notify On-shore ERT, vessels – Alert ERT, review actions
Stage 1	– Notified by On-shore ERT	– Support field operations – Identify potential technical resources – Maintain contact with OIM, and other operators – Media and Public Relations	– Control field operations – Notify First Response regulators (e.g., SAR) – Use platform resources – Maintain contact with On-shore ERT, vessels, and other platforms
Stage 2	– Maintain contact with On-shore ERT – Mobilize Corporate Emergency Response Team (CERT), review actions	– Coordinate overall response – Plan large scale response ops. – Support field operations – Maintain contact with OIM, CERT, regulators, and other operators – Media and Public Relations	– Control field operations – Request shore resources – Maintain contact with On-shore ERT, vessels, and other platforms
Stage 3	– Manage corporate position – Direct corporate aspects of response – Media and Public Relations	– Coordinate overall response – Plan large scale response operations – Support field ops. – Maintain contact with OIM, CERT, regulators, and other operators. – Family support. – Local media and public relations.	– Control field operations – Request shore resources – Maintain contact with On-shore ERT, vessels, and other platforms

7.6 Notification and Documentation

7.6.1 Notification

Once an emergency has been declared, timely notification of associated persons or agencies will be critical. In some cases, notification may include a written report (Section 7.6.2 of this Preliminary Safety Plan).

Contingency plans will include instructions for all personnel who have a notification responsibility. Initial notifications will be submitted by the OERT under the direction of the OIM. Where appropriate and convenient, further notifications may be delegated to shore personnel. All other notification actions will be included in the specific role descriptions of each response team member and will be summarized in an overall notification checklist.

7.6.2 Emergency Notification and Log Forms

All personnel will be required to keep an accurate record of events and actions in which they are personally involved. Good documentation will assist in describing the situation at any time, as well as recording events for incident reporting.

To ensure efficiency and accuracy of reporting, standard forms will be used wherever practical. Following is a list of forms that will be used:

- Initial Incident Report, which:
  - includes critical incident information for general distribution,
  - is completed by the OERT, and
  - includes Standard IMO format for vessel information;
- Initial Briefing Report, which:
  - includes detailed incident information, and
  - is for use of ERT personnel;
- Action Log, which:
  - documents specific actions, and
  - includes a personal log;
- Resources Summary, which:
  - includes current status of all vessels, equipment, and personnel involved in response;
- Daily Situation Report, which:
  - including detailed summary of the day’s activities,
  - makes recommendations for next day’s work, and
  - is for use of ERT and senior management personnel; and
- Bomb/Terrorism Threat Forms, which:
  - includes a report form for recording content of threatening communications, and
  - provides guidelines for personnel inexperienced in security issues.

7.7 Emergency Preparedness

7.7.1 Plan Distribution

Contingency plan distribution will be carefully controlled. Plans will be produced in limited numbers and provided only to designated personnel. Personnel will include ERT members, C-NOPB, FPSO and MODU owners’ representatives, standby vessels, St. John’s shorebase, and Canadian Coast Guard (SAR) as well as other agencies such as Royal Newfoundland Constabulary (RNC), Royal Canadian Mounted Police (RCMP), DFO and Environment Canada. Each plan copy will be identified by a unique code assigned to the plan holder.

7.7.2 Plan Maintenance

White Rose contingency plans will be dynamic documents which must be updated as needed to reflect changes in project operations. So that the version of any part of the plan can be identified, plans will be assembled in three-ring binders and each page will be clearly labelled with document identification code, plan version reference, and date that page was generated. Updates will be issued as they are produced to designated plan holders. Upon receipt of updates, plan holders will insert replacement pages and destroy those pages which have been replaced.

7.7.3 Personnel Training

All regular East Coast operations personnel, including contractors, will receive directed emergency training. External personnel who play some role in White Rose emergency operations will be provided with a general orientation and a specific review of personal roles.

Training will be conducted according to a matrix that links personnel positions with types and levels of training required for each position. Levels of training required for specific ERT and EAT personnel will range from basic awareness of an activity or function to achieving a working knowledge to becoming an expert in that function. In some cases, personnel will be required to be certified for certain activities. Wherever possible, training will be conducted to recognized standards and certified instructors will be used. A schedule for refreshers, retraining, and re-certification will be established for all plans.

All personnel will undergo an orientation to elements of emergency response planning. Offshore personnel will receive a general overview of evacuation alarms and procedures, and response organization. To ensure familiarity with emergency response planning, a portion of all HS&E meetings will be devoted to emergency response issues.

EATs will receive specialized training with emphasis on hands on experience. Emergency drills will be conducted weekly, bi-weekly, or monthly for all EAT activities.

7.7.4 Response Exercises

A regular program of exercises will be instituted to ensure the readiness of all personnel. The frequency of exercising will vary with each task but will be no less than annual. The purposes of exercises include:

- continuing training and familiarization of all personnel with emergency procedures;
- testing of the preparedness of all personnel; and
- a means of developing continued improvement to emergency procedures.

Exercises will be conducted in three areas:

- Communications, which includes
  - personnel call out,
  - inter-facility communications testing, and
  - media and public information training;
- Table Top, which includes
- methodical response to an emergency scenario by the on-shore and/or OERT, and
- an opportunity for interaction between ERT, operational, regulatory, and external personnel; and
- Logistics, which includes
  - hands-on training and experience for marine and technical personnel.
  - demonstration of field response operations for marine crews, ERT, other operators' personnel, and regulators, and
  - confirmation of the effectiveness of established field procedures.

7.8 Mutual Aid and Integration with Other Operators' Plans

Husky Oil has entered into a formal mutual aid agreement with other Grand Banks operators. This agreement provides for the release of personnel, vessels, and equipment for logistics support and exchange of operational information. Under this agreement, operators are required to provide support if requested by a second mutual aid operator. The level of this support is limited to that effort that can be provided without jeopardizing the safe operation of the supporting operators' facilities. Mutual aid will be most evident in logistics issues, ice management, and oil spill response efforts.

So that mutual aid may be effective, the mechanism for interaction between operators will be clearly stated in all White Rose contingency plans and other operators will be provided with controlled copies of appropriate plans.

7.8.1 Logistics

Other offshore platforms may be used to provide nearby staging or refuelling platforms in support of a Husky Oil emergency. These platforms may also provide temporary accommodation for evacuated platform personnel.

Several logistics services are shared by all operators. Cougar Helicopters has been contracted by all operators to provide helicopter transportation services to offshore facilities. Stratos Communications provides flight following and fleet tracking services as well as shorebased radio communications support to all Grand Banks operators. Vessel management, while not completely integrated between all operators, can be quickly coordinated through interaction between company and vessel owner's logistics personnel.

7.8.2 Ice Management

Ice data collected by all operators will be shared and efforts to manage oncoming icebergs will be taken with the advice and knowledge of neighbouring offshore facilities. All operators have currently contracted Provincial Airline Limited (PAL) for airborne surveillance activities. All PAL, Canadian Ice Service (CIS), and International Ice Patrol (IIP) ice data are integrated and readily available to all operators. When combined with site-specific information provided by individual operators, all operators have the benefit of complete and timely reports of ice conditions.

7.8.3 Oil Spill Response

In the event of a major offshore oil spill, countermeasures equipment will be available at each permanent production platform. As well, all operators have access to a dedicated oil spill response centre at Pier 12 on St. John's Harbour. This facility is permanently equipped with the resources to manage an offshore oil spill response. The layout and materials in this centre are geared to an ICS management effort, in keeping with the spill response plans of all operators, ECRC, and Canadian Coast Guard.

7.9 Response Contractors and Outside Agencies

Depending upon the nature of the emergency, Husky Oil will interact with a variety of external agencies who will participate actively in the response action. The roles and means of interaction for each of these groups or agencies will be clearly indicated in the appropriate plan. External agencies will be provided with controlled copies of the plan to ensure that cooperation with Husky Oil is efficient.

7.9.1 Regional Environmental Emergency Team

The Regional Environmental Emergency Team (REET) is a group of environmental specialists chaired by Environment Canada who can provide knowledgeable advice to support response operations. In the event of a spill, REET may be activated either by C-NOPB or Environment Canada.

Most REET members are government (federal and provincial) representatives from the local area. Private sector personnel may also be included in REET. Environment Canada may choose to draw on regional or national expertise, as required, to provide the best possible advice. Some REET members also have regulatory responsibilities and may be the best contact for permits for operational activities.

7.9.2 Rescue Coordination Centre/Marine Rescue Sub Centre

The federal government has the responsibility for coordinating all SAR activities in Canada. The Department of National Defence (DND) is responsible for aeronautical operations and the coordination of air and maritime SAR coordination. The Canadian Coast Guard is responsible for maritime operations. The Halifax RCC, staffed by DND personnel, is tasked with coordinating all SAR activities in the Atlantic Canada Search and Rescue Region (SRR). The MRSC in St. John's is staffed by Canadian Coast Guard personnel and is responsible for direct coordination of maritime SAR actions in Newfoundland waters.

The SAR Coordinator at either RCC or MSRC will be in command and control of all SAR actions. Where appropriate, the White Rose OIM may act as an at-site coordinator of local operations. All Husky Oil offshore installations and support vessels will be equipped with the IMO SAR Manual and the Merchantship SAR Manual. Husky Oil will immediately contact RCC and MSRC in any emergency involving:

- call to muster stations;
- fire or explosion;
- person overboard;
- structure damage;
- vessel collision; and
- all aircraft or marine incidents at or near the White Rose site.

7.9.3 Police

White Rose emergency planning will incorporate the support and responsibilities of police services. The RNC will provide local services in the City of St. John's and the RCMP will be responsible for offshore incidents.

7.9.3.1 Royal Newfoundland Constabulary

As well as its responsibility for investigating incidents within its own jurisdiction (northeast Avalon area), the RNC will assist in interactions with local fire, ambulance and hospital services. The RNC also plays a large role locally in the notification of next of kin as part of the Family Support Plan and assists in access control.

7.9.3.2 Royal Canadian Mounted Police

The RCMP will be responsible for any offshore incident requiring police involvement. Some of the incidents that will require the RCMP include:

- major injury or loss of life;
- bomb threat; or
- aggressive or threatening behaviour.

7.9.4 East Coast Response Corporation

Husky Oil has a subscriber's agreement in place with ECRC for the provision of operational and management services in the event of a major oil spill. ECRC is a full-time oil spill Response Organization certified by Canadian Coast Guard under Chapter 36 of the *Canada Shipping Act*. This contract allows Husky Oil to access ECRC personnel and equipment at any time.

Husky Oil intends to contract ECRC to carry out the routine management of a Stage 2 or Stage 3 oil spill response. By incorporating ECRC's existing Spill Management Team into the White Rose response structure, much of the administrative and planning work can be delegated to qualified contract personnel, thereby ensuring continuous availability of trained personnel reducing the work load of Husky Oil personnel and minimizing the delay to the resumption of normal operations at the White Rose site.

ECRC will manage the response and be responsible for developing tactical and strategic plans for spill response operations. All plans will be reviewed and authorized by the White Rose Incident Commander prior to implementation.

7.9.5 Canadian Coast Guard

The Canadian Coast Guard maintains an operational spill response staff as well as a large inventory of oil spill response equipment at its depot in Mount Pearl. As well, the Canadian Coast Guard operates a fleet of vessels suitable for offshore oil spill response activities. In the event of a major oil spill event, Canadian Coast Guard resources will be requested as required to bolster industry and ECRC resources. Recent oil spill exercises have included practising the integration of Operator, Coast Guard and ECRC resource to enhance preparedness for a major spill.

7.9.6 Relief Well Considerations

In the event of a wellsite loss control emergency, it may be necessary to drill a relief well. If a White Rose MODU is not on site or unable to do this, an alternate drilling vessel would be required. Throughout the lifetime of the White Rose production program, Husky Oil will maintain a listing of drilling vessels that could be brought to White Rose at short notice to drill the relief well.

7.10 Ice Management

Husky Oil and other Operators on the Grand Banks have implemented a "Grand Banks Ice Management Plan" (JBO et al. 1998). This plan represents a coordinated approach to the management of ice on the Grand Banks and emphasizes mutual support amongst the various operators. The Plan is prefaced by the following statements:

Policy and procedures for ice management
This manual has been prepared for the following reason:

- *to outline the companies policy and procedures as it relates to operations in waters where sea ice and glacial ice periodically occur;*
- *to outline the links between individual operations and the Regional Grand Banks Ice Management Plan;*
- *to define procedures to facilitate safe operations in an ice environment;*
- *to outline series of accepted procedures for ice management; and*
- *to define roles and responsibilities for those involved in ice management operation.*

Policy Statement
The Grand Banks Operators (Operators) are committed to operating in a safe, efficient, and environmentally responsible manner. These Operators will take all necessary actions to ensure that wells and facilities are protected from potential hazardous ice situations. This will involve early detection and reporting of ice, sharing of information and resources related to ice, ice tracking, ice deflection, securing the operation and, if necessary, moving off location if the ice threat cannot be averted.

The Operator will comply with all regulations and provide the necessary personnel and resources to effectively manage the ice threat to their facilities.

General Information

This Ice Management Plan is used in conjunction with other company documents regarding:

- *safety;*
- *monitoring procedures;*
- *alert response measures;*
- *offshore operations manuals; and*
- *alert and emergency response plans.*

7.10.1 Ice Detection

The shorebased ice centre will coordinate general ice and iceberg detection, using vessels and aircraft. However, it is the responsibility of each offshore unit to monitor for any small ice that may have escaped detection by other means.

Detection activities will include the following:

- all installations and all support will maintain a radar watch. This will provide close range detection watch for bergy bits and growlers as well as pack ice;
- support vessels following ice routes provided by the ice control center will conduct medium range detection and surveillance. These routes will be approved by the Ice Centre prior to vessel dispatch;
- long, medium and short-range aerial reconnaissance as required. The results will be downlinked in near real time to the installations. The completed mission will be transferred to the Shorebase Ice Management Network upon termination of the flight;
- flight requests can be initiated by any installation by contacting the Ice Centre;
- dedicated ice support vessels will be dispatched routinely on ice surveys; and
- special helicopter reconnaissance will be conducted when required.

7.10.2 Data Gathering Network

All ice detection reports will be assigned an initial validation code between one (the highest) and three (the lowest). The assigned code will depend on the age of the sighting and the reliability of the source. The purpose of the validation code is not to dismiss any ice data but rather, to provide a guide as to how this information should be assimilated into the overall Ice Management Plan, thereby avoiding duplication of existing ice data.

All ice data will be entered into an ice management computer system that will allow data from all sources to be assimilated into one overall view of the current ice situation.

Ice data will be distributed through the ice management computer system, with the installation acting as a focal point for all field data, and the shorebase ice management acting as the coordinating center for other data sources.

7.10.3 Tactical Predictions

Tactical models will be used primarily as a source to forecast the short-term movement of individual icebergs or the movement of the pack ice edge. While these types of models have had some success, especially in the area of pack ice movement, the output should be used only as a guide to what individual ice may do in the given conditions. The derived forecast should by no means be taken as absolute.

If direct action is in the form of towing, deflection or ice breaking, a dedicated ice support vessel will be instructed to commence the required operations. Data on these actions will be transmitted hourly (or less if required) to the installation that initiated the action. A designated offshore ice specialists will be assigned to each operation to facilitate coordination of the plan.

7.10.4 Multi-Operator Ice Management

The individual Operators Ice Management Plan will interface closely with other operators carrying out activities on the Grand Banks. A designated, trained offshore Ice Specialist will be assigned to each operation to facilitate coordination of the plans.

7.10.5 Communications

It is paramount that reliable communication channels be established to pass ice data from one operator to another and that these channels be used prior to initiating or concluding any active ice management procedure that may result in a disruption to another operations.

Each installation will have an Ice Data Network System (IDNS) installed and operated by a qualified Ice Specialist. The IDNS is a system of networked computers that allow the instant display of all current ice information, along with installation positions and management zones. Each installation is networked to a central computer server in the Ice Centre and the entire network can either parallel process (write data to all systems simultaneously) or will periodically update each system on the network automatically with the most up-to- date iceberg data.

Through the IDNS, each facility will have instant access to not only ice data related to their own operation but also ice data from all other operators. This ability allows a continuous update of all ice operations currently underway.

Any changes in T-time should be entered into the IDNS immediately. This will allow informed decisions with regard to ice management procedures, and will minimize potential disruptions to operations.

It is each Ice Specialist's duty to monitor all ice operations and anticipate any effects that other operators' ice management functions may have on their operation.

7.10.6 System Compatibility

Operators will exchange Ice Management Plans to ensure there are no fundamental conflicts in approach. Efforts will be made to ensure compatibility of plans and integration of resources where possible. While it is not a requirement for all operators to use the same Ice Management Plan, consistency of approach may provide benefits. The plans must be compatible in their approach to active ice management procedures. It is important that each operator's ice management display(s) show not only their own safety zone, but also the current safety zone(s) for each facility in the area.

7.10.7 Active Ice Management Control

Operators will agree and establish who is actively managing ice (towing, etc.) at any given time. The methods of managing and the direction of any deflection attempts will be determined after considering the following:

- the effects of ice management decisions on other operators;
- the position of the ice after active management; and
- the availability of logistics support to other operators.

7.10.8 Control Of Active Ice Management

The decision to conduct active ice management is under the control of the installation effected by the ice in question. Ice under active management (monitoring and towing, etc.) will be handled by the installation with the shortest TCPA on each particular piece of ice. Decisions on methods of management and the direction of any deflection attempts will be made only after considering the following:

- the position of ice after completion of active management;
- the effect of the ice management decision on any operators that are downstream; and
- the availability of logistics support (tow vessels etc.) to downstream operators.

If two or more installations are effected (that is, they have the same TCPA), then the Ice Centre will designate control.

All operators in the area are to be advised of proposed action through their onboard Ice Specialists.

Once a vessel engages in ice management, it will continue until the confirmation of Course Made Good (CMG).

7.10.9 Shared Logistics

A more effective operation will be afforded if there is a standard agreement in place for one operator to temporarily take control of a vessel engaged in ice management until it has cleared a specific safety zone. This becomes more important when the distance between operators is less than the size of their safety zones.

8 REFERENCES

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1995. Safety Plan Guidelines: Newfoundland Offshore Area. Prepared by C-NOPB, St. John's, NF.

Husky Oil. 1998a. Health, Safety and Environmental (HS&E) Loss Control Management Performance Standards. Prepared by Husky Oil Operations Ltd., East Coast Operations, St. John's, NF.

Husky Oil. 1998b. East Coast Operations Alert and Emergency Response Plan (AERP). Prepared by Husky Oil, St. John's, NF.

JBO (Jeanne D'Arc Basin Operations), Urban Williams, Don Sutherland, Ken Dyer. 1998. Grand Banks Ice Management Plan. Prepared by Roger Dugal, Urban Williams, Don Sutherland, Ken Dyer. St. John's, NF.

JWEL (Jacques Whitford Environment Limited). 2000. White Rose Oilfield Development Public Consultation Report. Part II Document prepared for Husky Oil Operations Limited, St. John's, NF.

WHITE ROSE OILFIELD DEVELOPMENT APPLICATION

VOLUME 5
PART TWO
CONCEPT SAFETY ANALYSIS

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED (AS OPERATOR)
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

January 2001

EXECUTIVE SUMMARY

A detailed Concept Safety Analysis (CSA) has been completed for the two technically and commercially viable options that were short-listed for the White Rose oilfield development on the Grand Banks, offshore Newfoundland. These options were:

- ship shaped floating production, storage and offloading (FPSO) facility; and
- steel semi-submersible with an attached floating storage unit (FSU).

The risk assessment for each option has been based on established techniques of event tree modelling of the major hazards identified for each option. Event trees allow offshore-industry generic (historical) data to be employed (leak frequency, ignition probabilities, iceberg frequencies, etc.) together with estimates of likely fatality, environmental spillage and Temporary Safe Refuge (TSR) impairment levels for each accident scenario, to generate a quantitative estimate of risk.

For risk to personnel, the quantitative measure of risk is expressed in terms of both the Probable Loss of Life (PLL) and average Individual Risk (IR). Major hazard environmental risk is expressed in terms of the 'frequency of oil spills in excess of 50 barrels' and TSR impairment is expressed in terms of the frequency with which the TSR can be impaired.

The PLL estimate is a statistical estimate of the average number of fatalities that might be expected per year on an installation of any given type. A PLL of 0.1 would indicate an average of 1 fatality every 10 years.

Dividing the PLL by the average number of people on board, and further dividing by two, to account for the fraction of time spent offshore, gives the IR estimate. This is a statistical estimate of the probability that any individual operative might become a fatality in any one-year period. An IR of 5×10^{-4} means that there is a 0.0005 probability of fatality per year on average for each operative. The Target Levels of Safety (TLS) that have been proposed for White Rose stipulate that the IR must be less than 1×10^{-3} per year. This criterion is a well-established acceptance criterion widely used in both the North Sea and more recently offshore Newfoundland.

The IR for the FPSO option is shown in the study to be 4.84×10^{-4} per year, which is well below the target of 1×10^{-3}. The semi-submersible option is shown to have a slightly lower IR of 3.29×10^{-4} due primarily to the higher combined number of Personnel on Board (POB) with the semi-submersible and attached FSU.

In addition, the frequency with which oil spills exceed 50 barrels and the frequency with which the TSR is impaired are also assessed in this CSA for the FPSO. These have been calculated as 7.11×10^{-4} and 1.01×10^{-4} pre year respectively for the environmental spillage and TSR impairment, both of which meet the stipulated TLS of 1×10^{-3}.

To fully comply with the TLS, it is necessary to demonstrate that risks are as low as reasonably practicable (ALARP). To achieve this, cost benefit studies must be performed at the detailed design stage to ensure that appropriate risk reduction measures are incorporated into the design.

It is concluded that no areas for concern have been identified that could prevent the risks from being shown to be ALARP at the detailed design stage. Several detailed studies will be required at detailed design stage to confirm or refine some of the assumptions and approximations that have been employed in this CSA.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Husky Oil Operations Limited (Husky Oil), as the operator in a co-venture with Petro-Canada, is proposing to develop the White Rose oilfield, located off the east coast of Newfoundland. Two viable options are being considered to develop this field, namely:

- ship-shaped floating, production, storage and offloading (FPSO) facility (with integral storage); and
- steel semi-submersible facility with a separate floating storage unit (FSU)[1].

The preferred option is the FPSO and a Concept Selection Study initiated in November 1999 concluded that the FPSO was the optimal system for developing the White Rose field based on technical, schedule and economic criteria.

This report presents a Concept Safety Analysis (CSA) of the major personnel safety and environmental hazards[2] and risks associated with both options. It considers each of the options from a safety and environmental risk perspective, but examines the preferred FPSO option in greater detail.

The White Rose oilfield development project will be the third oilfield development on the Newfoundland Grand Banks. As with the previous two projects, Hibernia and Terra Nova, safety of operations is of paramount importance. The proposed development contemplates using a FPSO similar in design to the Terra Nova FPSO, only smaller. Accordingly, design considerations for the White Rose facilities will build upon lessons learned from Terra Nova as well as other operations world-wide. Furthermore, industry cooperation in the area of safety and environmental protection is now actively being pursued with, for example, common ice management, oil spill response and mutual aid agreements being in place. It is Husky Oil's intention to integrate into these overall plans, further strengthening industry's commitment to safety and environmental protection for offshore Newfoundland.

Since the FPSO is the preferred option, the level of information available for this option is more substantial than that for the semi-submersible option and, as a result, this is reflected in the following analysis. Several assumptions have been made with respect to the design of the semi-submersible option and these are mainly based on similar structures/projects currently in operation or in development.

The White Rose oilfield development project is currently at the preliminary design stage. This CSA assesses the basic design concepts, layout and intended operations with respect to safety and environmental hazards and risks.

---

[1] For the purpose of this CSA, the steel FPSO and semi-submersible are referred to collectively as floating production facilities (FPFs).

[2] The definition of what constitutes a major accident hazard can vary. A typical definition (and the one assumed for the purpose of this CSA) is a hazard that involves ignited hydrocarbons, or any other hazardous events that have the potential for five or more fatalities.

Any remedial actions, therefore, can then be easily incorporated into the detailed design stage without any significant implications.

This CSA provides supporting documentation to the Development Application (DA) (see Section 1.1 of this CSA) submitted by Husky Oil to the Canada-Newfoundland Offshore Petroleum Board (C-NOPB).

1.1 Regulatory Framework/Requirement

1.1.1 Framework

Plans for offshore oil development projects in Newfoundland and Labrador must be approved by the C-NOPB. Companies proposing such projects must prepare and submit a DA to the C-NOPB. This DA initiates action under the *Atlantic Accord Implementation Act*.

The White Rose oilfield development must address the C-NOPB's guidelines for preparing a DA (C-NOPB 1988), as well as the environmental assessment requirements outlined in the *Canadian Environmental Assessment Act* (CEAA). As part of the DA, Husky Oil will submit a CSA in accordance with the stipulated requirements below.

1.1.2 Requirement

Section 43 of the *Newfoundland Offshore Petroleum Installations Regulations* (C-NOPB 1995a) stipulates that:

1) Every operator shall, at the time the operator applies for a Development Plan approval in respect of a Production Installation, submit to the Chief a Concept Safety Analysis of the installation in accordance with subsection (5), that considers all components and all activities associated with each phase in the life of the Production Installation, including the construction, installation, operation and removal phases.

2) The Concept Safety Analysis referred to in subsection (1) shall:

   (a) Be planned and conducted in such a manner that the results form part of the basis for decisions that affect the level of safety for all activities associated with each phase in the life of the production installation; and
   (b) Take into consideration the quality assurance program.

5) The Concept Safety Analysis referred to in subsection (1) shall include:

(a) For each potential accident, a determination of the probability or susceptibility of its occurrence and its potential consequences without taking into account the plans and measures described in paragraphs (b) to (d);

(b) For each potential accident, contingency plans designed to avoid the occurrence of, mitigate or withstand the accident;

(c) For each potential accident, personnel safety measures designed to:

i. Protect, from risk to life, all personnel outside the immediate vicinity of the accident site;
ii. Provide for the safe and organized evacuation of all personnel from the Production Installation, where the accident could lead to an uncontrollable situation;
iii. Provide for the safe location for personnel until evacuation procedures can be implemented, where the accident could lead to an uncontrollable situation; and
iv. Ensure that the control station, communications facilities or alarm facilities directly involved in the response to the accident remain operational throughout the time that personnel are at risk.

(d) For each potential accident, appropriate measures designed to minimize the risk of damage to the environment;

(e) For each potential accident, an assessment of the determination referred to in Paragraph (a) and of the implementation of the plans and measures described in Paragraphs (b) to (d);

(f) A determination of the effects of any potential additional risks resulting from the implementation of the plans and measures described in Paragraphs (b) to (d); and

(g) A definition of the situations and conditions and of the changes in operating procedures and practices that would necessitate an update of the Concept Safety Analysis.

In addition, Section 2.1.1 of the Canada-Newfoundland Offshore Petroleum Board Safety Plan Guidelines (C-NOPB 1995b) states that:

> Risk to individuals can emanate from "Major Accidents" which affect the entire, or large portions of, the installation or from what may be termed "Routine Occupational Exposures" which only have the potential to affect single, or small numbers of, individuals. It is expected that the risk from "Major Accidents" to both, the installation as a whole, and to individuals, be quantified. It is not expected that risk to individuals from each "Routine Occupational Exposure" be quantified. The method of assessment of risk to individuals from these exposures is left to the discretion of the operator.

The CSA performed for this report fulfils each of the above requirements.

1.2 Study Objectives and Scope of Work

1.2.1 Objectives

The objectives of this CSA are to:

- fulfil the CSA requirements stipulated in Section 1.1.2;
- identify the potential Major Hazards associated with the above development options;
- analyze and assess the identified Major Hazards with respect to the potential for harm to personnel and the environment;
- assess the risk to personnel and the environment from Major Hazards, and identify any risk reduction measures to ensure that the risks comply with Husky Oil's target levels of safety (TLS);
- based on the above information, develop an event tree-based Quantified Risk Assessment (QRA) model to quantify risks to personnel and the environment;
- determine the relative differences between the above development options from a safety perspective; and
- prepare a report documenting results, findings, conclusions and recommendations.

1.2.2 Scope of Work

- As mentioned in the previous section, the CSA is required to consider all components and activities associated with each phase in the life of the Production Installation, including the construction, installation, operational and removal phases of the installation. In particular, the CSA shall address the following technically and commercially viable options being considered for the development of the White Rose oilfield during these phases:

- FPSO; and
- semi-submersible facility and a separate FSU.

- The CSA shall comply with all the requirements stipulated in Section 1.1.2.

- The following types of Major Hazard are considered for each of the two options in the CSA:
  - process and non-process loss of hydrocarbon containment (fire and explosion) (above sea);
  - subsea loss of hydrocarbon containment (fire and explosion);
  - blowout;
  - ship impact;
  - iceberg impact;
  - dropped object;
  - helicopter operations;
  - fishing gear impact;
  - structural failure;
  - mooring failure; and
  - seismic activity.

- The assessment performed in this study is quantitative where it can be demonstrated that input data are available in the quantity and quality necessary to demonstrate confidence in results. Where quantitative assessment methods are inappropriate, qualitative methods are employed.

- The quantitative estimates of risk to personnel and the environment are based on event tree modelling of the Major Hazards affecting each option.

- The quantitative estimates of risk are compared with Husky Oil's specified TLS (see Section 1.4 of this CSA) to determine whether the TLS are met. In the event that such estimates do not meet the TLS, recommendations for risk reducing measures sufficient to achieve the TLS, and an estimate of the risk reduction achieved, shall be made.

- This CSA presents sensitivity study results to demonstrate the effect of various modelling assumptions on the quantitative estimate of risk. The sensitivity studies are designed to:
  - estimate the effect on risk levels of varying input data which, due to the early stage of project design, is only known within a broad band of uncertainty. In this way, the importance of reducing that uncertainty through further study or data acquisition can be established; or
  - examine the effect on risk levels of alternative design options.

1.3 Study Methodology

A preliminary Hazard Identification (HAZID) meeting was held to identify potential Major Hazards. The meeting was attended by representatives from the consulting team (RMRI and Conor-Pacific), Husky Oil and Kvaerner SNC Lavalin Offshore (KSLO), and considered a wide range of potential hazards based on a Major Hazard Checklist approach. Such information is readily available from the large number of CSAs, QRAs and Safety Cases compiled for similar offshore facilities.

Further (in-house) HAZID meetings were also conducted among a number of experienced engineers. Potential Major Hazards were identified through a series of in-depth discussions and reviews of appropriate documentation. In addition, experience gained from similar recent offshore developments was drawn upon by RMRI, in particular, the Hibernia, Terra Nova and several North Sea offshore field projects currently in operation/under development.

On identifying the potential Major Hazards associated with each of the development options, the risks were then modelled as a collection of event trees using the Data and Decision Management Tool (DDMT) software. This tool is based on a Risk-Based Decision Management (RBDM) methodology which accounts for all types of risk (personnel safety, environmental, etc.) and provides an auditable and traceable through-life record of all the risks.

The DDMT enables event tree-based risk profiles to be developed for any facility. Such profiles were developed for each of the options, which incorporate results from the frequency and consequence analyses that were performed as part of the input to the DDMT. Where feasible, possible risk reduction measures were identified and considered. Those measures with a significant risk reduction benefit are discussed in this report and recommendations are made accordingly.

Finally, the results from each of the risk profiles were then compared to determine any significant differences (from a safety and environmental risk perspective) between the proposed options.

It should be noted that the information available for review at the time of this study was at the conceptual design stage and as such, the level of detail of the analyses and assessment reflects this. Many key assumptions have had to be made, in particular, on the non-preferred option, and these are documented, as appropriate, in the relevant sections of this report. Sensitivity studies are also performed on some of the more significant assumptions and areas for further investigation are noted in the conclusions and recommendations.

There is limited experience of hydrocarbon production on the East Coast of Canada. However, there is considerable experience in areas such as the North Sea and Gulf of Mexico. Extensive databases for these areas have been developed and are used in this CSA.

1.4 Target Levels of Safety

As required by Section 43 of the *Newfoundland Offshore Petroleum Installations Regulations* (C-NOPB 1995a), Husky Oil have specified TLS (see Appendix A) that must be met at the conceptual and design stages of the White Rose Project to ensure that the risks associated with Major Hazards are acceptable. Husky Oil must subsequently demonstrate that the risks to personnel and the environment are as low as reasonably practicable (ALARP) by implementing risk reduction measures, if required.

Risk to personnel can be expressed in terms of Individual Risk (IR), which is a quantitative measure of the fatality rate per individual per annum. Such a measure can also be expressed as a function of the amount of time that an individual spends on the installation.

Risk to the environment can be expressed in terms of the amount of oil spillage associated with various accident scenarios along with the likelihood of these scenarios occurring.

The TLS stipulated for Husky Oil contain both risk-based and impairment-based criteria. The risk-based criteria are further sub-divided into the following categories:

- IR;
- Group Risk; and
- Environmental Risk.

The impairment-based criteria stipulate criteria for the following installation Safety Functions:

- the installation's primary structure;
- the temporary safe refuge (TSR);
- the escape routes; and
- the availability of the evacuation systems.

For risks to individuals, the IR criteria, developed as part of the risk-based criteria, are the overriding criteria and must be met by the final design. Installation staffing levels are required to quantitatively assess the IR associated with a facility and a comparison made with the stipulated criteria to determine the significance of the risk.

The remaining criteria, that is, the Group Risk and impairment-based criteria, are provided to allow the assessment of the design when staffing levels have not been defined or are uncertain, or when the overall risk assessment is still at a preliminary stage. Such criteria are used for design guidance only, specified, to allow design of the facility to proceed as the project progresses.

Impairment-based criteria can be used during the concept and design phase to distinguish between possible accidental events which have the potential to cause high-fatality accidents, and those which do not. Provided the impairment-based criteria are not exceeded, the accident can be considered to have low potential for preventing the escape of personnel away from the accident; or for threatening the integrity of the installation, the safe refuge or the means of evacuation within a time period that is long enough to safely evacuate personnel.

Meeting impairment-based criteria may not guarantee that the IR criteria are met, it will, however, make it more likely.

A summary of Husky Oil's TLS relevant to the CSA is presented in Appendix A.

1.5 Minimum Requirements Assessment

As discussed in Section 1.1, the *Newfoundland Offshore Petroleum Installations Regulations* (C-NOPB 1995a), require that the CSA should evaluate risk levels without taking into account the plans and measures for risk mitigation and reduction, and separately evaluate risk levels with such measures in place. These different cases (that is, with and without the risk reduction measures) are addressed first, by performing a detailed risk assessment with all mitigation systems being considered, in place, and then assessing the risk increase that would result if these measure were removed. The latter analysis was based on identifying what was required as a minimum (from an engineering perspective) and is presented in Section 9.5 of this CSA.

2 WHITE ROSE PROJECT DESCRIPTION AND DEVELOPMENT OPTIONS

This chapter provides a brief overview of the White Rose oilfield location and specific project features and is mainly based on Husky Oil (2000a). It then continues by providing an outline of the various facilities associated (as appropriate) with each of the proposed development options, specifically the:

- subsea facilities;
- drilling facilities;
- development option description;
- topside process facilities;
- installation support facilities;
- installation safety systems; and
- crude oil export systems.

As mentioned in Chapter 1, the following discussion is mainly applicable to the development of the White Rose oilfield by using an FPSO. However, where appropriate, this information is generalized across both of the options.

2.1 Field Location and Specific Project Features

The White Rose oilfield is located approximately 350 km off the East Coast of Newfoundland, on the eastern edge of the Jeanne d'Arc Basin. It is located in approximately 120 m of water.

The White Rose oilfield development contains an estimated 36 million m^3 (230 million barrels) of recoverable oil and covers an area of approximately 40 km^2 (10 km long by 4 km wide). Planning to date of the initial reservoir depletion plan estimates that the oil reservoir will require up to 10 to 14 producing wells and up to a further six to eight water injection wells will be used to maximize oil production.

Husky Oil plans to use produced gas for fuel and gas lift, and to inject surplus produced gas into the reservoir for gas conservation and, if necessary, to assist in reservoir pressure maintenance. There will be no flaring of the produced gas other than for specific operational or maintenance requirements.

Current planning anticipates that up to four to six production wells, one to three water injection wells and one gas injection well will be drilled and tied-in for First Oil production. Drilling will then continue over a two to four-year period until the reservoir is fully developed. Ongoing reservoir management may require further production optimization wells in the reservoir over the life of the project.

It is also anticipated that gas lift will be the artificial lift method used to optimize oil production later in the life of the field. Provisions for gas lift equipment will be included in the initial completion design of the wells.

The process facilities will be custom-designed to process the reservoir fluids, is currently assumed to have a 20-year design life (covering estimated project life span is 12 to 14 years) and comply with all statutory safety and environmental requirements.

2.2 Subsea Facilities

Subsea facilities will consist of up to 18 to 25 subsea wells, comprising up to 10 to 14 producing wells, six to eight water injection wells and two to four gas injection wells (see Section 2.1 of this CSA). These wells will be drilled in clusters or through templates and linked to manifolds, with fluids flowing through flowlines and flexible risers that connect to the floating production facility (FPF). Additional production and injection wells may be added to develop nearby ancillary oil pools if they are proven to be commercially viable.

The subsea facilities include all wellhead completion equipment, trees, manifolds, flowlines, umbilicals, risers, seabed structures and all control systems required to control and operate the facilities and associated test, installation, inspection and maintenance equipment.

2.3 Drilling Facilities

Drilling, workover and completion operations will be conducted in the field using an anchored semi-submersible mobile offshore drilling unit (MODU). The offshore complement on a MODU typically consists of approximately 70 to 100 personnel in drilling and marine roles. Each MODU will have a designated manager responsible for offshore operations on that facility.

2.4 Floating Production Facility Development Option Description

2.4.1 General Requirements

The process facilities will be sized and configured to process the reservoir fluids from the White Rose oilfield. It is currently assumed the facilities will be engineered for a 20-year life and comply with all statutory safety and environmental requirements. Export from White Rose will be by tankers.

The FPF shall be designed to remain on station, without disconnection from its mooring for dry dock maintenance or survey, for the life of the field.

2.4.2 Floating Production, Storage and Offloading Facility

At the time of performing this CSA, the FPSO is expected to be a ship-shaped structure, approximately 245 to 260 m long by 42 m wide, and comprise the main production deck supported on the hull. The main components are illustrated in Figure 2.4-1. Any changes/modifications/amendments to this assumed configuration will be addressed in the detailed design QRA.

2.4.2.1 Main Production Deck

A turret mooring system will be located towards the bow of the vessel to facilitate weathervaning. The mooring system will be designed to allow the vessel to be permanently moored in the field and will consist of an internal turret and catenary anchor legs. The turret will provide the attachment and rotation point of the mooring system for the FPSO and will provide the point for the connection and disconnection of the mooring and flexible riser system.

Aft of the turret area will be the flash gas and injection gas compression, process separation module, utilities, power generation, galley laydown and accommodation (Primary TSR).

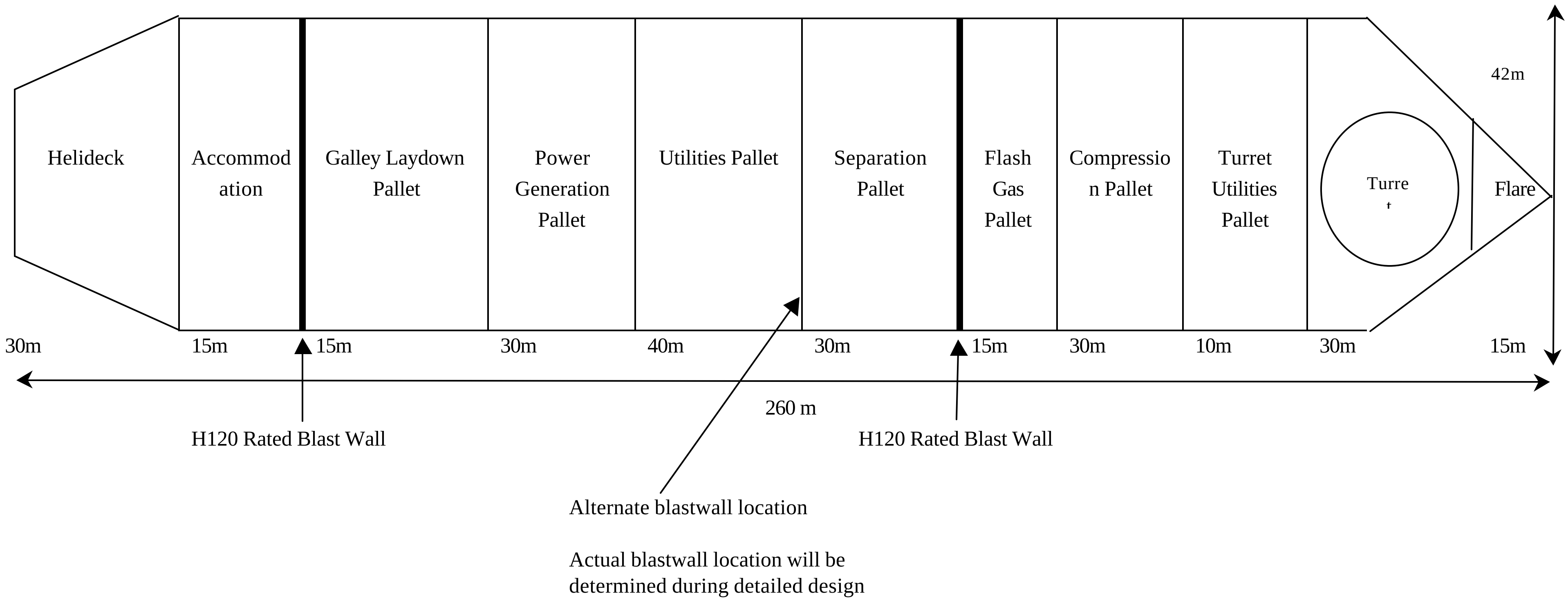
Forward of the turret area will be a secondary muster point area and flare area.

The configuration described above, with the TSR at the stern, is as per the layout being considered by the concept design team at the commencement of this CSA study. It is conceivable, however, that the final design may adopt a layout with the TSR at the bow. As this is undecided at the present time, the CSA has been performed on the assumption that the former layout applies (stern TSR). However, the implication on risk levels, should the TSR be located at the bow, is discussed in Section 10.6 of this CSA.

The FPSO will be provided with a minimum 200 percent persons on board (POB) capacity in both lifeboats and life rafts. Lifeboats and life rafts will be located close to the Primary TSR and on both sides (port and starboard) of the vessel. An additional lifeboat and life rafts will be provided at other suitable locations on the vessel.

Escape tunnels will be in place to enable personnel to transit safely from one end of the vessel to the other and for fire/emergency teams to access incident locations.

Figure 2.4-1 FPSO and Associated Dimensions



Typical staffing levels will range from 45 to 50 permanent crew. The accommodation requirement for the FPSO will be addressed and will consider the requirements for normal operation and also offshore hook-up and commissioning and maintenance operations. Utilities, such as the galley, food storage areas, potable water and sewage treatment, will be sized accordingly.

The FPSO must be capable of accommodating an Aerospatiale Super-Puma, EH101 or equivalent helicopter. The helideck will be designed to comply with governing legislation and for 1.5 x Super-Puma overall length (19.7 m).

Offshore rated cranes of sufficient type and number will be provided to allow safe and efficient re-supply, operation and maintenance of the FPSO. Provisions will be made for the safe and easy handling of provisions to the galley storage spaces and handling of equipment between the process and utility areas on deck and the workshop and stores areas.

The hydrocarbon processing equipment (see Section 2.5 of this CSA) will be primarily contained on a horizontal plane above the main vessel deck and crude storage tanks.

2.4.2.2 Hull

The hull will incorporate a double hull construction near all cargo tanks and have a segregated ballast system. It will have a storage capacity commensurate with the proposed throughput and offloading frequency. Typically, this will be between 111,300 to 135,150 m^3 (700,000 to 850,000 bbls). Integrated within the hull will be the vessel marine systems, including cargo handling, ballast, propulsion, bilge, etc. Crude oil will be stored in tanks (located in the hull).

The hull will be ice-strengthened as necessary. The hull should be capable of accepting the following ice criteria:

- 100,000-t iceberg at 0.5 m/s;
- pack ice, 0.3 m thick; and
- 5/10 (50 percent) ice cover.

In addition to the ice-strengthening detailed above, the FPF must be designed for the demands of Grand Banks operation and to withstand (as a minimum) the loads and motions imposed by the 100-year return period extreme environmental conditions for the full range of FPF operational draft, heel and trim.

2.4.3 Semi-Submersible

For the purpose of this CSA, the semi-submersible option is assumed to be of similar design to the one considered in the Terra Nova CSA (Magellan 1999). The following description is based on the Terra Nova CSA module components and associated equipment.

The semi-submersible is assumed to be a rectangular deck, approximately 90 m long by 70 m wide, with lifeboat platforms cantilevered off each end. The rectangular deck comprises upper and lower decks. A schematic of the assumed semi-submersible is illustrated in Figure 2.4-2.

A separate FSU is assumed to be required for crude oil storage. This unit is assumed to be moored approximately 2 km from the semi-submersible FPF.

The semi-submersible will be moored facing into the prevailing wind direction so that the accommodation area is generally upwind and the flare, risers and hydrocarbon processing modules generally downwind.

A flare tower is assumed to be located on the port aft corner and two deck cranes are assumed to facilitate loading and offloading of materials.

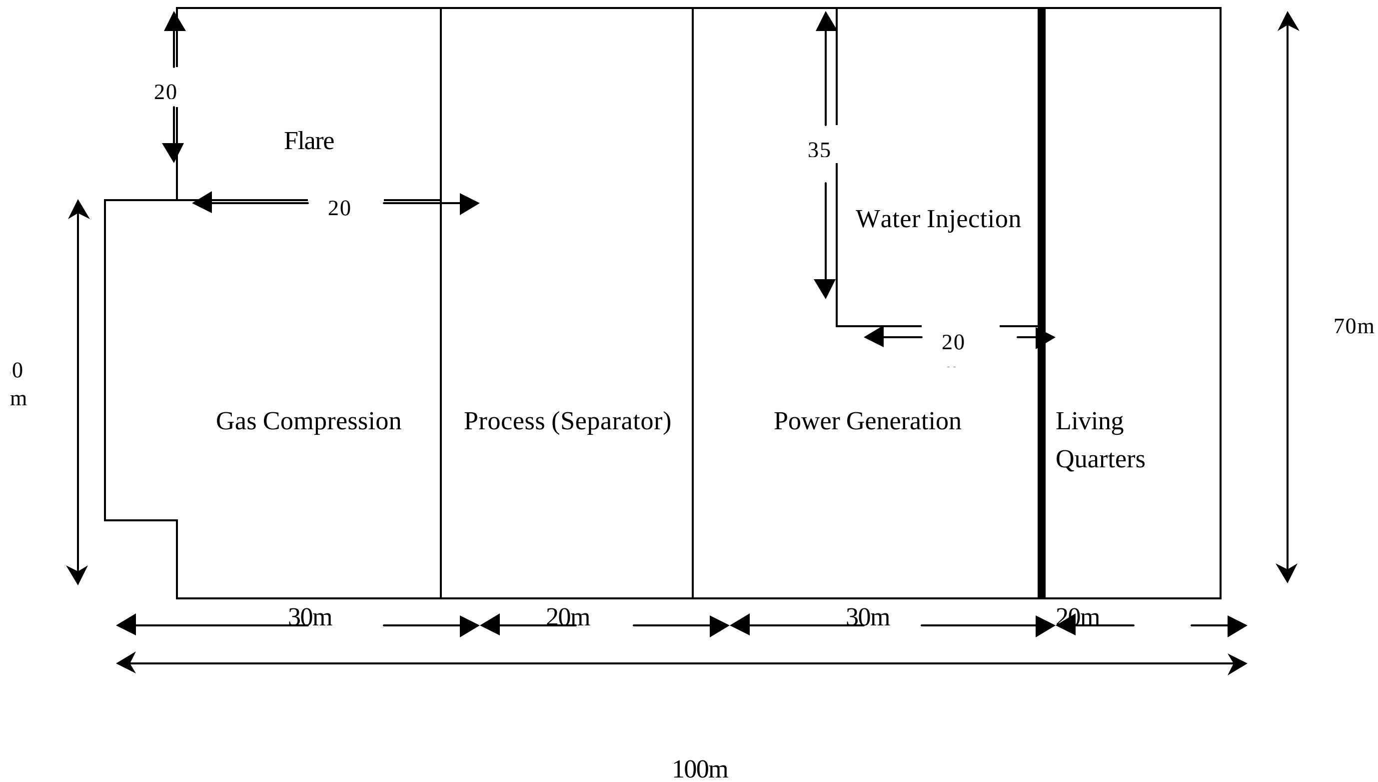
2.4.3.1 Upper Deck

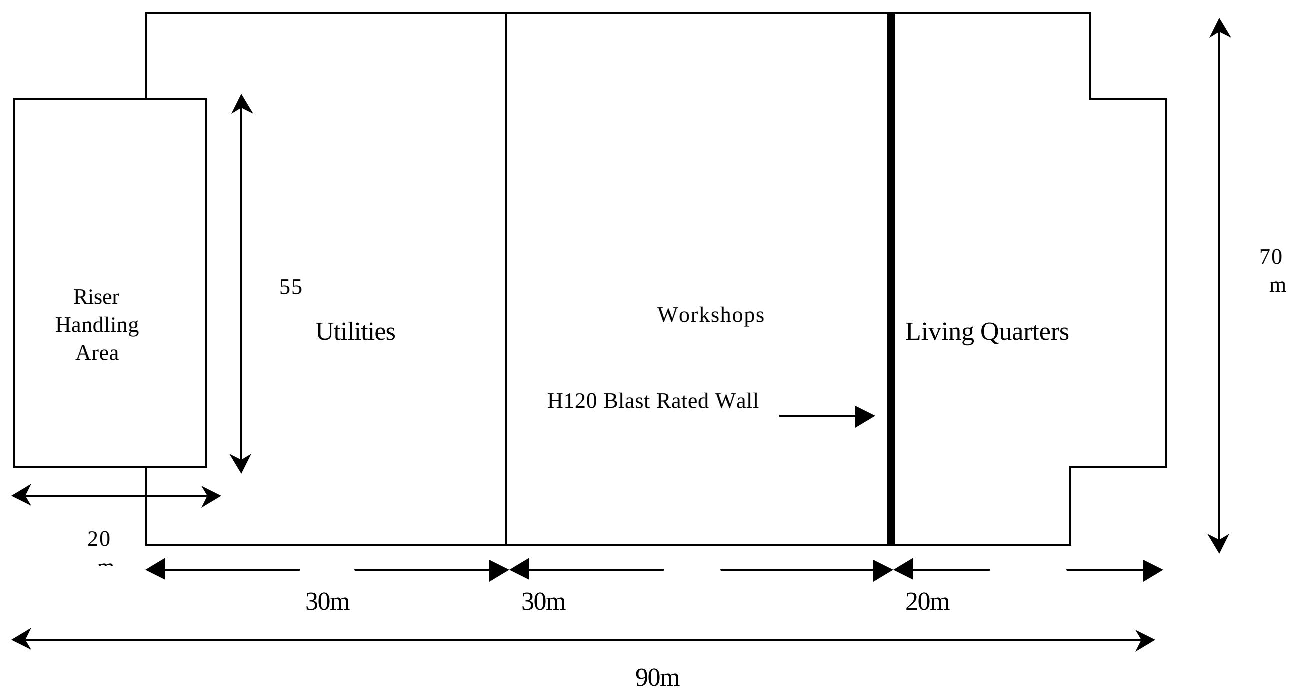
Water injection and power supply and support are located aft of the accommodation, with the process separation and gas compression and flare modules further aft.

2.4.3.2 Lower Deck

The workshops, utilities module and riser handling area are on the lower deck.

Figure 2.4-2 Semi-Submersible and Associated Dimensions





2.5 Topside Facilities

Preliminary engineering has determined that the White Rose production process will more than likely comprise a single train of facilities for both oil production and gas injection, supported by utilities. It also indicates that a two-stage separation process and a coalescer would be required to process the crude oil. Production wells will be tested and brought on-stream via a test separator. A preliminary process flow diagram for the White Rose hydrocarbon process flow is presented in Figure 2.5-1.

The associated gas from the reservoir (low hydrogen sulphide (H_2S)) will be treated, compressed and used for the following services:

- fuel gas; and
- lift gas.

There will be no flaring of produced gas other than that permitted by the *Newfoundland Offshore Area Petroleum and Conservation Regulations*. Surplus gas will, therefore, be normally re-injected for reservoir pressure maintenance or downhole conservation. Gas metering will comply with the overall metering philosophy.

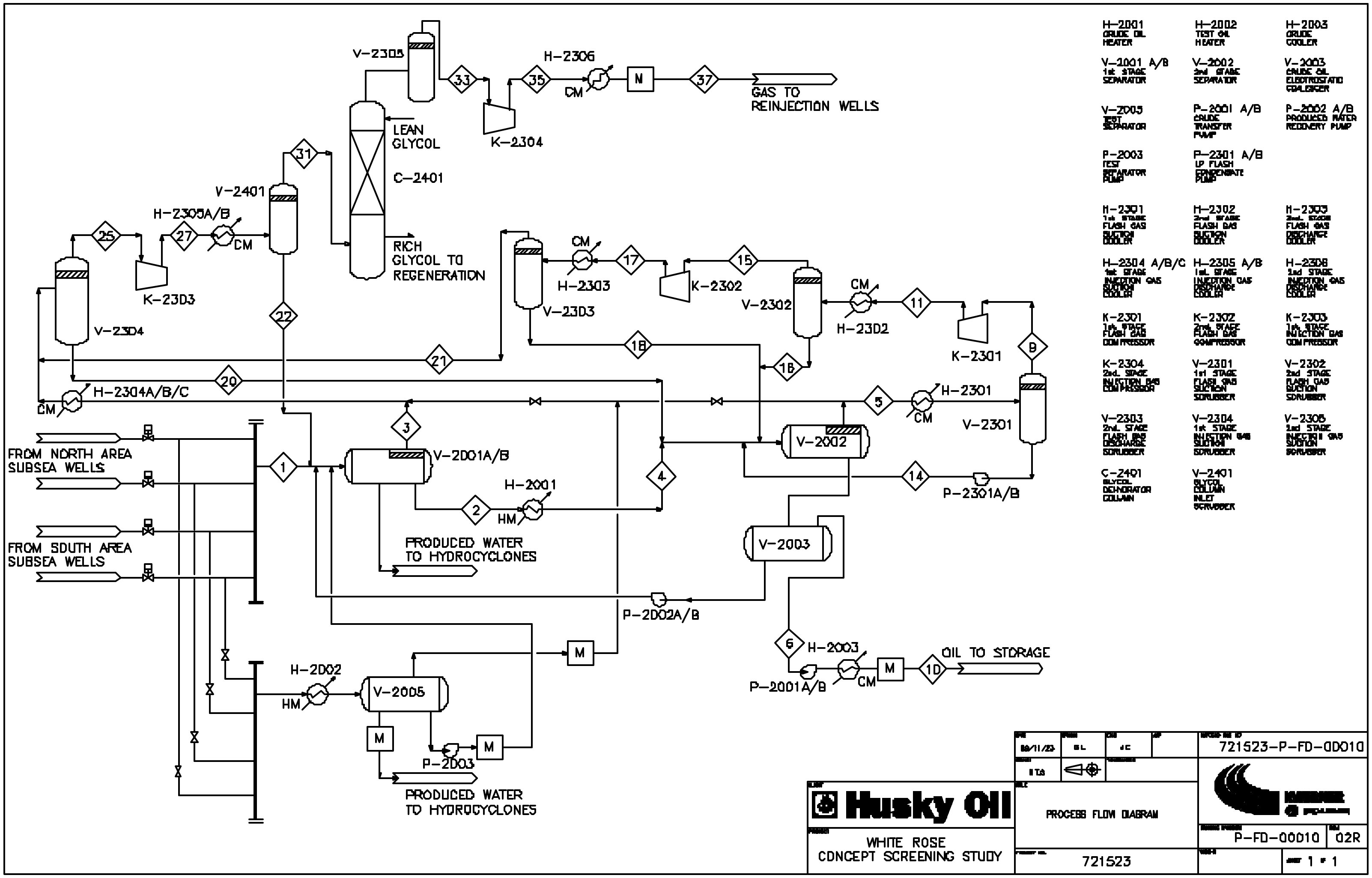
All produced water will be treated and disposed of directly overboard. All produced water disposed of overboard will meet the requirements of the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOBP 1996). This currently primarily requires produced water to be treated to reduce oil concentrations of dispersed oil to the following levels:

- 40 mg/L or less as averaged over a 30-day period; and
- 80 mg/L or less over any 48-hour period.

Water injection requirements will be met by treating and injecting seawater. Facilities for deoxygenating, filtering and preventing bacterial action will be included in the topsides.

Provision must be provided in topsides facilities for the launching and receiving of operational pigs. The facilities shall be configured such that pigs can be launched down and received from all production and production/test risers. Consideration shall be given to the optimum location of the required equipment.

Figure 2.5-1 Preliminary Process Flow Diagram for the White Rose Hydrocarbon Process Flow



2.6 Installation Support Facilities

The following support facilities will be provided, as appropriate, for the chosen option:

- suitable control and monitoring system for marine, production and subsea systems, allowing remote operation from the central control room (CCR) (located in the TSR);
- main power generation, emergency power generation and switchgear rooms;
- cooling medium;
- heating medium;
- chemical injection;
- flare and vent;
- open/closed hazardous drains;
- firewater/foam;
- potable/service water;
- hydraulic power;
- telecommunications (including external radio links, local UHF, hard wired systems such as PABX telephone, public address and alarm, close circuit television and internal data communication network);
- inert gas;
- ballast and bilge system with central control and monitoring system;
- mooring system with emergency disconnect system with central control and monitoring system;
- riser system with emergency disconnect system with central control and monitoring system;
- processed crude storage and transfer system with central control and monitoring system;
- diesel system;
- instrument/utility air system;
- nitrogen system; and
- steam system.

In addition, the offloading facilities will incorporate a fiscal metering system.

2.7 Installation Safety Systems

The safety of personnel shall be enhanced by the layout and construction of the selected option and by provision of dedicated safety systems. The following safety systems shall be provided, as appropriate, for the chosen option:

- fire and gas detection system (fire, gas, smoke, heat detectors)
- active and passive fire protection;
- personnel escape routes;
- temporary safe refuge;
- evacuation systems;
- audio/visual alarms;
- emergency shutdown system;
- flare and blowdown system;
- hazardous drains;
- inert gas system;
- emergency mooring and disconnect systems; and
- emergency riser disconnect system.

The safety systems shall be designed to minimize the consequences and prevent the escalation of accidental events.

2.8 Crude Export System/Offloading

2.8.1 Floating Production, Storage and Offloading Facility

The crude oil will be stored in the FPSO tanks and off-loaded to a tandem moored offtake tanker by a flexible hose. It is envisaged that the offloading facilities will be located at the stern of the FPSO and incorporate a fiscal metering system as an integrated package. The offloading hose will be of an appropriate length, circumference and specification. The tanker will approach the FPSO stern and oil will be offloaded via the flexible hose.

The offloading system and offloading rate shall be designed with regard to the environmental conditions in the oilfield, such that the operational capabilities of the FPSO are not compromized by weather limitations on a tanker connecting or remaining connected to the FPSO.

The offloading system will include a mooring hawser complete with messenger line suitable for mooring both dynamically positioned (DP) and non-DP shuttle tankers, and all equipment necessary for handling and storing of the hawser. The hawser will have an emergency quick release connection. The tension in the hawser will be monitored continually while the tanker is connected.

With a storage capacity for crude oil of between 111,000 and 135,000 m^3 (700,000 and 850,000 barrels), the FPSO will have sufficient storage for approximately seven to eight days of oil production. It is therefore estimated that a shuttle or export tanker will be required every five to six days to ensure that there is always a sufficient buffer in terms of storage capacity to account for delays due to poor weather.

Crude transfer will typically take place over a 12 to 18-hour period. However, the tanker may remain on location for longer period of time, receiving crude oil at the production rate until it has loaded the appropriate amount of crude.

2.8.2 Semi-Submersible

For the purpose of this CSA, it is assumed that for the semi-submersible, a single export pipeline and offloading system to a permanently moored FSU would be used. Offloading from the FSU to an external shuttle or export tanker would be similar to that for an FPSO described above.

3 SPECIFIC SAFETY FEATURES OF DEVELOPMENT OPTIONS

This chapter summarizes the key safety features associated with the proposed development options. The following key safety features are discussed:

- subsea well protection;
- marine systems;
- facility layout;
- topsides safety systems;
- escape routes;
- TSR;
- evacuation and rescue systems; and
- operating and maintenance procedures and contingency plans.

Pursuant to Section 1.1.2, this CSA must assess the risk from potential accidents without taking into account any emergency plans or measures. However, the safety features described in this chapter are planned to be incorporated into the final design and as such, this CSA has been performed based on this assumption. The impact on the risk of excluding plans and measures for risk mitigation is discussed in Section 9.5 of this CSA.

3.1 Subsea Well Protection

The White Rose oilfield is subject to scouring icebergs and the design of the subsea facilities must consider the following:

- the location of wellheads, christmas trees and manifolds in glory holes with the top of the equipment a minimum of 2 to 4 m below the seabed level. This does not apply to components not critical to the integrity of the well;
- flowline trenching;
- requirement for overtrawlability;
- design loads from fishing activities resulting from fishermen accidentally entering the exclusion zone;
- transfer of loads from impacts to flowlines and umbilicals to ensure well integrity is not compromised; and
- design loads of snags as well as dropped objects.

In addition, the following inherent safety features will be built into the design of the subsea facilities:

- all subsea systems will be designed to be fail-safe, that is, all hydraulically operated isolation valves will automatically close if hydraulic power is lost; and
- any abnormal operating conditions resulting from control system damage, which endangers the safe operation of the subsea facilities, will trigger an automatic system shutdown.

3.2 Marine Systems

Detailed investigations into weather conditions and their effect on the mooring and riser systems will be required to confirm environmental criteria for disconnection and reconnection. Typically, though, this will be based on the following environmental conditions:

- disconnection in a one-year ice season storm condition without damage and disconnection in more severe weather conditions accepting risk of damage;
- disconnect in sea ice exceeding 5/10 cover and/or exceeding 0.3 m thick;
- controlled disconnection in approximately four hours, including flushing of risers and flowlines;
- emergency disconnection capability will be provided; and
- reconnection in sea states up to 2-m significant wave height.

An Ice Management System (see Section 3.8 of this CSA) will be implemented to monitor and manage icebergs.

Regulatory requirements with respect to intact and damage stability will be satisfied. Superstructure icing shall be considered.

The vessel will have adequate propulsion for manoeuvring to avoid icebergs after disconnection of mooring and riser lines.

The vessel will be mechanically fitted with marine and utility systems, such as ballast and bilge systems, and sea water systems, which are necessary for safe operation.

3.3 Facility Layout

The facility layout for each of the options under consideration will be designed to optimize the separation between the accommodation (where the majority of personnel spend the majority of their time) and the hazardous hydrocarbon processing areas.

Flare systems are located at the opposite end to the accommodation to minimize the impact of energy flaring on personnel.

3.4 Topsides Safety Systems

Dedicated safety systems, including the following, shall be provided to minimize the consequences and prevent the escalation of accidental events:

- fire and gas system (fire, gas, smoke, heat detectors);
- active and passive fire protection;
- emergency shutdown system;
- flare and blowdown system; and
- hazardous drains.

Each is briefly discussed below.

3.4.1 Fire and Gas Detection System

Detection systems will be defined at the detailed design stage, but will typically include fire and gas detection in hydrocarbon containing areas, fire detection in all other areas, and smoke and gas detection in the inlet to the heating, ventilation and air condition (HVAC) systems.

The fire and gas detection system (FGS) continuously monitors the platform and provides automatic detection for fire, smoke and flammable gas. In the event of a confirmed fire or gas hazards (or upon operator input), the system will automatically:

- start firewater pumps;
- release extinguishants;
- initiate emergency shut-down (ESD) (confirmed detection will result in the appropriate level of shutdown);
- close fire dampers and shut down HVAC fans;
- activate platform audible and visual alarms through the platform telecommunications system; and
- blowdown hydrocarbon inventories.

3.4.2 Active Fire Protection

Two independent, 100 percent-capacity fire water pumps will supply a dedicated firewater ring main. The firewater pumps will be started automatically by a signal from the FGS. Dedicated deluge valves will provide activation of local deluge areas. Hydrants will cover all deck areas and hoses will be available for accommodation spaces. Deluge with provision for injection of foam will cover hydrocarbon processing areas. Accommodation areas will be covered by a sprinkler system. Water and foam cannons will be provided for the helideck. Fixed gas inerting systems will be provided for areas containing electrical equipment.

3.4.3 Passive Fire Protection

The passive fire protection (PFP) includes fire-rated walls and decks. These separate classified hazardous areas from non-hazardous areas and are designed to control the spread of fires between different areas.

PFP will be provided for key structural members and in the form of barriers between certain modules.

For the FPSO, preliminary engineering studies indicate that a blast wall (rating to be specified) will be located between the process separation area and the flash gas area (see Figure 2.4-1). An alternative location for this blastwall, as indicated in Figure 2.4-1, could be between the utilities pallet and process separation. The former location has been assumed for the purposes of this CSA, however, the optimal location (the one which minimizes risk levels) will be investigated at the detailed design stage. Preliminary engineering studies also indicate that an H-120 Fire Rated Wall will be installed between the accommodation and galley laydown areas.

It is expected that the fire and gas detection and protection (active and passive) systems will be developed and optimized during the detailed design stage using a risk-based approach.

3.4.4 Emergency Shutdown System

The ESD system isolates equipment or systems to protect personnel, environment and equipment from an incident or abnormal operating condition. There may be up to five levels of shutdown, as follows:

- Level 1: Abandon Platform Shutdown;
- Level 2: ESD;
- Level 3: Process Shutdown (PSD);
- Level 4: Partial Process Shutdown (PPSD); and
- Level 5: Unit Shutdown (USD).

Level 1 is initiated manually, but Levels 2 to 5 are initiated automatically as follows: Level 2 on confirmed fire and gas detection; Levels 3 and 4 on process control system; and Level 5 on equipment trips. These levels may vary during the detailed design phase.

Audio-visual alarms will be activated in the CCR and throughout the vessel to indicate a safety shutdown. The matrix and mimic panels for the safety shutdown systems will be located in the CCR.

Safety valves will be dedicated to safety shutdowns and will not be used for normal operations. The process facility will be isolated from reservoir flow by emergency shutdown valves (ESDVs) above the riser connection. Other ESDVs may be used in the process.

Depressurising of the topsides and vessel systems will be automatic for Level 1 only (all other levels are depressurized manually as a controlled operation, as and when necessary. The subsea lines will be left pressurized after a Level 2 shutdown. They may, depending on time frames, also be depressurized for a Level 1 shutdown.

3.4.5 Flare and Blowdown Systems

The flare is designed to handle high and low pressure gas from all process trains. The flare will typically be supported on a single boom inclined from the vertical so as to minimize noise and radiation levels at deck level.

Blowdown rapidly reduces the pressure in hydrocarbon pressure vessels, equipment and pipes following ESD. Process gas is discharged via blowdown valves to the flare systems. This minimizes the risk of equipment rupturing during a fire situation, and reduces the quantity of fuel that may feed a fire. Blowdown valves will be designed to fail-safe (open) and to meet the requirements of API RP 520 or equivalent.

3.4.6 Hazardous Drains

In order to ensure the safe disposal of flammable materials, there will be a drainage system comprising hazardous area drains (where oil spills are expected) and non-hazardous area drains.

The design intent is that the non-hazardous drainage system will be completely separate from the hazardous drainage system.

3.5 Escape Routes

Escape routes will be provided across the decks to allow personnel to move easily from any position on the deck to either the accommodation/main evacuation systems, or the secondary muster locations/ evacuation systems. There will be at least two exits from any location.

For the FPSO, two escape routes will run along the sides of the modules, one on each side of the vessel (port and starboard). These escape routes will be located on the main deck level, or suspended below the production deck level.

For the semi-submersible option, escape routes will run along the perimeter of each deck and there will be at least two access routes through each module. There will be main stairwells to allow access between decks, as well as stairwells within the accommodation module. Ladders and/or stairs will also be provided to allow escape from raised areas.

3.6 Temporary Safe Refuge

Each of the FPSO and semi-submersible options will have a designated TSR. This will provide a safe muster area for personnel during an emergency (including provision for giving first aid to injured personnel), control and communication systems to allow effective instructions, and access to evacuation systems, if required.

For each option, the accommodation module will be the TSR because this is where the majority of personnel will be located for most of the time. This module will contain the CCR, radio room, suitable areas for mustering and will have direct access to the helideck and lifeboat evacuation systems.

3.7 Evacuation and Rescue Systems

Evacuation systems will comprise helicopters, lifeboats and liferafts.

It is assumed that helicopter evacuation of the entire personnel compliment will, if available, be the preferred means of evacuating the facility in the event of an emergency. It is assumed that helicopters in the vicinity (flying to Terra Nova or Hibernia) would be used in an emergency to shuttle personnel to support vessels or the Terra Nova/Hibernia installation.

Lifeboats would be the primary means of evacuating the facility to sea in an emergency. Capacity for 200 percent of the POB will be provided, with a minimum of 100 percent capacity near the TSR.

Davit launched inflatable life-rafts will provide a back-up system to the lifeboats. A capacity of 200 percent of the POB will be provided.

Immersion suits, lifejackets and other lifesaving equipment will be provided in accordance with Section 22 of the *Newfoundland Offshore Petroleum Installation Regulations* (C-NOPB 1995a).

Rescue facilities will typically be provided as follows:

- an on-shore emergency command and logistics centre;
- standby vessel with fast rescue craft (FRC);
- means of recovery of persons from the water (by standby vessel and FRC);
- search and rescue helicopters (shorebased); and
- the facilities available on any other vessels in the field or vicinity.

Means of recovery of personnel from lifeboats will be given careful consideration and typically involve contained retrieval by the standby vessel, taking into account the potentially severe environment on the Grand Banks.

Specifications of these systems will be determined by an escape, evacuation and rescue analysis, and by the preparation of emergency response/contingency plans. Mutual aid arrangements with the Terra Nova and Hibernia installations will be in place to enhance rescue capabilities.

3.8 Operating and Maintenance Procedures and Contingency Plans

3.8.1 Operating and Maintenance Procedures

Operating and maintenance procedures include:

- Maintenance Procedures – A phase-specific, operations-integrity plan detailing maintenance and inspection procedures will be implemented. Operating parameters will ensure all systems and equipment do not exceed design specifications or environmental limits. A reliability centred maintenance (RCM) program will ensure the safe operation and optimum reliability of equipment.

- Production and Marine Procedures – A phase-specific integrity plan detailing the procedures associated with production and marine activities, including environmental concerns, mitigation procedures and roles, responsibilities and authority, will be implemented.

- Ice Management Plan and Procedures – Husky Oil has an existing ice management plan and procedures, which involve cooperation with the other operators on the Grand Banks (Hibernia and Terra Nova). This will be amended to include FPSO operations.

- Loss Control Management – Husky Oil follows the corporate-wide Health, Safety and Environment Loss Control Management System, which has been modified using recognized international protocols (for example, International Safety Management (ISM) Code) to incorporate working in the offshore environment.

- Emergency Procedures – Husky Oil has an existing emergency response plan that will be modified to include production operations.

- Facility-Specific Alert and Emergency Response Procedures - Vessel-specific contingency plans incorporating procedures necessary during operation and maintenance will be implemented.

- Environmental Protection and Monitoring Procedures – Both environmental effects monitoring (EEM) and environmental compliance monitoring (ECM) will be conducted. Environmental protection plan requirements such as effluent treatment will be incorporated into design considerations.

3.8.2 Contingency Plans

Husky Oil has an existing contingency plan for drilling and other exploration activities which includes ice management, oil spill response and emergency response. The plan currently addresses:

- emergency response organization and training;
- vessel surveillance and collision avoidance;
- operations safety;
- personal injury or death;
- fire or explosion;
- vessel collision and structural impairment;
- hydrocarbon and chemical spills;
- loss of ballast control or vessel stability;
- heavy weather;
- loss of well control;
- loss of mooring;
- loss of vessels or helicopters/fixed-wing aircraft; and
- diving emergencies.

These plans (described more fully in Chapter 7 of the Preliminary Safety Plan (Volume 5, Part One)) will be expanded to reflect production and operational issues (for example, subsea pipelines).

4 MAJOR HAZARD IDENTIFICATION AND ANALYSIS

This chapter identifies the potential major hazards associated with the development options. This is based on a checklist approach of Standard Major Hazards that have been identified as a result of many years of similar operations experience as well as projects under development. The following major hazards have been considered, as appropriate, in this CSA for each development option:

- process and non-process loss of hydrocarbon containment (fire and explosion) (above sea);
- subsea loss of hydrocarbon containment (fire and explosion);
- blowout;
- ship impact;
- iceberg impact;
- dropped object;
- helicopter operations;
- fishing gear impact;
- structural failure;
- mooring failure; and
- seismic activity.

Each of these is discussed individually in the following sections.

Note: the main fire and explosion hazards on the White Rose installation are associated with the inventory of pressurized hydrocarbons within its process train and riser system. However, lesser fire hazards also exist in the form of non-process hydrocarbons (such as diesel oil used to fuel various utilities) and non-hydrocarbon fires (such as fires in electrical equipment or the accommodation module). Owing to the early stage of the White Rose project, information pertaining to such hazards is very limited and, as a result, these other typically more minor hazards are not addressed in this CSA. They will, however, be included in the more refined analysis during the detailed design stage of the White Rose Project.

4.1 Process and Non-Process Loss of Hydrocarbon Containment

4.1.1 Identification of Isolatable Hydrocarbon Inventories

In order to identify potential hydrocarbon hazards, it is necessary to identify and define the isolatable hydrocarbon inventories that are to be used as the basis for further analysis (frequency assessment, etc.).

The characteristics of a hydrocarbon release and subsequent ignition leading to a fire are determined mainly by:

- type of hydrocarbon released (gas/liquid/two-phase);
- size of the release;
- conditions of the fluid (pressure, temperature); and
- quantity of hydrocarbon released to fuel the fire.

The type and conditions of the fluid, and the size of release, determine the initial characteristics of a hydrocarbon fire. The duration of the fire is also determined by the quantity of fluid available for release. The White Rose process stream will be provided with ESDVs at selected locations. However, at this early conceptual stage of the project, these locations have not been specified. For the purpose of this CSA, assumptions have been made as to the locations of the ESDVs. The design will incorporate the recommendations of API 14C, which addresses the safety requirements for offshore systems, particularly with regard to ESDVs.

In the event of an ESD (for example, following confirmed fire or gas detection), some ESDVs close to isolate sections of the total process inventory and other ESDVs open to release hydrocarbons from the isolated sections to the blowdown system. This reduces the amount of hydrocarbon available to fuel a fire.

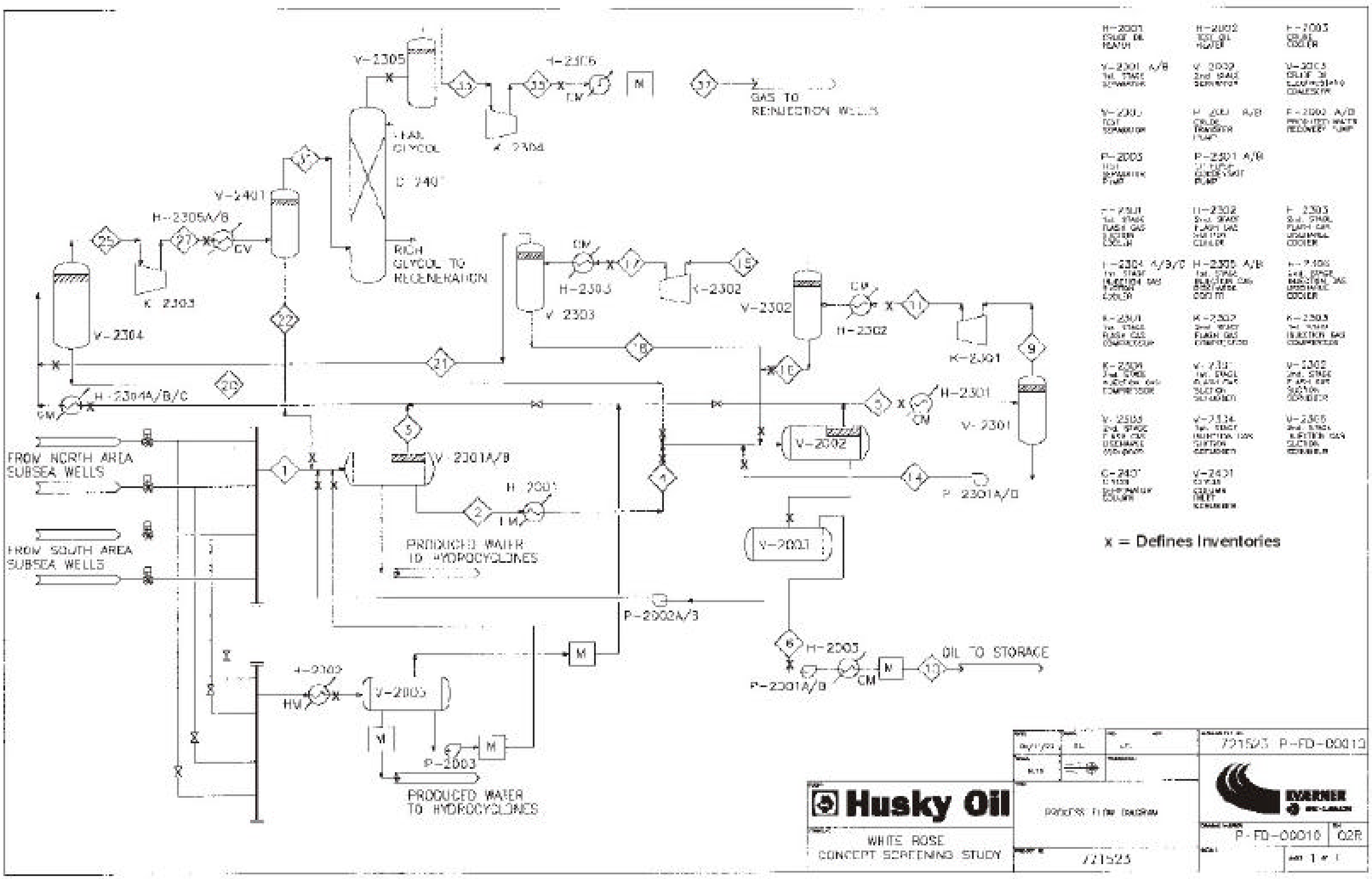
From a review of the White Rose process flow diagram (see Figure 2.5-1), this CSA:

- identifies the isolatable sections of the process;
- defines the isolatable sections in terms of what equipment is contained within the section;
- determines the location of the isolatable sections; and
- identifies the characteristics of hydrocarbon fluids in the isolatable sections.

The hydrocarbon inventories and corresponding locations are presented in Appendix B and are considered representative of an Offshore Process Flow System. They are generally based on grouping together equipment and associated pipework with similar/comparable operating conditions (pressure, temperature, etc.). However, for the purpose of the compression systems (1^{st} Stage, 2^{nd} Stage, 1^{st} Stage Injection, etc.), a representative system comprising a cooler, scrubber and compressor is assumed. The equipment in each section and the equipment operating conditions are also identified in Appendix B.

The identified inventories are marked on the PFD-00010 (see Figure 4.1-1) along with the type of hydrocarbon being processed (oil/gas).

Figure 4.1-1 Identified Inventories Marked on the PFD-00010



A number of assumptions have been made with regard to the operating conditions associated with the inventory equipment and pipework. These are generally based on the stream conditions provided in Kvaerner (2000). However, where such information is not specified for particular sections of the Process Flow, the assumed conditions and corresponding justification are detailed in the comments column in Appendix B.

Inventories are identified on Figure 4.1-1, however, this figure does not include all equipment and inventories typically found on offshore oil platforms. Therefore, additional representative inventories (process and non-process) are also included in Appendix B. As details (drawings, system descriptions, etc.) of these inventories are not currently available, assumptions are made about system components, conditions, etc. These inventories are indicated by an (*) in the appended tables in Appendix B.

A summary of the inventories identified in Appendix B is presented in Table 4.1-1 and representative operating conditions are assigned to each inventory. The conditions assigned to each inventory are the worst-case conditions identified for equipment in the inventory.

Subsea inventories, that is, subsea wells, manifolds, risers, etc., are not considered in this section. These are addressed in Section 4.2 of this CSA.

4.1.2 Initiating Events for Risk Assessment

As can be seen from Figures 2.4-1 and 2.4-2, each development option is divided into different modules (or areas). For the purpose of this CSA, it has been assumed that equipment defining the related process isolatable inventories are all contained in the same general area. For example, the gas compression equipment constituting the 1st Stage flash gas compression inventory is assumed to be located in the flash gas pallet.

The consequence of an ignited release from a particular isolatable inventory generally depends on the area of the platform on which the release occurs. On the basis of the identified isolatable sections in Table 4.1-1 and examination on an area-by-area basis of their potential release location, a collated set of hydrocarbon release events is presented in Tables 4.1-2 and 4.1-3.

The examination of areas for each development option is based on the identified locations of the inventories (and associated equipment). This identification is based on a review of Kvaerner (1999), and assigning inventories (and associated equipment) to the modules depicted in Figures 2.4-1 and 2.4-2.

Table 4.1-1 Summary of Isolatable Hydrocarbon Inventories

Inventory	Inventory Components	Process Conditions	
		Pressure (Bar a)	Temperature (^{o}C)
Above Sea Production Risers	• Production Riser	300	110
Above Sea Gas Injection Risers	• Gas Injection Riser	393	50
Production Manifold	• Production Flowlines & Manifold	300	110
Test Manifold	• Test Flowlines & Manifold	300	110
Gas Injection Manifold	• Gas Injection Flowlines and Manifold (Downstream of Gas Metering, see GR-I-1) • Test Oil Heater (H-2002)	393	50
1st Stage Separator	• 1st Stage Separator (V-2001 A/B) • Crude Oil Heater (H-2001)	27.1	84
Test Separator	• Test Separator (V-2005) • Test Metering • Test Separator Pump (P-2003)	27.1	84
2nd Stage Separator	• 2nd Stage Separator (V-2002)	1.5	67.8
Crude Oil Coalescer	• Crude Oil Coalescer (V-2003)	1.5	67.8
Crude Oil Storage	• Crude Transfer Pumps (P-2001 A/B) • Crude Cooler (H-2003)	4	55
1st Stage Flash Gas Compression	• 1st Stage Flash Gas Suction Cooler (H-2301) • 1st Stage Flash Gas Suction Scrubber (V-2301) • 1st Stage Flash Gas Compressor (K-2301)	6.5	113.3
2nd Stage Flash Gas Compression	• 2nd Stage Flash Gas Suction Cooler (H-2302) • 2nd Stage Flash Gas Suction Scrubber (V-2302) • 2nd Stage Flash Gas Compressor (K-2302)	27.7	111.7
2nd Stage Flash Gas Discharge Cooler and Scrubber	• 2nd Stage Flash Gas Discharge Cooler (H-2303) • 2nd Stage Flash Gas Discharge Scrubber (V-2303)	27.1	30
1st Stage Gas Injection Compression	• 1st Stage Injection Gas Suction Coolers (H-2304 A/B/C) • 1st Stage Injection Gas Suction Scrubber (V-2304) • 1st Stage Injection Gas Compressor (K-2303)	95	144.7
Glycol Treatment	• 1st Stage Injection Discharge Coolers (H-2305 A/B) • Glycol Column Inlet Scrubber (V-2401) • Glycol Dehydrator Column (C-2401)	95	30
2nd Stage Gas Injection Compression	• 2nd Stage Injection Gas Scrubber (V-2305) • 2nd Stage Injection Gas Compressor (K-2304)	393	155.5
Deck – Gas Re-Injection Wells	• 2nd Stage Injection Discharge Cooler (H-2306) • Gas Metering (Z-2701) (Upstream of Gas Injection Flowlines, see M-3)	393	50

Inventory	Inventory Components	Process Conditions	
		Pressure (Bar a)	Temperature (^oC)
Fuel Gas System*	• Fuel Gas KO Drum (V-4501) • Fuel Gas Filters (V-4502 x 2) • Fuel Gas Heater (H-4501)	80	100
Flare and Vent System*	• HP Flare KO Drum (V-4301) • LP Flare KO Drum (V-4302) • HP Flare Pump (P-4301 A/B) • LP Flare Pump (P-4302 A/B)	80	100
Main Power Generators*	• Main Power Generator Package (Z-8101 A/B/C)	80	100

Table 4.1-2 Loss of Hydrocarbon Events for FPSO

Release Ref.	Source Inventory Release (Type of Release Fluid)	Module Release Location
ASR-1	Above Sea Production Risers (Two-Phase Oil & Gas Mix)	Turret
ASR-1	Above Sea Gas Injection Risers (Gas)	Turret
M-1	Production Manifold (Two-Phase Oil & Gas Mix)	Turret
M-2	Test Manifold (Two-Phase Oil & Gas Mix)	Turret
M-3	Gas Injection Manifold (Gas)	Turret
S-1	1st Stage Separator (Oil & Gas)	Separation
S-2	Test Separator (Oil & Gas)	Separation
S-3	2nd Stage Separator (Oil & Gas)	Separation
S-4	Crude Oil Coalescer (Oil)	Separation
S-5	Crude Oil Storage (Oil)	Separation
GCT-1	1st Stage Flash Gas Compression Gas)	Flash Gas
GCT-2	2nd Stage Flash Gas Compression (Gas)	Flash Gas
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber (Oil & Gas)	Flash Gas
GCT-4	1st Stage Gas Injection Compression (Gas)	Gas Compression
GCT-5	Glycol Treatment (Gas)	Gas Compression
GCT-6	2nd Stage Gas Injection Compression (Gas)	Gas Compression
GR-I-1	Deck – Gas Re-Injection Wells (Gas)	Turret
FG-1	Fuel Gas System (Gas)	Utilities
FV-1	Flare and Vent System (Gas)	Flare and Vent
MPG-1	Main Power Generators (Gas)	Power Generation

Table 4.1-3 Loss of Hydrocarbon Events for Semi-Submersible

Release Ref.	Source Inventory Release (Type of Release Fluid)	Module Release Location
ASR-1	Above Sea Production Risers (Two-Phase Oil & Gas Mix)	Riser Handling Area
ASR-1	Above Sea Gas Injection Risers (Gas)	Riser Handling Area
M-1	Production Manifold (Two-Phase Oil & Gas Mix)	Riser Handling Area
M-2	Test Manifold (Two-Phase Oil & Gas Mix)	Riser Handling Area
M-3	Gas Injection Manifold (Gas)	Riser Handling Area
S-1	1st Stage Separator (Oil & Gas)	Process (Separation)
S-2	Test Separator (Oil & Gas)	Process (Separation)
S-3	2nd Stage Separator (Oil & Gas)	Process (Separation)
S-4	Crude Oil Coalescer (Oil)	Process (Separation)
S-5	Crude Oil Storage (Oil)	Process (Separation)
GCT-1	1st Stage Flash Gas Compression Gas)	Gas Compression
GCT-2	2nd Stage Flash Gas Compression (Gas)	Gas Compression
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber (Oil & Gas)	Gas Compression
GCT-4	1st Stage Gas Injection Compression (Gas)	Gas Compression
GCT-5	Glycol Treatment (Gas)	Gas Compression
GCT-6	2nd Stage Gas Injection Compression (Gas)	Gas Compression
GR-I-1	Deck – Gas Re-Injection Wells (Gas)	Riser Handling Area
FG-1	Fuel Gas System (Gas)	Utilities
FV-1	Flare and Vent System (Gas)	Flare and Vent
MPG-1	Main Power Generators (Gas)	Power Generation

In the case of the FPSO, for the purpose of assigning equipment to the flash gas and gas compression areas, it is assumed that all flash gas equipment is located in the flash gas area and all other gas compression and treatment equipment is located in the gas compression area.

The events in Tables 4.1-2 and 4.1-3 form the basis of assessing the risk to personnel from hydrocarbon release from the main process inventories (see Chapter 5).

4.2 Subsea Loss of Containment

The above sea riser releases were identified as a potential Major Hazard to the safety of personnel in Section 4.1 of this CSA. This section considers the risk associated with subsea inventories, such as, subsea wells, manifolds, risers, etc.

4.2.1 Subsea Wells and Manifolds

A subsea release of well fluid from oil producers and production manifolds would result in a pool forming on the sea surface. The location of the subsea wells and manifolds would be such that they would be a considerable distance from the main installation and releases with the potential to cause harm to personnel are considered remote. As a result of this, the unlikely potential for ignition (due to the subsea nature of the release) and the fact that the sea current would have to carry the pool towards the installation, the risk from releases from subsea wells and manifolds is not considered further in this CSA. However, such an assertion should be subject to review during the detailed design stage.

It is also feasible that a release of high-pressure gas may occur and consequently result in the formation of a gas bubble. This could, potentially, present a risk to personnel on the FPFs if the gas bubble is released from a location directly below the FPF. However, the frequency of a release large enough to present a significant risk is considered extremely low due to the low likelihood of the following conditions occurring coincidentally:

- a release large enough to produce a gas bubble capable of presenting a significant risk; and
- a release being located directly below the FPF.

Therefore, it has been qualitatively judged that the risk from such a scenario is insignificant. However, again, this assertion should be subject to review during the detailed design stage.

4.2.2 Subsea Risers

For the FPFs, the proximity of the risers to the installation would be such that an ignited release could, potentially, pose a threat to the safety of personnel. As a result, the risk from FPF subsea riser releases is assessed further in Section 7.1 of this CSA.

4.3 Blowout

Blowouts might arise as a result of well drilling, completion and workover operations. Such operations will be conducted in the field using an anchored semi-submersible MODU. These operations will be relatively remote from FPFs and will be subsea and, therefore, the probability of a blowout igniting and subsequently being carried by the sea current towards the FPFs is extremely low. Therefore, the risk to personnel on the FPFs from such scenarios is considered insignificant and is not considered further in this CSA.

In addition to the risk to personnel on the FPF, there is also the risk associated with the drilling, completion and workover operations to personnel on the MODUs. The hazards associated with such operations are further discussed in Section 4.3.1 of this CSA.

4.3.1 Risk to Personnel on the Mobile Offshore Drilling Units from Blowouts

As discussed in Section 4.3 of this CSA, personnel on the MODUs may be exposed to blowout scenarios which may arise during development drilling operations, from dropped objects and when mooring up the MODUs (damage to subsea equipment). However, it is anticipated that the field layout and associated activities will be such that the risk will be minimized and all operations will be in accordance with Husky Oil's operating procedures (see Section 3.8 of this CSA).

The Environmental Impact Statement (EIS) (Comprehensive Study Part One) (Husky 2000b) provides historical data on the frequency of blowout events for development drilling activities (that is, those activities specifically related to the MODU operation). These data, reproduced in Table 4.3-1, indicates that there have been four development drilling blowouts during this period. The EIS (Comprehensive Study Part One) estimates that there have been 51,000 development wells drilled in the above period, therefore equating to a development drilling blowout frequency of $4/51{,}000 = 7.8 \times 10^{-5}$ per well-drilled.

Table 4.3-1 Historical Large Oil Spills from Offshore Oilwell Blowouts

Area	Reported Spill Size (bbl)	Year	Operation Underway
Mexico (Ixtoc 1)	3,000,000	1979	Exploratory Drilling
Dubai	2,000,000	1973	Development Drilling
Iran[1]	?	1983	Production
Mexico	247,000	1986	Workover
Nigeria	200,000	1980	Development Drilling
North Sea/Norway	158,000	1977	Workover
Iran	100,000	1980	Development Drilling
USA, Santa Barbara	77,000	1969	Production
Saudi Arabia	60,000	1980	Exploratory Drilling
Mexico	56,000	1987	Exploratory Drilling
USA, S. Timbalier 26	53,000	1970	?
USA, Main Pass 41	30,000	1970	Production
USA, Timbalier Bay/Greenhill	11,500	1992	Production
Trinidad	10,000	1973	Development Drilling
[1] Caused by military action			

Development drilling blowout frequency (see also to Section 8.3.1 of this CSA) can be calculated by combining the above frequency with the predicted/proposed number of wells to be drilled. Precise work patterns, however, are unknown at this stage. Furthermore, the above frequencies are based on historical data and it is generally acknowledged that technical advancements have reduced the risk of blowouts significantly compared to the past few decades, over which the frequency data has been gathered. In addition, the White Rose oilfield development consists of known and relatively low formation pressures and therefore has a relatively low risk of 'kicks' resulting in a blowout situation.

The consequences of a blowout depend on the size of the release and the fluid type; gas or oil. Historical blowout incidents are shown in Table 4.3-1.

Ignition is possible if a blowout is directly beneath the MODU (probability of 0.3 – E&P Forum (1996)) and moving the MODU away by releasing the moorings, or even evacuating would be necessary. Water currents may move any sea fire away from the MODU, but it is very unlikely that the fire would affect the FPF because of field layout. The MODU is expected to have suitable contingency plans for well control and blowout.

The individual risk from blowout events depends on the staffing distributions and associated personnel locations on the MODU. In addition, the risk must take into account the time each individual spends on the MODU, both of which are unknown at this stage.

The risk to personnel on the FPFs from blowouts caused by dropped objects and mooring failure are discussed in Sections 4.6 and 4.10 of this CSA. These discussions are equally applicable to personnel on the MODU.

Currently, the location of specific wells as well as the selection of the MODU to be used for development drilling has not been determined. Drilling operations and other hazards associated with the MODU will be reviewed prior to selection of the MODUs and commencement of operations, as required by the C-NOPB regulations. Therefore, for the purpose of this CSA, the risk to personnel on the MODUs is not examined in further detail.

4.4 Ship Impact

As a result of the inevitable amount of shipping activity associated with an offshore installation, there is the potential for ships to impact the installation and cause either structural damage (resulting in loss of structural integrity) or, in the case of the FPFs, result in release of oil due to impact with the storage tanks. The risk associated with ship impact/collision is assessed in Section 7.2 of this CSA.

4.5 Iceberg Impact

The risk associated with iceberg impact is particularly associated with offshore installations on the Grand Banks. The potential consequences of an iceberg impacting the installation are analogous to that of ship impact, however, there is also the potential for iceberg scour of subsea equipment, in particular, the subsea wells and pipelines associated with the FPFs.

The risk associated with iceberg impact on the installation is assessed in Section 7.3 of this CSA. However, for the purposes of this CSA, the environmental risk associated with iceberg scour of the subsea wells and pipelines is considered insignificant based on the following:

- subsea wells will be submerged below the seabed in glory holes and therefore, any iceberg scour will pass over the top of the wellheads;
- subsea pipelines are assumed to be trenched below the seabed so that the pipelines will also be protected against any iceberg scour; and
- in the event that pipelines are not buried to be free from the risk of scour damage (for example, due to trenching difficulties), then a policy of isolating and purging the pipelines will be adopted, should an iceberg of potential scouring draft approach.

Again, such an assertion should be subject to review during the detailed design stage.

4.6 Dropped Object

The potential for dropped objects is inherent with offshore installations due to the craning and lifting operations that are carried out. Dropped loads on hydrocarbon-containing equipment, surface or subsurface, can lead to hydrocarbon releases and, if subsequently ignited, can result in fire or explosion. Dropped loads also present a risk to personnel if a load directly impacts a person and that person sustains fatal injuries.

Normal crane operations will cover almost all areas of the two FPF options, so it is feasible for objects to cause damage to structures and hydrocarbon-containing equipment, as well as directly onto personnel on the open decks. However, it is assumed that the cranes will be operated by suitably trained and competent personnel, and that suitably designed and certified cranes and lifting gear will be used, thereby reducing the potential for dropped loads. Lifting procedures will also be implemented, as appropriate, to restrict crane operating radii over sensitive areas.

The production decks of the FPF options will be open and live hydrocarbon-containing equipment may be exposed to dropped and swinging loads. Crane operations will be frequent, typically a daily activity, so dropped loads could significantly increase the possibility of hydrocarbon leaks if no special measures are taken to control lifting operations. However, current plans are to prohibit lifts over pressurised process equipment.

A review of lifting operations and activities will be necessary in the detailed design to ensure that damage to hydrocarbon-containing equipment cannot occur. Such a study will incorporate typical load paths and equipment types for the lifting equipment to be used on the installation.

Craning and lifting activity is particularly prevalent during drilling operations and as such, the potential for dropped loads is high during this time. For the FPFs, all drilling activities and associated lifting and offloading drilling are conducted by semi-submersible MODUs in the remote wells away from the installation. Therefore, in accordance with the discussion in Section 4.3 of this CSA, the risk to personnel on the production installation from dropped loads during drilling operations is considered in this CSA as insignificant. Risk of hydrocarbon releases from dropped loads on the MODU are minimized because of the relative lack of hydrocarbon inventories on a MODU. As outlined in Section 4.3 of this CSA, dropped object risks associated with the MODU will be reviewed in conjunction with the C-NOPB prior to drill operations commencing.

Dropped loads and mooring systems affecting subsea facilities has also been considered. The use of well clusters positioned along common flowline routes provides safe areas to drop the initial anchor when mooring up a drilling semi-submersible as well as leaving corridors for running out the rest of the anchors. However, the size of each cluster area requires careful consideration. To avoid the risk of damage to subsea equipment from mooring lines, it is essential to minimize further redeployment of anchors after a rig has moored up over a cluster. To minimize such redeployment and preferably avoid it altogether, the cluster arrangement and hence, mooring system, should be designed so that the rig can move anywhere over a particular cluster by simply adjusting mooring tensions. To avoid dropped objects such as tubulars or BOPs, guidelines for predicting dropped objects onto subsea equipment as suggested by the UK HSE Directorate and the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) can be followed. Such technical evaluations also need to take into account adjusting mooring tensions necessary to move the rig over the cluster arrangement. Comparison of the risks associated with dropped objects and those associated with incorrect adjustment of the mooring system may show that the use of a tight cluster or template should be considered.

Dropped objects and mooring lines damaging wellheads cannot be assessed in detail until drilling units are selected. It is assumed that the frequency of dropped objects and mooring lines causing blowouts is already included in the blowout frequency considered earlier.

The impact of mooring systems and dropped objects shall be evaluated prior to commencing drilling or workover activities over 'live' wellheads or flowlines.

Finally, it should be noted that downhole safety valves will close in all of the scenarios described above. In addition to which, wellhead ESDVs will close in the event of flowline damage.

4.7 Helicopter Operations

The transport of personnel to and from the installation also carries inherent risks associated with it. For the purpose of this CSA, such risks are estimated as the product of the following three components:

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

E&P Forum (1996) provides the above accident data for helicopter operations in the North Sea. This is considered to be the best source of data and most representative of conditions offshore in Newfoundland. These data enable risk from helicopter transportation to be assessed separately for in-flight accidents and for take-off and landing accidents (see Section 7.4 of this CSA).

There is also risk to the helideck crew as a result of helicopter operations, under normal circumstances as well as in accident situations. Any crash scenarios that cause fatalities among the helideck crew will be implicitly included in the accident data that is being used to quantify helicopter risks. Any other accident scenarios, that affect helideck crew only, are likely to be single or small numbers of persons incidents and these are therefore classed as occupational risk. As such, they are not addressed in this CSA, however, loss control management systems will be in place to minimize such risks.

The risk assessment of risk to platform personnel for helicopter transportation is described in Section 7.4 of this CSA.

4.8 Fishing Gear Impact

Fishing gear has the potential to impact subsea equipment and result in a hydrocarbon release. However, it is expected that there will be a restriction on fishing activity within the White Rose oilfield due to the presence of equipment on the seabed (flowlines, manifolds, etc.). In addition, the exclusion zone around the White Rose oilfield should prevent fishing activities in the immediate vicinity of the installation. On the basis of this, and the above discussion on subsea releases from manifolds and subsea wells (that is, the remote location of the wells and manifolds in relation to the installation), the risk to personnel from subsea releases due to fishing gear impact is considered insignificant. However, assertion is subject to review during the detailed design stage.

4.9 Structural Failure

Structural failure could potentially result in the total loss of the integrity of the installation and have catastrophic consequences in terms of the number of fatalities that would result. For the purpose of this CSA, structural failure is assumed to occur from any of the following:

- structural failure within design (that is, structural failure results due to design or construction error);
- structural failure due to extreme weather conditions; and
- structural failure due to ballast system failure.

The risk assessment in Section 7.5 of this CSA estimates the risk associated with the above events. It determines the probability of total loss and assigns potential fatalities to the consequences considered.

4.10 Mooring Failure

Mooring failure is defined as follows:

- a single mooring line fails initially;
- this is accompanied by bad weather condition; and
- in addition, the thrusters fail and the vessel is therefore unable to hold position, and progressive failure of the remaining mooring lines results.

However, in the event of any of the above occurring, the FPF would simply disconnect and move off location. Therefore, for the purpose of this CSA, the risk to personnel on the FPF associated with mooring failure is considered negligible.

4.11 Seismic Activity

The risk to subsea facilities due to direct seismic activity is considered insignificant due to the low seismic activity in the Grand Banks region and the low susceptibility of the subsea facilities to vibration damage. However, there may be a risk posed by ‘seismically induced submarine landslides’ on the slopes of the glory holes. This is still likely to be insignificant but it will be examined further as part of the later design stage QRA. In the unlikely event that this is identified as a problem, the scenario is easily mitigated by changing the angle or position of the glory hole slopes.

5 BASIS OF HYDROCARBON RISK ASSESSMENT

5.1 Process and Non-Process and Loss of Containment Event Trees

Each of the loss of containment events identified in Tables 4.1-2 and 4.1-3 could result in any one of several possible outcomes (for example, fire, explosion or unignited release). This is attributable to the fact that the actual outcome depends on other events that may or may not occur following the initial release. Therefore, event tree analysis is used to identify and quantify the potential outcomes of a hydrocarbon release.

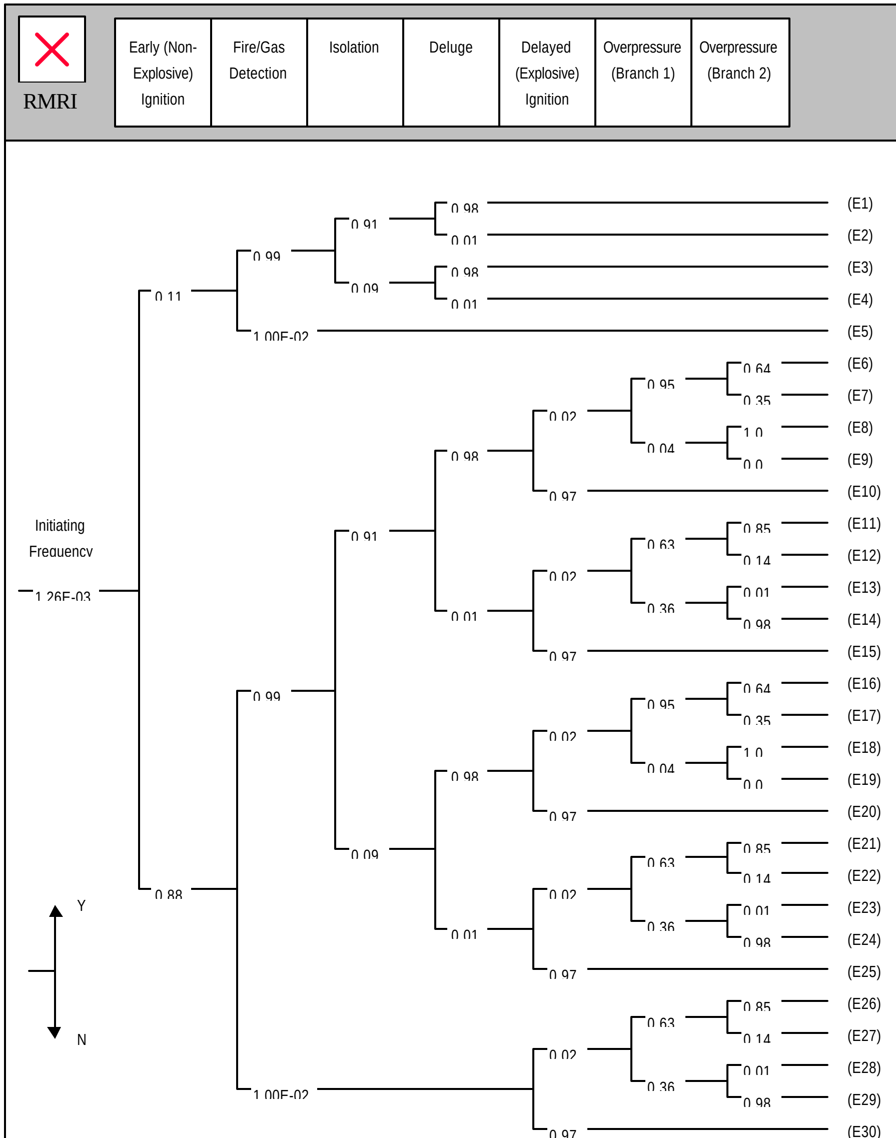
A schematic example of a typical event tree used to identify and quantify the possible outcomes of process hydrocarbon releases on the White Rose platform is provided in Figure 5.1-1. The root of the tree represents the initiating event, that is, a particular hydrocarbon release. From the root, the tree branches at various nodes. Each node (branch*)* represents the occurrence (or non-occurrence) of a subsequent event that determine the ultimate outcome. In the event tree in Figure 5.1-1, the following branch events are considered:

- early (non-explosive) ignition;
- fire or gas detection;
- inventory isolation/blowdown;
- deluge;
- late (explosive) ignition; and
- explosion overpressure.

These event tree branches enable the following factors to be accounted for in the risk assessment:

i) whether ignition occurs and the timing of an ignition (relative to the time of release); and
ii) any benefit provided by the platform safety systems.

Figure 5.1-1 Example of Loss of Hydrocarbon Containment Event Tree



Event	PLL Contribution	=	Event Frequency	X	Total Fatalities
(E1)	1.72E-04		1.29E-04		1.3372
(E2)	2.62E-06		1.96E-06		1.3372
(E3)	2.46E-05		1.27E-05		1.9372
(E4)	3.75E-07		1.94E-07		1.9372
(E5)	2.81E-06		1.45E-06		1.9372
(E6)	1.85E-05		1.73E-05		1.0732
(E7)	1.81E-05		9.68E-06		1.8732
(E8)	3.13E-05		1.24E-06		25.1732
(E9)	0.00E+00		0.00E+00		25.1732
(E10)	1.27E-04		9.61E-04		0.1316
(E11)	2.49E-07		2.32E-07		1.0732
(E12)	7.60E-08		4.06E-08		1.8732
(E13)	6.94E-08		2.76E-09		25.1732
(E14)	3.87E-06		1.54E-07		25.1732
(E15)	1.93E-06		1.46E-05		0.1316
(E16)	2.86E-06		1.71E-06		1.6732
(E17)	2.37E-06		9.57E-07		2.4732
(E18)	3.17E-06		1.23E-07		25.7732
(E19)	0.00E+00		0.00E+00		25.7732
(E20)	1.25E-05		9.51E-05		0.1316
(E21)	3.84E-08		2.30E-08		1.6732
(E22)	9.93E-09		4.01E-09		2.4732
(E23)	7.02E-09		2.72E-10		25.7732
(E24)	3.92E-07		1.52E-08		25.7732
(E25)	1.91E-07		1.45E-06		0.1316
(E26)	2.88E-07		1.72E-07		1.6732
(E27)	7.43E-08		3.00E-08		2.4732
(E28)	5.25E-08		2.04E-09		25.7732
(E29)	2.93E-06		1.14E-07		25.7732
(E30)	1.43E-06		1.08E-05		0.1316
	4.29E-04				

Hazard: Loss of Containment | Release Location: Test Separator | Hole Size: Large | Project: White Rose

i) Ignition Timing

The timing of an ignition strongly influences the nature of an ignited event. For example, if a gas release ignites rapidly, a jet fire is likely to result. Because insufficient time elapses for a volume of gas/air mixture to accumulate, an explosion is unlikely. Alternatively, if an ignition occurs later, a volume of stochiometic gas/air mixture may accumulate, and a strong explosion could result.

The event trees therefore distinguish between early, non-explosive ignition scenarios that result in a fire, and late ignition scenarios that may result in a possible explosion. The factors that determine the strength of an explosion in terms of overpressure are complex. To model these factors accurately, one must take account of all structures and equipment. This can only be done during the detailed design stage when the layout of the equipment is defined. The potential for explosion overpressure ranges is discussed in Section 5.7 of this CSA. Event tree branches are provided in Figure 5.1-1 to distinguish between explosions at different overpressures.

ii) Platform Safety Systems

The platform safety systems are designed to reduce the duration of a release event and reduce the impact of a fire or explosion.

Confirmed fire or gas detection in an area will initiate an ESD, so that the leaking inventory is isolated and depressurised. This reduces the amount of hydrocarbon released and so reduces the duration of a fire event. It also reduces the likelihood of the event escalating to other inventories.

On confirmed fire detection, the ESD System will also initiate deluge systems in the main process areas. Deluge reduces the likelihood of escalation. On this basis, the mitigating effect of deluge is modelled in the event trees.

Each event tree outcome, therefore, represents an event where ignition occurs early, late or not at all, and whether different platform safety systems have functioned effectively or not. This enables these factors to be accounted for in the risk estimate for the release event. The risk (statistical fatalities per year) from a particular release event is the total risk from its identified outcomes. The risk from each outcome is the product of outcome frequency and consequence (in terms of statistical fatalities).

Each outcome frequency is determined by estimating:

- the frequency of the initiating event, that is, the release event; and
- the probability of occurrence of the events represented by the event tree branches.

Each outcome frequency is the product of the initiating event frequency and the combined probability of the branch events in the event tree sequence leading to that outcome. The initiating event frequencies are considered in Section 5.2 below, the event tree branch probabilities in Sections 5.3 to 5.7 of this CSA.

Assessing an outcome consequence involves:

- modelling the physical consequences produced by the fire (or explosion) event; and
- assessing the impact of those consequences in terms of impact on personnel and potential statistical fatalities.

Assessment of outcome consequences is described in Chapter 6 of this CSA.

5.2 Hydrocarbon Release Frequency

5.2.1 Event Leak Frequencies

CMPT (1999) provides North Sea hydrocarbon leak frequency data for various individual items of process equipment (for example, vessels and pipework). It also provides leak frequency data for typical representative process systems (for example, separation system).

The release frequency for each event in Tables 4.1-2 and 4.1-3 is estimated from CMPT (1999) leak frequency data. This was done by inspecting the White Rose Process Flow Diagram (PFD) (Figure 2.5-1) to identify the equipment associated with each release location. The White Rose equipment was then compared with that listed for each of the CMPT (1999) representative systems.

Where possible, the leak frequency given in CMPT (1999) for a representative system (or part of a system) similar to the White Rose equipment was chosen as the basis of the leak frequency for that event. However, for some release locations (for example, the crude oil coalescer), representative leak frequency data for individual items of process equipment was used and an allowance made for associated pipework, etc.

The overall leak frequency assigned to each release event is given in Table 5.2-1 and their corresponding derivations are presented in Appendix C.

Table 5.2-1 Loss of Hydrocarbon Event Tree Overall Leak Frequencies (for Both Options)

Release Ref.	Source Inventory Release	Leak Frequency (per year)
ASR-1	Above Sea Production Risers	0.011
ASR-1	Above Sea Gas Injection Risers	0.00255
M-1	Production Manifold	0.184
M-2	Test Manifold	0.196
M-3	Gas Injection Manifold	0.0351
S-1/1	1st Stage Separator (Gas)	0.12
S-1/2	1st Stage Separator (Oil)	0.132
S-2/1	Test Separator (Gas)	0.06
S-2/2	Test Separator (Oil)	0.105
S-3/1	2nd Stage Separator (Gas)	0.06
S-3/2	2nd Stage Separator (Oil)	0.06
S-4	Crude Oil Coalescer	0.00286
S-5	Crude Oil Storage	0.0617
GCT-1	1st Stage Flash Gas Compression	0.29
GCT-2	2nd Stage Flash Gas Compression	0.29
GCT-3/1	2nd Stage Flash Gas Discharge Cooler and Scrubber (Gas)	0.00726
GCT-3/2	2nd Stage Flash Gas Discharge Cooler and Scrubber (Oil)	0.00143
GCT-4	1st Stage Gas Injection Compression	0.425
GCT-5	Glycol Treatment	0.0174
GCT-6	2nd Stage Gas Injection Compression	0.22
GR-I-1	Deck – Gas Re-Injection Wells	0.0278
FG-1	Fuel Gas System	0.029
FV-1	Flare and Vent System	0.0218
MPG-1	Main Power Generators	0.00572
	TOTAL	**2.36**

From Section 2.1 of this CSA, the initial reservoir depletion plan estimates that the oil reservoir will require up to 10 to 14 producing wells and up to a further six to eight water injection wells will be used to maximize oil production. It is also assumed that two gas injection wells will be required to reinject gas. Therefore, for the purpose of this CSA, the worst-case projection is assumed, and predicated on, 14 production wells, eight water injection wells and two gas injection wells.

5.2.2 Selection of Representative Hole Sizes

A major factor influencing the characteristics of a release event is the release hole size. The hole size (in conjunction with inventory conditions such as pressure) determine the initial hydrocarbon release rate and, if ignited, the magnitude of the resultant fire. The hole size and release rate (in conjunction with inventory size) also determine release duration.

In reality, a range of hole sizes is possible. It is not practicable to assess the likelihood and consequences of releases represented by a range of possible releases sizes. In order to rationalize the hydrocarbon risk assessment, it is industry practice to select three distinct hole sizes (small, medium and large) to be representative of the range of possible hole sizes.

E&P Forum (1992) provides hole size probability data for the equipment for which it also provides leak frequency data. From an "in-house" study (RMRI 1999) of this hole size probability data and a representative offshore installation equipment parts counts, the representative hole sizes and hole size distribution in Table 5.2-2 were selected for this risk assessment.

Table 5.2-2 Representative Hole Sizes and Distribution

Representative Hole Size (mm)		Range Represented (mm)	Proportion of Leaks Allocated (%)
Small	7	0-1	91.26
Medium	33	14-5	6.06
Large	76	52+	2.68
Total			100
Source: RMRI 1999.			

Therefore, for each hydrocarbon release event identified in Tables 4.1-2 and 4.1-3, three event trees are actually required, one for each of the small, medium and large hole size. The total leak frequency for each release event, as shown in Table 5.2-1, is allocated to each representative hole size according to the distribution shown in Table 5.2-2.

5.3 Ignition Probability

Cox et al. (1980) provide ignition probability data for hydrocarbon releases (assumed to be based on typical offshore semi-confined modules). The data are based on a survey of historical ignition data sources. Ignition probability data are provided for both gas and oil releases, based on mass release rate. For gas releases, explosion probability data are also given, based on gas mass release rate.

In Cox et al. (1980), the ignition data for oil releases and for gas releases is presented as a graphical relationship between release rate and ignition probability. In addition, for gas releases, the explosion probability data are presented as a graphical relationship between release rate and explosion probability. Representative ignition and explosion probabilities are given in Tables 5.3-1 and 5.3-2, respectively.

Table 5.3-1 Historical Ignition Probabilities

Release Rate (kg/s)	Ignition Probability	
	Oil	Gas
Minor (< 1)	0.01	0.01
Major (1-50)	0.03	0.07
Massive (> 50)	0.08	0.3
Source: Cox et al. 1980.		

Table 5.3-2 Historical Explosion Probabilities

Release Rate (kg/s)	Explosion Probability[1]
Minor (< 1)	0.04
Major (1-50)	0.12
Massive (> 50)	0.3
Source: Cox et al. 1980. [1] For gas release, **given that ignition occurs**.	

The above data are assumed to be gas ignition probabilities for semi-confined modules. The FPFs will be exposed modules and as such, gas leaks on exposed modules will disperse much quicker than in a confined module, accordingly they are less likely to ignite.

Limited data are available on the strength of this effect. It is subjectively judged that the above gas ignition probabilities should be reduced to account for the less likely chance of ignition on the more exposed FPFs.

For the oil releases, the above ignition probabilities in Table 5.3-1 are retained for the FPFs risk assessments. This judgement is based on the fact that as oil releases spread over a large area, it is deemed to be less affected by the more exposed conditions of the FPFs. The ignition probabilities used in the FPFs risk assessment are presented in Table 5.3-3.

Table 5.3-3 Ignition Probabilities Used in FPFs Risk Assessment

Release Size	Release Rate (kg/s)	Ignition Probability	
		Oil	Gas
Small	Minor (< 1)	0.01	0.0025
Medium	Major (1-50)	0.03	0.03
Large	Massive (> 50)	0.08	0.2

The explosion probability data in Table 5.3-2 are retained and used in the FPFs risk assessment.

As described in the previous section, three representative hole sizes have been selected for the small, medium and large release size categories. A reasonable approach for this CSA is to equate the small, medium and large release sizes to the minor, major and massive release rates and corresponding ignition probabilities quoted above.

5.3.1 Early Ignition (Fire Events)

In the event trees (see Figure 5.1-1), the first branch represents early ignition. These events are represented in the risk assessment as fire events. In this scenario, sufficient time is unlikely to elapse before ignition for a gas/air mixture to accumulate and cause an explosion. Subsequent branches for these events represent fire detection, inventory isolation and deluge.

5.3.2 Late Ignition (Explosion Events)

In the event trees, explosive ignitions are represented as late ignition events (fifth branch). This is because, in the time taken for an explosive mixture of gas and air to accumulate prior to ignition, sufficient time is more likely to elapse for gas detection, inventory isolation and for deluge to be initiated. For these explosive ignition events, branches are also provided to distinguish between explosion events of different overpressure.

5.3.3 Calculating Ignition Probability

5.3.3.1 Gas and Oil Releases

As described, ignition probability and explosion probability are each a function of mass release rate. As mentioned above, for the purpose of this CSA, representative release rates (minor, major and massive) have been assumed and equated to the small, medium and large hole size releases. Corresponding ignition and explosion probabilities have been determined from the minor, major and massive release rates.

Note: For the early ignition branch for gas releases only, the probability of a fire (P_{FIRE}) is derived by subtracting the (total) ignition probability (from Table 5.3-3) from the explosion probability (P_{EXP}) calculated below. For the early ignition branch for oil releases, P_{FIRE} is assumed to be the total ignition probability (for the appropriate hole sizes) listed in Table 5.3-3.

Explosion probability is presented in Table 5.3-2, given that (any) ignition occurs ($P_{EXP|IGN}$). The probability of an explosion (P_{EXP}) is the product of the total ignition probability (P_{IGN}) and the probability of an explosion given that an ignition occurs ($P_{EXP|IGN}$).

In the event trees, explosions are represented by the late ignition branch. This branch is only encountered in an event sequence if an early ignition does not occur. In other words, the branch represents the explosion probability given that early ignition does not occur ($P_{EXP|NOEIGN}$). Therefore, for gas releases only, the probability assigned to the fifth branch is calculated to represent the logical order of the sequence of events described.

Cox et al. (1980) provide explosion probabilities for gas releases only. For oil releases, the explosion probability is assumed to be negligible. This is based on the fact that the Cox et al. (1980) data (a major source of data for ignition probabilities) for delayed ignitions (for gas releases) are based on confined modules. The highly exposed conditions on the FPFs, coupled with the fact that only a small fraction of an oil release will 'flash-off' as gas, means it is reasonable to assume that, for oil releases, a flammable gas mixture will not accumulate to an ignitable level.

The only area which is not exposed is in the FPSO turret area. In this area, releases are either gas (from the gas injection risers) or two phase (from the production risers), both of which are effectively modelled as gas releases (see below for assumptions pertaining to two-phase releases), and this correctly addresses any explosion risks.

A summary of the branch probabilities used in the FPFs risk assessments is presented in Table 5.3-4.

Table 5.3-4 Event Tree Branch Probabilities Used in FPFs Risk Assessment

Release Size	Early Ignition (Branch 1)		Delayed Ignition (Branch 5)	
	Oil	Gas	Oil	Gas
Small	0.01	0.0024	negligible	0.0001
Medium	0.03	0.026	negligible	0.004
Large	0.08	0.14	negligible	0.07

5.3.3.2 Two-Phase Releases

Based on the fluid compositions specified in Kvaerner (1999), two-phase releases can potentially result from the production risers and production and test flowlines/manifolds. The fluid compositions in Kvaerner (1999) indicate that 87 percent of the fluid will comprise vapour. Therefore, for the purpose of this CSA, potential releases from the production risers and production and test flowlines/manifolds are modelled as gas releases. The gas ignition probabilities (explosion and fire) presented in Table 5.3-4 will also be used in the risk assessment for small, medium and large two-phase releases from the production risers and production and test flowlines/manifolds.

5.4 Fire and Gas Detection Probability

E&P Forum (1996) provides failure data for fire and gas detection systems. The data identify:

- Critical Failure-To-Operate (FTO) failure rates of detectors, based on component failure data.

- Test Independent Failure (TIF) probability (that is the probability that a component that has just been tested will fail on demand, based on expert judgement). This accounts for failures due to factors such as inadequate location and ineffective testing of the detectors.

The following sections derive fire and gas detection system probabilities from the above data based on the failure mechanisms (FTO and TIF) described.

In the event trees (see Figure 5.1-1), fire detection probabilities are assigned for those releases with the potential to ignite early.

Gas detection probabilities are assigned for those gas release scenarios where ignition does not occur early (delayed ignition scenarios) and gas can potentially build-up and activate the gas detectors.

For oil releases, the delayed ignition probability is considered negligible (see Section 5.3.3 of this CSA). Therefore, the gas detection probability branch in the event tree becomes redundant and the value assigned to that branch is not relevant (for simplicity, this value is set to zero in the event trees).

The following discussion is generic in its application to the two FPF options being considered.

5.4.1 Fire Detection

E&P Forum (1996) indicates a FTO rate of 1.5 per million hours. For a single Fire and Gas Detection (FGD) Programmable Logic Controller (PLC) node, the FTO rate is 2 per million hours. Therefore, assuming that three monthly test periods (8,760/4 = 2,190 hours) are conducted, the total failure on demand probability is $(1.5 + 2.0) \times 10^{-6} \times 2{,}190 \approx 0.008$.

E&P Forum (1996) indicates a TIF probability range for fire detectors of between 0.0003 and 0.5. The lower TIF is stated as being that for flame fires and the upper TIF is that for smoke fires.

5.4.1.1 Small Release Fires

For small releases, the TIF probability dominates the probability estimates. Smaller fires are more likely to be obscured from fire detectors; they are more likely to be outside the detectable range of the detectors even if the detectors are functional.

Due to the exposed nature of the FPFs and the fact that the modules will be well-ventilated, fires can be assumed to produce significant visible flames and not be 'smoke-only' fires. This would justify the lower TIF of 0.0003. However, as a conservative measure, a mean TIF of 0.25 has been applied.

Note: There is a contribution due to failure of the detectors themselves (0.008, see above), however, in relation to the TIF probability, the contribution is insignificant.

5.4.1.2 Large Release Fires

For large releases, the event is more likely to be detectable. In this case, critical FTO failure rate dominates (0.008) the estimated probabilities. Therefore, for large ignited (oil and gas) releases, a successful fire detection probability of 0.99 is assumed.

5.4.1.3 Medium Release Fires

For medium releases, the successful fire detection probability is derived by interpolating between the probabilities estimated for small and large releases respectively. A value of 0.87 (the approximate midpoint between the values) is assumed.

5.4.2 Gas Detection

The derivation and justification of the values used in the event trees for successful gas detection is analogous to that of the fire detector probabilities discussed in Section 5.4.1 of this CSA.

5.4.2.1 Small Gas Release

Based on the above justification for small fires, the upper bound TIF probability of 0.1 is assumed. Therefore, a successful gas detection probability of 0.9 is used in the event trees for small gas releases.

5.4.2.2 Large Gas Release

Again, based on the above justification for large fires, the FTO probability of 0.008 is assumed. Therefore, a successful gas detection probability of 0.99 is used in the event trees for small large releases.

5.4.2.3 Medium Gas Release

A value of 0.95 (the approximate midpoint between the values) is assumed for successful gas detection probability (based on interpolating between the probabilities estimated for small and large releases).

5.5 Inventory Isolation and Blowdown Probability

Each event tree represents a release from an isolatable section of the White Rose process stream. Due to the early stage of the White Rose oilfield development, isolatable sections have not yet been specified for the process inventory. They have, however, been estimated in Chapter 4 of this CSA and as such, are used to define the isolatable inventories for the event trees. The probabilities derived in this section are applicable to both of the FPF options being considered in this CSA.

5.5.1 Calculation of Isolation and Blowdown Probabilities

The probability of the inventory being isolated and de-pressurised ('blowndown') on ESD (following automatic fire or gas detection) is determined by three main factors:

- the number of ESDVs that must close 'on demand' (on emergency shutdown) for the inventory to be effectively isolated from others;
- the number of blow down valves (BDVs) that must open 'on demand' for effective blowdown of the isolated inventory; and
- the probability of each isolating ESDV or BDV operating successfully on demand (closing or opening effectively when initiated by the emergency shutdown system).

For the purpose of this CSA, the following typical assumptions for offshore CSAs are made;

- it is assumed that each process inventory is successfully isolated if two ESDVs and one BDV operate successfully; and
- it is assumed that the riser and manifolds inventories are successfully isolated if two ESDVs operate successfully.

The probability of an ESDV closing or BDV opening on demand is estimated from OREDA (1997), based on the ESDV failure rate due to random failures and the assumption that two ESDVs and one BDV must operate successfully.

OREDA (1997) indicates a mean critical failure rate of 10.51 per million hours for ESDVs. It is assumed that BDV have the same failure rate as the ESDVs. Assuming a three-month test[3] period (8,760/4 = 2,190 hours), the probability of failure on demand for *one valve* is (10.51 x 10^{-6} x 2,190) = 0.02. Therefore, the probability of an ESDV or BDV operating successfully is (1-0.02) = 0.98.

Based on the assumption that two ESDVs and one BDV must operate successfully to isolate each process inventory, the probability of successful isolation and blowdown is (0.98 x 0.98 x 0.98) = 0.94. This probability is applied equally to all inventories.

Based on the assumption that two ESDVs must operate successfully to isolate each riser and manifold inventory, the probability of successful isolation and blowdown is (0.98 x 0.98) = 0.96. This probability is applied equally to all inventories.

5.6 Deluge Probability

The effect of deluge (in terms of reducing explosion overpressure or fire escalation) is not explicitly modelled in the CSA for the FPFs due to the fact that deluge is primarily in place to prevent escalation of the incident. Consequently, the deluge probability branch in the event trees for the FPFs is effectively redundant. However, deluge system effectiveness may be modelled in subsequent updates/reviews and as such, was included for the purpose of this CSA.

It has been assumed that deluge will be initiated upon successful fire detection. E&P forum (1996) gives detailed reliability data for components of active fire protection systems, including an overall on-demand failure probability of 0.015 for deluge systems. Therefore, a successful deluge probability of 0.985 (1-0.015) is assumed for those fire events that activate the fire detectors and subsequently result in deluge initiation.

It has been assumed in this CSA that deluge will not be initiated upon successful gas detection. Such a policy is sometimes employed on more confined installations to mitigate the effects of explosion overpressure. However, the potential for explosion overpressures in the exposed FPF conditions is small, so mitigation is less of a requirement. It has been assumed that there is no general area platform deluge system; there is only equipment

[3] The reference to an assumed three month test interval does not refer to the interval to be implemented on White Rose, but to the typical interval stipulated in the OREDA (1997) data. Prescriptive regulations have generally required testing on a three month basis and this, therefore, justifies this assumption.

specific deluge. Typically, general area platform deluge is more capable of mitigating explosions. Therefore, to be conservative for the events where 'early ignition' does not occur, deluge mitigation is not modelled and a successful deluge probability of zero has been assigned.

5.7 Explosion Overpressure Branch Probability

The consequence of an explosion is determined largely by the magnitude of the overpressure produced.

In the loss of hydrocarbon containment event trees, two overpressure branches follow the delayed ignition branch (see Figure 5.1-1). This enables 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. The specific range of overpressures and actual probabilities assigned to the explosion overpressure branches in the event trees are derived below and are based on the following:

- the probability of an explosion exceeding any particular overpressure (see Section 5.7.1 of this CSA); and
- the overpressure range that each of the four possible outcomes represents (see Section 5.7.2 of this CSA).

For the purpose of this CSA and for ease of modelling the event trees, overpressure range branches have been included in the event trees for oil releases. However, as previously mentioned in Section 5.3.4 of this CSA, it is assumed that there is minimal potential for explosion from oil releases (delayed ignition probability is assumed to be negligible). The overpressure range branch probabilities are, therefore, redundant for oil releases.

Overpressure ranges and associated branch probabilities are derived in the following sections for the FPFs.

5.7.1 Selection of Overpressure Range for Explosion Outcomes

The two overpressure branches that follow the delayed ignition branch in the event trees (see Figure 5.1-1) enable each explosion 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. Potentially, there are several explosion overpressure thresholds of interest with respect to risk assessment, for example:

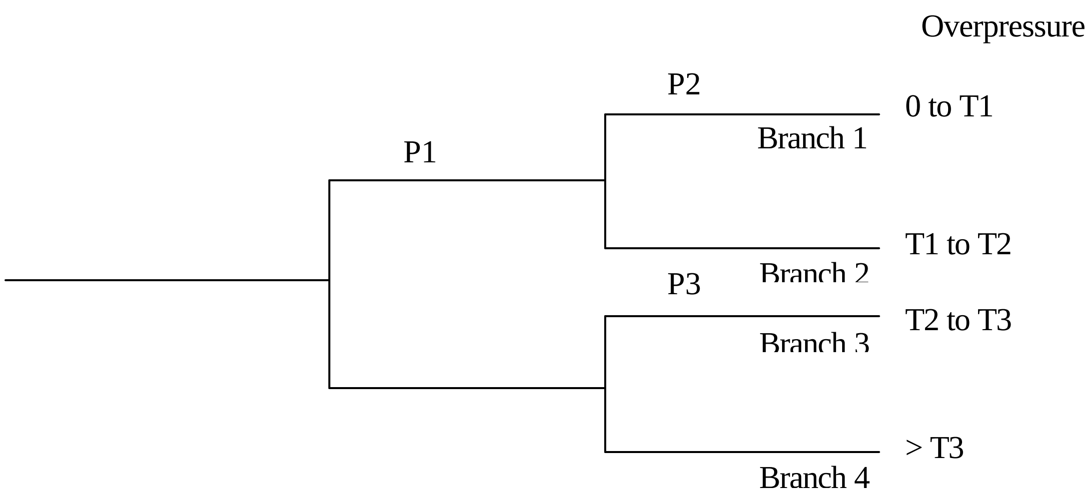
- the overpressure at which personnel in the affected area may be fatally injured;
- the overpressure at which partitions and bulkheads may fail, resulting in escalation of the effects of the explosion to other platform areas; and
- the overpressure at which the structural steel in the affected area may fail, leading to impairment of the platform structure in the vicinity of the explosion.

Other overpressures of interest can be identified (for example, the overpressure at which escapeways are likely to become impaired), however, the above three thresholds are assumed to be the most relevant.

As illustrated in Figure 5.7-1:

- Branch 1 is assigned to represent all overpressures between 0 and T1 bar.
- Branch 2 is assigned to represent all overpressures between T1 and T2 bar.
- Branch 3 is assigned to represent all overpressures between T2 and T3 bar.
- Branch 4 is assigned to represent all overpressures above T3 bar.

Figure 5.7-1 Schematic Showing Typical Four-branch Representation for Explosion Events



The following overpressure ranges (Table 5.7-1) are assigned to all the event trees for each of the development options being considered in this CSA.

Table 5.7-1 Explosion Overpressures Ranges for FPFs

Explosion Outcome	Overpressure Range
Branch 1	0 to 0.2 bar
Branch 2	0.2 to 0.8 bar
Branch 3	0.8 to 2 bar
Branch 4	> 2 bar

The four overpressure ranges identified in Table 5.7-1 are defined by three explosion overpressure thresholds:

- Threshold 1 (T1) - 0.2 Bar: This represents the explosion overpressure above which in the risk assessment, it is considered that all personnel in the affected module will be fatally injured by the explosion (see Chapter 6 of this CSA); below 0.2 bar, 50 percent of the personnel are considered to be fatally injured;

- Threshold (T2) - 0.8 Bar: This is the overpressure above which the blast walls will fail, resulting in escalation of the effects of the explosion to other platform areas. For example, in the risk assessment, it is assumed that, for modules separated by blast walls, above 0.8 bar, 100 percent of personnel in the affected area and 50 percent of personnel in the immediately adjacent area are fatally injured (see Chapter 6 of this CSA) and evacuation is initiated;

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

The probability that an explosion exceeds each of these thresholds is determined from the worst-case overpressures and corresponding overpressure exceedance curves (OECs). These are discussed, together with the derivation of the event tree branch probabilities, in Sections 5.7.2, 5.7.3 and 5.7.4 of this CSA, respectively.

5.7.2 Worst-Case Overpressure

The worst case overpressure in any module depends on:

- module size;
- confinement; and
- congestion.

The worst-case overpressures assumed for this CSA are presented in Table 5.7-2. These are based on experience of other offshore platforms where overpressure prediction software has been employed. Depending on the contribution to overall risk from explosion events, it may be necessary to perform more accurate overpressure studies during the White Rose detailed design phase. These worst-case overpressures are used to determine the specific OECs.

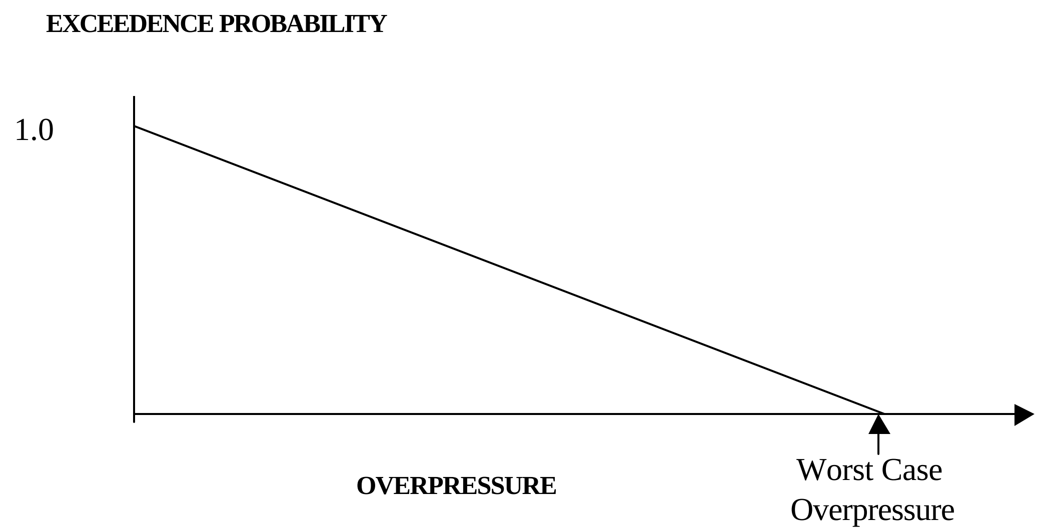
Table 5.7-2 Worst-Case Overpressures Assumed for this CSA

Development Option	Small	Medium	Large
FPFs (Except Turret in FPSO) : Exposed + Congested	0.2 Bar	1.0 Bar	1.0 Bar
Confined + Congested (e.g., Turret Area[1])	0.5 Bar	2.5 Bar	2.5 Bar
[1] For the FPSO, due to the more confined and congested arrangement in the Turret, higher representative worst-case overpressures are assumed.			

5.7.3 Overpressure Exceedance Curve

In the absence of detailed explosion overpressure probability modelling, a straight line (linear relationship) exceedence curve is the best estimate (see Figure 5.7-2). By definition, an OEC is bounded by an exceedence probability of 1 and the worst-case overpressure.

Figure 5.7-2 Example of Linear Overpressure Exceedence Curve



Comparing this linear OEC with the detailed OECs derived in the Hibernia QRA indicates that this approach is conservative (that is, by using the linear exceedence curve), higher probabilities are assigned to the higher overpressures).

Specific OECs are calculated from the worst-case overpressures discussed in Section 5.7.2 of this CSA.

5.7.4 Derivation of Event Tree Overpressure Branch Probabilities

The event tree overpressure branch probabilities (P1, P2 and P3 in Figure 5.7-1) are determined from the OECs, accounting for the event tree structure which is used as follows:

- the first overpressure branch (‘P1’) is used to distinguish between overpressures below or above T2;
- for overpressures below T2, the second overpressure branch (‘P2’) is used to distinguish between overpressures below or above T1; and

- for overpressures above T2, the second overpressure branch ('P3') is used to distinguish between overpressures below or above T3.

Once the thresholds have been selected, then the branch probabilities can be determined from the OECs.

The first step is to identify the exceedence probabilities for the three thresholds T1, T2 and T3, from the OECs; these are referred to as E1, E2 and E3, that is:

- Probability (Overpressure > T1) = E1;
- Probability (Overpressure > T2) = E2; and
- Probability (Overpressure > T3) = E3.

In order to convert these exceedence probabilities to branch probabilities in the event trees, it is necessary to take account of the structure of the event tree. As shown in the Figure 5.7-1, three probabilities must be specified for the event trees:

- P1 – The probability that the overpressure will be <T2
- P2 – The probability that the overpressure will be <T1 *given* that it is <T2
- P3 – The probability that the overpressure will be <T3 *given* that it is >T2

The event tree branch probabilities used in the event tree risk assessment for small, medium and large gas releases are presented in Tables 5.7-3 and 5.7-4.

Table 5.7-3 Event Tree Overpressure Range Branch Probabilities for FPFs (Except Turret Areas in the FPSO)

Probability	Release Size		
	Small	Medium	Large
E1	0	0.8	0.8
E2	0	0.2	0.2
E3	0	0	0
P1	1	0.8	0.8
P2	1	0.25	0.25
P3	N/A[1]	1	1

[1] N/A (Not Applicable) – Since P1 = 1, the 3rd and 4th event tree branches cannot occur, therefore, P3 becomes redundant (refer to Figure 5.7-1).

Table 5.7-4 Event Tree Overpressure Range Branch Probabilities for FPSO Turret Areas

Probability	Release Size		
	Small	**Medium**	**Large**
E1	0.6	0.92	0.92
E2	0	0.68	0.68
E3	0	0.2	0.2
P1	1	0.32	0.8
P2	0.4	0.25	0.25
P3	N/A	0.71	1

6 HYDROCARBON CONSEQUENCE ASSESSMENT

6.1 Introduction

The risk presented by a hydrocarbon release event is determined by the frequency and consequence of its possible outcomes. The frequency of each outcome is determined by the event trees (that is, from the release event frequencies and branch probabilities discussed in Chapter 5 of this CSA). This chapter considers each outcome in terms of physical consequences and potential statistical fatalities.

The consequence of igniting a hydrocarbon release depends on the type of material released, the mass release rate, the timing of the ignition, and the environment into which the hydrocarbon is released. Platform safety systems act to mitigate the consequences. Briefly, typical outcomes are:

- **Jet fires:** produced by an ignited jet of gas or liquid spray released from a process vessel under pressure;
- **Pool fires:** produced by ignition of a liquid release that accumulates on a deck (or sea) surface and ignites;
- **Flash fires:** produced by igniting a gas cloud so that a fire propagates through the gas cloud (without generating a significant overpressure);
- **Explosions:** produced by igniting a gas cloud in conditions where the resultant accelerating flame front produces a significant overpressure.

Note that a jet fire emanating from the release source may follow a flash fire or explosion.

<u>i) Early Ignition</u>

In the event tree risk assessment, gas and two-phase events that ignite early are modelled as jet fires. Liquid releases that ignite early are modelled as pool fires. The event tree risk assessment for each release event is presented in Appendix H.

Details of the jet fire consequence modelling are provided in Section 6.2 of this CSA but, briefly, jet fires are modelled as follows:

- Mass release rate is determined (for each representative hole size) based on the operating temperature and pressure at the point of release (extracted from Kvaerner (1999) and Appendix B).
- From the mass release rate, the jet flame length and associated fatality area (accounting for the potential impact of heat radiation around the release point).

The mass release rates and fire dimensions are determined from standard empirical formulae (CMPT 1999). All assumptions and calculations are presented in the relevant sections below.

For oil/liquid releases, a pool would spread forming a pool of flammable liquid on the deck or the sea surface depending on the release location. The pooled material would continue to expand until a bund or dike prevents further expansion. At this time the pool will continue to build depth. If the pool subsequently ignites, a burning pool will continue to collect spilled material until a point that burning exceeds the rate of material addition. Assumptions with regard to pool fire fatalities are detailed in Section 6.2 of this CSA.

ii) Late Ignition

In the event tree risk assessment, gas and two-phase releases that ignite late are modelled as explosions. Delayed ignition is not assumed to occur for oil releases (see Section 5.3.3 of this CSA). The event tree risk assessment for each release event is presented in Appendix H.

The consequential effect of a hydrocarbon gas explosion on personnel is determined by a variety of factors, including:

- direct effects of blast overpressure;
- whole body translation due to the blast wave;
- impact from projected missiles; and
- thermal effects on personnel inside the burning gas cloud.

There are no suitable techniques for modelling the combined effects in detail. However, to be conservative, it is assumed that all personnel caught inside the burning gas cloud are likely to be fatally injured due to thermal radiation effects and inhalation of burning gases. Outside the gas cloud, personnel may still suffer from the effects of blast overpressure. In the risk assessment, the fatalities are assigned for explosion events based on a criterion related to the explosion overpressure produced. The criterion is derived from consideration of both the thermal effects and the overpressure effects of an explosion, see Section 6.2.4 of this CSA.

iii) Fatalities

Irrespective of the type of outcome from an ignited hydrocarbon release, fatalities are classified as:

- Immediate Fatalities: These are fatalities local to the event and which are produced by the immediate thermal or overpressure effects of the hydrocarbon ignition;

- Mustering Fatalities: These are fatalities that occur because the event results in impairment of a platform main safety function, (see below). They occur outside the immediate area of the event, due to escalation, or while personnel not immediately affected by the event are escaping to, or mustering within, the TSR. Mustering fatalities also include those that occur during the process of evacuating the platform because the TSR, or other safety function, is impaired by the event. These evacuation fatalities include fatalities due to failure of the evacuation systems and fatalities whilst rescuing survivors from the lifeboats or from the sea;
- Pre-cautionary Lifeboat Evacuation Fatalities: It is recognized in the risk assessment that the Offshore Installation Manager (OIM) would not necessarily wait for the TSR to be impaired before ordering a platform evacuation. Under certain circumstances, the OIM may initiate an evacuation by lifeboat as a precautionary measure because, for example, the event is not considered to be fully under control or because there are early indications that the TSR could become impaired by the event. Precautionary evacuation fatalities are fatalities that occur during the process of evacuating the platform by lifeboat as a precautionary measure. They include potential for fatalities due to failure of the lifeboat evacuation systems, and potential for fatalities while rescuing personnel from lifeboats or survivors from the sea.

During design, the platform's main safety functions will be identified and examined in detail to ensure that the frequency of events capable of impairing them is acceptably low. The platform's main safety functions are defined as the:

- primary structure;
- escape routes to the TSR;
- TSR (including the CCR); and
- the evacuation systems.

Immediate events (events that only affect personnel in the immediate vicinity of the hazard) do not have the potential to impair the main safety functions. Such events do not prevent other personnel from moving to the TSR, mustering and, if necessary, safely evacuating the platform.

Mustering events are capable of impairing the main safety functions. Such events may impair the escape routes, the TSR, the evacuation systems or the platform support structure. In so doing, it may result in fatalities other than those defined as immediate fatalities, including those that occur during evacuation when the TSR, or other safety function, is impaired.

Immediate fatalities are considered in Section 6.2 of this CSA. Mustering fatalities are considered in Section 6.3 of this CSA. Precautionary evacuation fatalities are considered in Section 6.4 of this CSA.

6.2 Immediate Fatalities

6.2.1 Thermal Radiation Hazard

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.

CMPT (1999) discusses thermal radiation impact criteria for use in offshore risk assessment. Criteria discussed are as follows:

- 12.5 kW/m² 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 s, and second degree burns on exposed skin in about 40 s;
- 37.5 kW/m² is taken as the criterion for immediate fatality. At this level the pain threshold is virtually instantaneous, and second degree burns on exposed skin occur in about 8 s;
- Between 12.5 and 37.5 kW/m² – personnel in this zone may use escape routes, providing this allows them to leave the area within a few seconds ... but they suffer second degree burn injuries.

Personnel exposed initially to heat radiation less than 37.5 kW/m² may be seriously or even fatally injured if their escape from the effects of the radiation is not rapid. For radiation of 25 kW/m², pain is virtually instantaneous, second degree burns occur within approximately 12 s, third degree burns after approximately 30 s and '50 percent lethality' very soon after (CPMT 1999).

6.2.2 Jetfire Immediate Fatalities

For the purpose of this CSA, all the main modules on the platform are assumed to be separated by fire partitions/screens. This restricts the number of immediate fatalities from fire events to the module within which the fire occurs. For the risk assessment, immediate fatalities from jet fires are calculated as follows:

$$\text{Immediate Fatalities} = \text{Fatality Area x Population Density}$$

The above model conservatively assumes that there will be a probability of 1.0 that anyone within the fatality area will be fatally injured.

6.2.2.1 Fatality Area

Heat Radiation

The fatality area is based on the jet flame length. However, there is the additional threat posed by heat radiated outside the flame itself which is incorporated into the risk assessment. In the absence of more sophisticated techniques, the approach adopted in the risk assessment to model the heat radiation around the jet flame is to apply a scaling factor to the calculated jet flame length. Determination of the scaling factor depends on the level of radiation considered as potentially fatal.

From the discussion in Section 6.2.1 of this CSA, the risk assessment considers the fatality area to be that within the 25kW/m^2 heat flux contour around the jet flame. Within this contour, all personnel are assumed to be fatally injured. Outside the contour, personnel are assumed to be able to escape from 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 in Section 6.2.1 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 by the third criterion in Section 6.2.1 of this CSA. The 25kW/m^2 heat flux contour has been chosen to represent the mid-point of the 12.5 to 37.5kW/m^2 heat flux range indicated in the third criterion.

Based on the above discussion, a scaling factor should be applied to the jet flame length to account for the 25kW/m^2 heat flux contour around the jet flame. From CMPT (1999), a factor of 1.325 is applied to the jet flame length. (Scaling factors of 1.2 and 1.45 are specified in CMPT (1999) for 37.5kW/m^2 and 12.5kW/m^2 heat flux contours, respectively. The factor of 1.325 has been assumed based on the 25kW/m^2 heat flux contour being the mid-point of the 12.5 to 37.5kW/m^2 heat flux range (1.325 is the mid-point of 1.2 and 1.45)).

Calculation of Jet Flame Length and Fatality Area

The base of the jet flame is usually not attached to the release point, due to the high velocity and richness of the hydrocarbon near the release source. This lift-off distance must be accounted for in reducing the predicted radiation level on the release source. A value of 10 percent is typically used in QRAs (CMPT 1999). For the purpose of this CSA, a lift-off distance of 10 percent is assumed, therefore, the effective flame length is taken as 0.9 x 1.325 x jet flame length, where jet flame length is calculated using the following correlation (CMPT 1999):

$$\text{Jet Flame Length} = 11.14 \times (\text{Initial Mass Gas Release Rate})^{0.447}$$

and the Initial Gas Mass Release Rate is calculated as follows (CMPT 1999):

$$\text{Initial Gas Mass Release Rate} = C_D \times A \times P_o \times Z$$

Where:

C_D	=	Discharge coefficient (assumed to be 0.85)
A	=	Hole Area (m^2)
P_o	=	Initial Pressure of Gas (N/m^2) (from Table 4.1-1)
Z	=	Square Root Term, as follows:

$$Z = \sqrt{\frac{M\,g}{R\,T_o}\left(\frac{2}{g+1}\right)^{\frac{g+1}{g-1}}}$$

M	=	Molecular Weight of Gas (assumed to be 16 for Methane)
γ	=	Ratio of Specific Heats (assumed to be 1.31 for Methane)
R	=	Universal Gas Constant (= 8314 J/kg mol K)
T_o	=	Initial Temperature of Gas (from Table 4.1-1)

For the purpose of this CSA, it is assumed that the fatality area for a jet flame is that of the area of a circle, diameter 0.9 x 1.325 x jet flame length. Therefore, the fatality is area is calculated as follows:

$$\text{Fatality Area} = \pi \times \left(^{(0.9 \times 1.325 \times \text{jet flame length})}/_{2}\right)^2$$

Note, two-phase releases from the production risers and production and test flowlines/manifolds are modelled as gas releases (see Section 5.3.4 of this CSA).

Fatality areas for the hydrocarbon events identified in Table 4.1-2 and 4.1-3 [refer to Tables 6.2-5 and 6.2-6 for the FPSO and semi-submersible options, respectively].

6.2.2.2 Population Density

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

$$\text{Population Density} = {}^{\text{Number of Personnel on Module}}/_{\text{Module Area}}$$

As mentioned in Section 6.2.2 of this CSA, it is assumed that all modules are separated by fire partitions/screens and, therefore, this restricts the number of immediate fatalities from fire events to the module within which it occurs. The number of immediate fatalities is both a function of the ‘fatality area to module area ratio’ and the number of personnel in the module. Therefore, the fatality area to module area ratio is limited to one to prevent the calculation from predicting more fatalities than possible.

Staffing Distribution Assumptions

Owing to the early stage of the White Rose oilfield development project, personnel staffing distributions for the intended White Rose options have not been stipulated. However, it is likely that the design of the White Rose FPSO will be similar, although slightly smaller, than the Terra Nova FPSO. As a result, the staffing distributions used in this CSA for the FPSO and semi-submersible will be based on the percentage staffing distributions used in the Terra Nova Project (see Tables 6.2-1 and 6.2-2).

Table 6.2-1 Staffing Distributions Assumed for White Rose FPSO

Installation Area	Distribution (%)	Average Staffing Distribution
Accommodation	75	45
Galley Laydown	-	0
Power Generation	4.1	2.46
Utilities	4.7	2.82
Process (Separator)	2.7	1.62
Flash Gas	2.35	1.41
Gas Compression	2.35	1.41
Turret Utilities	5.4	3.24
Turret	2	1.2
Flare	1.4	0.84
TOTAL	**100**	**60**

Table 6.2-2 Staffing Distributions Assumed for White Rose Semi-Submersible

Deck Level	Installation Area	Distribution (%)	Average Staffing Distribution
Upper	Accommodation	42.5	25.5
	Process (Separator)	2.7	1.62
	Gas Compression	3.4	2.04
	Power Generation (inc. Flash Gas)	4.1	2.46
	Water Injection	2.7	1.62
	Flare	1.4	0.84
Lower	Accommodation	32.9	19.74
	Riser Handling	1.4	0.84
	Utilities	3.4	2.04
	Workshops	5.5	3.3
	TOTAL	**100**	**60**

The percentage of personnel in each module is applied to the following anticipated POB staffing levels (see below):

- FPSO – It is estimated that the total POB on the FPSO is in the range of 50 to 60 personnel. The upper bound estimate of 60 is used in the CSA to identify worst-case estimates; and
- semi-submersible and FSU – 60 + 25 = 85.

Staffing Distribution Derivation

Based on the percentage staffing distributions presented in Tables 6.2-1 and 6.2-2, and the POBs for the respective options discussed above, the personnel staffing distributions assumed for the White Rose FPSO and semi-submersible are calculated by applying the percentage staffing distributions in Tables 6.2-1 and 6.2-2 to the POBs for the respective options.

6.2.2.3 Module Area

Floating Production, Storage and Offloading Facility

The overall dimensions (260 m long x 42 m wide x 22 m high) of the FPSO option and assumed individual module dimensions are indicated in Figure 2.4-1. The module dimensions assumed for the FPSO are summarized in Table 6.2-3.

Table 6.2-3 Assumed Module Areas for FPSO

Location	Dimensions (m)		Module Area (m^2)
	Length	Width	
Helideck	30	42	1,260
Accommodation	15	42	630
Galley Laydown	15	42	630
Power Generation Pallet	30	42	1,260
Utilities Pallet	40	42	1,680
Separation Pallet	30	42	1,260
Flash Gas Pallet	15	42	630
Compression Pallet	30	42	1,260
Turret Utilities Pallet	10	42	420
Turret	30	42	1,260
Flare	15	25	375

Semi-Submersible

As mentioned in Section 2.4.1 of this CSA, for the purpose of this CSA, the semi-submersible is assumed to be 90 m long by 70 m wide. The module dimensions have been estimated by proportioning the overall length accordingly.

The module dimensions assumed for the semi-submersible are presented in Table 6.2-4.

Table 6.2-4 Assumed Module Areas for Semi-Submersible

Deck Level	Location	Dimensions (m)		Module Area (m^2)
		Length	Width	
Upper Deck	Accommodation	20	70	1,400
	Process (Separator)	20	70	1,400
	Gas Compression (inc. Flash Gas)	30	50	1,500
	Power Generation	30 20	35 35	1,050 700
	Water Injection	20	35	700
	Flare	20	20	400
Lower Deck	Accommodation	20	70	1,400
	Riser Handling	20	55	1,100
	Utilities	30	70	2,100
	Workshop	30	70	2,100

6.2.2.4 Calculation of Jet Fire Immediate Fatalities

Based on the foregoing discussion, the jet flame lengths, jet fire fatality areas (accounting for 25 kW/m^2 heat radiation contour, see Section 6.2.2 of this CSA) areas and corresponding immediate fatalities used in the event tree risk assessment are shown in Tables 6.2-5 and 6.2-6.

6.2.3 Pool Fire Immediate Fatalities

For the purpose of this CSA, it is assumed that a pool fire large enough to pose an immediate risk to personnel, will only occur if the initial release is sustained for a period of time sufficient enough to enable the formation of a significant pool. However, personnel will be aware of the gradual formation of the pool and will move away from the area before it ignites. Therefore, it is assumed that there will be no immediate fatalities from a pool fire.

Table 6.2-5 Jetfire Characteristic and Associated Immediate Fatalities for Gas Releases on FPSO

Ref.	Inventory	Jetfire Length (m)			Jetfire Fatality Area (m²)			Immediate Fatalities[1]		
		7 mm	33 mm	76 mm	7 mm	33 mm	76 mm	7 mm	33 mm	76 mm
ASR-1	Above Sea Production Risers[2]	13	53	112	195	3,125	13,888	0.52	4.44	4.44
ASR-1	Above Sea Gas Injection Risers	15	62	131	268	4,293	19,079	0.71	4.44	4.44
M-1	Production Manifold	13	53	112	195	3,125	13,888	0.52	4.44	4.44
M-2	Test Manifold	13	53	112	195	3,125	13,888	0.52	4.44	4.44
M-3	Gas Injection Manifold	5	19	39	268	4,293	19,079	0.71	4.44	4.44
S-1	1st Stage Separator	5	19	39	24	392	1,740	0.03	0.5	1.62
S-2	Test Separator	15	62	131	24	392	1,740	0.03	0.5	1.62
S-3	2nd Stage Separator	1	5	11	2	29	128	0	0.04	0.16
GCT-1	1st Stage Flash Gas Compression	2	10	20	6	101	450	0.01	0.23	1.01
GCT-2	2nd Stage Flash Gas Compression	5	18	38	23	371	1,647	0.05	0.83	1.41
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber	5	19	40	25	404	1,797	0.06	0.91	1.41
GCT-4	1st Stage Gas Injection Compression	8	31	65	67	1,075	4,779	0.08	1.2	1.41
GCT-5	Glycol Treatment	8	33	70	78	1,241	5,517	0.09	1.39	1.41
GCT-6	2nd Stage Gas Injection Compression	15	58	123	237	3,784	16,815	0.26	1.41	1.41
GR-I-1	Deck – Gas Re-Injection Wells	15	62	131	268	4,293	19,079	0.71	4.44	4.44
FG-1	Fuel Gas System	7	29	62	61	970	4,311	0.1	1.63	2.82
FV-1	Flare and Vent System	7	29	62	61	970	4,311	0.14	0.84	0.84
MPG-1	Main Power Generators	7	29	62	61	970	4,311	0.12	1.89	2.46

[1] Note, for the purpose of this CSA, two-phase releases from the production risers, production flowlines/manifolds and test flowlines/manifolds are modelled as gas releases (see Section 5.3.4 of this CSA). Also, a fire from the risers is initiated to affect the turret area (comprising both the turret and turret utilities). Therefore, for the purpose of this CSA, the immediate effects from a fire from the risers is assumed to affect both the turret and turret utilities, that is, the area affected is the sum of the turret and turret utilities areas (from Table 6.2-4) and the number of personnel affected is the sum of the average staffing distributions assumed for the turret and turret utilities (from Table 6.2-1).

[2] Note, if the fatality area exceeds the affected module area, 100% of personnel contained within the module are assumed to be fatally injured.

Table 6.2-6 Jetfire Characteristics and Associated Immediate Fatalities for Gas Releases on Semi-Submersible

Ref.	Inventory	Jetfire Length (m)			Jetfire Fatality Area (m²)			Immediate Fatalities[1]		
		7 mm	33 mm	76 mm	7 mm	33 mm	76 mm	7 mm	33 mm	76 mm
ASR-1	Above Sea Production Risers	13	53	112	195	3,125	13,888	0.15	0.84	0.84
ASR-1	Above Sea Gas Injection Risers	15	62	131	268	4,293	19,079	0.2	0.84	0.84
M-1	Production Manifold	13	53	112	195	3,125	13,888	0.15	0.84	0.84
M-2	Test Manifold	13	53	112	195	3,125	13,888	0.15	0.84	0.84
M-3	Gas Injection Manifold	5	19	39	268	4,293	19,079	0.2	0.84	0.84
S-1	1st Stage Separator	5	19	39	24	392	1,740	0.03	0.45	1.62
S-2	Test Separator	15	62	131	24	392	1,740	0.03	0.45	1.62
S-3	2nd Stage Separator	1	5	11	2	29	128	0	0.03	0.15
GCT-1	1st Stage Flash Gas Compression	2	10	20	6	101	450	0.01	0.14	0.61
GCT-2	2nd Stage Flash Gas Compression	5	18	38	23	371	1,647	0.03	0.5	2.04
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber	5	19	40	25	404	1,797	0.03	0.55	2.04
GCT-4	1st Stage Gas Injection Compression	8	31	65	67	1,075	4,779	0.09	1.46	2.04
GCT-5	Glycol Treatment	8	33	70	78	1,241	5,517	0.11	1.69	2.04
GCT-6	2nd Stage Gas Injection Compression	15	58	123	237	3,784	16,815	0.32	2.04	2.04
GR-I-1	Deck – Gas Re-Injection Wells	15	62	131	268	4,293	19,079	0.2	0.84	0.84
FG-1	Fuel Gas System	7	29	62	61	970	4,311	0.06	0.94	2.04
FV-1	Flare and Vent System	7	29	62	61	970	4,311	0.13	0.84	0.84
MPG-1	Main Power Generators	7	29	62	61	970	4,311	0.09	1.36	2.46

[1] Note, if the fatality area exceeds the affected module area, 100% of personnel contained within the module are assumed to be fatally injured.

6.2.4 Immediate Explosion Fatalities

ICE (1989) gives fatality probability for the effects of explosion overpressure on personnel. The fatality probabilities are provided in Table 6.2-7.

Table 6.2-7 Explosion Overpressure Fatality Probability

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

CMPT (1999), 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 a module area, this suggests that all personnel in that area will be fatally injured, irrespective of the overpressure produced.

However, not all explosions will result from a gas cloud that fills a module or module level. It is not unreasonable to assume that for a large majority of small releases, a module or module level may be as little as 10 percent full at the time of an explosion. Furthermore, it is also assumed in Section 5.7.2 of this CSA that, in general, for these small releases, the worst-case overpressure generated is likely to be lower than 0.2 Bar for the FPFs, which the fatality probabilities indicated in Table 6.2-7 are 0.1 or less. This would indicate that for low overpressure explosions, it is less likely that all personnel in a module will be fatally injured.

In assessing the effect of explosions involving small gas clouds, however, account must be taken of the fact that, in an explosion, the cloud of explosion products expands and finally occupies a volume larger than the initial gas/air mixture that produced the explosion.

It is not possible, therefore, to apply a precise analysis to this issue. In the absence of a precise approach, the following rule set is applied in order to determine the immediate fatalities in a module area in the event of a delayed ignition:

Explosion Overpressure	**Fatality Probability**
<0.2 Bar	0.5
>0.2 Bar	1.0

The above rule set gives the probability of fatality to be applied to each person in the immediate platform area (source module) affected by the explosion

As an example of the explosion immediate fatality calculations performed for the risk assessment, consider the following:

The number of personnel in the process module for the FPSO option (1.62) is indicated in Table 6.2-1. For a <0.2 Bar explosion in the process module, the risk assessment accounts for 50 percent immediate fatalities, that is, 0.81 fatalities, in the (source) module in which the explosion occurs. For a >0.2 Bar explosion, the risk assessment accounts for 100 percent immediate fatalities, that is, 1.62 fatalities, in the (source) module in which the explosion occurs.

The explosion immediate fatalities used in the event trees for the FPSO and semi-submersible options, for each hole size, are shown in Tables 6.2-8 and 6.2-9, respectively, for the overpressure ranges stipulated above.

Table 6.2-8 Immediate Explosion Fatalities for FPSO Event Trees

Ref.	Inventory	Staffing Distribution in Inventory Location	Immediate Fatalities			
			0.2	0.2-0.8	0.8-2	> 2
ASR-1	Above Sea Production Risers[1]	4.44	2.22	4.44	4.44	4.44
ASR-1	Above Sea Gas Injection Risers	4.44	2.22	4.44	4.44	4.44
M-1	Production Manifold	4.44	2.22	4.44	4.44	4.44
M-2	Test Manifold	4.44	2.22	4.44	4.44	4.44
M-3	Gas Injection Manifold	4.44	2.22	4.44	4.44	4.44
S-1	1st Stage Separator	1.62	0.81	1.62	1.62	1.62
S-2	Test Separator	1.62	0.81	1.62	1.62	1.62
S-3	2nd Stage Separator	1.62	0.81	1.62	1.62	1.62
GCT-1	1st Stage Flash Gas Compression	1.41	0.705	1.41	1.41	1.41
GCT-2	2nd Stage Flash Gas Compression	1.41	0.705	1.41	1.41	1.41
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber	1.41	0.705	1.41	1.41	1.41
GCT-4	1st Stage Gas Injection Compression	1.41	0.705	1.41	1.41	1.41
GCT-5	Glycol Treatment	1.41	0.705	1.41	1.41	1.41
GCT-6	2nd Stage Gas Injection Compression	1.41	0.705	1.41	1.41	1.41
GR-I-1	Deck – Gas Re-Injection Wells	4.44	2.22	4.44	4.44	4.44
FG-1	Fuel Gas System	2.82	1.41	2.82	2.82	2.82
FV-1	Flare and Vent System	0.84	0.42	0.84	0.84	0.84
MPG-1	Main Power Generators	2.46	1.23	2.46	2.46	2.46

[1] An explosion from the risers is assumed to be initiated in either the turret area or turret utilities. Therefore, for the purpose of this CSA, the immediate effects from an explosion from the risers is assumed to affect both the turret and turret utilities, that is, the area affected is the sum of the turret and turret utilities areas and the number of personnel affected is the sum of the average staffing distributions assumed for the turret and turret utilities.

Table 6.2-9 Immediate Explosion Fatalities for Semi-Submersible Event Trees

Ref.	Inventory	Staffing Distribution in Inventory Location	Immediate Fatalities			
			0.2	0.2-0.8	0.8-2	> 2
ASR-1	Above Sea Production Risers	0.84	0.42	0.84	0.84	0.84
ASR-1	Above Sea Gas Injection Risers	0.84	0.42	0.84	0.84	0.84
M-1	Production Manifold	0.84	0.42	0.84	0.84	0.84
M-2	Test Manifold	0.84	0.42	0.84	0.84	0.84
M-3	Gas Injection Manifold	0.84	0.42	0.84	0.84	0.84
S-1	1st Stage Separator	1.62	0.81	1.62	1.62	1.62
S-2	Test Separator	1.62	0.81	1.62	1.62	1.62
S-3	2nd Stage Separator	1.62	0.81	1.62	1.62	1.62
GCT-1	1st Stage Flash Gas Compression	2.04	1.02	2.04	2.04	2.04
GCT-2	2nd Stage Flash Gas Compression	2.04	1.02	2.04	2.04	2.04
GCT-3	2nd Stage Flash Gas Discharge Cooler and Scrubber	2.04	1.02	2.04	2.04	2.04
GCT-4	1st Stage Gas Injection Compression	2.04	1.02	2.04	2.04	2.04
GCT-5	Glycol Treatment	2.04	1.02	2.04	2.04	2.04
GCT-6	2nd Stage Gas Injection Compression	2.04	1.02	2.04	2.04	2.04
GR-I-1	Deck – Gas Re-Injection Wells	0.84	0.42	0.84	0.84	0.84
FG-1	Fuel Gas System	2.04	1.02	2.04	2.04	2.04
FV-1	Flare and Vent System	0.84	0.42	0.84	0.84	0.84
MPG-1	Main Power Generators	2.46	1.23	2.46	2.46	2.46

As discussed in Section 5.7 of this CSA, high-overpressure explosions might damage the platform structural steel or bulkheads. Fatalities from such events are classified in the risk assessment as mustering fatalities (see Section 6.3 of this CSA).

6.3 Mustering Fatalities

As defined in Section 6.1 of this CSA, mustering fatalities occur because an event results in impairment of a platform main safety function. They occur outside the immediate area of the event, due to escalation, or while personnel that are not in the area immediately affected by the event are escaping to, or mustering within, the TSR. Mustering fatalities also include fatalities that occur during the process of evacuating the platform because a main safety function (for example, escape route, structural integrity or TSR) is impaired.

Fatalities that occur as a result of impairment of the escape routes to the TSR are considered in Section 6.3.1 of this CSA. Fatalities that result from impairment of the platform structure or main bulkheads are considered in Section 6.3.2 of this CSA. Fatalities that occur as a result of impairment of the TSR or evacuation systems are considered in Section 6.3.3 of this CSA.

6.3.1 Fatalities from Impairment of Escape Routes to the Temporary Safe Refuge

Each of the main modules (for all options) is a single area running the entire width of the platform, with escape routes assumed to run along both edges of the installation. Therefore, a large fire on any level could impair the escape routes to the TSR on the side nearest to the fire, from the effect of flame and heat radiation. The fire could also impair the escape routes on the other side, if wind conditions were unfavourable and smoke was blown across the platform to the escape routes and accumulated to impairment levels.

In most cases, the FPFs are very exposed vessels and, therefore, the potential for smoke accumulation will be low. In the majority of scenarios, the wind will disperse any accumulating smoke quite rapidly and, although smoke may reduce the speed at which personnel move along escape routes, it is considered that it is unlikely to render an escape route impassable.

Escape routes will be protected against fire and, for the purpose of this CSA, it is assumed that they will provide sufficient protection to personnel for the short time required to escape from the immediate vicinity of the fire.

Alternatively, assuming the worst-case scenario where a fire prevents personnel escaping to the TSR via any of the escape route means described, personnel would still not become entrapped on the installation due to the location of the secondary lifeboat muster areas at the other end of the vessel.

In each of the above cases, personnel will not be entrapped on the installation and therefore, for the purpose of this CSA, it is assumed that fatalities are unlikely to result from impairment of the escape routes.

Owing to the early stage of the White Rose oilfield development, the design of the escape routes for the considered options has not been specified and as such, the above assessment is very much assumption based. Smoke movement, in particular, is difficult to model accurately, and to predict the concentrations in various areas of the platform due to any given event is very complex. The above assessment of the availability/accessibility of escape routes should, therefore, be reviewed in a detailed escape, evacuation and rescue study at the detailed design stage, and a revised risk assessment conducted to reflect more accurate information.

6.3.2 Fatalities from Impairment of Fire Partitions, Blast Walls or Structural Steel

Modules are separated by either a blast wall or fire screens/partitions (see Figures 2.4-1 and 2.4-2). Both of these are assumed to provide protection up to 0.8 Bar and 0.2 Bar, respectively. Even if modules are not separated by either of these structures, the distance between areas (centre to centre) is large (approximately 30 m) and it is considered unlikely that a 0.2 Bar blast will have significant effect over these distances.

In the event of an explosion in a module separated by fire partitions/screens, it is assumed that, for an overpressure in excess of 0.2 Bar, an explosion will result in fatalities in the module adjacent to the module in which the explosion originally occurs.

In the event of an explosion in a module separated by blast walls, it is assumed that, for an overpressure in excess of 0.8 Bar, an explosion will result in fatalities in the module adjacent to the module in which the explosion originally occurs.

In the event trees, each explosion event is represented by four possible outcomes, where each outcome represents an overpressure range that is of interest in the risk assessment. In the event trees, Branches 2, 3 and 4 (in Figure 5.7-1) represent explosions for which the fire partitions, blast walls and structural steel, respectively, may be impaired by an explosion.

For such impairment events, that is, those events with the potential to result in Outcomes 2, 3 and 4, it is possible that the explosion may escalate to effect other areas, beyond the immediate area of the explosion. Fatalities from such events are classified as escalation fatalities and are accounted for in the risk assessment.

It is not possible to apply precise analysis when estimating the number of fatalities that may occur when an explosion escalates from one platform area to another. Such fatalities are, therefore, based on subjective judgement by applying the rule-sets in Tables 6.3-1 and 6.3-2. The estimates are, however, considered to be conservative.

Table 6.3-1 Rule Set and Criteria for Estimating Explosion Escalation Fatalities on FPSO

Overpressure Range	Escalation Criteria
< 0.2	• It is assumed that there is no escalation.
0.2-0.8	• For modules separated by a blast wall, it is assumed that there is no escalation to adjacent modules. • For modules not separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 50% of personnel in those modules being fatally injured.
0.8-2	• For modules separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 50% of personnel of personnel in those modules being fatally injured. • For modules not separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 100% of personnel in those modules being fatally injured. In addition, it is also assumed that escalation to modules adjacent to the modules next to the source module will occur, and that 50% of personnel in those modules will be fatally injured.
> 2	• In all cases, it is assumed that escalation to adjacent modules will occur and result in 100% of personnel in those modules being fatally injured. In addition, it is also assumed that escalation to modules adjacent to the modules next to the source module will occur, and that 50% of personnel in those modules will be fatally injured.

Table 6.3-2 Rule Set and Criteria for Estimating Explosion Escalation Fatalities on Semi-Submersible

Overpressure Range	Escalation Criteria
< 0.2	• It is assumed that there is no escalation.
0.2-0.8	• For modules separated by a blast wall, it is assumed that there is no escalation to adjacent modules. • For modules not separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 50% of personnel in those modules being fatally injured.
0.8-2	• For modules separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 50% of personnel of personnel in those modules being fatally injured. It is also assumed that escalation to lower and upper levels (depending on release location) will occur and result in 25% of personnel in those modules being fatally injured. • For modules not separated by a blast wall, it is assumed that escalation to adjacent modules will occur and result in 100% of personnel in those modules being fatally injured. In addition, it is also assumed that escalation to modules adjacent to the modules next to the source module will occur, and that 50% of personnel in those modules will be fatally injured. Escalation to lower and upper levels (depending on release location) will also occur and result in 25% of personnel in those modules being fatally injured.
> 2	• In all cases, it is assumed that escalation to adjacent modules will occur and result in 100% of personnel in those modules being fatally injured. In addition, it is also assumed that escalation to modules adjacent to the modules next to the source module will occur, and that 50% of personnel in those modules will be fatally injured. Escalation to lower and upper levels (depending on release location) will also occur and result in 50% of personnel in those modules being fatally injured.

The escalation fatalities for those events identified as having the potential escalate to other modules by applying the rule-sets in Table 6.3-1 and 6.3-2 are derived in Appendix F. Note that, for an explosion overpressure > 0.8 Bar, it is assumed in the risk assessment that surviving personnel evacuate the platform. This is to account for the possibility that the explosion may cause further hydrocarbon release, damage deluge systems or other fire-fighting equipment, or damage the PFP that prevents the spread of fire from one platform area to another.

Thus, Appendix F identifies the fatalities that result from escalation of the explosion into an adjacent area and, also, the evacuation fatalities that could result from a subsequent evacuation. The following statistical fatality rates for evacuating personnel from the White Rose installation by lifeboat are assumed (based on similar values used for Hibernia):

- an evacuation initiated due to an explosion causing local structural damage (overpressure between 0.8 and 2 Bar) assumes a statistical fatality rate of 1 percent; and
- an evacuation initiated due to an explosion causing major (global) structural damage (overpressure in excess of 2 Bar) assumes a statistical fatality rate of 5 percent.

In Appendix F, evacuation fatalities are calculated as follows:

Evacuation Fatalities = Evac. Fatal. Rate x (POB – (No. of Immed. Fatals + No. of Escal. Fatals))

Where,

POB	=	Persons On Board
No. of Immed. Fatals	=	Number of Immediate Fatalities
No. of Escal. Fatals	=	Number of Escalation Fatalities

In Appendix G, the escalation risk from explosions is estimated in the event tree risk assessment, by assigning the fatalities identified in Appendix F to the identified explosion outcomes, for each release event in each specified area.

6.3.3 Fatalities from Impairment of the Temporary Safe Refuge or Evacuation Systems

Specific designs for the layout of the FPFs have not yet been completed, therefore, the location of the TSR is yet to be determined. Typically, in the FPSO, the TSR is located at either the bow of the vessel (upwind of any potential smoke or gas ingress) or in the stern.

The following discussion on the FPSO reflects the initial layout contemplated in KSLO (1999) (see Figure 2.4-1), in which the TSR is located at the stern of the vessel. The layout considered for the semi-submersible is based on the layout used in the Terra Nova CSA (Magellan 1999) (see Figure 2.4-2).

As mentioned in Section 2.4, this CSA will be updated to reflect detailed design parameters. A further discussion of the implications of the TSR being in the bow of the vessel can be found in Section 10.6 of this CSA.

In accordance with similar studies for process hydrocarbon releases, the following impairment mechanisms are considered:

- smoke ingress; and
- gas ingress to the TSR, followed by explosion in the TSR.

Any unisolated release from a manifold or flowline inventory could result in a long duration fire that could eventually impair the platform structure. It is therefore assumed that, if such an event occurs, the OIM will initiate a precautionary evacuation.

Evacuation may also be required as a result of loss of containment events with the potential to impair the TSR due to smoke ingress, gas ingress or high temperature. In situations where the TSR is impaired, an emergency evacuation may be initiated. In addition, in situations where the integrity of the TSR is threatened (but the TSR is not actually impaired), a precautionary evacuation may be initiated.

In order for the TSR to be impaired, an event with the potential to cause impairment must occur coincident with other unfavourable conditions (for example, wind blows from the release area towards the TSR, smoke reaches TSR HVAC inlets, TSR doors or other penetrations, or HVAC fails to shut down or doors are left open). Therefore, for any loss of containment event which has the potential to cause TSR impairment, there will be a number of possible outcomes. Some of these outcomes will lead to precautionary evacuation, some will lead to emergency evacuation and others will require no evacuation. To apply an evacuation fatality rate of either 1 or 5 percent to all potential impairment events would, therefore, result in an overly conservative assessment.

In order to account for this in the risk assessment, a precautionary evacuation fatality rate of 1 percent will be applied, but only to large unisolated gas releases. Precautionary evacuation fatalities are further addressed in Section 6.4 of this CSA.

6.4 Precautionary Evacuation Fatalities

As mentioned above, it is assumed that, in the event of a large unisolated gas release, the OIM will initiate a precautionary lifeboat evacuation before impairment conditions are reached. A precautionary evacuation fatality rate of 1 percent has been assumed for the purpose of this CSA based on similar data used for Hibernia. This fatality rate is conservatively applied to the POB for each FPF option (that is, no account is taken for the number of immediate fatalities that result from large unisolated gas releases), and a value of (0.01 x 60) = 0.6 is assigned to large unisolated gas release events for the FPFs.

7 OTHER MAJOR HAZARDS RISK ASSESSMENT

7.1 Subsea Riser Releases

The risk associated with subsea riser releases is assessed using event tree analysis (see Appendix H). The event trees comprise three main parameters:

- subsea riser release frequency;
- ignition probability; and
- successful isolation probability.

The event tree consequences are modelled in terms of the number of fatalities associated with each outcome and these are combined with the event tree parameters to obtain a quantitative measure of risk from subsea riser releases. Each of the above parameters and consequences are discussed below.

7.1.1 Subsea Riser Release Frequency

From PARLOC 94 (1996), there have been two flexible riser incidents in 576.4 operational years. This equates to a leak frequency of 3.52×10^{-3} per riser-year for flexible risers. Of this leak frequency, 80 percent of leaks are assumed to be subsea (PARLOC-94), therefore, the leak frequency assigned to subsea flexible riser releases is 2.82×10^{-3} leaks per year.

In addition, each flexible riser is assumed to have two valves, each with a leak frequency of 4.5×10^{-4} (CMPT 1999), and two flanges, each with a leak frequency of 1.2×10^{-4} (CMPT 1999). The number of production risers (seven) and gas injection risers (two), gives an overall subsea flexible riser leak frequency of 3.56×10^{-2} per year.

7.1.2 Ignition Probability

Due to the subsea nature of the release, the potential for ignition is low. For the purpose of this CSA, a subjectively estimated ignition probability of 0.001 is assumed for all subsea riser scenarios.

7.1.3 Successful Isolation

In accordance with Section 5.5 of this CSA, it is assumed that riser inventories are successfully isolated if two ESDVs operate successfully.

The probability of an ESDV closing or opening on demand is estimated from OREDA (1997), based on the ESDV failure rate due to random failures and the assumption that two ESDVs and must operate successfully.

OREDA (1997) indicates a mean critical failure rate of 10.51 per million hours for ESDVs. It is assumed that BDVs have the same failure rate as the ESDVs. Assuming a three-month test period (8,760/4 = 2,190 hours), the probability of failure on demand for one valve is ($1.51 \times 10^{-6} \times 2{,}190$) = 0.02. Therefore, the probability of an ESDV or BDV operating successfully is (1-0.02) = 0.98.

Based on the assumption that two ESDVs must operate successfully to isolate each riser and manifold inventory, the probability of successful isolation and blowdown is (0.98 x 0.98) = 0.96, that is, an unsuccessful probability of 0.04.

7.1.4 Consequences

For the purpose of this CSA, it was assumed that no immediate fatalities could result from a subsea riser release and that precautionary evacuation fatalities would result if the sea current carried the pool fire towards the installation. Assuming that:

- the probability of the sea current carrying the pool fire towards the installation is 0.25;
- the fatality rate during precautionary evacuation is 0.01; and
- the POB is 60.

This gives the number of precautionary evacuation fatalities of (0.25 x 0.01 x 60) = 0.15.

7.2 Ship Impact

Ship impact risk falls into two categories: authorized vessels and passing vessels. Authorized vessels are further sub-divided into supply/standby vessels and the shuttle tanker.

The derivation of the input initiating frequencies (IFFs) for each of the above categories is discussed in Appendix D. The extent of potential damage from a ship impact incident will depend on both the mass and velocity of the impacting vessel. The kinetic energy of the impacting vessel is the key parameter that will determine the level of damage. The distribution of the impact frequencies among different kinetic energy bands is assessed in Appendix D.

The FPSO hull will be designed to withstand an impact of a 100,000-t iceberg impacting at 0.5 m/s. This equates to a kinetic energy of approximately 15 MJ. In reality, however, the energy required to cause damage will be significantly greater than 15 MJ for a number of reasons:

- in designing the hull for 15 MJ there will be significant safety margins built in;
- the hull will be double-skinned so even if the outer skin is breached, significantly more energy would be required to breach the inner skin or seriously jeopardize vessel trim;
- only a portion of incident kinetic energy must be absorbed by the hull. The total incident kinetic energy in the errant ship (or iceberg) will be converted into a number of forms:
  - translational kinetic energy imparted to the FPSO (that is, the FPSO is made to move forward under the force of the impact);
  - rotational kinetic energy imparted to the FPSO (when the point of impact is off-centre the FPSO will be given a rotational impulse);
  - kinetic energy remaining with the iceberg/ship (only if it is brought fully to a standstill will all of the incident kinetic energy have been absorbed; oblique impacts will thus leave the iceberg/ ship with significant residual kinetic energy);
  - energy absorbed in damage to the iceberg/ship (crushing and local failure of the iceberg/ship near the point of impact will absorb energy);
  - energy absorbed in causing damage to the hull of the FPSO.

Only the last of the above categories is of interest when estimating likely damage to the FPSO. The other categories will account for a significant proportion of the incident kinetic energy, leaving less to cause hull damage to the FPSO.

In view of the above discussion, it is clear that in the majority of cases, only a fraction of the incident kinetic energy in an iceberg/errant ship will be absorbed in the form of hull damage. Conversely, to cause hull damage, the incident kinetic energy must in general exceed the nominal design value of 15MJ by a significant margin. Based on the above discussion, it has been subjectively assumed in the risk assessment that the incident kinetic energy must exceed 30MJ before excessive hull damage is likely.

The derived frequencies (based on Appendix D) are presented in Table 7.2-1.

Table 7.2-1 Input Initiating Frequencies for Ship Impact Events

	Energy (MJ)	
	30-100	**> 100**
Authorized Vessels (FPSO) Includes supply/standby vessels and shuttle tanker	0.00183 per year	0.000477 per year
Authorized Vessels (semi-sub) includes supply/standby vessels but excludes shuttle tanker	0.0006 per year	0
Authorized Vessels (FSU) Shuttle tanker only	0.00127 per year	0.000477 per year
Passing Vessels	See note 1	0.00038 per year
Note 1: All passing vessels are assumed to have kinetic energy in excess of 200 MJ by virtue of their size and velocity (see Appendix D). The 30 to 100 MJ category of impact is therefore not used.		

The impact frequency for passing vessels is based on the frequency of actual impacts with fixed installations and therefore, does not incorporate the probability of disconnecting the FPSO (or other floating option) to allow the FPSO to move out of the path of the errant vessel in the extreme case. This is accounted for in the event trees. The following sections describe the construction of the event trees for ship impact risk assessment.

7.2.1 Authorized Vessels

Impact from authorized vessels will not be accompanied by any warning since these vessels normally operate in close proximity to the installation. The questions of interest are therefore whether or not the impact will result in an ignited oil spill and also, whether or not the damage will cause the vessel to list sufficiently to impair an orderly evacuation. The following subjective assumptions have been made in developing the event trees for authorized vessel impacts:

- the probability of oil being released as a result of the impact is assumed to be 0.1 for low energy (30 to 100 MJ) impacts and 0.5 for high energy (>100 MJ) impacts;
- the probability of a release igniting has been assumed to be 0.3 for low energy (30 to 100 MJ) impacts and 0.5 for high energy (>100 MJ) impacts;
- the probability of a severe list is assumed to be 0.1 following an impact;
- it is assumed there will be an average of 1.5 fatalities as a direct result of fire following the ignited release scenarios; and
- it is assumed that in all cases of impact an evacuation will be ordered with the following evacuation fatalities likely:
    - 1 percent fatalities in cases of no list and no fire;
    - 3 percent fatalities in cases where there is a severe list but no fire;
    - 5 percent fatalities where there is both a severe list and a fire.

7.2.2 Passing Vessels

7.2.2.1 Floating Production, Storage and Offloading Facilty

As an errant passing vessel approaches the FPSO on a potential collision course, intervention by support vessels would be attempted and, concurrently, personnel would move from their designated working areas and muster in the TSR. As the passing vessel approaches, the thrusters would be used to rotate the TSR away from the point of contact, so as to protect the personnel located in the TSR. In this case, the policy would be for personnel to remain in the TSR as disconnection from the spider buoy is attempted. Should this fail, personnel would still remain in the TSR until an assessment of any damage following the collision has been made. It is assumed that, only in the case where it is determined that the vessel has inflicted severe damage, would the OIM initiate an emergency lifeboat evacuation.

The frequency of potential vessel impact (3.8×10^{-4} per year) is derived in Appendix D. This is based on actual impacts and, therefore, can be assumed to implicitly include cases in which intervention has been attempted, but has failed.

The probability of failing to disconnect is subjectively estimated as 1 percent. Therefore, the frequency of actual vessel impact is 3.8×10^{-6}. The probability of a passing vessel causing severe damage is estimated as 50 percent, since, as shown in Appendix D, all passing vessel impacts are likely to involve kinetic energies exceeding 100 MJ.

Evacuation of personnel in the circumstances of severe damage has been assigned a 10 percent fatality rate, which is higher than the fatality rate previously assumed for emergency evacuation (5 percent). This is mainly attributable to the potential for the escape and evacuation systems being impaired as a direct result of the impact.

7.2.2.2 Semi-Submersible

It is assumed that in some cases there will be sufficient time to organise a precautionary lifeboat evacuation in cases where an errant vessel is on a potential collision course. The frequency of 3.8×10^{-4} per year presented in Appendix D for passing vessel ship impact is, however, based on actual impacts and does not provide any information about near misses which contribute to risk levels because they necessitate precautionary evacuations as well. The frequency of 3.8×10^{-4} per year has been multiplied by 5 to provide an estimate of the total of vessels on actual collision course and vessels that would actually result in a near miss but would be close enough to require precautionary evacuation.

Note that the frequency of $3.8x10^{-4}$ per year is assumed to include the effect of standby vessels attempting to intervene by contacting the errant vessel, since it represents actual impact incidents (in which the intervention must have failed).

It is assumed that once intervention has been attempted without success, then precautionary lifeboat evacuation will be commenced. In accordance with above sections, a 1 percent fatality rate has been assumed for such evacuation. In parallel with the evacuation, disconnection will be initiated and this is assumed to be successful in 99 percent of cases. However, in 1 percent of cases, disconnection is assumed to fail and an emergency evacuation will be ordered. A higher fatality rate (10 percent) is assigned for an emergency evacuation to account for the potential for the escape and evacuation systems being impaired as a direct result of the impact.

7.3 Iceberg Impact

The derivation of the IFFs for iceberg impact are discussed in Appendix E. The impact frequency depends on the frequency of icebergs in the White Rose area, the width of each facility (the larger the target the greater the chance of iceberg impact) and the probability that the ice management vessels will be unable to intervene and deflect the iceberg. This latter probability has been determined to be relatively low, with a typical 86 percent success rate based on field trials. The impact frequencies from Appendix E also take into account the probability that the floating facilities will fail to disconnect. This has been taken as 0.5 percent, half of the failure probability used for the case of passing vessel impacts. This reflects the fact that there will be significant warning available for potential iceberg impact and this will facilitate resolution of any problems that may occur with the disconnection systems.

The derived frequencies (based on Appendix E) are presented in Table 7.3-1.

Table 7.3-1 Input Initiating Frequencies for Iceberg Impact Events

	Energy (MJ)	
	30-100	**> 100**
FPSO	$1.28x10^{-5}$ per year	$4.7x10^{-6}$ per year
FSU	$1.28x10^{-5}$ per year	$4.7x10^{-6}$ per year
Semi-Sub	$9.63x10^{-6}$ per year	$3.53x10^{-6}$ per year

It is assumed that in all cases there will be ample time to execute an orderly precautionary lifeboat evacuation, however, this could still result in 1 percent fatality rate (average of 0.6 fatalities per evacuation for the FPSO).

7.4 Helicopter Operations

E&P Forum (1996) indicates a helicopter accident rate during departure/landing of 7.4 per 10^6 flight stages (that is, take-off from on-shore and landing on installation). Assuming the number of flights is 170 ([120 people * 17shifts/person] / 12 people/flight), the helicopter crash frequency is estimated to be: $7.4x10^{-6}$ * 2 * 170 = $2.516x10^{-3}$ crashes per year.

E&P Forum (1996) also indicates a helicopter accident rate of $1.35x10^{-5}$ per aircraft flying hour. Assuming the duration of the flight is 2 hours and the number of total flights is 170 ([120 people * 17shifts/person] / 12 people/flight), the helicopter crash frequency is estimated to be: 1.35 $x10^{-5}$ * 2 * 170 = $4.59x10^{-3}$ crashes per year. E&P Forum (1996) estimates the probability of a crash being one that causes injuries to be 15 percent for crashes during flight and 35 percent for crashes during take-off and landing.

It further estimates the fatality rate to be 48 percent (that is, 48 percent of the 12 people on board = 5.76) for crashes during flight and 82 percent (that is, 82 percent of the 12 people on board = 9.84) for crashes during take-off and landing.

7.5 Structural Failure

Det Norske Veritas (DNV 1997) states that the total structural failure frequency is comprised of:

- structural failure within design: 2.4E-05 per year;
- structural failure due to extreme weather: 1.2E-05 per year;
- structural failure due to ballast failures: 1.2E -05 per year; and
- turret failures leading to loss of weathervaning: no significant risk.

Therefore, the total structural failure frequency is 4.8E-05 per year, including failure in design, extreme weather, ballast failures and loss of weathervaning.

CMPT (1999) states that when capsize takes place in a few minutes (which would be the case in a total loss structural failure), typically 84 percent fatalities occur, depending on crew members and sea temperature.

The above information is stated for semi-submersibles. Due to their similar design, it is conservatively assumed that the above fatality percentage will be analogous to the FPSO.

Assuming a POB of 60, there will be 50.4 evacuation fatalities.

8 ENVIRONMENTAL RISK ASSESSMENT

8.1 Requirements

The TLS for the White Rose oilfield project, reproduced in Appendix A, identifies the criteria for major environmental accidents and states that:

> During the design phase, any scenario capable of producing an oil spill in excess of 50 barrels, shall be designed out. Scenarios (of spills greater than 50 barrels) that cannot be designed against should be demonstrated to have an aggregate frequency of $< 1 \times 10^{-3}$ per year.

8.2 Method

The DDMT Risk Profile models for the White Rose CSA options include oil spill size estimates for scenarios where oil could enter the sea. This will allow a quantitative measure of environmental damage to be produced in the form of estimated frequency of various oil spill sizes occurring.

The approach employed has been as follows:

1. Identifying those scenarios that may lead to oil entering the sea;
2. For batch releases - estimating the volume of oil in the inventory and the fraction of that volume likely to be released;
3. For continual releases - estimating the release rates involved and the duration for which the release is likely to remain unisolated;
4. Entering the release size estimates into the event tree model in which the frequencies of each scenario are estimated.

The EIS (Comprehensive Study Part One) provides estimated oil spill sizes for several spill scenarios at White Rose (Husky 2000b) produced as part of the oil spill fate analysis studies. Where possible, these estimates are used in this study to ensure consistency between different parts of the DA, however, the basis of these estimates is examined in order that the underlying assumptions are fully understood.

8.3 Identified Spill Scenarios

The following scenarios are considered:

- process leaks;
- production and well intervention blowouts - subsea;

- development drilling;
- tanker transfer spills;
- iceberg/ship impact/structural failure leading to cargo oil tank (COT) breach; and
- scour damage to intra-field pipelines.

8.3.1 Spill Estimates

8.3.1.1 Process Leaks

It is assumed that small and medium process leaks (whether isolated or unisolated) and large leaks from all inventories except the 1st and 2nd stage separators will all be contained in the hazardous drain system and will not result in any oil entering the sea.

Furthermore, isolated process leaks (isolated either remotely or automatically) from the 1st and 2nd stage separators will also be contained in the hazardous drain system and will not result in any oil entering the sea. Unisolated large oil releases from large inventories could, in principle, produce sufficient spill quantities to overwhelm the hazardous drain system and lead to oil entering the sea. However, it is assumed that in these cases the isolation will be achieved through process control and/or operation of manual shutdown valves before the spill exceeds that hazardous drain capacity.

For a production riser release to result in a spill in excess of 50 barrels, a catastrophic failure would have to occur whereby the whole riser inventory would be released onto the sea. For such a scenario to occur, the riser structure would need to be totally severed or split and the likelihood of this is considered extremely unlikely. Furthermore, any release of oil above the spider buoy is likely to be contained inside the turret and not reach open water. Therefore, for the purpose of this CSA, oil spills from the risers are not considered any further in this CSA.

8.3.1.2 Production and Well-Intervention Blowouts - Subsea

The EIS (Comprehensive Study Part One) (Husky 2000b), also quotes the fact that there have been seven production blowouts in 107,717 producing oil well-years. This gives a frequency of 6.5×10^{-5} blowouts/well-year. The EIS (Comprehensive Study Part One) also reports that the average size of these seven spills was only 130 barrels.

Table 8.3-1 Blowout Frequency Data

Phase of Operation	Blowout Frequency	
Production & Wirelining	6.5×10^{-5}	per well year

The above frequency can be combined with the expected number of oil producing wells (11 over three years) to give the following (note – Table 5.6-1 of the EIS (Comprehensive Study Part One) uses a figure of 20 wells, which conservatively includes water and gas injection wells):

Table 8.3-2 Calculation of Subsea Blowout Frequencies

Phase of Operation	Blowout Frequency (per well-year)	Number of wells	Blowout Frequency (blowouts/year)
Production & Wirelining	6.5×10^{-5}	11 over 3 years	2.38×10^{-4}

8.3.1.3 Development Drilling

EIS (Comprehensive Study Part One) (Husky 2000b) Table 5.2-1, reproduced as Table 4.3-1 of this CSA, indicates that there have been four blowouts of greater than 10,000 barrels, worldwide, during the period 1955 to 1988. The EIS estimates that there have been 51,000 development wells drilled in that period giving a frequency of $4/51{,}000 = 7.8 \times 10^{-5}$ blowouts per well drilled. The EIS uses this value in Table 5.6-1 by multiplying the frequency by 20 wells over three years. However, this is conservative, since only 11 of the 20 wells will be oil production wells (the rest being gas injection or water injection – therefore not presenting any significant environmental risk). Using the figure of 11 wells over a three-year period, together with the blowout frequency of 7.8×10^{-5} per well, gives an annual frequency of 2.86×10^{-4} blowouts per year during the drilling phase.

The above estimate is, however, still very conservative for a number of reasons. Firstly, the data on which the above frequency is based cover several decades and the last development drilling blowout in Table 5.2-1 of the EIS (Comprehensive Study Part One) was in fact in 1980. Drilling technology has improved significantly since that time and the risk of a development drilling blowout will inevitably be lower than the above frequency suggests. Secondly, the White Rose oilfield is relatively low pressure by world standards and this fact will help to ensure that blowout risks are lower than average. Finally, the drilling rig will operate in accordance with stringent operating procedures, defined by the operator and these are in line with the best practice of any development worldwide. This last point is supported by additional data shown in Table 5.2-2 of the EIS (Comprehensive Study Part One), which lists blowout incidents for US Federal Offshore Wells, 1971-95. This table shows that, during development drilling, during that period, although there were some blowouts, none of those incidents led to oil entering the sea. All spills were small and fully contained. This is testament to the rigorous standards applied in the US, and as the Husky Oil drilling procedures are equivalent to, or exceed, the US standards, then it can be concluded that the risk on White Rose will be insignificant.

8.3.1.4 Tanker Transfer Spills

The transfer operation will be highly automated, with stringent controls in place to prevent spills. The design is not yet finalized, however, it is expected that the DP systems on both the FPSO and shuttle tanker will be interlinked with subsea transponders to ensure real-time control of the position of both vessels. The transfer will be shut down should tolerances on the relative position of the vessels be exceeded. Furthermore, each end of the transfer hose will be fitted with automatic valves that will close on accidental disconnection. The worst credible spill during a transfer is therefore an accident that will result in the hose disconnecting, the valves on each vessel closing and the only oil entering the sea being the contents of the hose. This is less than the 50 barrels stipulated in the TLS and as such, can be dismissed from further consideration in this CSA.

8.3.1.5 Iceberg Impact/Ship Impact/Structural Failure Leading to Cargo Oil Tank Breach (Floating Production, Storage and Offloading Facility and Floating Storage Unit)

The FPSO capacity will be approximately 775,000 barrels (approximately 123,000 m^3) and assuming that the hull is divided into five compartments, this gives 24,600 m^3 per compartment. Assuming that a moderate sized accident only breaches a single compartment and assuming that the compartment is on average only half full this gives a spill size of 12,300 m^3. Husky (2000b) quotes an estimate of 10,000 m^3, which is consistent with the above calculation, if one allows for the fact that the entire 775,000 barrels capacity is not normally fully used (the 12,300 m^3 is therefore a conservative estimate).

Husky (2000b) also mentions a spill of 30,000 m^3 (as used in Hibernia studies) as a potential, but unlikely possibility. For extreme scenarios such as high kinetic energy iceberg or ship impact, it is possible that more than one COT compartment will be breached and 30,000 m^3 is therefore feasible.

8.3.1.6 Scour Damage to Intra-Field Pipelines

Maximum observed scour depth is 1.5 m (see Appendix E). Currently, it is intended to bury the pipelines for thermal insulation reasons, and if 1.5 to 2 m of cover is provided to the pipelines, then scour damage risk will be eliminated. As design parameters proceed, depth of cover will be considered in further CSA reports.

In the event that pipelines are not buried deep enough to be free from the risk of scour damage (for example, due to trenching difficulties), then a policy of isolating and purging the pipelines will be adopted, should an iceberg of potential scouring draft approach.

8.4 Results

All of the spill scenarios discussed in this section exceed 50 barrels. Thus, the frequency of all oil spill greater than 50 barrels is obtained from Appendix I (Other Major Hazards Event Trees for FPSO) by summing the frequency of all spills greater than 50 barrels.

The results for the FPSO and corresponding reference pages are presented in Table 8.4-1.

Table 8.4-1 Frequency of Oil Spill Results for FPSO

Source of Hazard	Leak Frequency (per year)	Reference/Comments
Attendant Vessel (low energy impact)	1.83×10^{-4}	Page I.1, frequency = $1.83 \times 10^{-3} \times 0.1$
Attendant Vessel (high energy impact)	2.38×10^{-4}	Page I.2, frequency = $4.77 \times 10^{-4} \times 0.5$
Passing Vessel	1.9×10^{-6}	Page I.3, frequency = $3.8 \times 10^{-4} \times 0.01 \times 0.5$
Iceberg (low energy impact)	6.40×10^{-7}	Page I.4, frequency = $1.28 \times 10^{-5} \times 0.05$
Iceberg (high energy impact)	1.41×10^{-6}	Page I.5, frequency = $4.7 \times 10^{-6} \times 0.3$
Blowouts (production and wirelining)	2.38×10^{-4}	See Section 8.3.
Structural Failure	4.80×10^{-5}	Page I.11
TOTAL	**7.11×10^{-4}**	

In summary, the total frequency of oil spills exceeding 50 barrels is 7.11×10^{-4} leaks per year.

8.5 Conclusions

The results of the environmental risk analysis for the FPSO indicate that the target of an aggregate frequency (for spill greater than 50 barrels) of $< 1 \times 10^{-3}$ spills per year is met.

9 RESULTS

The event trees representing all of the hazards discussed in this CSA have been developed using DDMT, an interactive event tree modelling and tracking tool developed primarily for QRA work. The input frequencies, branch probabilities and consequences have all been entered as described in the foregoing sections and the resulting event trees are presented in Appendices H and I.

The probable loss of life (PLL) for each of the development options together with the estimated frequency of oil spills is calculated in DDMT. The PLL estimates can be converted into average individual risk estimates as follow (see Appendix A):

$$\text{Average Individual Risk (IR)} = 0.5 \times \frac{\text{PLL}}{\text{POB}}$$

The POB is conservatively estimated at 60 for the FPSO options and 85 for the semi-submersible/FSU. The 0.5 factor is to account for the proportion of time spent offshore by the average employee.

9.1 Individual Risk and Probable Loss of Life

The results for each option are presented in Table 9.1-1.

Table 9.1-1 Summary of PLL and Individual Risk Estimates for Both Options

Option	PLL (per year)	POB	Average IR (per year)
FPSO	5.81×10^{-2}	60	4.84×10^{-4}
Semi-Sub & FSU	5.59×10^{-2}	85	3.29×10^{-4}
Semi-Sub	4.92×10^{-2}	60	4.09x10-4
FSU	6.78×10^{-2}	25	1.34×10^{-4}

It can be seen from Table 9.1-1 that both options meet the TLS requirement that $IR<10^{-3}$ per year (see Appendix A).

9.2 Environmental Risk

The results for environmental damage are expressed as the frequency with which an oil spill (in excess of 50 barrels) will occur. These are tabulated in Table 9.2-1.

Table 9.2-1 Frequency of Oil Spills for Both Options

Option	Frequency of Oil Spill > 50bls (per year)
FPSO	$7.11x10^{-4}$
Semi-Sub & FSU	$6.52x10^{-4}$
Semi-Sub	$2.38x10^{-4}$
FSU	$4.14x10^{-4}$

It can be seen from Table 9.2-1 that both options meet the TLS requirement that the frequency of oil spills exceeding 50 barrels < 10^{-3} per year (see Appendix A).

9.3 Probable Loss of Life Contributions

The PLL estimates in Table 9.1-1 are composed of contributions from the various hazards, as shown in Tables 9.3-1 and 9.3-2.

Table 9.3-1 Contributions to PLL for FPSO Option

Hazard	PLL (per year)
Process Loss of containment	$4.26x10^{-2}$ (73.4%)
Ship Collision	$2.33x10^{-3}$ (4%)
Iceberg Impact	$1.05x10^{-5}$ (0%)
Riser Releases Subsea	$3.24x10^{-7}$ (0%)
Helicopter Crash	$1.18x10^{-2}$ (20.4%)
Structural Failure	$1.28x10^{-3}$ (2.2%)
TOTAL	**$5.81x10^{-2}$**

Table 9.3-2 Contributions to PLL for Semi-Submersible + FSU Option

Hazard	SemiSub PLL (per year)	FSU PLL (per year)	Total PLL (per year)
Process Loss of Containment	$3.43x10^{-2}$ (69.9%)	See Note 1	$3.43x10^{-2}$ (61.4%)
Ship Collision	$1.65x10^{-3}$ (3.4%)	$1.40x10^{-3}$ (15.5%)	$3.05x10^{-3}$ (5.5%)
Iceberg Impact	$7.90x10^{-6}$ (~0%)	$4.37x10^{-6}$ (0.1%)	$1.23x10^{-5}$ (0.02%)
Riser Releases Subsea	$3.24x10^{-7}$ (~0%)	See Note 2	$3.24x10^{-7}$ (~0%)
Helicopter Crash	$1.18x10^{-2}$ (24.1%)	$4.95x10^{-3}$ (54.8%)	$1.68x10^{-2}$ (30.1%)
Structural Failure	$1.28x10^{-3}$ (2.6%)	$4.27x10^{-4}$ (4.7%)	$1.71x10^{-3}$ (3.1%)
TOTAL	**$4.91x10^{-2}$**	**$6.78x10^{-3}$**	**$5.59x10^{-2}$**
Note 1: The main hydrocarbon risks will come from ship and iceberg impact scenarios which are modelled separately. Loss of containment risks due to random leaks are assumed to be negligible. Note 2: As riser release risks were shown to produce a negligible contribution to risk for the semi-submersible then the FSU, with fewer risers, can also be assumed to have a negligible contribution from this hazard.			

It is worth noting that the 73.4 percent contribution from process loss of containment is made up as follows:

Fire fatalities	40 percent
Explosion fatalities	28 percent
Precautionary evacuation fatalities	5.4 percent
Sub Total	**73.4 percent**

9.4 Impairment Frequencies of Temporary Safe Refuge

In accordance with the discussion in Section 6.3.3 of this CSA, the following scenarios are deemed to have the potential to impair the integrity of the TSR on the FPSO:

- large unisolated gas releases (unignited) producing potential gas ingress in TSR;
- large unisolated gas releases (ignited) producing potential jetfire impingement on TSR;
- large pool fires (isolated and unisolated) producing smoke impairment; and
- explosion in the main power generation area.

Large unisolated (unignited) gas releases are assumed to have the potential to impair the TSR if there is gas ingress into the TSR. The frequency of these events has been estimated as 3.08×10^{-3} per year. With the TSR in the stern, it is likely that the prevailing wind will initially carry the release towards the TSR, however, the situation will be easily mitigated by employing the thrusters to rotate the vessel to move the TSR so that it is no longer downwind of any release. It has been conservatively assumed that there is a 25 percent probability that this cannot be achieved, either because the thrusters are unavailable or the wind is variable and the release affects the TSR whatever the vessel orientation.

It can further be assumed that the air circulation HVAC dampers in the TSR will successfully prevent gas ingress with a reliability of 90 percent. Therefore the frequency of gas ingress impairment of the TSR will be $3.08 \times 10^{-3} \times 0.25 \times 0.1 = 7.7 \times 10^{-5}$ per year.

Large unisolated (ignited) gas releases are assumed to have the potential to impair the integrity of the TSR if the flame impinges on the TSR structure. This contribution can be discounted, however, as there will be a H120 rated firewall in front of the TSR.

Smoke generated from large pool fires is assumed to have the potential to impair the TSR with smoke ingress. The frequency of poolfires, capable of generating sufficient smoke quantities has been estimated to be 8.71×10^{-4} per year. This can be multiplied by a factor of 0.25 as above, to allow for the probability that the vessel cannot be rotated to move the TSR out of the path of the smoke. A further factor of 0.1 can be applied to allow for damper failure giving an impairment frequency of $8.71 \times 10^{-4} \times 0.25 \times 0.1 = 2.18 \times 10^{-5}$ per year.

Explosions of sufficient overpressure (> 0.8 Bar) in the power generation area are also assumed to have the potential to impair the TSR as a result of structural damage of the main TSR structures. The frequency with which such explosions occur has been estimated to be 2.07×10^{-6} per year.

In summary:

• Gas ingress impairment of TSR	7.7×10^{-5} per year
• Smoke ingress impairment of the TSR	2.18×10^{-5} per year
• Explosion impairment of TSR	2.07×10^{-6} per year
TOTAL	**1.01×10^{-4} per year**

This compares favourably with a criterion frequency of 1×10^{-3} per year for TSR impairment.

9.5 Minimum Requirements Assessment

The *Newfoundland Offshore Petroleum Installations Regulations* (C-NOPB 1995a), require the CSA to evaluate risk levels without taking into account the plans and measures for risk mitigation and reduction and separately evaluate risk levels with such measures in place. For the purpose of this CSA, the effect on the risk levels of not including following measures has been assessed in the “minimum requirements” case:

- use of ice management vessels;
- assuming an approximate 15-minute disconnect time for the mooring system;
- blast resistance of blast rated walls (assuming blast resistance of partitions is 0.2 Bar as opposed to 0.8 Bar); and
- protection of evacuation systems.

9.5.1 Ice Management Vessels

When an iceberg is on a collision course, ice management techniques will be used to deflect the icebergs off their course and thereby avoid a collision with the facility. Field trials have shown that these techniques are 86 percent reliable in deflecting icebergs and on this basis, the frequency of icebergs reaching the site of the facility has been taken to be 14 percent of the actual frequency that would occur in the absence of ice management vessels. For the minimum requirements assessment, it is assumed that the ice management vessels are not used.

Based on the discussion above, the following change in PLL is observed:

PLL (assuming use of Ice Management Vessels) = 5.81×10^{-2}
PLL (assuming no Ice Management Vessels) = 5.81×10^{-2}
Δ PLL = 6.45×10^{-5} (0.1 percent increase)

The small change in PLL reflects the fact that 9 percent of potential iceberg impacts are avoided by disconnecting the facility and in the remaining cases a full precautionary evacuation is assumed to be possible.

9.5.2 Disconnect Time

It has been assumed that the facility will be able to disconnect within 15 to 25 minutes in cases where an impact is imminent. However, the provision of this "15-minute" disconnect option may not be optimal and a 1-hour disconnect option may be sufficient in cost-benefit terms. The 15-minute disconnection option will only affect risks from passing vessels. Collisions from attendant vessels provide insufficient warning to disconnect and collisions from icebergs provide sufficient warning for the one-hour disconnect option to be sufficient.

Based on the discussion above, the following change in PLL is observed:

PLL (assuming 15 minute disconnect time) = 5.81×10^{-2}
PLL (not assuming 15 minute disconnect time) = 5.92×10^{-2}
Δ PLL = 1.1×10^{-3} (1.9 percent increase)

9.5.2.1 Reduction in Blast Resistance of Blast Walls

The explosion escalation fatalities calculated using the fatality rule set and criteria established in Section 6.3 of this CSA, has been revised to account for the lower assumed blast capacity of the two blast rated walls (from 0.8 to 0.2 Bar) for the minimum requirements case (see Table 9.5-1).

Table 9.5-1 Minimum Requirement Rule Set and Criteria for Estimating Explosion Escalation Fatalities on FPSO

Overpressure Range	Escalation Criteria
< 0.2	It is assumed that there are no fatalities in the adjacent modules. Modules are separated by either a blast wall or fire screen/partitions. Both of these are assumed to provide protection up to 0.2 Bar. Even if the fire screens/partitions are not used, the distance between adjacent areas (centre to centre) is large (approximately 30 m in most case) and is considered unlikely that a 0.2 Bar blast will have significant effect over these distances.
0.2-0.8	In accordance with Table 6.3-1, for all modules, it is assumed that escalation to adjacent modules will occur and result in 50% of personnel in those modules being fatally injured.
> 0.8	In all cases, it is assumed that escalation to adjacent modules will occur and result in 100% of personnel in those modules being fatally injured. In addition, it is also assumed that escalation to modules adjacent to the modules next to the source module will occur, and that 50% of personnel in those modules will be fatally injured.

Based on criteria specified in Table 9.5-1, the following change in PLL is observed:

PLL (assuming blast resistance of 0.8 Bar) = 5.81×10^{-2}

PLL (assuming blast resistance of 0.2 Bar) = 6.67×10^{-2}

Δ PLL = 8.6×10^{-3} (14.8 percent increase)

9.5.3 Protection of Evacuation Systems

For the purpose of this CSA, it was assumed in Section 6.4 that in the event of a large unisolated gas release, the OIM would initiate a precautionary lifeboat evacuation before impairment conditions are reached. A precautionary evacuation fatality rate of 1 percent has been assumed for the purpose of this CSA based on similar data used for Hibernia.

To model the effect of assuming that protection of the evacuation systems is not optimized, the above fatality rate was increased to 5 percent (a subjective assessment on the impact on fatality rates of not fully optimising protection of the evacuation rates). The impact on the risk levels is as follows:

PLL (assuming PE fatality rate of 1%) = 5.81×10^{-2}

PLL (assuming PE fatality rate of 5%) = 6.12×10^{-2}

Δ PLL = 3.1×10^{-3} (5.3 percent increase)

9.5.4 Summary

The ‘minimum requirements’ design can be defined as follows:

- no ice management vessels;
- no 15-minute disconnect option;
- no blast walls between TSR and power generation or between separators and flash gas area; and
- no protection of evacuation systems (lifeboat stations).

The above configuration will have a PLL of 7.1×10^{-2} per year[4] (IR = 5.91×10^{-4} per year). This level of IR is still below the TLS of 1×10^{-3} per year. Consequently, the measures that have been assumed for the main assessment should be subject to cost-benefit assessment to determine whether they are cost effective measures.

[4] Based on summing the ΔPLL's for the four changes considered.

10 SENSITIVITY STUDIES

The risk assessment reported in this CSA has employed a number of assumptions. These have been necessary in cases where the design is still insufficiently specified or where alternative design solutions are still being considered. In other cases, assumptions have been made due to unknown inputs such as hull impact capacity. This chapter reports on the results of sensitivity studies performed to investigate the significance of these assumptions on the calculated risk levels.

Sensitivity runs are reported in this section only for the FPSO option, however, the results of these sensitivity runs will give some indication as to the sensitivity of risk levels on the other development options to these inputs.

The following sensitivity runs have been performed:

- sensitivity of risk estimates to the assumed impact resistance of the FPSO hull;
- sensitivity of risk estimates to the frequency of potential ship collisions;
- sensitivity of risk estimates to the assumed time required for quick-disconnect; and
- sensitivity of risk estimates to the assumed work rotation (number of weeks spent offshore each trip).

These are discussed in further detail below.

10.1 Sensitivity of Risk Estimates to the Assumed Impact Resistance of the Floating Production, Storage and Offloading Facility Hull

In Section 7.2 of this CSA, the impact resistance was discussed and a capacity of 30 MJ was demonstrated. This value is somewhat uncertain, however, and has therefore been subjected to a sensitivity analysis. The risk assessment results have been re-evaluated for an assumed hull capacity of 50 MJ. The effect of this is to reduce the initiating frequency for impact incidents in the low impact energy event tree. This event tree represents events in the 30 to 100 MJ category in the base case analysis and this has been changed to represent the 50 to 100 MJ category.

10.2 Sensitivity of Risk Estimates to the Frequency of Potential Ship Collisions (Passing Vessels)

Very little data are available on ship impact frequencies for the Grand Banks. A generic frequency of 3.8×10^{-4} incidents per year for the frequency of passing vessels being on a collision course is used in Appendix D. The value is based on world-wide data and does not account for the fact that the Grand Banks has a very low density of shipping activity. For the purposes of the sensitivity study, it will be assumed that the frequency of passing vessels being on a collision course (3.8×10^{-4}) reduces to 50 percent of its original value (that is, 1.9×10^{-4} per year).

10.3 Sensitivity of Risk estimates to the Assumed Time Required for Quick-Disconnect

Both one-hour and 15-minute disconnection options are being considered. The base case risk assessment assumes that both of these alternatives will be available. If, however, the 15-minute option were not employed, it is of interest to assess the effect on risk levels.

For attendant vessel impact there will be no warning of impact and the availability of the 15-minute disconnection option will be of no benefit. For iceberg impacts there will be several hours warning and, provided the disconnection order is given in sufficient time, then the one-hour disconnection option will be adequate. The availability of the 15-minute option will not affect this risk contribution significantly. For passing vessel ship impact, however, there will generally be of the order of one-hour warning and by the time support vessel intervention has been tried, then it is unlikely that there will be sufficient time left to employ the 1-hour disconnection option. There would, however, be sufficient time to employ the 15-minute option, if it were available.

For passing vessel impacts, the FPSO risk assessment assumes that an emergency evacuation will only be initiated when both disconnection has been attempted (and fails), and severe damage to the FPSO occurs. Such a scenario is assumed to result in 10 percent of the POB being fatally injured. The probability that the quick-disconnect system will fail is assumed to be 1 percent. However, the effect of not employing a 15-minute disconnection option is that all unavoidable passing vessel ship impacts (those for which intervention has failed) will result in actual impacts and an emergency evacuation will be ordered. This can be represented by setting the probability of failure to disconnect to 100 percent in the event tree.

10.4 Sensitivity of Risk Estimates to the Assumed Work Rotation (number of weeks spent offshore each trip)

It has been assumed that the average rotation will be three weeks offshore and three weeks on-shore. This assumption affects the calculation of helicopter risks since it dictates the number of flights per person per year.

One alternative shift rotation pattern would be two weeks on - two weeks off. The effect of this would be to increase the number of flights that everyone makes by 50 percent. The PLL contribution from helicopter flights would then increase from 1.18×10^{-2} fatalities per year to 1.77×10^{-2} fatalities per year.

10.5 Results of Sensitivity Runs

The results of the above sensitivity runs on both the PLL and on the frequency of spills greater than 50 barrels are shown in Table 10.5-1.

Table 10.5-1 Results of Sensitivity Runs Showing Effect on both PLL and Spill Frequency

	PLL (per year) Individual Risk in Brackets	% Increase/ Decrease on Base Case	FREQUENCY OF SPILLS > 50 BLS (per year)	% Increase on Base Case
Base Case	$5.81x10^{-2}$ ($IR=4.84x10^{-4}$)	-	$6.51x10^{-4}$	-
Increased Hull Capacity from 30MJ to 50MJ	$5.73x10^{-2}$ ($IR=4.78x10^{-4}$)	-1.4%	$5.59x10^{-4}$	-14%
Reduced Frequency of Passing Vessels (to 50% of value used in base case)	$5.81x10^{-2}$ ($IR=4.84x10^{-4}$)	Insignificant	$6.5x10^{-4}$	-0.15%
No 15-minute Disconnect Option	$5.92x10^{-2}$ ($IR=4.93x10^{-4}$)	+1.9%	$8.39x10^{-4}$	+29.2%
Change to '2 weeks on -2 weeks off' shift pattern	$6.4x10^{-2}$ ($IR=5.33x10^{-4}$)	+10.2%	N/A	N/A

10.6 Implication of Temporary Safe Refuse Location in Final Design

For the purposes of this CSA, it has been assumed that the TSR will be positioned at the stern of the vessel, as that is the layout being considered by the concept design team at the commencement of this study. It is conceivable, however, that the final design may adopt a layout with the TSR at the bow. This section discusses the implication on risk levels should it be decided to locate the TSR at the bow in the final design.

The following points are considered to assess potential risk implications of altering the TSR location:

- fire and blast loads on the TSR;
- potential for smoke and gas releases to impair the TSR;
- ship/iceberg impact consequences on the TSR; and
- escape/evacuation considerations.

Whether the TSR is located in the stern or the bow, it will be segregated from the process plant by a H120 blastwall. A stern TSR will be further separated from the process plant by the galley laydown pallet and power generation pallet. A bow TSR is slightly more vulnerable as it would be close to the turret, with the associated explosion risks that that entails. However, precise explosion risks will be evaluated as part of the detailed design and the blastwall will be designed so as to ensure that the risk from an explosion in the turret area is maintained at an ALARP level. Thus, the potential slight increase in fire and blast risk incurred by placing the TSR at the bow is easily mitigated by an appropriate blastwall design.

Smoke and gas releases have the potential to impair the TSR (see Section 9.4 of this CSA) but only if the wind carries the releases towards the TSR and the vessel is unable for some reason to rotate to move the TSR out of the path of the release. With the TSR in the stern, the prevailing wind is likely to be from the process plant towards the TSR, by virtue of the weathervaning action of the vessel. However, with the TSR in the bow the opposite is true - the prevailing wind is more likely to carry smoke or gas releases away from the TSR. In both cases, it is highly likely that the vessel will be able to rotate to mitigate any problem, however, there is clearly a slightly increased risk from this hazard with the TSR in the stern.

Ship and iceberg impact scenarios may involve rotating the vessel to position the TSR at the opposite end of the vessel from the anticipated point of impact, thereby minimizing the potential threat to personnel who will have mustered to the TSR. This scenario will be unaffected by whether the TSR is in the bow or the stern.

Escape and evacuation strategies involve mustering personnel to the TSR and from the TSR to the main lifeboat stations. The majority of the lifeboat capacity will be located adjacent to the TSR, whether that be at the bow or the stern. Consequently, there will be no implications on escape and evacuation scenarios caused by the choice of TSR location.

To summarize, the explosion risks are lower with a stern TSR, whereas the smoke and gas ingress risks are lower with a bow TSR. In both cases, the difference is likely to be small. The detailed design will assess the risks more precisely and ensure that any cost-effective mitigation is incorporated into the design to minimize these risks.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

A CSA has been performed for the technically and commercially viable development options that were short-listed for the White Rose oilfield development on the Grand Banks offshore Newfoundland. These options were:

- FPSO; and
- semi-submersible and FSU.

Particular emphasis has been placed on the FPSO risk assessment as this is the designated preferred option of Husky Oil. However, the approach adopted has been very similar for both options and the degree of detail in each model is similar.

In order to ensure safe design and operation of the selected option, Husky Oil have adopted the following TLS (see Appendix A):

- IR Criteria;
- Group Risk Criteria;
- Environmental Risk Criteria; and
- Safety Function Impairment Criteria (that is, primary structure, TSR, escape routes and means of evacuation).

  - **IR Criteria**

  Since the semi-submersible and the FSU have the larger combined POB of 85, this leads to this option having the lower average individual risk of the two options; 3.29×10^{-4} per year compared to 4.84×10^{-4} per year for the FPSO. It is emphasized, however, that both options have an average IR that falls well below the TLS stipulated for the project ($<10^{-3}$ per year).

  - **Group Risk Criteria**

  The group risk criteria has not been quantified at this stage due to the many design uncertainties that remain. It can be concluded, however, from the low level of IR being predicted, that it is highly likely that the Group Risk Criteria will be easily shown to be met at detailed design stage.

- **Environmental Risk Criteria**

The frequency with which oil spills exceed 50 barrels has been estimated as 7.11×10^{-4} for the FPSO and 6.52×10^{-4} for the semi-submersible. Both frequencies are well within the stipulated TLS of 1×10^{-3}.

- **Safety Function Impairment Criteria**

Impairment frequencies for which the TSR is impaired has been estimated for the FPSO. The frequency with which the TSR is impaired has been estimated as 1.01×10^{-4} per year, compared to a criterion of 1×10^{-3} per year. Impairment of the TSR may be from gas ingress, smoke ingress or explosion damage. Jetfire impairment of the TSR is minimized by virtue of a H120 firewall specified to run between the TSR and the power generation module.

Impairment frequencies for the primary structure, escape routes and means of evacuation have not been quantified at this stage due to the many design uncertainties that remain. The requirements of the safety function impairment criteria, for primary structure, escape routes and means of evacuation can all be met during the detailed design stage through appropriate selection of materials, components and design features. Such detail is, however, as yet unspecified.

The chosen option must also be shown to be ALARP to meet the TLS. This can only be done in the detailed design phase, at which point various risk reduction options should be considered and cost-benefit studies performed to determine which risk reduction measures are cost-effective. Those that are shown to be cost-effective should be implemented in the final design if that design is to shown to be ALARP. It is clear from this CSA, however, that it should be possible to demonstrate the ALARP status of the FPSO or any other of the options.

Many of the assumptions employed in this CSA will need to confirmed and refined as part of the detailed design work and the design QRA study. The assumptions are well-founded and on the basis of this CSA study, there are no areas relating to risk assessment that are expected to pose a problem for the design team.

11.2 Recommendations

In order to confirm and/or refine the analyses and assumptions in this CSA, it is recommended that the following be performed as part of the detailed design of the White Rose facility:

1. An escape, evacuation and rescue study should be performed to refine the estimates for the number of fatalities expected in precautionary and emergency evacuations. This study should also review which scenarios will require evacuations, whether precautionary or emergency.
2. A TSR impairment study should be performed to assess the vulnerability of the TSR to fire, explosion, smoke and gas ingress. This should include smoke and gas dispersion modelling where appropriate.
3. Review/refine fire and explosion modelling. The largest contribution to risk is from fires and explosions following a process loss of containment event (73.4 percent of the risk). The QRA performed at detailed design stage should therefore concentrate on the modelling of these risk contributions. The explosion overpressures in particular have been approximated in this study, based on the experience for other similar production operations.
4. Cost-benefit analyses should be considered to determine whether the following features are cost-effective in ALARP terms: ice management vessels; “15-minute” disconnect option; high capacity blast walls; protection of evacuation systems (lifeboat stations); and increase in design impact capacity of hull above 15 MJ. The ‘minimum requirements’ assessment and sensitivity analyses have shown that risk levels are still shown to be tolerable with some of these features omitted.

12 SUMMARY OF SIGNIFICANT ASSUMPTIONS

Due to the early stage of the design for the White Rose project, there are many design details not yet fully specified. As a consequence, several assumptions have had to be made in order to perform this CSA. Where these assumptions could have a significant effect on calculated risk levels, then they will require reviewing/confirming as part of the design stage QRA study. The key assumptions are listed below.

1. The configuration and layout of each option has been based on the concept design. This includes dimensions, number of wells, POB, process flow design and process flow parameters (pressures, temperatures, etc.). The assumed POBs were: FPSO – 60; semi-submersible + FSU - 60+25=85.

2. ESDV positions (defining the interface between adjacent inventories) have been assumed based on previous QRA studies.

3. The staffing distribution (percentage of POB in each area) were based on the distribution identified for Terra Nova.

4. It was assumed that any evacuation would be via lifeboats. No account was taken for helicopter evacuation.

5. Precautionary evacuations (by lifeboat) are assumed to cause 1 percent fatalities. Emergency evacuations (by lifeboat) are assumed to cause 5 percent fatalities. These values are based on previous QRA studies.

6. The hull is assumed to be designed to withstand a 15 MJ impact. However, accounting for the various mechanisms for dispersion of the incident kinetic energy, it is assumed that only an iceberg or errant ship with a kinetic energy in excess of 30 MJ will be capable of causing hull damage.

7. It is assumed that a "15-minute" quick-disconnect option will be provided. However, a sensitivity study has been performed to assess the effectiveness of this option.

8. It has been assumed that intra-field flowlines are either buried deep enough to avoid iceberg scour damage or will be shut down and purged whenever an iceberg of sufficient draft approaches.

9. It has been assumed that due to the exposed conditions on the floating options, the probability of delayed ignition (explosions) following an oil release is negligible. (Delayed ignitions from gas releases and two-phase releases (in the turret) have been modelled).

10. It has been assumed that there will be no immediate fatalities from poolfire scenarios, since the time required for a pool to form and ignite will allow personnel to escape from the immediate vicinity of the release.

11. It has been assumed that two blast walls will be provided on the FPSO: one immediately in front of the TSR and one between the gas compression area and the separator area. Both of these blast walls have been assumed to have a capacity of 0.8 Bar. The precise location of these blastwalls may be revised during detailed design.

12. Worst case overpressures have been assumed to be 1.0 Bar in the exposed modules. The enclosed turret area of the FPSO was assumed to have a higher worst case overpressure of 2.5 Bar.

13. Overpressures have been assumed to be lower than their worst case values in most cases due to reduced cloud sizes and non-stoichiometric gas/air mixtures. The modelling of the various scenarios has been accomplished by means of adopting an assumption of a linear 'overpressure exceedence curve' in each module.

14. No deluge mitigation of explosions has been assumed.

15. It has been assumed that ice management vessels will be provided and it has further been assumed that they will be 86 percent effective in deflecting icebergs that may otherwise collide with the facility.

16. It has been assumed that there will be a 1 percent probability that the floating options will fail to disconnect when required.

17. For the purpose of estimating helicopter risk, it has been assumed that the standard shift pattern will be three-weeks on and three-weeks off. This defines the number of flights each individual must make.

18. It has been assumed that individual offshore workers will work and be on days off for equal time.

13 REFERENCES

CMPT (Centre for Marine and Petroleum Technology). 1999. A Guide to Quantitative Risk Assessment for Offshore Installations, CMPT Publication 99/100.

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1988. Development Application Guidelines, Newfoundland Offshore Area.

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1991. Information Letter on Installation Safety Analysis.

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1995a. *Newfoundland Offshore Petroleum Installation Regulations*.

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1995b. Safety Plan Guidelines.

Cox, Lees and Ang. 1990. Classification of Hazardous Locations, Institute of Chemical Engineers, Rugby, UK.

DNV. 1997. Quantitative Risk Assessment Schiehallion FPSO. Report no. C7140/09.

E&P Forum. 1992. Hydrocarbon Leak and Ignition Database. Technical Project N658, Report 11.4/180, E&P Forum, London.

E&P Forum. 1996. Quantitative Risk Assessment datasheet Directory. Report 11.8/250, E&P Forum, London.

Husky Oil Operations Limited. 2000a. White Rose Oilfield Project Description.

Husky Oil Operations Limited. 2000b. White Rose Oilfield Comprehensive Study Part One: Environmental Impact Statement.

KSLO (Kvaerner–SNC Lavalin Offshore). 2000. White Rose Concept Screening Report. Husky Oil consultant report.

NEB, C-NOBP and C-NSOPB (National Energy Board, Canada-Newfoundland Offshore Petroleum Board and Canada-Nova Scotia Offshore Petroleum Board). 1996. Offshore Waste Treatment Guidelines.

OREDA. 1997. Offshore Reliability Data Handbook. Sintef, Trondheim, Norway. (Distributed by DnV, Hϕvik, Norway).

PARLOC 94. 1996. The Update of Loss of Containment data for Offshore Pipelines. Prepared by AME Ltd for Health & Safety Executive. Published 1996.

RMRI. 1999. The Probability Distribution of Hole Sizes for Process Leaks Offshore. RMRI In-House Study.

APPENDIX A

Target Levels of Safety

WHITE ROSE
DEVELOPMENT APPLICATION

APPENDIX A

TARGET LEVELS OF SAFETY

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED AS OPERATOR
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

July 2000

TABLE OF CONTENTS

Page No.

LIST OF TABLES

Page No.

1 INTRODUCTION

Husky Oil Operations Limited. (Husky Oil) is responsible for the concept and design, construction, installation and operation of the White Rose Oilfield Development.

A fundamental aspect of the concept and design phase is the selection of clear design goals to ensure the safety of personnel and the environment during the project. These design goals are used as part of the overall process to ensure that:

- a chosen installation design provides personnel with a safe work environment and the ability to effectively evacuate in an emergency; and
- the risk to personnel and the environment is *As Low As Reasonably Practicable (ALARP).*

The design goals are expressed in the form of *Target Levels of Safety (TLS)* or *Criteria*. Such criteria can be used at the conceptual and design phase to ensure that the risk from *Major Accident Hazards* is acceptable[1].

Husky Oil seeks to reduce the risk to personnel and the environment to levels that are ALARP. Risk to personnel can be measured in terms of *Individual Risk (IR),* which is a quantitative measure of the fatality rate per individual per annum. Such a measure can also be expressed as a function of the amount of time that an individual spends on the installation. Risk to the environment *(Environmental Risk (ER))* can be measured in terms of the amount of oil spillage associated with various accident scenarios along with the likelihood of these scenarios.

As outlined in Chapter 3, the TLS stipulated in this document contain both *risk-based* and *impairment-based* criteria.

For risks to individuals, the IR criteria, developed as part of the risk-based criteria, are the *overriding* criteria and must be met by the final design. Installation manning levels are required to quantitatively assess the IR associated with a facility and a comparison made with the stipulated criteria to determine the significance of the risk.

The remaining *secondary* criteria, that is, GR and impairment-based criteria, are provided to allow the assessment of the design when manning levels have not been defined or are uncertain, or when the overall risk assessment is still at a preliminary stage. Such criteria are used for *design guidance only*, specified, to allow design of the facility to proceed as the project progresses. Provided that, in the final design, the risk to

[1] The definition of what constitutes a major accident hazard can vary. A typical definition is a hazard that involves ignited hydrocarbons, or any other hazardous events that have the potential for five or more fatalities.

personnel can be shown to be both tolerable and ALARP, that is, *meet the IR criteria,* then the secondary criteria *need not* be considered further.

Impairment-based criteria can be used during the concept and design phase to distinguish between possible accidental events which have the potential to cause high-fatality accidents, and those which do not. Provided the impairment-based criteria are not exceeded, the accident can be considered to have no potential for preventing the escape of personnel away from the accident; nor for threatening the integrity of the installation, the safe refuge or the means of evacuation within a time period that is long enough to safely evacuate personnel.

Meeting impairment-based criteria will not guarantee the IR criteria are met, it will, however, make it more likely. Conversely, if impairment-based criteria are not ultimately met, this may be acceptable *provided* that the IR can still be shown to be ALARP.

2 REGULATORY REQUIREMENTS

The *Newfoundland Offshore Petroleum Installation Regulations* state (C-NOPB 1995a):

> (3) Target levels of safety for the risk to life and the risk of damage to the environment associated with all activities within each phase of the life of the installation shall be defined and shall be submitted to the Chief at the time the operator applies for a development plan approval
>
> (4) The target levels of safety referred to in subsection (3) shall be based on assessments that are:
>
> (a) quantitative, where it can be demonstrated that input data are available in the quantity and of the quality necessary to demonstrate the reliability of the results; and
>
> (b) qualitative, where quantitative assessment methods are inappropriate or not suitable.

3 TARGET LEVELS OF SAFETY

Based on the experience of offshore operators in Canada and the North Sea, Husky Oil has selected seven TLS that specify performance standards for an installation's safety and evacuation systems. Husky Oil TLS for the White Rose Oilfield Development fall into two main categories:

- Risk-Based Criteria; or
- Impairment-Based Criteria.

The risk-based criteria are further sub-divided into the following categories:

- Individual Risk (IR);
- Group Risk (GR); and
- Environmental Risk (ER).

Impairment-Based criteria are stipulated for the following installation *Safety Functions*:

- the installation's primary structure;
- the Temporary Safe Refuge (TSR);
- the escape routes; and
- the availability of the evacuation systems.

All installations will be designed to Canadian and internationally accepted design standards and recommended practices, and deviations from such standards or practices will only be accepted if they meet or exceed the safety level implied by those standards.

Each installation as a whole will have a design life appropriate to the anticipated project life, and will be designed to withstand environmental criteria such that the risk from external events does not violate the TLS.

TLS # 1 consists of an ALARP requirement for IR. As mentioned in Section A1, the IR criteria are the *overriding* criteria and the remaining *secondary* criteria should be used for *design guidance only*. Whilst every effort should be made to meet the secondary criteria during design, late design changes may lead these criteria not being fully met. This may be acceptable *provided* there is compliance with the IR criteria.

The risk-based criteria are discussed in Section 3.1 and the impairment-based criteria are described in Section 3.2.

Note that Sections 3.1 and 3.2 only provide TLS for the Drilling and Production Phases of the Project. Section 3.3 discusses TLS for *other* phases.

3.1 Risk-Based Criteria

The IR and GR criteria for *Major Accident Hazards* falls into one of three risk regions:

- An upper level, above which the risk is unacceptable and risk control measures *must* be taken.
- A lower level, below which the risk is considered broadly acceptable (negligible) and there is no need for consideration of further safety measures.
- An intermediate region where the risk may be tolerable, but it must be demonstrated that all practical means of risk reduction have been employed to the extent that further reduction would incur disproportionate cost, that is, the risk is ALARP.

Each of the three risk regions (negligible, unacceptable and ALARP) identified above are specified for IR and GR in TLS #1 and TLS #2 (Sections 3.1.1 and 3.1.2, respectively). ER is discussed in TLS #3 (Section 3.1.3).

3.1.1 TLS # 1: Individual Risk Criteria

Husky Oil have considered operations in areas such as the North Sea, to develop tolerable and intolerable risk levels to workers on offshore installations.

Until recently, there have been no offshore production operations off the East Coast of Canada, so there is no *track-record* that can be used to determine a suitable criterion for IR. The most comparable offshore sector to the East Coast of Canada (based on severity of weather and type of offshore developments) is the North Sea. Husky Oil have obtained historical data for the Norwegian and UK sectors of the North Sea to determine historical average IRs for the offshore industry. Assuming average risks over a ten year period (and excluding the Piper Alpha data), average IRs for a variety of operations were predicted in Table 3.1-1.

Table 3.1-1 Historical Average Individual Risk Data

Occupation	Average IR* (Excluding Piper Alpha)
Construction	1.05×10^{-3}
Drilling	8.76×10^{-4}
Production	8.76×10^{-4}
Maintenance	1.93×10^{-3}
Diving	2.19×10^{-3}
Cranes	2.72×10^{-3}
Domestic	1.75×10^{-4}
Average	$\mathbf{1.4 \times 10^{-3}}$

Source: Norwegian Petroleum Directorate (NPD) and the UK Department of Energy's annual Brown Book.
* The general consensus when considering risk criteria, is that the criteria should always be set lower than the current record so as to strive to improve safety. Setting risk criteria based on data that includes Piper Alpha would lead to more lenient criteria. Therefore, the target should be based on the above data (excluding Piper Alpha) and should then be set to an even lower target as White Rose is a new installation.

In addition to the above information, the UK Health and Safety Executive (HSE) who took over responsibility for offshore safety after the Piper Alpha disaster, have published a document entitled *Tolerability of Risk from Nuclear Power Stations* (HSE 1988), which specifies tolerability levels of individual risk to workers. HSE (1988) states that:

(169) The level of risk borne by the very small number of workers.....would probably approximate to that of many workers in the riskier groups in risky industries; such as that of workers in the offshore oil industry, faceworkers in mining or roofworkers in the construction industry. The level of these risks is difficult to estimate, but we can say that broadly, a risk of death around 1 in 1000 per annum is the most that is ordinarily accepted in any industry in the UK,....It seems therefore reasonable to adopt a risk of death of around 1 in 1000 as the dividing line between what is just about tolerable as a risk to be accepted...

HSE (1988) goes on to state that:

(175) Having considered what might be regarded as levels of risk that are *just tolerable* we must now consider what might be a *broadly acceptable* risk to an individual dying from some particular cause, that is, what is the level of risk below which, so long as precautions are maintained, it would not be reasonable to consider further improvements to standards if these involved a cause. *This level might be taken to be 1 in* 10^6 *per annum…*

This IR intolerability level (10^{-3}) and negligible region (10^{-6}) has subsequently become fundamental to the setting of risk criteria in a wide range of industries, and in particular, the offshore industry.

Taking note of the above information, the following *IR TLS* for *personnel* will be used.

Intolerable	**IR > 10^{-3}**
ALARP	**10^{-3} > IR >10^{-6}**
Negligible	**IR < 10^{-6}**

Where hazards are assessed as having a risk that is in the ALARP region, it must be demonstrated that all practicable means of risk reduction have been employed to ensure that the risk is ALARP.

To re-iterate, the above criteria are the *overriding* criteria that should be met by the final design.

3.1.1.1 Exposure Time

Offshore workers are not exposed to the dangers 100 percent of the time due to the time spent onshore. Work-rotations vary from operator to operator but can be approximated by assuming that the workers are exposed to the hazardous events 50 percent of the time. Logically, therefore, the 10^{-3} limit on IR should be compared with the average IR calculated for the installation, accounting for exposure time. In other words, calculate the average IR for some hypothetical individual who is offshore 365 days a year and then multiply this by 0.5 to obtain his true IR. This is the value that should be compared with the IR criteria above.

This is also consistent with the origins of the 1 x 10^{-3} criterion in HSE (1988), in which risk levels in other industries were applicable for typical workers and shift patterns in those industries.

The inclusion of exposure time in the calculation of individual risk is further justified by the fact that helicopter risk will be included in the calculation. Individuals cannot be exposed 365 days per year offshore *and* be exposed to helicopter risks as well.

3.1.1.2 Occupational Incidents and Helicopter Transportation

Quantified TLS can only be compared against quantifiable measures of risk. In accordance with C-NOPB Safety Plan Guidelines (C-NOPB 1995b), a Quantified Risk Assessment (QRA) is only required (expected) to be performed for *Major Accident Hazards*. The risk associated with Occupational Hazards (slips, trips, falls, etc.) is not traditionally quantified; such risks are generally assessed *qualitatively*.

From past experience in QRA, the risk associated with helicopter transportation is generally large and usually a significant proportion of the total risk; it is a major contributor to offshore risk and cannot be ignored. It is normal practice, certainly in the North Sea, to include this contribution in the calculated IR for comparison with the criteria.

As a result of the above, for the White Rose TLS, occupational risks are to be *excluded* when comparing the calculated IR with the IR criteria since they do not fall under the definition of *Major Accident Hazards*. Helicopter risks, however, shall be *included* since they do fall within the definition of major accident hazards and it is normal practice to include this contribution.

3.1.2 TLS # 2: Group Risk Criteria

Group Risk (GR) is a measure of the risk of multiple fatality accidents and can be expressed in terms of a frequency distribution (F-N Curve) or simply as the frequency with which fatalities exceed a specified level.

A commonly used technique for establishing a criteria on the frequency of multiple fatality accidents, that is GR, is the criterion F-N line. This line is a plot of the cumulative frequency (F) of accidents causing N or more fatalities, and normally (but not necessarily) takes the form of a straight line with a slope of '-1' on a log-log plot.

An alternative to specifying the full F-N curve is to simply specify certain points on the F-N criterion line, for example, for exceeding 10 or 50 fatalities (Table 3.1-2).

Table 3.1-2 Frequency of Exceeding 10 or 50 Fatalities

	Frequency of ³ 50 Fatalities	**Frequency of ³ 10 Fatalities**
Intolerable	$\geq 2.6 \times 10^{-4}$ yr^{-1}	$\geq 1.3 \times 10^{-3}$ yr^{-1}
ALARP	$\geq 2.6 \times 10^{-7}$, $< 2.6 \times 10^{-4}$ yr^{-1}	$\geq 1.3 \times 10^{-6}$, $< 1.3 \times 10^{-3}$ yr^{-1}
Negligible	$< 2.6 \times 10^{-7}$ yr^{-1}	$< 1.3 \times 10^{-6}$ yr^{-1}

GR criteria, to be consistent across different facilities, must be based on the average manning level for each facility. A facility with a Persons On Board (POB) of 100 personnel should have GR criteria with frequencies half as large as for a facility of 200 personnel, if the two facilities are to have comparable GR criteria.

For the above reason, GR criteria cannot be developed generically, nor can criteria from one facility be used for another facility unless both the number of people on the installation and the target IR level are the same.

3.1.2.1 Group Risk and Persons On Board

The above criteria are for illustrative purposes only and are applicable to an installation with a POB of approximately 60. These criteria may need to be revised to reflect the POB proposed for the chosen option.

3.1.3 TLS # 3: Environmental Risk Criteria

For Environmental Risk (ER), specific risk criteria cannot, generally, be quantitatively defined because of the varied nature of possible routes to environmental impairment that are difficult to assess using subjectively generated probabilities.

However, considerable data for oil spill frequencies exist for offshore drilling, production and transport loading operations. These can be expressed in terms of historical frequencies of oil spill sizes on a per well basis, per well-year basis or per billion barrels of oil produced basis (for transport loading). Specific operations for White Rose can be estimated (assuming equivalent operations) to give an indication of the possible frequencies of oil spills.

Where quantitative predictive methods allow, the expected oil spill frequency for actual operations, for example, iceberg scour collision damage to subsea facilities, can be compared with historical experience to determine whether the risk of oil spill is significantly different. These risks can then be managed and reduced using reasonable and practicable measures.

For design purposes, a *trigger* value of *50 barrels* is defined (Terra Nova 1998). An event in excess of this criterion will require more examination as to whether steps should be taken to reduce the risk.

During the design phase, any scenario capable of producing an oil spill in excess of 50 barrels, shall be designed out. Scenarios (of spills > 50 barrels) that cannot be designed against should be demonstrated to have an *aggregate frequency of* $< 1 \times 10^{-3}$ *per year*.

3.2 Impairment-Based Criteria

Husky Oil has defined impairment-based criteria to distinguish between accidental events that have the potential to cause high-fatality accidents, and those which do not. Such criteria are to be employed as *secondary* criteria to the *overriding* IR criteria that must be met at final design.

High-fatality accidents are those where the consequences are sufficiently severe that they have the potential to escalate and cause fatalities to personnel other than those in the immediate vicinity of the incident.

High-fatality accidents can occur if the following criteria are *not* met:

- at least one escape route from any position, which may be subject to an accident, to an area of shelter, shall remain intact;
- TSR shall remain intact until safe evacuation is possible;
- the main supporting structure must maintain the load carrying capacity for a specified time, until safe evacuation is possible; and
- evacuation systems remain useable.

From the definitions above, it is possible to define the installation's key *Safety Functions* as follows:

- the installation's Primary Structure;
- the TSR;
- the escape routes (from any position which may be subject to an accident) to the TSR; and
- the availability of the evacuation systems.

In order to distinguish between those accidental events which can cause impairment of the key safety functions, and those which do not, impairment-based criteria are defined by the TLS described in Sections 3.2.1 to 3.2.4.

The impairment-based criteria set out below (TLS #4 to TLS #7) present basic criteria that should not be exceeded. Incidents may occur that exceed the criteria. However, the intent is that every reasonable and practicable precaution is taken to ensure that those incidents that exceed the criteria, are so unlikely that they can be considered tolerable because their risk is negligible. While IR is the *overriding* risk-based criteria, the impairment-based criteria should meet the following:

- the frequency for loss of integrity to the installations safety functions *from any Single Major Accident Hazard* should not exceed 1×10^{-4} per year; and
- the frequency for loss of integrity to the installations safety functions from *all Major Accident Hazards* should not exceed 1×10^{-3} per year.

3.2.1 TLS # 4: Integrity of the Installation Primary Structure

There should be no overall loss of integrity of the installation, after an accidental event, for a period of two hours to:

- respond to the accident;
- attempt to control the accident; and, if necessary,
- to organise evacuation and to abandon the installation.

Loss of integrity is defined as:

- structural collapse of the installation;
- collapse of the structure supporting the TSR or evacuation systems;
- loss of structural stability;
- collision from an Iceberg;
  - > 100,000-t iceberg at 0.5 m/s.
- collision with vessels (this is classified according to impact energy);
  - > 14 MJ for sideways collisions.
  - > 11 MJ for bow or stern collisions.

3.2.2 TLS # 5: Integrity of Temporary Safe Refuge

The TR should retain its integrity for two hours to:

- respond to the accident;
- attempt to control the accident; and, if necessary,
- organise evacuation and abandon the installation.

Loss of integrity is defined as follows:

- failure of external walls, allowing entry of fire and/or smoke. Impairment criteria are covered as follows:
  - failure of external walls due to fires,
  - failure of external walls due to explosion, and
  - failure of external walls due to failure of structure underneath TSR;
- fire within TSR;
- deterioration of physical conditions within the TSR render it uninhabitable, that is, if there loss of breathable atmosphere, or intolerable heat build-up, etc.; and
- list, trim or heel in excess of 15^{o}.

A loss of breathable atmosphere may be due to depletion of oxygen, or the ingress and accumulation of smoke or toxic gases such as carbon monoxide, carbon dioxide or other toxic products of combustion.

3.2.3 TLS # 6: Integrity of Escape Routes

There must be at least two escape routes, from any position which may be subject to an accident, to the TSR. One of the two escape routes should remain passable for 30 minutes to enable the escape of workers who initially remained at their posts to shut-down the process or to fight a growing fire. Therefore, for the purpose of establishing criteria, impairment of the escape routes is defined when an event has the potential to impair both escape routes simultaneously within 30 minutes.

An escape route is deemed impassable by:

- thermal radiation over 6.3 kW/m^2 if the escape route is unprotected[2];
- blockage due to blast damage;
- collapse of the structure supporting the escape route;
- loss of breathable atmosphere or poor visibility, if there is a potential for the accumulation of smoke or toxic gases such that the atmosphere or visibility is not tolerable for the time period required to use an escape route;
- list, trim or heel in excess of 15^o; and
- flooding over 1 m deep in machinery spaces.

Since there should be more than one escape route from any point which may be subject to an accident, an incident which makes one escape route impassable is not a violation of the criterion.

3.2.3.1 Radiation Level

Offshore personnel working near hydrocarbon hazards will be dressed in fire retardant overalls and other Personal Protective Equipment (PPE). There will therefore, be very little skin exposed to the direct effects of incident radiation. Escape from or past a fire generating 6.3 kW/m^2 is a reasonable assumption, particularly as there will be intermittent shelter provided by equipment, containers, weather cladding and other structures.

3.2.4 TLS # 7: Means of Evacuation

The evacuation systems must remain effective for two hours to evacuate all personnel in a safe and controlled manner.

[2] Based on the American Petroleum Institute (API) Recommended Practice 521.

Impairment of the evacuation systems is generally split into the following two factors; Helideck and Lifeboats impairment. The impairment criteria of these evacuation systems is only violated if both the following are true:

(i) Helideck is not operable for long enough to evacuate all personnel. The helideck is deemed inoperable if:

- tilt over 15^o;
- loss of access, as defined by the escape route impairment criteria;
- smoke directed by wind towards helideck (due to lack of visibility);
- unignited gas over helideck (due to fear of helicopter igniting it);
- thermal radiation over 6.3 kW/m^2; and
- collapse of helideck supporting structure, or collapse of other structures due onto the helideck due to fire or blast.

and

(ii) Lifeboats are not operable with at least 10 percent spare capacity over and above the two times (200 percent) POB normal requirement to allow for partly loaded launching for long enough to evacuate all personnel. Lifeboats are deemed inoperable if:

- tilt over 15^o;
- loss of access, as defined by the escape route impairment criteria;
- thermal radiation over 6.3 kW/m^2 affecting embarkation points:
- fire or blast damage (damaging launching gear and access walkways or support structure);
- unignited gas over lifeboats;
- loss of breathable atmosphere if there is potential for the accumulation of smoke (unless smoke masks are used) or toxic gases such that the atmosphere is not tolerable for the time period required to use the lifeboats; and
- severe environmental conditions prevent safe launching and recovery of personnel from the lifeboats to a safe location.

3.2.4.1 Radiation Levels

When embarking lifeboats, personnel should be dressed similarly to that described in TLS #6 and it should not take long to enter the lifeboat. Thus, 6.3 kW/m^2 is also used for lifeboat stations. The lifeboats themselves should be able to withstand higher radiation levels than 6.3 kW/m^2 as they are normally designed to withstand the short-term effects of flame contact.

3.2.4.2 Additional Equipment

In addition to the evacuation systems discussed above, other means of escape to sea should also be provided, as well as personal survival equipment, including; life jackets, survival suits, liferafts, etc., as required by the assessment of major accidental events that might require evacuation of the installation.

3.3 Construction, Commissioning and Abandonment

The preceding sections and stipulation of TLS are applicable during the Drilling and Production Phases. This section addresses the criteria to be applied during the construction, commissioning and abandonment stages of the WRDP life.

3.3.1 Construction and Commissioning

The occupational incident frequency for Lost Time Incidents (LTIs) is to achieve better than the industry average. LTIs cannot be designed against in any quantitative manner. All that can be done is that good practice be followed in the design of the workplace environment. This includes the avoidance of trip hazards, provision of handrails, none-slip surfaces, eye-wash facilities, adequate first-aid cover, safe ladders and stair flights, etc. Normal Canadian industrial health and safety at work regulations should be applied, in line with those applicable to any shore-based industrial facility or construction site.

3.3.2 Abandonment

The facilities used to develop the White Rose field must be designed in order to minimise the risk to persons and the environment when the field has reached the end of its useful life. As the field nears the end of its useful life, studies shall be carried out to determine the best environmental option for disposal of the facilities.

4 REFERENCE LIST

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1995a. Newfoundland Offshore Petroleum Installation Regulations. Regulation 43 (3) & (4).

C-NOPB (Canada-Newfoundland Offshore Petroleum Board). 1995b. Safety Plan Guidelines. Section 2.1.1.

HSE (Health and Safety Executive). 1988. The Tolerability of Risk from Nuclear Power Stations. London. Her Majesty's Stationary Office (HMSO).

Terra Nova. 1998. Petro Canada Target Levels of Safety for the Terra Nova Field. Revision M1.

5 GLOSSARY

ALARP	As Low As Reasonably Practicable
C-NOPB	Canada-Newfoundland Offshore Petroleum Board
DPA	Development Plan Application
ER	Environmental Risk
GR	Group Risk
Husky Oil	Husky Oil Operations Limited
HSE	Health and Safety Executive
IR	Individual Risk
LTI	Lost Time Incident
NPD	Norwegian Petroleum Board
POB	Persons On Board
PPE	Personal Protective Equipment
QRA	Quantified Risk Assessment
TLS	Target Levels of Safety
TSR	Temporary Safe Refuge

APPENDIX B

Identification of Process Hydrocarbon Inventories

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (^oC)	
ASR-1	Above Sea Production Risers.	Riser to Topside ESDV.	Below Platform Deck, Turret Area, Riser Handling Area, Drilling.	Mixed (Oil/Gas/Water)	300	110	1. Pressure and Temperature taken from: White Rose Oilfield Project Description, Husky Oil, March 17, 2000.
ASR-2	Above Sea Gas Injection Risers.	Riser to Topside ESDV.	Below Platform Deck, Turret Area, Riser Handling Area, Drilling.	Mixed (Gas/Water)	393	50	2. Pressure and Temperature are based on the Gas Reijection Wells.
M-1	Production Flowlines/Manifold	Flowlines from Topside ESDV & Production Manifold to 1st Stage Separator (V-2001 A/B).	Turret Area, Riser Handling Area, Drilling.	Mixed (Oil/Gas/Water)	300	110	See Comment 1.
M-2	Test Flowlines/Manifold	Flowlines from Topside ESDV & Test Manifold to Test Separator (V-2005), excluding Test Oil Heater (H-2002).	Turret Area, Riser Handling Area, Drilling.	Mixed (Oil/Gas/Water)	300	110	See Comment 1.
S-1	1st Stage Separator (V-2001 A/B)	• Piping & equipment from Production Manifold to Separator.	Separator Area, Process	Mixed (Oil/Gas/Water)	300	110	See Comment 1.
		• Separator Vessel.	Separator Area, Process	Oil/Gas/Water	27.6	65	3. Operating conditions within Separator were not specified in PFD-00010 & Kvaerner (1999). As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream Nos. 2 & 3 (Kvaerner 1999).
		• Piping & equipment to:	-	-	-	-	
		– 2nd Stage Separator (V-2002), including Crude Oil Heater (H-2001).	Separator Area, Process	Oil/Water	27.6/27.1	65/84	4. Kvaerner 1999 (Stream Nos. 2 & 4) defines two varying operating conditions within this inventory. However, they have been grouped together into the one inventory since the variation is not considered significant.
		– 1st Stage Injection Gas Cooler (H-2304 A/B/C).	Separator Area, Process	Gas	27.6	65	Based on Stream No. 3.
S-2	Test Separator (V-2005)	• Piping & equipment from:	-	-	-	-	
		– Test Manifold, including Test Oil Heater and Metering.	Separator Area, Process	Mixed (Oil/Gas/Water)	27.6	65	See Comment 1.
		• Separator Vessel.	Separator Area, Process	Mixed (Oil/Gas/Water)	27.6	65	5. Based on Stream 2, PFD-00010

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions Pressure (Bar a)	Process Conditions Temperature (°C)	Comments
		• Piping & equipment to:	-	-	-	-	
		– 1st Stage Separator, including Test Separator Pump (P-2003); and	Separator Area, Process	Oil/Water	27.6	65	6. Operating conditions within Separator were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are based on Stream 2, PFD-00010
		– 1st Stage Injection Gas Cooler.	Separator Area, Process	Gas	27.6	29.9	7. Operating conditions within Cooler were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Inlet conditions of the 1st Stage Injection Gas Suction Cooler (defined below, see GCT-4).
S-3	2nd Stage Separator (V-2002)	• Piping & equipment from 1st Stage Separator/1st Stage Injection Suction Scrubber to 2nd Stage Separator.	Separator Area, Process	Oil/Water	1.5	67.8	8. From Kvaerner 1999, the operating pressure for the 1st Stage Separator/1st Stage Injection Suction Scrubber piping is approximately 27 bar (a). However, as the pressure must be reduced for the 2nd Stage Separator to perform its function, i.e. separate the oil & gas, a pressure of 1.5 is assumed. This is based on the 1st Stage Flash Gas Suction Scrubber Inlet pressure and Separator Outlet pressure of 1.5 (a) bar (as defined by Stream Nos. 5 & 14 respectively in Kvaerner 1999).
		• Separator Vessel.	Separator Area, Process	Mixed (Oil/Gas/Water)	1.5	67.8	9. Operating conditions within Separator were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 5 (Kvaerner 1999).
		• Piping & equipment to:	-	-	-	-	
		– 1st Stage Flash Gas Suction Cooler (H-2301); and	Separator Area, Process	Gas	1.5	67.8	Based on Stream No. 5.
		– Crude Oil Coalescer (V-2003).	Separator Area, Process	Oil/Water	1.5	67.8	10. Operating conditions for pipe to Coalescer were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 5 (Kvaerner 1999).
S-4	Crude Oil Coalescer (V-2003)	• Coalescer.	Separator Area, Process	Oil/Water	1.5	67.8	See Comment 8.

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (°C)	
		• Piping & equipment to:	-	-	-	-	
		– Oil Storage, excluding Crude Transfer Pumps (P-2001 A/B), Crude Cooler (H-2003) and Metering; and	Separator Area, Process	Oil	1.5	67.8	Based on Stream No. 6.
		– 1st Stage Separator, including Produced Water Recovery Pumps.	Separator Area, Process	Water	1.5	67.8	11. Operating conditions for pipe to 1st Stage Separator were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 6 (Kvaerner 1999).
E1	Crude Oil Storage (Crude Transfer Pumps (P-2001 A/B) & Crude Cooler (H-2003).	• Piping & equipment from Coalescer to Storage Tanks, including Crude Transfer Pumps and Crude Cooler.	Separator Area, Process	Oil	4	55	Based on Stream No. 10.
GCT-1	1st Stage Flash Gas Suction Scrubber (V-2301) & Compressor (K-2301).	• 1st Stage Flash Gas Suction Cooler.	Flash Gas Area, Gas Compression	Gas	1.5	30	12. Pressure based on Stream No. 5. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet temperature defined by Stream No. 9, that is, a temperature of 30.
		• Piping & equipment from:	-	-	-	-	
		– 1st Stage Flash Gas Suction Cooler to Suction Scrubber.	Flash Gas Area, Gas Compression	Gas	1.5	30	See Comment 10.
		• Suction Scrubber.	Flash Gas Area, Gas Compression	Gas/Water	1.2	30	13. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 9 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Scrubber to 2nd Stage Separator, including LP Flash Condensate Pumps (P-2301 A/B); and	Flash Gas Area, Gas Compression	Water	1.5	30	Based on Stream No. 14.
		– Scrubber to Compressor.	Flash Gas Area, Gas Compression	Gas	1.2	30	Based on Stream No. 9.

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (^oC)	
		• Compressor.	Flash Gas Area, Gas Compression	Gas	6.5	113.3	14. Operating conditions within Compressor were not specified in PFD-00010 & TI-018. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 11 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Compressor to 2nd Stage Flash Gas Suction Cooler (H-2302).	Flash Gas Area, Gas Compression	Gas	6.5	113.3	Based on Stream No. 11.
GCT-2	2nd Stage Flash Gas Suction Scrubber (V-2302) & Compressor (K-2302).	• 2nd Stage Flash Gas Suction Cooler	Flash Gas Area, Gas Compression	Gas	6.5	30	15. Pressure based on Stream No. 11. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet temperature defined by Stream Nos. 15 & 16, that is, a temperature of 30.
		• Piping & equipment from:		-	-	-	
		– 2nd Stage Flash Gas Suction Cooler to Scrubber.	Flash Gas Area, Gas Compression	Gas	6.5	30	See Comment 13.
		• Suction Scrubber.	Flash Gas Area, Gas Compression	Mixed (Oil/Gas/Water)	6.3	30	16. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream Nos. 15 and 16 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Scrubber to 2nd Stage Separator; and	Flash Gas Area, Gas Compression	Oil/Water	6.3	30	Based on Stream No. 16.
		– Scrubber to Compressor.		Gas	6.3	30	Based on Stream No. 15.
		• Compressor.	Flash Gas Area, Gas Compression	Gas	27.7	111.7	17. Operating conditions within Compressor were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 17 (Kvaerner 1999).
		• Piping & equipment from:		-	-	-	
		– Compressor to 2nd Stage Flash Gas Discharge Cooler (H-2303).	Flash Gas Area, Gas Compression	Gas	27.7	111.7	Based on Stream No. 17.

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (°C)	
GCT-3	2nd Stage Flash Gas Discharge Scrubber (V-2303).	• 2nd Stage Flash Gas Discharge Cooler.	Flash Gas Area, Gas Compression	Gas	27.7	30	18. Pressure based on Stream No. 17. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet temperature defined by Stream Nos. 18 & 21, that is, a temperature of 30.
		• Piping & equipment from:	-	-	-	-	
		– 2nd Stage Flash Gas Discharge Cooler to Discharge Scrubber.	Flash Gas Area, Gas Compression	Gas	27.7	30	See Comment 14.
		• Discharge Scrubber.	Flash Gas Area, Gas Compression	Oil/Gas/Water	27.1	30	19. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream Nos. 18 and 21 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Scrubber to 2nd Stage Separator; and	Flash Gas Area, Gas Compression	Oil/Water	27.1	30	Based on Stream No. 18.
		– Scrubber to 1st Stage Injection Gas Suction Scrubber.	Flash Gas Area, Gas Compression	Gas	27.1	30	Based on Stream No. 21.
GCT-4	1st Stage Injection Gas Suction Scrubber (V-2304) & 1st Stage Injection Gas Compressor (K-2303).	• 1st Stage Injection Gas Suction Coolers.	Gas Compression	Gas	27.6	29.9	20. Pressure based on Stream No. 3. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet temperature defined by Stream No. 25, that is, a temperature of 29.9.
		• Piping & equipment from:	-	-	-	-	
		– 1st Stage Injection Gas Suction Coolers to Scrubber.	Gas Compression	Gas	27.6	29.9	See Comment 16.
		• Suction Scrubber.	Gas Compression Area	Gas/Water	27	29.9	21. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 25 (Kvaerner 1999).

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (°C)	
		• Piping & equipment from:	-	-	-	-	
		– Scrubber to 2nd Stage Separator; and	Gas Compression Area	Water	27	29.9	Based on Stream No. 20.
		– Scrubber to 1st Stage Injection Compressor.	Gas Compression Area	Gas	27	29.9	Based on Stream No. 25.
		• Compressor.	Gas Compression Area	Gas	95	144.7	22. Operating conditions within Compressor were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 27 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Compressor to 1st Stage Injection Gas Discharge Cooler (H-2305 A/B).	Gas Compression Area	Gas	95	144.7	Based on Stream No. 27.
GCT-5	Glycol Column Inlet Scrubber (V-2401) & Glycol Dehydrator Column (C-2401).	• 1st Stage Injection Gas Discharge Coolers	Gas Compression Area	Gas	95	30	23. Pressure based on Stream No. 27. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet temperature defined by Stream Nos. 22 and 31, that is, a temperature of 30.
		• Piping & equipment from:	-	-	-	-	
		– 1st Stage Injection Gas Discharge Coolers to Inlet Scrubber.	Gas Compression Area	Gas	95	30	See Comment 21.
		• Inlet Scrubber.	Gas Compression Area	Gas/Water	94.4	30	24. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream Nos. 22 and 31 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Inlet Scrubber to 1st Stage Separator; and	Gas Compression Area	Water	94.4	30	Based on Stream No. 22.
		– Inlet Scrubber to Glycol Dehydrator Column;	Gas Compression Area	Gas	94.4	30	Based on Stream No. 31.
		• Glycol Dehydrator Column	Gas Compression Area	Gas	94.4	30	Based on Stream No. 31.

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (°C)	
		• Piping & equipment from:	-	-	-	-	
		– Glycol Dehydrator Column to 2nd Stage Injection Gas Scrubber (V-2305).	Gas Compression Area	Gas	94.4	30	Based on Stream No. 31.
GCT-6	2nd Stage Injection Gas Scrubber (V-2305) & 2nd Stage Injection Gas Compressor (K-2304).	• 2nd Stage Injection Gas Scrubber	Gas Compression Area	Gas	93.5	30	25. Operating conditions within Scrubber were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 33 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Injection Scrubber to Compressor.	Gas Compression Area	Gas	93.5	30	Based on Stream No. 33.
		• Compressor.	Gas Compression Area	Gas	393	155.5	26. Operating conditions within Compressor were not specified in PFD-00010 & Kvaerner 1999. As a result, operating conditions are assumed to be the same as the Vessel Outlet conditions defined by Stream No. 35 (Kvaerner 1999).
		• Piping & equipment from:	-	-	-	-	
		– Compressor to 2nd Stage Injection Gas Discharge Cooler (H-2306).	Gas Compression Area	Gas	393	155.5	Based on Stream No. 35.
GR-I -1	Gas Re-Injection Wells	• 2nd Stage Injection Gas Discharge Cooler.	Gas Compression Area	Gas	393	50	27. Pressure based on Stream No. 35. The function of the Cooler is to cool the temperature of the hydrocarbons to a temperature that facilitates removal of fluids (essentially water) by the Scrubber. The operating temperature therefore, is assumed to be that of the Scrubber Outlet pressure defined by Stream No. 37, that is, a temperature of 50.
		• Piping & equipment from:	-	-	-	-	
		– 2nd Stage Injection Gas Discharge Cooler (H-2306) to Re-injection Wells.	Gas Compression Area & Below Deck	Gas	392.4	50	Based on Stream No. 37.
FG-1	Fuel Gas System*	• Fuel Gas KO Drum (V-4501); • Fuel Gas Filters (V-4502 x 2); and • Fuel Gas Heater (H-4501).	Assumed to be in Utilities area.	Gas	80	100	28. Details of the Fuel Gas system are not included in P-FD-00010, therefore the inventory conditions are based on engineering judgement.
FV-1	Flare & Vent System*	• HP Flare KO Drum (V-4301);	Assumed to be in Flare & Vent area.	Gas	80	100	29. Details of the Fuel Gas system are not included in P-FD-00010, therefore the inventory conditions are based on engineering judgement.

Inventory Ref.	Hydrocarbon Equipment Inventory	Inventory Components/Description	Location	Inventory/ Hydrocarbon Type	Process Conditions		Comments
					Pressure (Bar a)	Temperature (^{o}C)	
		• LP Flare KO Drum (V-4302); • HP Flare Pump (P-4301 A/B); and • LP Flare Pump (P-4302 A/B).					
MPG-1	Main Power Generators*	• Main Power Generators	Assumed to be in Power Supply	Gas	80	100	30. Details of the Fuel Gas system are not included in P-FD-00010, therefore the inventory conditions are based on engineering judgement.

APPENDIX C

Derivation of Leak Frequencies for Process Hydrocarbon Events

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
Above Sea Production Risers.	• Riser to Topside ESDV.	(i) From PARLOC (1994), Flexible Riser Leak Frequency of 3.52 x 10^{-3} is assumed (there have been 2 Flexible Riser incidents in 576.4 years of operation). (ii) 20% of Flexible Riser Releases occur above sea. (iii) Each Riser is assumed to have 2 Valves (each with a leak frequency[2] of 4.5 x 10^{-4} (CMPT 1999)) and 2 Flanges (each with a leak frequency of 1.2 x 10^{-4} (CMPT 1999)).	**Years 4+ (14 Producing Wells):** 1.1 x 10^{-2} per year. [(14 x 0.2 x 3.52 x 10^{-3}) + (2 x 4.5 x 10^{-4}) + (2 x 1.2 x 10^{-4})]	**Years 4+:** S - 1 x 10^{-2} M - 6.6 x 10^{-4} L - 3.3 x 10^{-4}	1. Above Sea Releases modelled as occurring in Turret Area for Steel FPSO option. 2. Above Sea Releases modelled as occurring below Platform Deck & in Riser Handling Area for Semi-Submersible option.
Above Sea Gas Injection Risers.	• Riser to Topside ESDV.	(i) From PARLOC (1994), Flexible Riser Leak Frequency of 3.52 x 10^{-3} is assumed (there have been 2 Flexible Riser incidents in 576.4 years of operation). (ii) 20% of Flexible Riser Releases occur above sea. (iii) Each Riser is assumed to have 2 Valves (each with a leak frequency[3] of 4.5 x 10^{-4} (CMPT 1999)) and 2 Flanges (each with a leak frequency of 1.2 x 10^{-4} (CMPT 1999)).	**Years 4+ (2 Gas Injection Wells):** 2.55 x 10^{-3} per year. [(2 x 0.2 x 3.52 x 10^{-3}) + (2 x 4.5 x 10^{-4}) + (2 x 1.2 x 10^{-4})]	**Years 4+:** S - 2.32 x 10^{-3} M - 1.53 x 10^{-4} L - 7.65 x 10^{-5}	See Comments 1 & 2.
Production Manifolds	• Flowlines from Topside ESDV. • Manifolds (inc. piping upstream of 1st Stage Separator).	(i) Flowline Leak Frequency for an Oil Platform is 1.2 x 10^{-2} per flowline year (CMPT 1999, Table IX.3.2). (ii) Representative Manifold Leak Frequency for an Oil Platform is 1.6 x 10^{-2} per manifold year.	**Years 4+ (14 Producing Wells):** 1.84 x 10^{-1} per year. (Based on 14 Flowlines and one Production Manifold).	**Years 4+:** S - 1.67 x 10^{-1} M - 1.1 x 10^{-2} L – 5.52 x 10^{-3}	3. Releases modelled as occurring in the Turret Area for the FPSO option and Riser Handling Area for the Semi-Submerible option. 4. It is assumed that the Flowline and Manifold Frequencies includes leak rate data for associated ancillary equipment such as flanges, valves, etc. 5. CMPT (1999) does not detail the types, size and numbers of Flowlines and Manifolds the system frequencies take into account, i.e. subsea flowlines and manifolds, production flowlines and manifolds, etc. For the purpose of this calculation, it is assumed that the frequencies are PER FLOWLINE/MANIFOLD and only incorporates on deck production/test flowlines/manifolds.

[1] Leak Frequency for Small (S), Medium (M) & Large (L) Hole Sizes distributed according to the Hole Size Distribution used for Hibernia, i.e. S: 91%, M: 6% and L: 3%.

[2] The Leak Frequencies assumed for Valves and Flanges are the worst-case leak frequencies obtained from Table IX.3.3 of CMPT (1999), that is, leak frequencies for a Valve of > 11" Diameter and Flange of > 11" Diameter are assumed.

[3] The Leak Frequencies assumed for Valves and Flanges are the worst-case leak frequencies obtained from Table IX.3.3 of CMPT (1999), that is, leak frequencies for a Valve of > 11" Diameter and Flange of > 11" Diameter are assumed.

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
Test Manifolds	• Flowlines from Topside ESDV. • Manifolds (inc. piping upstream of 1st Stage Separator). • Test Oil Heater (& associated equipment).	(i) Flowline Leak Frequency for an Oil Platform is 1.2 x 10^{-2} per flowline year. (ii) Manifold Leak Frequency for an Oil Platform is 1.6 x 10^{-2} per manifold year. (iii) A Test Oil Heater is assumed to be a type of Heat Exchanger. Therefore, based on Table IX.3.3 of CMPT 1999, a representative HEAT EXCHANGER EQUIPMENT[4] leak frequency of 1.1 x 10^{-2} is assumed. An additional factor of 10% is applied to this leak frequency to account for the additional equipment associated with the Heater.	**Years 4+:** 1.96 x 10^{-1} per year. [1.84 x 10^{-1} + 1.1 x 10^{-2} + (0.1 x (1.1 x 10^{-2}))]	**Years 4+:** S - 1.78 x 10^{-1} M - 1.18 x 10^{-2} L - 5.88 x 10^{-3}	See Comments 3 - 5. 6. It is assumed that the representative Test Manifold System Leak Frequency does not account for the Test Oil Heater.
Gas Injection Manifold	• Flowlines (Downstream of Gas Metering, see GR-I-1) to Gas Injection Manifold	(i) From Table IX.3.2 of CMPT 1999, the Gas Flowline System Leak Frequency is 1.1 x 10^{-2} per flowline year. (ii) From Table IX.3.2 of CMPT 1999, the Gas Manifold System Leak Frequency is 1.3 x 10^{-2} per manifold year.	**Years 4+ (2 GI Wells):** 3.5 x 10^{-2} per year. (Based on two Gas Re-Injection Wells and one Gas Manifold).	**Years 4+:** S - 3.19 x 10^{-2} M - 2.1 x 10^{-3} L - 1.05 x 10^{-3}	See Comments 3 - 5.
1st Stage Separator	• Separator x 2 (inc. piping upstream of 2nd Stage Separator & 1st Stage Injection Gas Cooler). • Crude Oil Heater (& associated equipment).	(i) Production Separator System Leak Frequency for an Oil Platform is 1.2 x 10-^{1} per Separator year. Appendix B, identifies that both oil and gas can be released from the Separator. Therefore, the above frequency is factored by 50% based on the assumption that 50% of releases could be gas and 50% could be oil. (ii) A Crude Oil Heater is assumed to be a type of Heat Exchanger. Therefore, based on Table IX.3.3 of CMPT 1999, a representative HEAT EXCHANGER EQUIPMENT leak frequency of 1.1x 10^{-2} is assumed. An additional factor of 10% is applied to this leak frequency to account for the additional equipment associated with the Heater.	**For Oil Releases:** 1.32 x 10^{-1}. [1.1 x 10^{-2} + (0.1 x (1.1 x 10^{-2})) + (0.5 x 2 x (1.2 x 10^{-1}))] **For Gas Releases:** 1.2 x 10^{-1} (0.5 x 2 x 1.2 x 10^{-1})	**For Oil Releases:** S - 1.2 x 10^{-1} M - 7.93 x 10^{-3} L - 3.96 x 10^{-3} **For Gas Releases:** S - 1.09 x 10^{-1} M - 7.2 x 10^{-3} L - 3.6 x 10^{-3}	7. CMPT 1999 does not differentiate between 1st, Stage, 2nd Stage and Test Separators. Therefore, the Production Separator System leak frequency quoted in CMPT 1999 is used for 1st and 2nd Stage and Test Separators. 8. It is assumed that the Separator System Frequency includes leak rate data for associated ancillary equipment such as flanges, valves, etc. 9. It is assumed that the representative Production Separator System Leak Frequency does not account for the Crude Oil Heater.

[4] The Heat Exchanger Leak Frequency quoted here is the worst-case leak frequency for Heat Exchangers in Table IX.3.3 of CMPT 1999, that is the Heat Exchanger, Plate.

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
Test Separator	• Separator (inc. piping upstream of 2nd Stage Separator & 1st Stage Injection Gas Cooler). • Test Metering (& associated equipment). • Test Separator Pump (& associated equipment).	(i) Production Separator System Leak Frequency for an Oil Platform is 1.2×10^{-1} per Separator year. Appendix B, identifies that both oil and gas can be released from the Separator. Therefore, the above frequency is factored by 50% based on the assumption that 50% of releases could be gas and 50% could be oil. (ii) Metering System Leak Frequency for an Oil Platform is 3.7×10^{-2} per Metering System year. (iii) A Test Separator Pump is assumed to be a Centrifugal, Double Seal, type pump[5]. Therefore, based on CMPT 1999, a Centrifugal, Double Seal Pump EQUIPMENT leak frequency of 7.3×10^{-3} is assumed. An additional factor of 10% is applied to this frequency to account for the additional equipment associated with the pump.	**For Oil Releases:** 1.05×10^{-1}. $[(0.5 \times 1.2 \times 10^{-1}) + (3.7 \times 10^{-2}) + (7.3 \times 10^{-3}) + (0.1 \times (7.3 \times 10^{-3}))]$ **For Gas Releases:** 6×10^{-2}.	**For Oil Releases:** S - 9.6×10^{-2} M - 6.3×10^{-3} L - 3.15×10^{-3} **For Gas Releases:** S - 5.46×10^{-2} M - 3.6×10^{-3} L - 1.8×10^{-3}	See Comments 7 & 8. 10. It is assumed that the representative Production Separator System Leak Frequency does not account for the Test Oil Metering.
2nd Stage Separator	• Separator (inc. piping upstream of 1st Stage Flash Gas Suction Cooler & Crude Oil Coalescer). .	(i) Production Separator System Leak Frequency for an Oil Platform is 1.2×10^{-1} per Separator year.	**For both Oil & Gas Releases:** 6×10^{-2}. (Based on the assumption that 50% of releases are oil and 50% are gas, refer to 1st Stage & Test Separator Derivations).	S - 5.46×10^{-2} M - 3.6×10^{-3} L - 1.8×10^{-3}	See Comments 7 & 8.
Crude Oil Coalescer	• Coalescer (inc. piping upstream of Crude Transfer Pumps).	(i) The Coalescer is assumed to be a type of Pressure Vessel. Therefore, based on CMPT 1999, a representative Pressure Vessel EQUIPMENT leak frequency of 2.6×10^{-3} is assumed. An additional factor of 10% is applied to this frequency to account for the additional equipment associated with the Coalescer.	2.86×10^{-3} $[(2.6 \times 10^{-3}) + (0.1 \times (2.6 \times 10^{-3}))]$	S - 2.6×10^{-3} M - 1.72×10^{-4} L - 8.58×10^{-5}	
Crude Oil Storage	• Crude Transfer Pumps x 2 (& associated equipment).	(i) A Crude Transfer Pump is assumed to be a Centrifugal, Double Seal, type pump. Therefore, based on CMPT 1999, a Centrifugal, Double Seal Pump EQUIPMENT leak frequency of 7.3×10^{-3} is assumed. An additional factor of 10% is applied to this frequency to account for the additional equipment associated with the pump.	6.16×10^{-2} $[(2 \times (7.3 \times 10^{-3})) + 5.3 \times 10^{-3} + 2.5 \times 10^{-3} + 3.7 \times 10^{-2} + (0.1 \times ((2 \times 7.3 \times 10^{-3}) + 5.3 \times 10^{-3} + 2.5 \times 10^{-3}))]$	S - 5.61×10^{-2} M - 3.7×10^{-3} L - 1.85×10^{-3}	

[5] These are assumed to be the most commonly used pumps (Centrifugal as opposed to Reciprocating) on an offshore installation. Such an assumption is based on the significantly larger 'population' used in E&P Forum (1992) to derive pump leak frequency data.

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
	• Crude Cooler (& associated equipment). • Crude Oil Metering (& associated equipment). • Crude Storage Tanks (& associated equipment).	(ii) The Crude Cooler is assumed to be a type of Fin Fan Cooler. Therefore, based on CMPT 1999, a representative EQUIPMENT leak frequency of 5.3×10^{-3} is assumed for the Crude Cooler. An additional factor of 10% is applied to this frequency to account for the additional equipment associated with the Cooler. (iii) Metering System Leak Frequency for an Oil Platform is 3.7×10^{2} per Metering System year. (iv) From CMPT 1999, a Crude Storage Tank EQUIPMENT LEAK frequency of 2.5×10^{-3} is assumed. In addition, a factor of 10% is applied to this frequency to account for the additional equipment associated with the tanks.			
1st Stage Flash Gas Suction Cooler, Scrubber & Compressor.	• 1st Stage Flash Gas Suction Cooler (inc. piping upstream of Suction Scrubber). • 1st Stage Flash Gas Suction Scrubber (inc. piping upstream of Compressor). • 1st Stage Flash Gas Compressor (inc. piping upstream of 2nd Stage Flash Gas Suction Cooler).	(i) Compression System Leak Frequency for an Oil Platform is 2.9×10^{-1} per system year.	2.9×10^{-1}	S - 2.64×10^{-1} M - 1.74×10^{-2} L - 8.7×10^{3}	11. CMPT 1999 does not differentiate between 1st Stage & 2nd Stage Flash Gas and Injection Compression Systems.. Therefore, the Compression System leak frequency quoted in CMPT 1999 is used for 1st Stage & 2nd Stage Flash Gas and Injection Compression Systems. 12. It is assumed that the representative Compression System leak frequency stated in CMPT 1999 comprises leak frequency contributions from each of the following; a Cooler, Scrubber and Compressor. It is assumed that the Compression System Frequency includes leak rate data for associated ancillary equipment such as flanges, valves, etc.
2nd Stage Flash Gas Suction Cooler, Scrubber & Compressor.	• 2nd Stage Flash Gas Suction Cooler (inc. piping upstream of Suction Scrubber). • 2nd Stage Flash Gas Suction Scrubber (inc. piping upstream of 2nd Stage Separator and Compressor). • 2nd Stage Flash Gas Compressor (inc. piping upstream of 2nd Stage Flash Gas Discharge Cooler).	(i) Compression System Leak Frequency for an Oil Platform is 2.9×10^{-1} per system year.	2.9×10^{-1}	S - 2.64×10^{-1} M - 1.74×10^{-2} L - 8.7×10^{3}	See Comments 11-13.

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
2nd Stage Flash Gas Discharge Cooler & Scrubber.	• 2nd Stage Flash Gas Discharge Cooler (inc. piping upstream of Discharge Scrubber). • 2nd Stage Flash Gas Discharge Scrubber (inc. piping upstream of 2nd Stage Separator and 1st Stage Injection Gas Scrubber).	(i) The Discharge Cooler is assumed to be a type of Fin Fan Cooler. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Fin Fan Cooler EQUIPMENT leak frequency 5.3 x 10^{-3} is assumed for the Discharge Cooler. An additional factor of 10% is applied to this leak frequency to account for the additional equipment (piping, etc.) associated with the Cooler. (ii) The Scrubber is assumed to be a type of Pressure Vessel. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Pressure Vessel EQUIPMENT leak frequency of 2.6 x 10^{-3} is assumed for the Scrubber. An additional factor of 10% is also applied to this frequency to account for the additional equipment (piping, etc.) associated with the Scrubber. Appendix B, identifies that both oil and gas can be released from the Discharge Scrubber. Therefore, the above frequencies are factored by 50% based on the assumption that 50% of releases could be gas and 50% could be oil.	**For Gas Releases:** 7.26 x 10^{-3} [5.3 x 10^{-3} + (0.5 x 2.6 x 10^{-3}) + (0.1 x (5.3 x 10^{-3} + (0.5 x 2.6 x 10^{-3})))] **For Oil Releases:** 1.43 x 10^{-3} [0.5 x (2.6 x 10^{-3} + (0.1 x 2.6 x 10^{-3}))]	**For Gas Releases:** S - 6.61 x 10^{-3} M - 4.36 x 10^{-4} L - 2.18 x 10^{-4} **For Oil Releases:** S - 1.3 x 10^{-3} M - 8.58 x 10^{-5} L - 4.29 x 10^{-5}	
1st Stage Injection Gas Suction Coolers, Suction Scrubber & Compressor	• 1st Stage Injection Gas Suction Coolers x 3 (inc. piping upstream of Suction Scrubber). • 1st Stage Injection Gas Suction Scrubber (inc. piping upstream of 1st Stage Injection Discharge Coolers).	(i) Compression System Leak Frequency for an Oil Platform is 2.9 x 10^{-1} per system year. (ii) From Comment 12 above, a representative Compression System is assumed to comprise a Cooler, a Scrubber and a Compressor. To account for the fact that this compression system has 3 Coolers, the above frequency is increased as follows: The compression system frequency (2.9 x 10^{-1}) is distributed as follows between the Cooler, Scrubber and Compressor (and their associated equipment); 25% Cooler, 25% Scrubber & 50% Compressor. Therefore, an additional frequency of 1.45 x 10^{-1} (2.9 x 10^{-1} x 0.25 x 2) is assumed for the two additional coolers (and associated equipment).	4.35 x 10^{-1}	S - 3.96 x 10^{-1} M - 2.61 x 10^{-2} L - 1.31 x 10^{-2}	

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
1st Stage Injection Discharge Coolers, Glycol Column Inlet Scrubber & Glycol Dehydrator Column.	• 1st Stage Injection Discharge Coolers x 2 (inc. piping upstream of Glycol Scrubber). • Glycol Column Inlet Scrubber (inc. piping upstream of Glycol Dehydrator Column). • Glycol Dehydrator Column (inc. piping upstream of 2nd Stage Injection Gas Suction Scrubber).	(i) The Discharge Cooler is assumed to be a type of Fin Fan Cooler. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Fin Fan Cooler EQUIPMENT leak frequency 1.06×10^{-2} ($2 \times 5.3 \times 10^{-3}$) is assumed for the Discharge Cooler. An additional factor of 10% is applied to this leak frequency to account for the additional equipment (piping, etc.) associated with the Cooler. (ii) The Column Scrubber and Dehydrator Column are assumed to be types of Pressure Vessel. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Pressure Vessel EQUIPMENT leak frequency of 2.6×10^{-3} is assumed for the Scrubber and Dehydrator Column. An additional factor of 10% is also applied to this frequency to account for the additional equipment (piping, etc.) associated with the Scrubber and Column.	1.738×10^{-2} $[1.06 \times 10^{-2} + (2 \times 2.6 \times 10^{-3}) + (0.1 \times (1.06 \times 10^{2} + 5.2 \times 10^{-3}))]$	S - 1.58×10^{-2} M - 1.04×10^{-3} L - 5.21×10^{-4}	
2nd Stage Injection Gas Scrubber & Compressor	• 2nd Stage Injection Gas Scrubber • 2nd Stage Injection Gas Compressor	(i) Compression System Leak Frequency for an Oil Platform is 2.9×10^{-1} per system year. (ii) From Comment 12 and Assumption (ii) in GCT-4 above, a representative Compression System is assumed to comprise a Cooler, a Scrubber and a Compressor. To account for the fact that this compression system has no Coolers, the above frequency is decreased by a factor of 25%.	2.2×10^{-1}	S - 2×10^{-1} M - 1.31×10^{-2} L - 6.6×10^{3}	
Deck - Gas Re-Injection Wells	• 2nd Stage Injection Gas Discharge Cooler (& associated equipment).	(i) In accordance with Assumption (i) of GCT-5, the Discharge Cooler is assumed to be a type of Fin Fan Cooler. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Fin Fan Cooler EQUIPMENT leak frequency of 5.3×10^{3} is assumed for the Discharge Cooler. An additional factor of 10% is applied to this leak frequency to account for the additional equipment (piping, etc.) associated with the Cooler.	2.78×10^{-2} $[5.3 \times 10^{-3} + (0.1 \times 5.3 \times 10^{-3}) + 2.2 \times 10^{-2}]$	S - 2.53×10^{2} M - 1.67×10^{-3} L - 8.35×10^{-4}	

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
	• Gas Metering.	(ii) From CMPT 1999, Gas Metering System Leak Frequency is 2.2 x 10^{-2} per Metering System year.			
Fuel Gas System	• Fuel Gas KO Drum (& associated equipment) • Fuel Gas Filters x 2 (& associated equipment) • Fuel Gas Heater (& associated equipment)	(i) The Fuel Gas KO Drum is assumed to be a type of Pressure Vessel. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Pressure Vessel EQUIPMENT leak frequency of 2.6 x 10^{-3} is assumed for the Fuel Gas KO Drum. An additional factor of 10% is also applied to this frequency to account for the additional equipment (piping, etc.) associated with the Drum. (ii) The representative leak frequency assumed for the Filters is 7.2 x 10^{3} (2 x the EQUIPMENT leak frequency from CMPT 1999). To account for the additional equipment (piping, etc.) associated with the Filters, an additional 10% of this frequency is added to the Filter leak frequency. (iii) A Fuel Gas Heater is assumed to be a type of Heat Exchanger. Therefore, based on Table IX.3.3 of CMPT 1999, a representative HEAT EXCHANGER EQUIPMENT leak frequency of 1.1 x 10^{-2} is assumed for the Fuel Gas Heater. An additional factor of 10% is applied to this leak to account for the additional equipment associated with the Heater.	2.29 x 10^{-2} [2.6 x 10^{-3} + 7.2 x 10^{3} + 1.1 x 10^{-2} + (0.1 x (2.6 x 10^{3} + 7.2 x 10^{-3} + 1.1 x 10^{-2}))]	S - 2.08 x 10^{-2} M – 1.37 x 10^{-3} L - 6.87 x 10^{-4}	14. Documented details (Drawings, etc.) containing information/data on the Fuel Gas System was not available at the time of preparing this calculation.
Flare & Vent System	• HP Flare KO Drum (& associated equipment) • LP Flare KO Drum (& associated equipment) • HP Flare Pump x 2 (& associated equipment)	(i) The HP & LP KO Drum are assumed to be types of Pressure Vessels. Therefore, the representative leak frequency assumed for the Drums is 2.6 x 10^{-3} (the EQUIPMENT Pressure Vessel leak frequency from CMPT 1999). An additional factor of 10% is applied to this frequency to account for the additional equipment (piping, etc.) associated with the Drums. (ii) A HP Flare Pump is assumed to be a Centrifugal, Double Seal, type pump. Therefore, based on CMPT 1999, a Centrifugal, Double Seal Pump EQUIPMENT leak frequency of 1.46 x 10^{2} (2 x 7.3 x 10^{-3}) is assumed for the HP Flare Pumps. An additional factor of 10% is applied to this frequency to account for the additional equipment associated with the pump.	2.18 x 10^{-2} [(2 x 2.6 x 10^{3}) + 1.46 x 10^{-2} + (0.1 x (2 x 2.6 x 10^{2} + 1.46 x 10^{2}))]	S - 1.98 x 10^{-2} M - 1.31 x 10^{-3} L - 6.54 x 10^{-4}	

Inventory	Invent. Component(s)	Leak Frequency Assumptions	Leak Frequency Derivation (Per System Year)	Leak Frequency for S, M & L Hole Sizes[1]	Comments
Main Power Generators	• Main Power Generators x 2 (& associated equipment)	(i) The Main Power Generators are assumed to be types of Pressure Vessels. Therefore, based on Table IX.3.3 of CMPT 1999, a representative Pressure Vessel EQUIPMENT leak frequency of 5.2×10^{-3} ($2 \times 2.6 \times 10^{-3}$) is assumed for the Main Power Generators. An additional factor of 10% is also applied to this frequency to account for the additional equipment (piping, etc.) associated with the Generators.	5.72×10^{-3} $[5.2 \times 10^{-3} + (0.1 \times 5.2 \times 10^{-3})]$	S - 5.2×10^{-3} M - 3.43×10^{-4} L - 1.72×10^{-4}	

APPENDIX D

Assessment of Ship Impact Frequencies

WHITE ROSE
DEVELOPMENT APPLICATION

APPENDIX D

ASSESSMENT OF SHIP IMPACT FREQUENCIES

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED AS OPERATOR
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

July 2000

TABLE OF CONTENTS

Page No.

LIST OF FIGURES

Page No.

LIST OF TABLES

Page No.

1 INTRODUCTION

This Appendix presents the Input Initiating Frequencies (IIFs) for ship-installation collision risks due to authorized and passing vessels, for the White Rose project, using Fault Tree Analysis. These IIFs will be used as inputs to the event trees in the QRA Risk Profile model, in order to estimate risk levels.

1.1 Authorized Vessels

Any offshore installation must be supported by various vessels, providing a variety of specific services. The close proximity of shuttle tankers, supply/standby vessels, and other specialized ocean crafts (e.g., diving operations vessel) are essential to any installation. Therefore, the approach in determining the risks due to authorized vessel collision is similar for all installations, regardless of location. However, the categories of authorized vessels that service a facility will depend on the type of installation utilized. For example, a ship-shaped floating, production, storage and offloading (FPSO) vessel will typically be serviced by supply/standby vessels and shuttle tankers because hydrocarbon production, storage, and offloading operations are carried out at the same location, whereas a semi-submersible is normally serviced by supply/standby vessels only. A semi-submersible is not typically used for storage. The White Rose semi-submersible will be accompanied in the field by a floating storage unit (FSU), to store the crude as it is produced and carry out shuttle tanker offloading operations. Therefore, there is no direct need for shuttle tankers to venture within close proximity of the semi-submersible installation. For the semi-submersible option, there will still be a risk of shuttle tanker/FSU collision, though the FSU has a much smaller manning level.

It should be noted that because the authorized vessels maneuver close to an installation, it has been assumed that the installation is not able to take measures to avoid a collision.

The frequency of collision between a shuttle tanker and an installation, or storage unit, is estimated to be 0.0046/year due to failure of the dynamic positioning system [Ref. 1]. It is assumed that 20 percent (i.e., 0.0009/year) of shuttle tanker collisions occur after loading operations are complete and the fully loaded vessel is leaving the field. This relatively low percentage is due to the fact that the shuttle tanker is holding and maintaining position, in order to achieve loading, and is aware of the installation’s location. In addition, it is usual practice to perform shuttle tanker loading operations at a safe distance from the facility. The remaining 80 percent (i.e., 0.0037/year) of shuttle tanker collisions are assumed to occur while the tanker is empty and on approach to the facility.

The failure of the dynamic positioning system on a maintenance support vessel, causing a collision, is estimated to be 0.0137/year [Ref. 1].

In the event of a collision, the severity of damage that an installation experiences differs, depending on the impact energy of the collision. The following equation is used to determine vessel collision impact energy [Ref. 2]:

$$E = 1/2\ (M/1000)\ kV^2$$

Where:

E = impact energy (MJ)
M = vessel mass (tonnes)
V = vessel speed (m/s) = 0.514 x (speed in knots)
k = hydrodynamic added mass constant
= 1.1 for head-on (powered) impact
= 1.4 for broadside (drifting) impact

Note: It is assumed that for supply/standby vessel collisions, ‘k’ is equal to 1.4, and for shuttle tanker collisions, ‘k’ is equal to 1.1.

It is presumed that for supply/standby vessel collisions, the vessel is at maximum mass (i.e., Total Displacement = Deadweight Tonnage + Light Ship Weight) since collisions will be more likely during approach to the installation. Table 1 illustrates The mass of the vessels that service current Grand Banks production facilities, which are used as the basis for this assessment, are provided in Table 1.1-1.

Table 1.1-1 Vessel Displacement

Vessel[1]	Light Ship Weight (t)	Deadweight Tonnage (t)	Total Displacement[2] (t)
Maersk Bonavista/Placentia	2,500	1,800	4,300
Maersk Norseman/Nascopie	4,654	2,088.2	6,742.2
MCM Kometik	27,094.5	126,646.6	153,741.1

[1] Maersk data is from Reference 3 and Kometik data is from Reference 4.
[2] All of the Maersk vessels serve as supply and standby duties. Therefore, in this conservative analysis, the Total Displacement of Maersk vessels is 6,745 t.

It is conservatively assumed that vessel collisions occur during maneuvering. The percentage of incidents, at various speeds, for historically recorded occurrences is presented in Table 1.1-2 [Ref. 2].

Table 1.1-2 Maneuvering Collision Mean Speed and Percentage of Incidents

Speed Range (kts)	Mean Speed (m/s)	% of Incidents
0 – 1	0.3	27
1 – 2	0.8	26
2 – 3	1.3	13
3 – 4	1.8	7
4 – 5	2.3	20
5 – 6	2.8	7

The following categories of impact energy are chosen on the basis of potential damage to the installation:

- 0 to 30 MJ: minor damage to facility
- 30 to 100 MJ: moderate damage to facility
- 100 to 200 MJ: heavy damage to facility
- 200 MJ: catastrophic loss of facility

Impact frequencies have been estimated for each category to allow the event tree modelling to represent the different consequence levels.

Design rules typically require all offshore installations to be capable of withstanding at least 15MJ impacts, however it is likely that actual capacity will exceed this value by a significant amount. The risk assessment assumes that impacts of energy less than 30MJ will not cause damage to the hull, hence the choice of energy bands in this analysis.

The calculated impact energy, and percentage of incidents are illustrated in Figures 1.1-1 to 1.1-3.

Figure 1.1-1 Probability Distribution of Impact Energy for Supply/Standby Vessels

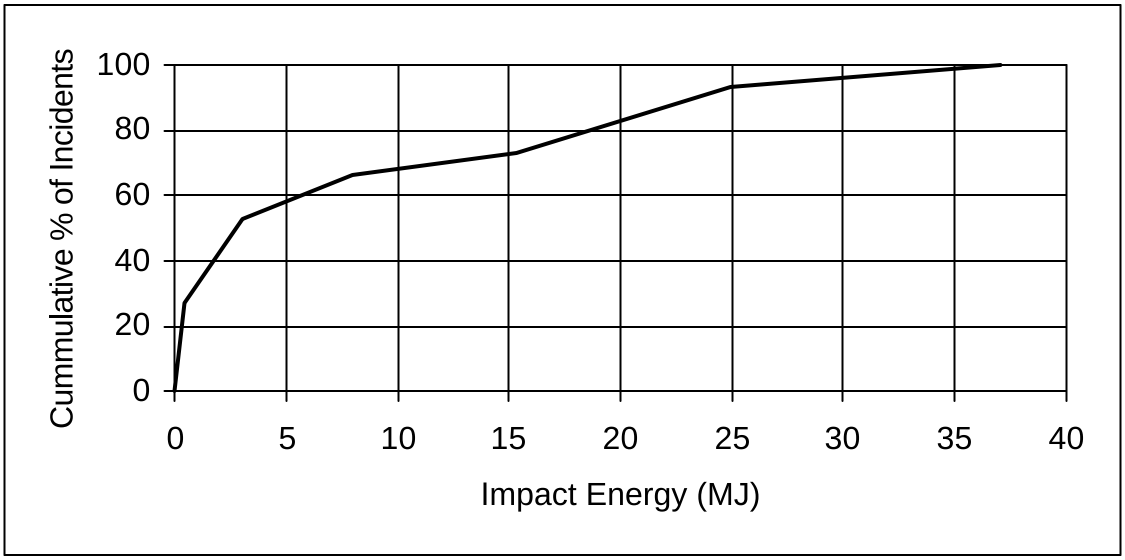


Figure 1.1-2 Probability Distribution of Impact Energy for Shuttle Tanker (Full)

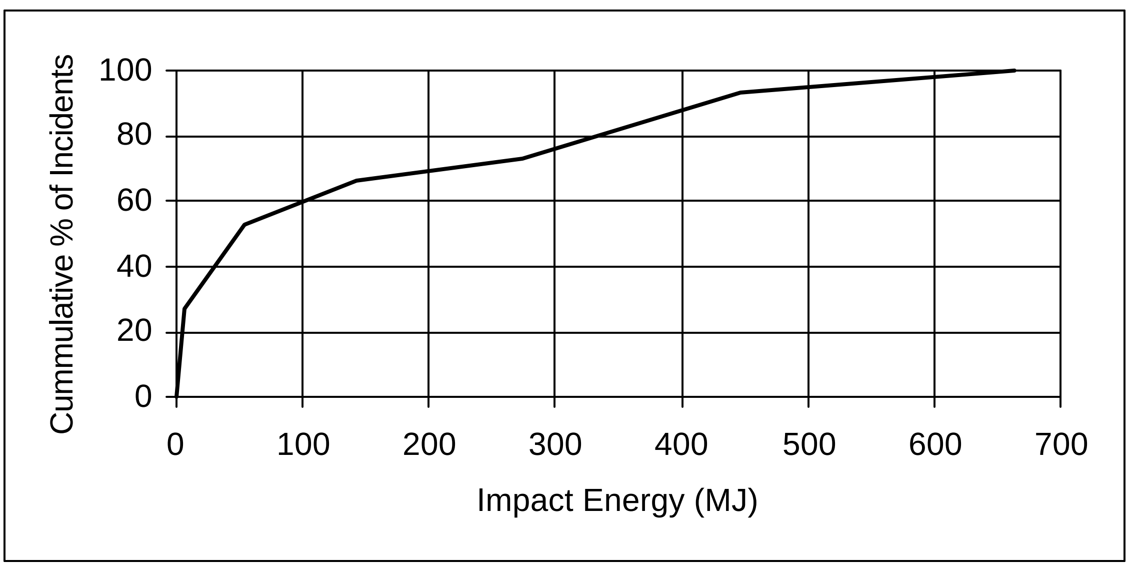
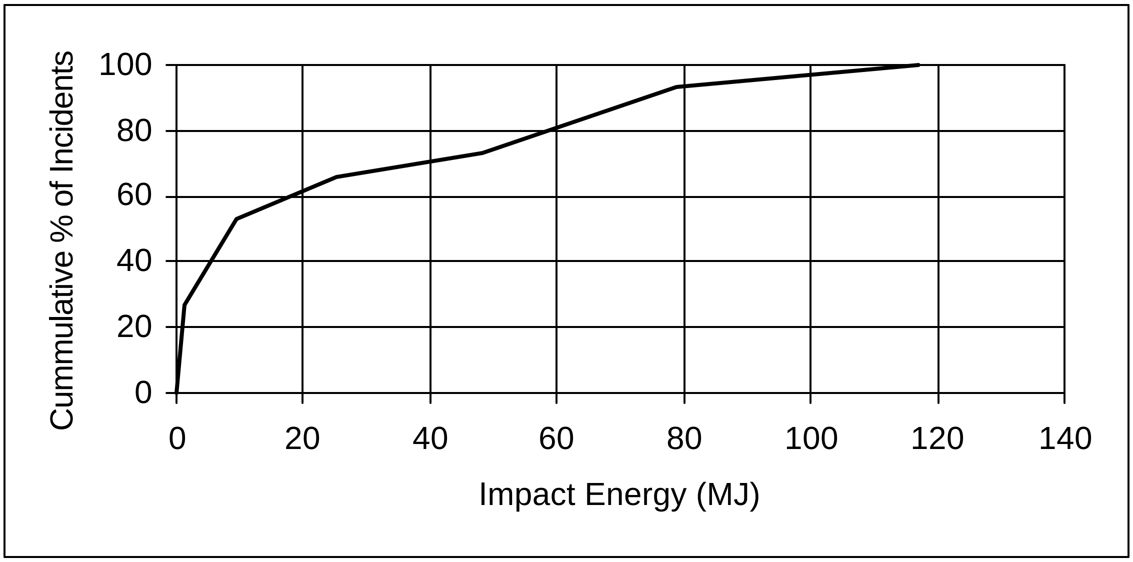


Figure 1.1-3 Probability Distribution of Impact Energy for Shuttle Tanker (Empty)



The resulting IIFs from the above approach are presented in the Fault Trees illustrated in Figures 1.1-4 to 1.1-6.

Figure 1.1-4 Fault Tree to Estimate Frequency of Collisions by Authorized Vessels (FPSO)

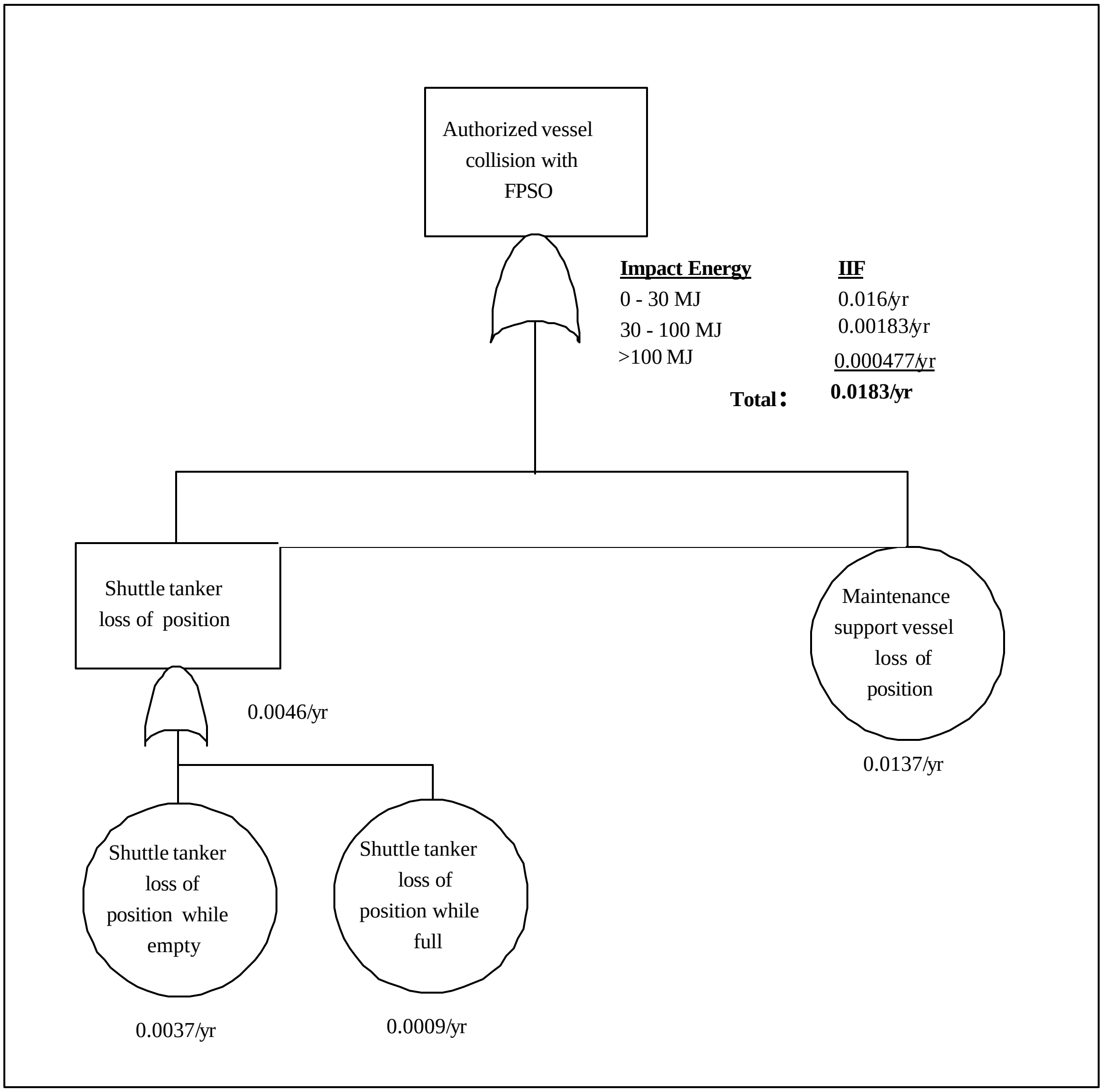


Figure 1.1-5 Fault Tree to Estimate Frequency of Collisions by Authorized Vessels (Semi-submersible)

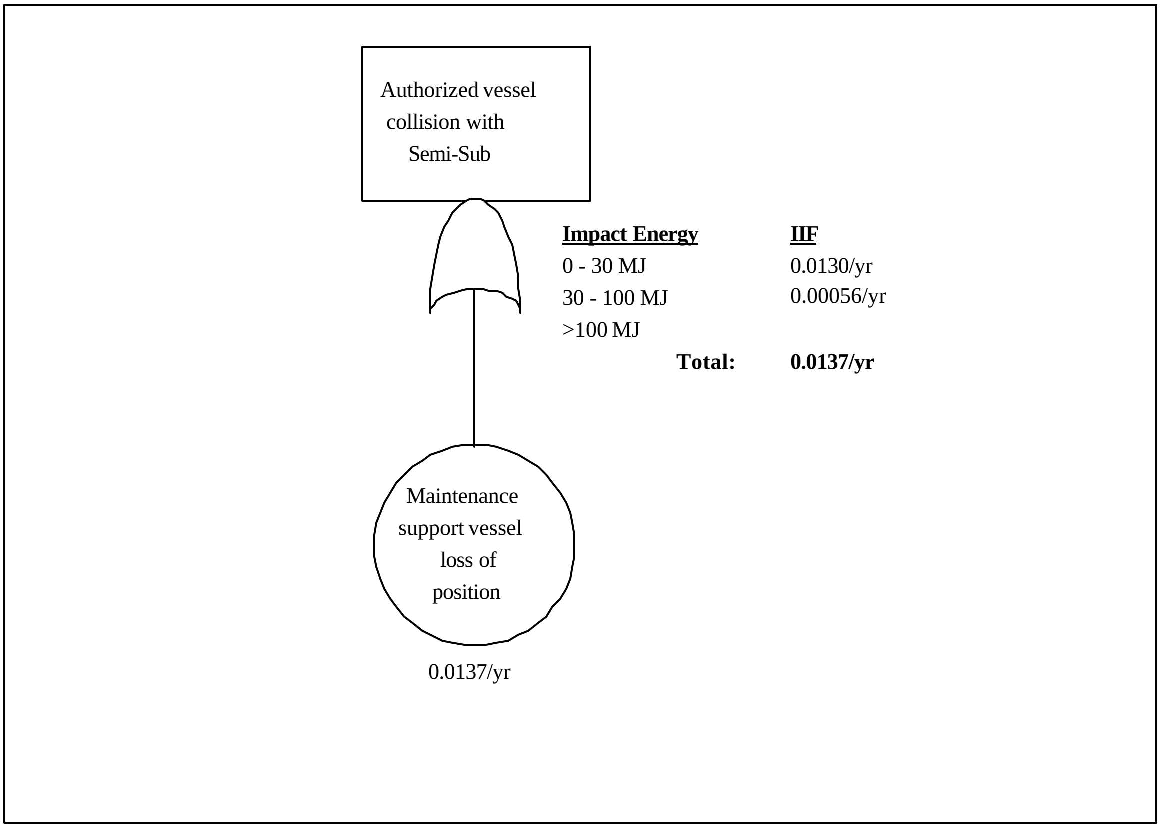
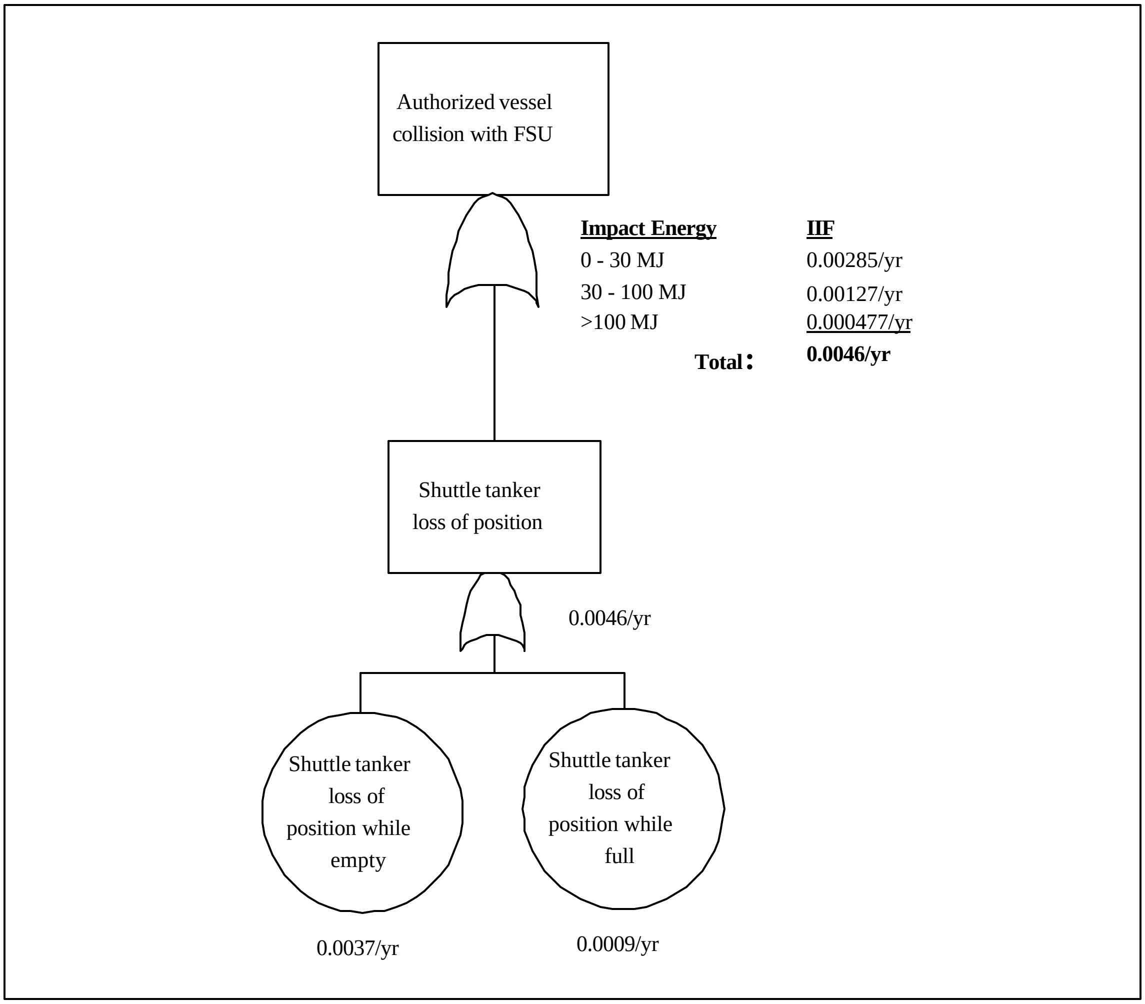


Figure 1.1-6 Fault Tree to Estimate Frequency of Collisions by Authorized Vessels (FSU)



1.2 Passing Vessels

Risks due to passing vessel collisions are highly dependent on the installation location. Installations in areas with heavily travelled shipping lanes (such as the North Sea) would expect greater risks from passing vessel collision than an area with relatively low ocean traffic (such as the Grand Banks). The most common types of non-oil related vessels encountered on the Grand Banks include tankers, container ships, bulk carriers, fishing vessels, and naval vessels. “Naval vessels cause relatively low risks of ship-[installation] collisions due to their high standards of operation, which makes errancy and breakdown relatively unlikely” [Ref. 2]. Therefore, the risks due to naval vessel collisions are excluded.

In considering a passing vessel collision, the vessel has to be on a collision course with the installation. Due to a lack of historical shipping lane information and traffic data for non-oil related vessels on the Grand Banks in relation to oil and gas operations, passing vessel frequencies can only be estimated approximately. A value of 0.00038/year has been recorded for the frequency of passing vessel collisions with fixed installations [Ref. 5]. This value is based on worldwide data, collected over 89,000 installation years, and is conservatively assumed for the White Rose analysis.

One of the main advantages of a floating installation, as opposed to a fixed facility, is the ability to move off-station, as a precautionary measure, in the event that an approaching vessel poses a threat of collision. Riser and mooring systems are designed for controlled and emergency releases. The controlled release includes measures to depressurize risers prior to disconnecting, whereas an emergency release may not.

The disconnection ability for the FPSO will be a highly reliable system, with extensive design effort devoted to ensuring a high level of availability-on-demand. It is assumed, therefore, that for the FPSO, FSU and Semi-Sub, the overall probability of disconnection failure is equal to 1 percent.

Once disconnected the facility must also move out of the path of any approaching ship (or iceberg) and this requires the availability of the thrusters (and power to the thrusters). There will be multiple thrusters, and partial manoeuvrability will be possibility even with only one or two thrusters available. However, even if the facility loses all ability to move under its own power there will still be the option of a support vessel towing the facility clear of any errant ship or iceberg. It can be concluded therefore that provided the facility can disconnect then it will be able to avoid a collision.

As with the analysis for authorized vessels, it is clear that the severity of damage that an installation would experience differs, depending on the impact energy of the collision. Passing vessels are generally larger than authorized vessels, with the possible exception of shuttle tankers, and in the case of powered impacts would generally be travelling at much higher speeds during impact. Sample vessel fleet data obtained from Maersk and Oceanex are illustrated in Table 1.2-1.

Table 1.2-1 Sample Vessel Data

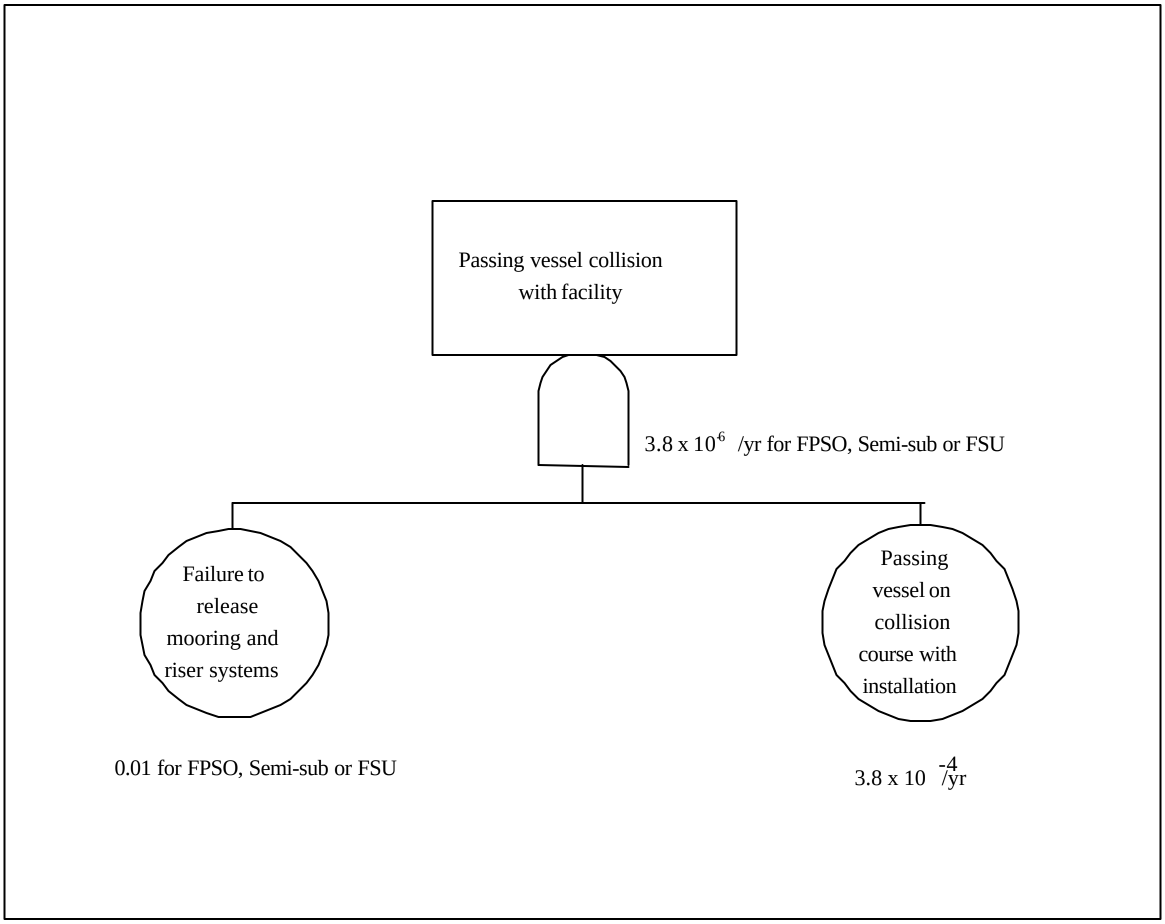
Company[1]	Vessel Type	Deadweight Tonnage (DWT)
Maersk	Crude Carrier	308,300
Maersk	Crude Carrier	299,700
Maersk	Crude Carrier	277,000
Maersk	Bulk Carrier	68,166
Oceanex	Container ship	21,849
Oceanex	Container ship	10,919
Oceanex	Container ship	14,597
[1] Maersk data are from Reference 6 and Oceanex data are from Reference 7.		

Considering a powered collision between the smallest of the above vessels (i.e., 10,919 DWT), at a speed of 12 kts (this particular vessel is listed with a speed of 18 kts), the calculated impact energy is greater than 200 MJ. Consequently, powered passing vessel collisions will conservatively be assumed to result in catastrophic failure of the installation.

It should be noted that a drifting vessel collision would cause considerably less damage than a powered collision. The Terra Nova Concept Safety Analysis [Ref. 1] demonstrates that drifting vessels contribute 10 percent of the frequency for all passing vessel collisions. Therefore, it is reasonable to assume a similar proportion for White Rose. Because this is such a small portion of the overall frequency, it is not justified to investigate this issue any further. Consequently, it is reasonable, but conservative, to assume that all passing vessel collisions (i.e., both powered and drifting) result in the loss of the installation.

The results of the above approach are presented in the Fault Tree illustrated in Figure 1.2-1.

Figure 1.2-1 Fault Tree to Estimate Frequency of Collisions by Passing Vessels



2 REFERENCES

1. Terra Nova Concept Safety Analysis, Magellan Engineering Consultants, 1996

2. A Guide to Quantitative Risk Assessment for Offshore Installations, CMPT Publication 99/100, 1999.

3. Personal Communication between David Randell and Captain Bill Morgan (Maersk), March 15th, 2000.

4. MCM Kometik company brochure.

5. Quantitative Risk Assessment Datasheet Directory, E&P Forum Report No. 11.8/250, 1996.

6. Maersk Website: www.mearsk.com

7. Oceanex Website: www.oceanex.com

APPENDIX E

Assessment of Iceberg Impact Frequencies

WHITE ROSE
DEVELOPMENT APPLICATION

APPENDIX E

ASSESSMENT OF ICEBERG IMPACT FREQUENCIES

SUBMITTED BY:

HUSKY OIL OPERATIONS LIMITED AS OPERATOR
SUITE 801, SCOTIA CENTRE
235 WATER STREET
ST. JOHN'S, NF, A1C 1B6
TEL: (709) 724-3900
FAX: (709) 724-3915

July 2000

TABLE OF CONTENTS

Page No.

LIST OF FIGURES

Page No.

LIST OF TABLES

Page No.

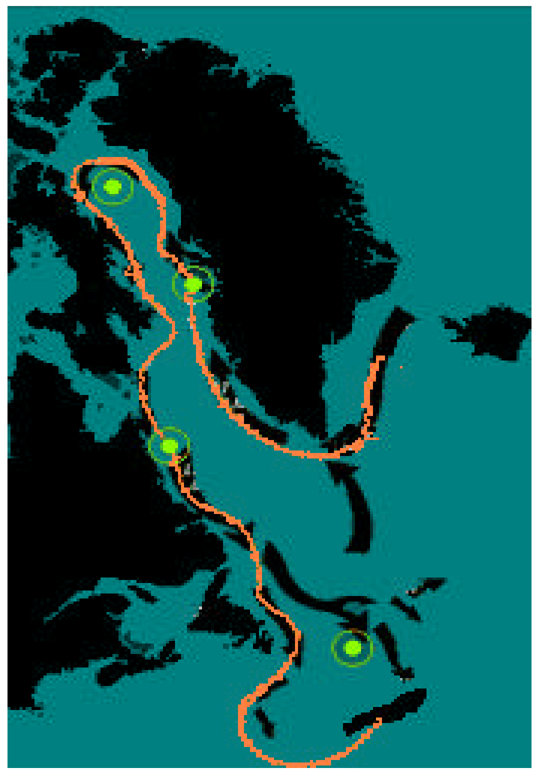
1 ASSESSMENT OF ICEBERG IMPACT FREQUENCIES

1.1 Introduction

The Husky Oil White Rose oilfield development site is located approximately 350 km east of Newfoundland on the Jean d'Arc Basin region of the Grand Banks. The Grand Banks is an area frequented by icebergs, and any offshore development plan must take into consideration the danger that icebergs, and sea ice, pose to any installation.

The majority of icebergs that are found on the Grand Banks originate from the 100 glaciers that are present on the West Coast of Greenland, while others originate from the east coast of Greenland or from Ellesmere Island. These icebergs are captured in pack ice and drift north as a result of West Greenland current where they are stopped due to the pack ice present in Baffin Bay.

Figure 1.1-1 Iceberg Circulation



Upon emerging from the edge of Baffin Bay these icebergs then travel southwards along the coast of Labrador as a result of the Labrador Current. They continue to travel southwards and upon reaching the Straight of Belle Isle where some icebergs drift directly southward to the north coast of Newfoundland, while others continue in a more southeasterly route to the Grand Banks.

Upon reaching the shallow and warmer waters of the Grand Banks some of the icebergs will ground, and eventually all will melt during the early summer months. Typical seasons for icebergs range from early April to the latter part of June and early July, however, icebergs have been seen on the Grand Banks during every calendar month of the year. A typical circulation pattern is shown in Figure 1.1-1.

The maximum number of icebergs observed on the Grand Banks occurred in 1984, when 2,202 icebergs were sighted passed 48° N while in 1966, there were no recorded iceberg sightings. The White Rose site is located on the edge of the Grand Banks, adjacent to the Labrador Current. As a result of this, the number of icebergs that pass through this area are higher than those for Hibernia and Terra Nova. Consequently, any installation located in this area will be more exposed to the risks associated with icebergs.

1.2 Data Sources

There were three major iceberg data sources specific to the Grand Banks of Newfoundland:

- PERD (Program on Energy Research and Development) Grand Banks Iceberg Database, Ref. [1].
- PAL (Provincial Airlines) Iceberg Data, Ref. [2].
- Terra Nova Concept Safety Analysis (CSA) and Terra Nova Detailed Development Plan – Environmental Impact Statement, Refs. [3] and [4].

The PERD Database was compiled by Fleet Technologies for the National Research Council in 1999. The database was a result of the compilation of several different sources of data. These being:

1. IIP (International Ice Patrol) – This data was very extensive and was recorded from 1960 to 1998
2. MEDS (Marine Environmental Data Services) – Industry compiled data gathered from well and drilling sites.
3. Isometrics (Isometrics Consulting Corp.) – Information compiled for the Terra Nova project between 1984 – 1990.
4. C-CORE (Center for Cold Ocean Research Engineering) – Small data set containing position and size.
5. Agra Earth and Environmental – Information gathered from the Hibernia platform for 1998.
6. CORETEC – Data gathered from a well site in 1985.
7. IMD (Institute for Marine Dynamics) – Historical data compiled by Brain Hill.

Fleet Technologies was responsible for compiling this data and refining it in order to produce a searchable database, which now contains nearly 170,000 entries.

PAL (Provincial Airlines) has been responsible for tracking icebergs and pack ice on the Grand Banks for several years, and thus has created their own iceberg database. The draft report presented to the White Rose project from PAL outlines the iceberg data that they have gathered. Along with using their own information, the report also cites several sources of information, including the PERD database.

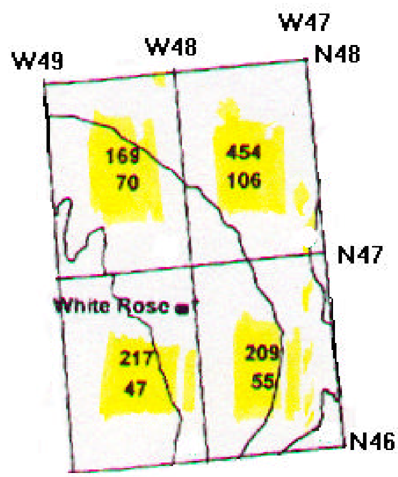
While some use was made of the iceberg analysis data specific to the Terra Nova and Hibernia development projects, this was of limited value for the White Rose project, where increased water depth and closer proximity to the Labrador current has to be taken into account.

Current data, specific to the White Rose site, was compiled by Ocean ltd. of St. John's. This is reported in Ref. [5] and the key data is also reproduced in Ref. [6]. This data was used to determine the drift rates and travelling speeds of any icebergs in the White Rose region.

1.3 Frequency of Icebergs At the White Rose Site

Part of the iceberg count data from the PAL database (of Ref. [2]) is shown in Figure 1.3-1.

Figure 1.3-1 White Rose Geographical Detail



The top number shown in each grid square represents the maximum number of icebergs sighted in this region since 1966. The bottom number represents the average number of icebergs sighted in this area. As can be seen from the picture, the White Rose site occupies the 1 degree grid square with an average iceberg count of 47 and a maximum number of 217. The maximum number was observed in 1990 with the majority of the sightings were from the Petro-Canada drilling semi-submersible, King's Cove A-26.

It can also be seen from this chart that the White Rose site sits in close proximity to three other grid squares. As such, the frequency of icebergs in these areas must also be taken into account. The upper right hand grid square represents an area with much deeper water than White Rose and is also located in the path of the Labrador current. Subsequently, a greater number of icebergs will frequent this area. It is anticipated that due to the wind current and water depth conditions, the majority of icebergs which will be observed at White Rose will originate from the area directly North of the White Rose Grid Square. As such, it is important that the number of icebergs which have been witnessed here are taken into account. Consequently, the average iceberg flux on the White Rose site will be taken to be 70, the average number seen for the square directly north of White Rose. While this provides for a conservative estimate, it is considered more reliable than any calculations completed using the maximum values.

1.4 Iceberg Size Distribution At the White Rose Site

Icebergs are generally classified by their estimated mass, however since proven mass determination techniques do not presently exist there is some discrepancy in the associated values. Along with the definitions of the size classifications, a breakdown of the percentage of each size is shown. These percentages are specific to the White Rose area and were taken from PAL (Table 1.4-1).

Table 1.4-1 Iceberg Size Classification

Size Classifications	
Category	**Estimated Mass (tonne)**
Growlers and Bergy Bits	< 10, 000
Small	< 100, 000
Medium	100, 000 to 1 million
Large	1 million to 10 million
Very Large	> 10 million

With the total iceberg flux now available, and using the iceberg size breakdown shown previously. A more in-depth model of the size distribution and frequency can now be defined specifically for the White Rose site (Figure 1.4-1).

Of the 70 (average) icebergs per year assumed for the White Rose site (Figure 1.4-2):

- 21.7 - Growlers or Bergy Bits
- 23.8– Small
- 17.5 – Medium
- 7 - Large.

Figure 1.4-1 Iceberg Distribution at White Rose

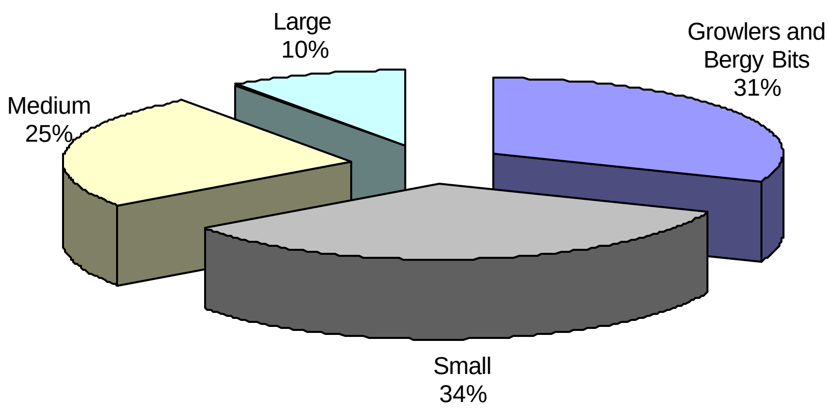
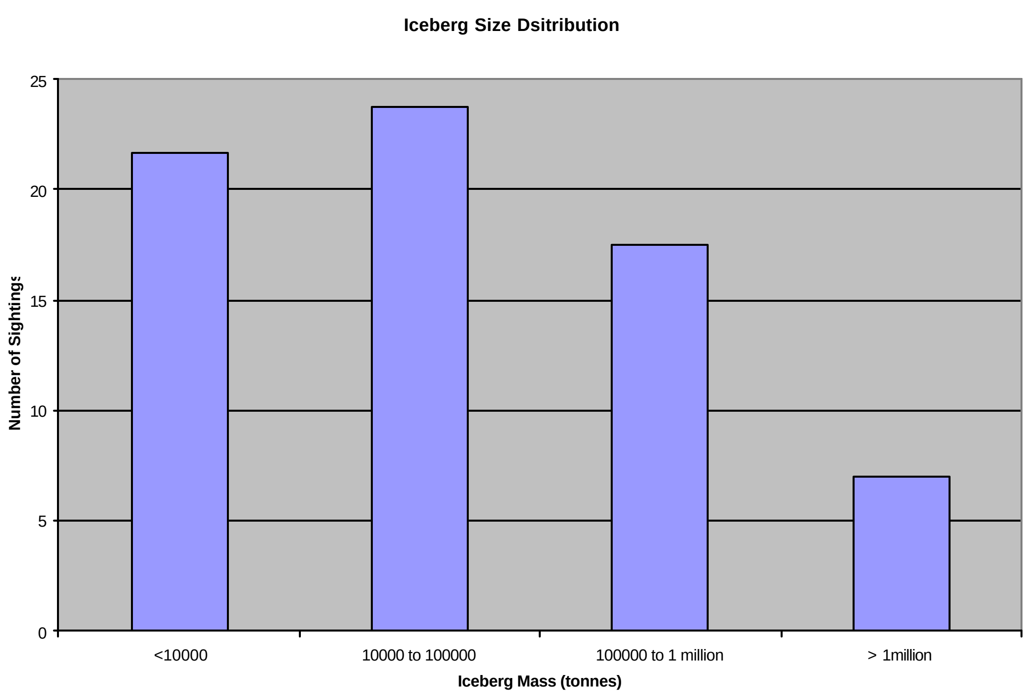


Figure 1.4-2 Iceberg Frequency at White Rose

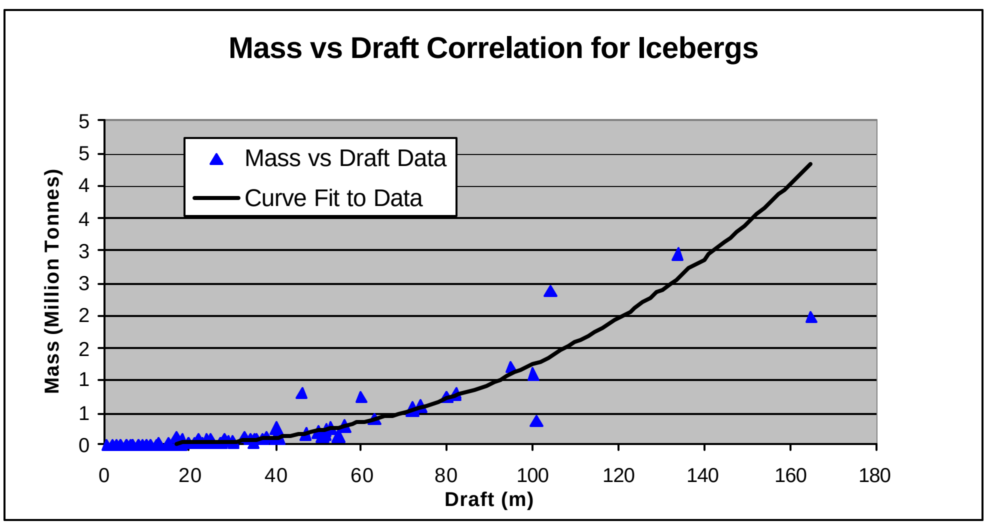


1.5 Iceberg Drafts

In order to determine the likelihood of iceberg scouring at the White Rose site a list of the observed mass and corresponding drafts was gathered from the PERD database, Ref. [1]. From this information a relationship between the mass of an iceberg and its draft was determined (see Figure 1.5-1). This relationship was used to estimate the range of iceberg sizes that would cause scour at the White Rose site. The maximum observed scour depth observed in the White Rose area is approximately 1.5 m, with an average scour depth observed to be 0.6 m (Ref. 2).

From this draft data set the associated mass could be found using the correlation established earlier. Thus a size classification of the icebergs could be determined and the frequency of the particular iceberg size. It was then shown that 3 percent of icebergs that may reach White Rose could be of significant draft to cause scouring. This corresponds with actual numbers from the observations of the White Rose site gathered during previous operations. The total data set of 248 icebergs in the White Rose area Ref [1] was subdivided using a 50-km radius area around the proposed White Rose location. This resulted in 102 observed icebergs of significant size. Of these reported icebergs, only three were reported to have sufficient drafts to cause scour. This data agrees with the 3 percent gathered using the mass-draft correlations.

Figure 1.5-1 Mass vs. Draft Correlation



1.6 Velocity Distribution

The ocean currents at the White Rose site vary significantly depending on season and water depth. Icebergs however only appear during the period from late February to Early July. Currents present at the upper water depths will influence the movement and speed of an iceberg. The effect of waves and wind may also effect icebergs however their influence is small compared to that of the current and has been ignored in this study.

The seasonal information for the current at the White Rose site are shown in Tables 1.6-1 and 1.6-2.

Table 1.6-1 Seasonal Current Speeds (Ref. [5])

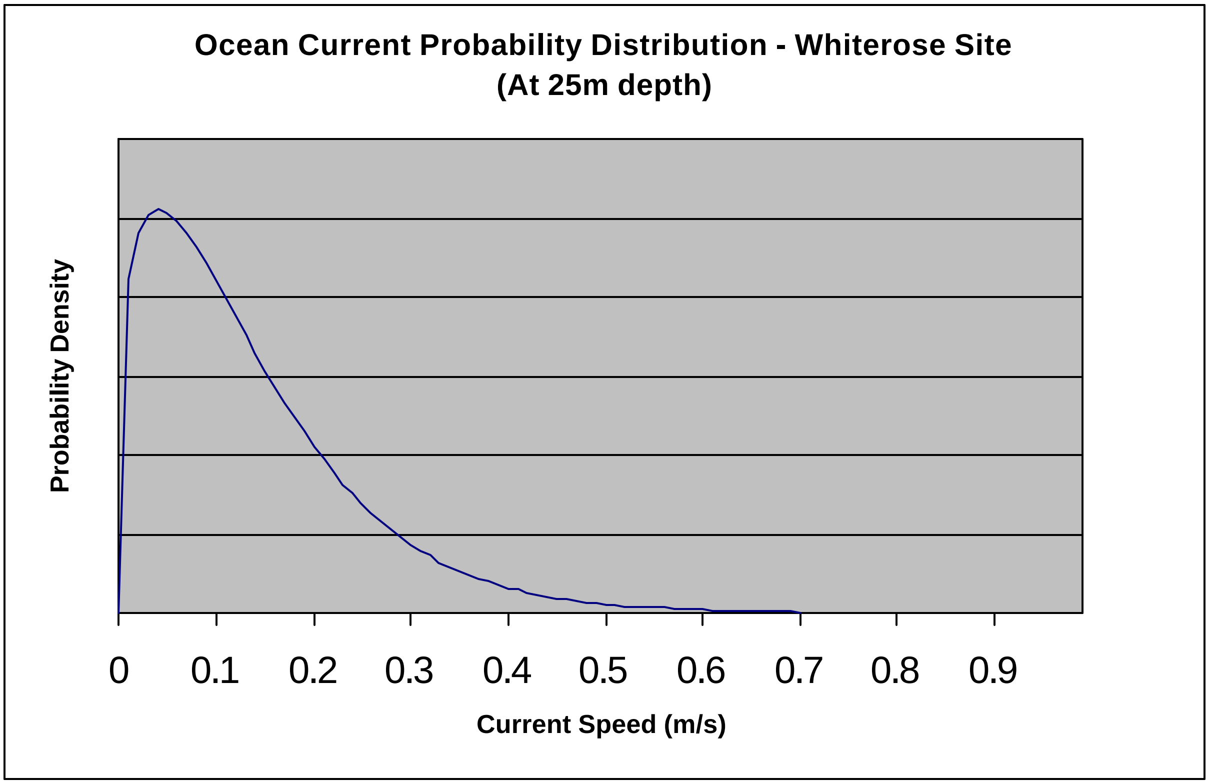
Depth	Season	Mean	Maximum
20m Below Surface	Fall (Sept/Oct/Nov)	0.20 m/s	0.90 m/s
	Winter (Dec/Jan/Feb)	0.12 m/s	0.40 m/s
	Spring (Mar/Apr/May)	0.10 m/s	0.46 m/s
	Summer (Jun/Jul/Aug)	0.11 m/s	0.52 m/s

Table 1.6-2 Estimated Current Velocities for Different Return Periods (Ref. [6])

Estimated Return Current Speeds			
Return Period	**1 year**	**10 year**	**100 year**
Current Speed (m/s) Mid Depth – 25m	0.60	0.76	0.95

From the return periods in Table 1.6-2, the probability distribution of current velocities was determined for the White Rose site (see Appendix 1). The resulting distribution I shown in Figure 1.6-1.

Figure 1.6-1 Probability Distribution of Current Speed at 25m Depth



The above distribution has been used, in combination with the mass distribution from Figure 1.4-2 to determine the distribution of likely kinetic energy values for incident icebergs. This is described further in Section 1.8.

1.7 Risk to Personnel

The main hazard to personnel will occur when the facility, whether a fixed or floating structure, is impacted by an iceberg. The Terra Nova FPSO has been designed to withstand the impact of a 100,000 t iceberg, and has the capability to move off station in the event that an iceberg of greater size threatens the platform.

Ice management systems have been established by both groups to ensure that any iceberg within radar range is tracked to determine its proper path. There are also frequent fly-overs which ensure that new icebergs are tracked as they proceed along the Grand Banks.

The extent of any impact damage is governed by the kinetic energy of the impacting body[1]. The kinetic energy is dependent on both the mass of an object, and on the velocity at which it is travelling. As discussed, both the mass of icebergs in the area and the speed with which they are travelling (i.e., the current speed) are both random variables. Consequently, the kinetic energy of any iceberg that may impact a facility will also be a random variable. The following section describes how the probability distribution of the kinetic energy of the icebergs can be estimated from the probability distribution of iceberg mass and the probability distribution of current speeds.

1.8 Kinetic Energy Analysis

A kinetic energy frequency table was generated which determined both the kinetic energy generated by the iceberg masses and current velocities, as well as the frequency of such combinations. The kinetic energy was calculated using:

$$KE = \frac{1}{2} MkV^2$$

Where:

- KE – Kinetic Energy
- M – mass of iceberg
- V – velocity of iceberg
- k – added mass coefficient (1.2)

The added mass coefficient is included to account for the entrained mass of water surrounding the iceberg. Typical values for ship collisions are 1.1 for head on impact, and 1.4 for broadside impact, Ref. [8]. The difference reflects the fact that a broadside drifting vessel will entrain a greater amount of water than a powered vessel proceeding normally. For the case of an iceberg impact the value of 1.2 has been assumed.

The frequency of a specific mass iceberg moving at a specific speed was calculated as:

Frequency of iceberg of specific mass and specific speed
*= Frequency of specific iceberg mass * Prob. of specific current speed.*

[1] More correctly, damage is governed by the amount of kinetic energy absorbed by the impacted facility. Glancing, oblique impacts mean that not all of the incident kinetic energy will be absorbed and damage will thus be less than it would be for full head-on impacts. This study conservatively ignores oblique impacts and assumes that 100 percent of incidents kinetic energy must be absorbed by the target (e.g., the FPSO).

The above frequency was determined for four separate mass values,

- 10,000 t (Growlers and Bergy Bits)
- 100,000 t (Small)
- 1 million t (Medium)
- 2 million t (Large).

And for a range of current values from zero to a maximum value of 1.0 m/s, in 0.1 m/s steps.

The associated frequency of iceberg masses was taken from the distribution shown in Figure 1.4-2 and the current distribution was taken from the distribution shown in Figure 1.6-1. The results of this analysis are shown in Table 1.8-1.

Table 1.8-1 Frequency of Occurrence of Various Kinetic Energy Levels

		Iceberg Mass (MTonnes)	0.01	0.1	1	2
		Mass + Added Mass	0.012	0.12	1.2	2.4
		Frequency (per year)	21.7	23.8	17.5	7
Current Speed (m/s)	Probability (%)					
0.1	0.465813	KE (MJ)	6.00E-02	6.00E-01	6.00E+00	1.20E+01
		Frequency	1.01E+01	1.11E+01	8.15E+00	3.26E+00
0.2	0.310373	KE (MJ)	2.40E-01	2.40E+00	2.40E+01	4.80E+01
		Frequency	6.74E+00	7.39E+00	5.43E+00	2.17E+00
0.3	0.140942	KE (MJ)	5.40E-01	5.40E+00	5.40E+01	1.08E+02
		Frequency	3.06E+00	3.35E+00	2.47E+00	9.87E-01
0.4	0.054824	KE (MJ)	9.60E-01	9.60E+00	9.60E+01	1.92E+02
		Frequency	1.19E+00	1.30E+00	9.59E-01	3.84E-01
0.5	0.019216	KE (MJ)	1.50E+00	1.50E+01	1.50E+02	3.00E+02
		Frequency	4.17E-01	4.57E-01	3.36E-01	1.35E-01
0.6	0.006215	KE (MJ)	2.16E+00	2.16E+01	2.16E+02	4.32E+02
		Frequency	1.35E-01	1.48E-01	1.09E-01	4.35E-02
0.7	0.001882	KE (MJ)	2.94E+00	2.94E+01	2.94E+02	5.88E+02
		Frequency	4.08E-02	4.48E-02	3.29E-02	1.32E-02
0.8	0.000538	KE (MJ)	3.84E+00	3.84E+01	3.84E+02	7.68E+02
		Frequency	1.17E-02	1.28E-02	9.42E-03	3.77E-03
0.9	0.000146	KE (MJ)	4.86E+00	4.86E+01	4.86E+02	9.72E+02
		Frequency	3.18E-03	3.49E-03	2.56E-03	1.03E-03
1	0.000038	KE (MJ)	6.00E+00	6.00E+01	6.00E+02	1.20E+03
		Frequency	8.27E-04	9.07E-04	6.67E-04	2.67E-04

To summarize the results, the impact energies in Table 1.8-1 have been sorted into five categories:

- 0 to 30 MJ
- 30 to 100 MJ
- 100 to 200 MJ
- 200 to 600 MJ
- Greater than 600 MJ.

The frequency of icebergs in each of the above kinetic energy bands and the associated percentage of the total frequency are summarized in the table below.

Table 1.8-2 Summary Table of Kinetic Energies

Kinetic Energy (MJ)	**0 to 30**	**30 to 100**	**100 to 200**	**200 to 450**	**> 450**	**Total**
Relative Frequency	89.0385%	8.0226%	2.4381%	0.4702%	0.0307%	100%
Actual Frequency	62.3269	5.6158	1.7067	0.3291	0.0215	70

1.9 Frequency of Iceberg Impact

The frequency of iceberg impact has been calculated using the following formulae:

*Frequency of iceberg impact = Total flux in 1 degree square * Prob. that trajectory could be on collision course * Probability that facility will fail to move aside*

As discussed earlier the average iceberg flux at White Rose site has been taken to be 70 icebergs per year.

The probability of an iceberg being on a collision course with the structure was determined as follows:

Prob. That a trajectory could be on Collision Course

$$= \frac{\textit{(Project Width of Target + Average Waterline Length of Iceberg)}}{\textit{Total Width of White Rose grid square}}$$

The proposed FPSO for the White Rose site is expected to be approximately 245 m in length. The FSU will also be a similar length. The semi-submersible will have projected widths of approximately 100 m. The maximum projected width, and thus highest chance of impact, for the FPSO and FSU, will occur when the iceberg path is perpendicular to the vessel orientation, exposing the entire length of the vessel. However, the vessel can be assumed to be randomly orientated with respect to the iceberg trajectory and in many orientations the projected width will be significantly less than the vessel length. It can be shown that the average projected width of the vessel is approximately two-thirds of its total length, assuming that the orientation is equally likely to be in any direction.

The average waterline length for an iceberg was assumed to 75 m (from Ref. [2]). The width of the 1 degree grid square at the White Rose latitude is 40 nautical miles (74 km).

If an iceberg is on a collision course the ice management vessels will attempt to deflect the iceberg by either towing, water jetting or pushing the iceberg to alter its course. As several hours warning will be available and only a moderate deflection is required to avoid a collision then this strategy is quite feasible. Tests have shown that there is an 86 percent success rate for such attempts. Thus, only 14 percent of the icebergs that are on a potential collision course will evade the ice management vessels and actually reach the site of the FPSO.

The probability that the target will fail to move aside in time is addressed in Appendix D as part of the ship impact risk assessment.

Probability that the facility will fail to move away (ship collision) = 0.01

The above values however were based on ship impact risk where only 1 hour or less may be available as warning time in order to effect a disconnection. The warning time for potential iceberg impact will be significantly greater, thus allowing more time to disconnect in the event of any problems. For this reason the above probability has been halved for use in the iceberg risk analysis (i.e., probability that the facility will fail to move away (iceberg collision) = 0.005).

The calculation of impact frequencies for the FPSO and semi-submersible and FSU are summarized in Table 1.9-1.

Table 1.9-1 Iceberg Impact Frequencies for Various Facilities

Total Flux in 1 degree White Rose Site (60 nautical miles)	70 icebergs per year entering grid square		
Total Width of White Rose 1 degree site (60 nautical miles)	74,080 m		
	FPSO	**FSU**	**Semi-submersible**
Average Projected Width of Target (m)	163	163	100
Iceberg Width (m)	75	75	75
Probability that Trajectory will be on Collision Course - projected width of target/total width of White Rose	0.00322	0.00322	0.00236
Probability that Ice Management Vessels Fail	0.14	0.14	0.14
Probability that Facility will Fail to Move Aside	0.005	0.005	0.005
Annual Frequency of Iceberg Impact	0.00016	0.00016	0.00012
Annual Frequency in 30 to 100 MJ Category	1.28E-05	1.28E-05	9.63E-06
Annual Frequency in >100 MJ Category	4.70E-06	4.70E-06	3.53E-06

It should be noted that Table 1.9-1 gives the total impact frequency of all icebergs. In practice, a significant proportion of these impacts will cause little or no damage. Eighty-one percent of icebergs will have less than 15MJ of kinetic energy (Table 1.8-2). The floating installations will be designed to withstand at least this level of impact energy. Thus the frequency of iceberg impacts that are capable of causing damage will be no more than 19 percent of the values in Table 1.9-1. The frequency of iceberg impacts in each kinetic energy band of Table 1.8-2 will be used as input initiating frequencies for event trees modelling of the consequences. More severe consequences will be applied to the event trees in the case of the higher impact kinetic energies. Note that the consequences of iceberg impact will be primarily environmental, since the warning time for iceberg impact will be sufficient to allow a full precautionary evacuation to have been completed.

It should also be noted that the analysis does not take into account the possibility of ice management vessels successfully deflecting any iceberg that may be on collision course. The effect of the ice management program as a means of reducing this risk will be addressed through sensitivity studies in the main CSA report.

2 SCOUR DAMAGE TO FLOWLINES

The average frequency of groundings per year is estimated in Ref. [8] to be 0.25 groundings per 100 km² per year ($0.25x10^{-8} m^{-2} yr^{-1}$) at the White Rose site. The frequency with which scours are likely to cross intra-field pipelines depends both on this grounding frequency and on the chance that any given grounding will produce a scour that is long enough to reach the pipe. Scour lengths have a large degree of variation. Ref. [2] indicates that the average scour length is 566 m but this has a standard deviation of 623 m. The maximum observed scour is 3,370 m.

An exact calculation of the frequency of scour/pipe crossings is complex due to the number of random variables involved (variable scour length combined with variable scour orientation). However, the following simplified approach gives a first approximation to the required frequency. Assume that all scours that originate within a band extending 283 m (half the average scour length) either side of the pipeline will result in a scour that crosses the pipe route. Further assume that all scours originating outside that band will not cross the pipe route. The frequency of scour/pipe crossings will thus be $0.25x10^{-8}x566=1.415x10^{-6}$/yr/m pipe. For example, a 10-km pipe[2] will be subject to $1.415x10^{-2}$ scour crossings per year.

The proportion of the above scour crossings that will cause damage to the pipe will depend on the depth of cover above the top of the pipe in its trench. Ref. [2] states that the average scour depth is 0.6 m with a standard deviation of 0.3 m. Thus, for various depths of cover above the top of the pipes, it can be shown that:

Depth of Cover Above Top of Pipe (m)	Proportion of Scour Crossings that will Damage the Pipe (%)
0	100
0.3	84
0.6	50
0.9	16
1.2	2
1.5	0.135

Thus the value of $1.415x10^{-2}$ scour crossings per year for a 10km pipeline would equate to $2.26x10^{-3}$ ($1.415x10^{-2}$x16%) damage incidents per year if the pipe was buried with 0.9 m of cover above it.

Currently, it is intended to bury the intra-field pipelines for thermal insulation. In this case, consideration will be given to providing enough cover to minimize the risk of scour damage if soil conditions permit.

[2] or bundle of pipes in the same trench

3 ICE IMPACT ON SPIDER BUOY AND ANCHORING SYSTEM

There is potential for damage resulting from iceberg collision with the spider buoy following disconnection by the FPSO to avoid iceberg impact. This scenario poses no risk to personnel since the FPSO has disconnected, however, there is a slight environmental risk that could occur.

The risk of riser releases is considered to be insignificant on the basis that (a) provided isolation works, there is only slightly more than 50 barrels available in any one riser to spill and (b) the frequency of large leaks from the riser large enough to spill the majority of the isolated riser content would be insignificant. Small to medium-sized riser leaks may be more frequent, however, these would be unlikely to spill more than a few barrels and could therefore be discounted in the Concept Safety Analysis. The scenario of icebergs hitting the spider buoy, however, could potentially cause a large enough breach to release the whole of the content of the isolated riser(s), but only the bigger icebergs would be likely to cause such a breach. The high degree of flexibility of the spider buoy, designed to move significant distances as the FPSO moves around, will most likely ensure that most icebergs ride over the buoy or deflect it to one side, with little or no damage. In addition, ice management vessels, even though they may have failed to intervene sufficiently to prevent a disconnection being necessary, will still continue to try and avoid a spider buoy impact even after the FPSO is safely out of the way. This should be a much easier task for the ice management vessels, as they need only deflect the iceberg a few tens of metres to avoid a direct hit on the spider buoy. If such a situation were to occur, lines would also be flushed with water to minimize potential impact. Therefore, the risk associated with an iceberg impact on the spider bouy and riser is expected to be minimal.

It is recommended that at detailed design stage this potential should be reviewed further.

4 SUMMARY AND CONCLUSIONS

A review has been carried out of available data on iceberg frequencies, masses, velocities and drafts in the vicinity of the proposed White Rose facility.

An average of 70 icebergs per year in a 1 degree grid square, has been identified as the frequency that should be used for risk assessment purposes.

The probability distribution of masses has been combined with the probability distribution of velocities to generate a probability distribution of kinetic energies. It has been shown that 81 percent of all icebergs will be of insufficient kinetic energy to cause any damage in the event of an impact.

Annual impact frequencies have been estimated for each of the main design options. These are:

Facility	Impact Frequency
FPSO	0.00016
Semi-submersible	0.00012

The frequencies are total impact frequencies and as already mentioned, 81 percent of these impact will be of insufficient energy to cause damage.

The risk of iceberg impact is primarily an environmental risk, since it is likely that there will be sufficient warning time for an orderly precautionary evacuation to take place.

The risk of scour damage to intra-field flowlines has been assessed. It is concluded that the annual frequency of scour damage to flowlines will be 1.415×10^{-2} incidents per year (for a 10-km pipe) assuming the pipe has no protection by being buried. This risk will halve if 0.6 m of cover is provided by burying the pipe and will further reduce to 2.26×10^{-3} incidents per year if 0.9 m of cover is provided. These frequencies must be pro-rated to reflect the actual length of pipelines that are installed.

5 REFERENCES

1. PERD (Program on Energy Research and Development) Grand Banks Iceberg Database

2. PAL (Provincial Airlines) Iceberg Data

3. Terra Nova Concept Safety Analysis (CSA)

4. Terra Nova Detailed Development Plan – Environmental Impact Statement

5. Oceans Ltd.

6. Husky Oil Operations Ltd., "White Rose Project Description", March 17, 2000.

7. M Granger Morgan and Max Henrion. "Uncertainty - A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis". Cambridge University Press, 1990.

8. D'Apollonia, S. J. and Lewis, C.F.M., 1986. Numerical model for calculating longer-term spatial distribution and mean frequency of iceberg-grounding events. In: Scour and Seabed Engineering, Canada Environmental Sciences Research Funds. Report No. 49: 221-232

Addendum to Appendix E
Probability Distribution
for White Rose Current Data

Ref. [6] gave the following current velocities for 1-year, 10-year and 100-year return periods (Table A1.1-1):

Table A1.1-1 Estimated Current Velocities for Different Return Periods

Estimated Return Current Speeds			
Return Period	**1 year**	**10 year**	**100 year**
Current Speed (m/s) Mid Depth – 25m	0.60	0.76	0.95

On any given day:

The probability of exceeding the 1-yr return period current is (1-1/365)=0.99726
The probability of exceeding the 10-yr return period current is (1-1/3650)=0.999726
The probability of exceeding the 100-yr return period current is (1-1/36500)=0.9999726

This gives three points on a probability distribution; (0.6 m/s, 0.99726), (0.76 m/s, 0.999726), (0.95 m/s, 0.9999726). Through these points it is possible to fit a probability distribution. The Weibull distribution has been used for this analysis and the fit has been achieved using the method described in Ref. [7]. The resulting probability distribution is:

$$\mathbf{F(v) = 1 - e^{[-(v/c)^k]}}$$

Where 'F(v)' is the cumulative distribution of current velocity 'v'.

'c' and 'k' are the parameters of the distribution which were determined to be:
$c = 0.145$ and $k = 1.2555$

The probability density form of the above distribution function is shown in Figure 1.6-1.

APPENDIX F

Event Tree Escalation and Evacuation Explosion Fatalities for FPSO and Semi-Submersible Options

Table F.1-1: Event Tree Escalation and Evacuation Explosion Fatalities for FPSO

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Turret	• Above Sea Production Risers • Above Sea Gas Injection Risers • Production Flowlines/ Manifold • Test Flowlines/Manifold • Gas Injection Flowlines/ Manifold • Gas Injection Wells (Deck)	0.2-0.8	Turret Partitions (Bulkheads) separating Turret and Utilities from Compression & Flare Areas.	1.13	
		0.8-2	Turret Partitions separating Turret and Utilities from adjacent Compression & Flare Areas. Compression Area Partition separating Flash Gas Area from Compression Area.	2.955 + 0.53 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (4.44 + 2.955)) Immediate fatalities (4.44) obtained from Table 6.2-13.
		> 2	Turret Partitions separating Turret and Utilities from adjacent Compression & Flare Areas. Compression Partition separating Flash Gas Area from Compression Area.	2.955 + 2.63 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (4.44 + 2.955))
Separation	• 1st Stage Separator • Test Separator • 2nd Stage Separator	0.2-0.8	Separation Blast Wall separating Separation from Flash Gas Area. Separation Partition separating Separation from Utilities Area.	1.41 (0.5 x 2.82)	From rule set, there are no fatalities to adjacent area if separated by blast wall.
		0.8-2	Separation Blast Wall separating Separation from Flash Gas Area. Separation Partition separating Separation from Utilities Area. Utilities Partition separating Utilities from Power Generation Area.	4.76 + 0.54 (Evacuation Fatalities)	Evac. Fatals = 0.01 x (60 – (1.62 + 4.76)) Immediate fatalities (1.62) obtained from Table 6.2-13.
		> 2	Separation Blast Wall separating Separation from Flash Gas Area. Separation Partition separating Separation from Utilities Area. Utilities Partition separating Utilities from Power Generation Area. Flash Gas Partition separating Flash Gas Area from Compression Area.	6.17 + 2.61 (Evacuation Fatalities)	Evac. Fatals = 0.05 x (60 – (1.62 + 6.17))

Table F.1-1: Event Tree Escalation and Evacuation Explosion Fatalities for FPSO

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Flash Gas Area	• 1st Stage Flash Gas Compression • 2nd Stage Flash Gas Compression • 2nd Stage Flash Gas Discharge Scrubber	0.2-0.8	Flash Gas Blast Wall separating Separation from Flash Gas Area. Flash Gas Partition separating Flash Gas Area from Gas Compression Area.	0.71 (0.5 x 1.41)	From rule set, there are no fatalities to adjacent area if separated by blast wall.
		0.8-2	Flash Gas Blast Wall separating Separation from Flash Gas Area. Flash Gas Partition separating Flash Gas Area from Gas Compression Area. Compression Partition separating Compression Area from Turret Utilities Area.	3.84 + 0.55 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (1.41 + 3.84))
		> 2	Flash Gas Blast Wall separating Separation from Flash Gas Area. Flash Gas Partition separating Flash Gas Area from Gas Compression Area. Compression Partition separating Compression Area from Turret Utilities Area. Separation Partition separating Separation Area from Utilities Area.	6.06 + 2.63 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (1.41 + 6.06))
Gas Compression Area	• 1st Stage Gas Injection Compression • Glycol Treatment • 2nd Stage Gas Injection Compression	0.2-0.8	Gas Compression Partitions separating Gas Compression Area from Flash Gas Area and Turret Utilities.	2.33	
		0.8-2	Gas Compression Partitions separating Gas Compression Area from Flash Gas Area and Turret Utilities. Turret Utilities Partition separating Turret Utilities Area	5.25 + 0.53 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (1.41 + 5.25))

Table F.1-1: Event Tree Escalation and Evacuation Explosion Fatalities for FPSO

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
			from Turret Area.		
Gas Compression Area (Contd.)		> 2	Gas Compression Partitions separating Gas Compression Area from Flash Gas Area and Turret Utilities. Turret Utilities Partition separating Turret Utilities Area from Turret Area. Flash Gas Blast Wall separating Flash Gas Area and Separation Area.	6.06 + 2.63 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (1.41 + 6.06))
Utilities	• Fuel Gas System	0.2-0.8	Utilities Partitions separating Utilities Area from Power Generation Area and Separation Area.	2.04	
		0.8-2	Utilities Partitions separating Utilities Area from Power Generation Area and Separation Area. Power Generation Partition separating Power Generation Area from Galley Laydown Area.	4.08 + 0.53 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (2.82 + 4.08)) Immediate fatalities (2.82) obtained from Table 6.2-14.
		> 2	Utilities Partitions separating Utilities Area from Power Generation Area and Separation Area. Power Generation Partition separating Power Generation Area from Galley Laydown Area. Separation blast wall separating Separation Area from Flash Gas Area.	4.79 + 2.62 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (2.82 + 4.79))
Flare and Vent Area	• Flare and Vent System	0.2-0.8	Flare Partition separating Flare Area from Turret Area.	0.6	
		0.8-2	Flare Partition separating Flare Area from Turret Area. Turret Partition separating Turret Area from Turret Utilities Area.	2.82 + 0.56 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (0.84 + 2.82)) Immediate fatalities (0.84) obtained from Table 6.2-14.

Table F.1-1: Event Tree Escalation and Evacuation Explosion Fatalities for FPSO

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
		> 2	Flare Partition separating Flare Area from Turret Area. Turret Partition separating Turret Area from Turret Utilities Area.	2.82 + 2.82 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (0.84 + 2.82))
Main Power Generators	• Main Power Generators	0.2-0.8	Main Power Generator Partitions separating Main Power Generator Area from Galley Laydown Area and Utilities Area.	1.41	
		0.8-2	Main Power Generator Partitions separating Main Power Generator Area from Galley Laydown Area and Utilities Area. Utilities Partition separating Utilities Area from Separation Area.	3.63 + 0.54 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (2.46 + 3.63))
		> 2	Main Power Generator Partitions separating Main Power Generator Area from Galley Laydown Area and Utilities Area. Utilities Partition separating Utilities Area from Separation Area. Accommodation blast wall separating accommodation from Galley Laydown Area.	26.1 + 1.57 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (26.1 + 2.46))

Table F.1-2: Event Tree Escalation and Evacuation Explosion Fatalities for Semi-Submersible

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Riser Handling Area	• Above Sea Production Risers	0.2-0.8	Riser Handling Partition separating Riser Handling Area from Utilities Area	1.02	
	• Above Sea Gas Injection Risers • Production Flowlines/ Manifold • Test Flowlines/Manifold • Gas Injection Flowlines/ Manifold • Gas Injection Wells (Deck)	0.8-2	Riser Handling Partition separating Riser Handling Area from Utilities Area Utilities Area Partition separating Utilities Area from Workshops Area. Deck Plating below Gas Compression, Flare and Process (Separation) Areas.	4.82 + 0.54 (Evacuation Fatalities).	Esc. Fatals = 2.04 + (0.5 x 3.3) + (0.25x(2.04+0.84+1.62)) Evac. Fatals = 0.01 x (60 – (0.84 + 4.82))
		> 2	Riser Handling Partition separating Riser Handling Area from Utilities Area Utilities Area Partition separating Utilities Area from Workshops Area. Deck Plating below Gas Compression, Flare and Process (Separation) Areas.	5.94 + 2.67 (Evacuation Fatalities).	Esc. Fatals = 2.04 + (0.5 x 3.3) + (0.5x(2.04+0.84+1.62)) Evac. Fatals = 0.05 x (60 – (0.84 + 5.94))
Separation	• 1st Stage Separator • Test Separator • 2nd Stage Separator	0.2-0.8	Separation Partitions separating Separation from Gas Compression, Flare, Power Generation and Water Injection Areas.	3.48	
		0.8-2	Separation Partitions separating Separation from Gas Compression, Flare, Power Generation and Water Injection Areas. Deck Plating above Utilities and Workshops.	8.3 + 0.51 (Evacuation Fatalities)	Evac. Fatals = 0.01 x (60 – (1.62 + 8.3))

Table F.1-2: Event Tree Escalation and Evacuation Explosion Fatalities for Semi-Submersible

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Separation (Contd.)		> 2	Separation Partitions separating Separation from Gas Compression, Flare, Power Generation and Water Injection Areas. Deck Plating above Utilities and Workshops. Accommodation Blast Wall separating accommodation from Power Generation and Water Injection Areas.	22.4 + 1.8 (Evacuation Fatalities)	Esc. Fatals =0.84 + 2.04 + 1.62 + 2.46 + (0.5 x 25.5) + (0.5 x (2.04 + 3.3)) Evac. Fatals = 0.05 x (60 – (22.4 + 1.62))
Gas Compression Area (inc. Flash Gas)	• 1st Stage Flash Gas Compression • 2nd Stage Flash Gas Compression • 2nd Stage Flash Gas Discharge Scrubber • 1st Stage Gas Injection Compression • Glycol Treatment • 2nd Stage Gas Injection Compression	0.2-0.8	Gas Compression Partition separating Gas Compression from Flare Area. Gas Compression Partition separating Gas Compression from Process (Separator) Area.	1.23	
		0.8-2	Gas Compression Partition separating Gas Compression from Flare Area. Gas Compression Partition separating Gas Compression from Process (Separator) Area. Process (Separator) Partition separating Process (Separator) from Power Generation and Water Injection Areas. Deck Plating above Riser Handling and Utilities Areas.	5.22 + 0.53 (Evacuation Fatalities).	Esc. Fatals =0.84 + 1.62 + (0.5 x (2.46 + 1.62)) + (0.25 x (0.84 + 2.04)) Evac. Fatals = 0.01 x (60 – (2.04 + 5.22))

Table F.1-2: Event Tree Escalation and Evacuation Explosion Fatalities for Semi-Submersible

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Gas Compression Area (Contd.)		> 2	Gas Compression Partition separating Gas Compression from Flare Area. Gas Compression Partition separating Gas Compression from Process (Separator) Area. Process (Separator) Partition separating Process (Separator) from Power Generation and Water Injection Areas. Deck Plating above Riser Handling and Utilities Areas.	5.94 + 2.6 (Evacuation Fatalities).	Esc. Fatals =0.84 + 1.62 + (0.5 x (2.46 + 1.62)) + (0.5 x (0.84 + 2.04)) Evac. Fatals = 0.05 x (60 – (2.04 + 5.94))
Utilities	• Fuel Gas System	0.2-0.8	Utilities Partitions separating Utilities Area from Riser Handling Area and Workshops.	2.07	
		0.8-2	Utilities Partitions separating Utilities Area from Riser Handling Area and Workshops. Deck Plating below Gas Compression, Flare and Process (Separator) Area.	5.27 + 0.53 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (2.04 + 5.27))
		> 2	Utilities Partitions separating Utilities Area from Riser Handling Area and Workshops. Accommodation blast wall separating accommodation from Workshops. Deck Plating below Gas Compression, Flare and Process (Separator) Area.	16.26 + 2.09 (Evacuation Fatalities).	Esc. Fatals =0.84 + 3.3 + (0.5 x 19.74)) + (0.5 x (0.84 + 2.04 + 1.62)) Evac. Fatals = 0.05 x (60 – (2.04 + 16.26))
Flare and Vent Area	• Flare and Vent System	0.2-0.8	Flare Partition separating Flare Area from Gas Compression and Process (Separator) Area.	1.83	

Table F.1-2: Event Tree Escalation and Evacuation Explosion Fatalities for Semi-Submersible

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
Flare and Vent Area (Contd.)		0.8-2	Flare Partition separating Flare Area from Gas Compression and Process (Separator) Area. Process (Separator) Partition separating Process (Separator) from Power Generation. Deck Plating above Riser Handling and Utilities Areas.	5.61 + 0.54 (Evacuation Fatalities).	Evac. Fatals = 0.01 x (60 – (0.84 + 5.61))
		> 2	Flare Partition separating Flare Area from Gas Compression and Process (Separator) Area. Process (Separator) Partition separating Process (Separator) from Power Generation. Deck Plating above Riser Handling and Utilities Areas.	6.33 + 2.64 (Evacuation Fatalities).	Evac. Fatals = 0.05 x (60 – (0.84 + 6.33))
Main Power Generators	• Main Power Generators	0.2-0.8	Main Power Generator Partitions separating Main Power Generator Area from Water Injection Area and Process (Separator) Area.	1.62	
		0.8-2	Main Power Generator Partitions separating Main Power Generator Area from Water Injection Area and Process (Separator) Area. Process (Separator) Partition separating Process (Separator) Area from Gas Compression and Flare Area. Accommodation blast wall separating	23.19 + 0.34 (Evacuation Fatalities).	Esc. Fatals =1.62 + 1.62 + (0.5 x (2.04 + 0.84 + 25.5)) + (0.25 x (3.3 + 19.74)) Evac. Fatals = 0.01 x (60 – (2.46 + 23.19))

Table F.1-2: Event Tree Escalation and Evacuation Explosion Fatalities for Semi-Submersible

Explosion Location	Inventories	Overpressure Range (Bar)	Area Impairment	Escalation & Evacuation Fatalities (via Rule Set)	Comment
			accommodation from Power Generation and Water Injection. Deck Plating above Workshops and Living Quarters.		
Main Power Generators (Contd.)		> 2	Main Power Generator Partitions separating Main Power Generator Area from Water Injection Area and Process (Separator) Area. Process (Separator) Partition separating Process (Separator) Area from Gas Compression and Flare Area. Accommodation blast wall separating accommodation from Power Generation and Water Injection. Deck Plating above Workshops and Living Quarters.	41.7 + 0.79 (Evacuation Fatalities).	Esc. Fatals =1.62 + 1.62 + 25.5 + (0.5 x (2.04 + 0.84)) + (0.5 x (3.3 + 19.74)) Evac. Fatals = 0.05 x (60 – (2.46 + 41.7))

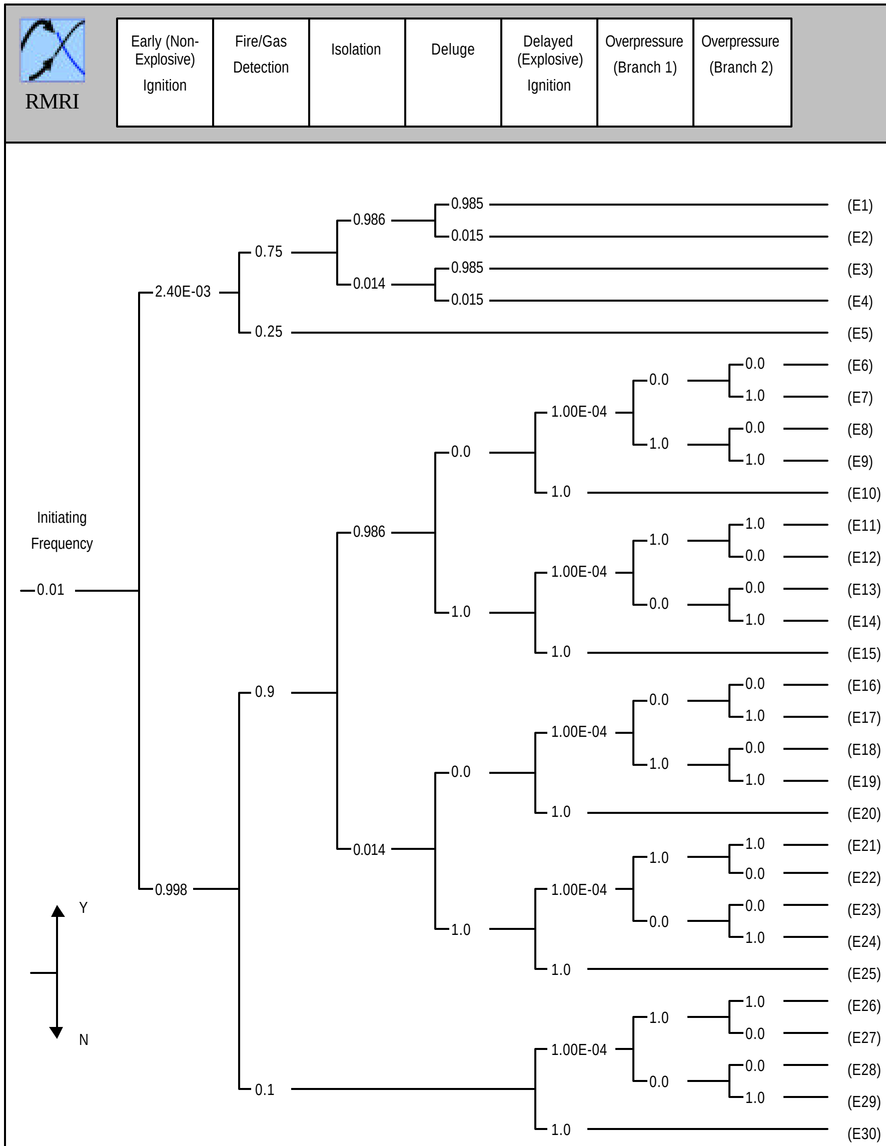
APPENDIX G

(Not Used)

APPENDIX H

Process Loss of Containment Event Trees for FPSO

RMRI



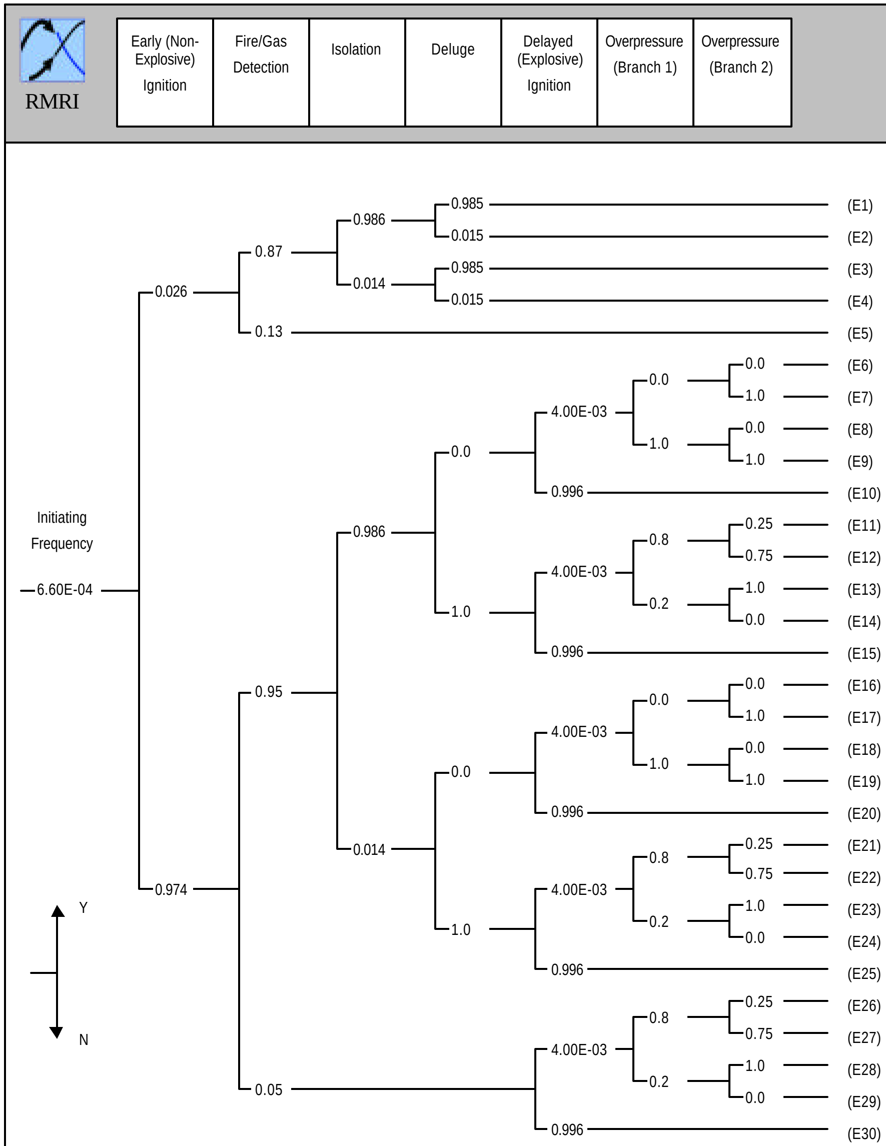
Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.75E-05	0.52	0.0	0.0	0.52	9.09E-06
(E2)	2.66E-07	0.52	0.0	0.0	0.52	1.38E-07
(E3)	2.48E-07	0.52	0.0	0.0	0.52	1.29E-07
(E4)	3.78E-09	0.52	0.0	0.0	0.52	1.97E-09
(E5)	6.00E-06	0.52	0.0	0.0	0.52	3.12E-06
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	8.85E-07	2.22	0.0	0.0	2.22	1.97E-06
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	8.85E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.26E-08	2.22	0.0	0.0	2.22	2.79E-08
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.26E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	9.98E-08	2.22	0.0	0.0	2.22	2.21E-07
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	9.98E-04	0.0	0.0	0.0	0.0	0.00E+00
						1.47E-05

Hazard :
Process Loss of Containment

Sub Category 1 :
Abovesea Prod/n Risers Y 4+

Sub Category 2 :
Small

Project : FPSO4



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.45E-05	4.44	0.0	0.0	4.44	6.44E-05
(E2)	2.21E-07	4.44	0.0	0.0	4.44	9.80E-07
(E3)	2.06E-07	4.44	0.0	0.0	4.44	9.14E-07
(E4)	3.14E-09	4.44	0.0	0.0	4.44	1.39E-08
(E5)	2.23E-06	4.44	0.0	0.0	4.44	9.90E-06
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	4.82E-07	2.22	0.0	0.0	2.22	1.07E-06
(E12)	1.45E-06	4.44	1.125	0.0	5.565	8.04E-06
(E13)	4.82E-07	4.44	2.955	0.5261	7.9211	3.82E-06
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	6.00E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	6.84E-09	2.22	0.0	0.0	2.22	1.52E-08
(E22)	2.05E-08	4.44	1.125	0.0	5.565	1.14E-07
(E23)	6.84E-09	4.44	2.955	0.5261	7.9211	5.42E-08
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	8.52E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.57E-08	2.22	0.0	0.0	2.22	5.71E-08
(E27)	7.71E-08	4.44	1.125	0.0	5.565	4.29E-07
(E28)	2.57E-08	4.44	2.955	0.5261	7.9211	2.04E-07
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	3.20E-05	0.0	0.0	0.0	0.0	0.00E+00
						9.00E-05

Hazard : Process Loss of Containment

Sub Category 1 : Abovesea Prod/n Risers Y 4+

Sub Category 2 : Medium

Project : FPSO4

RMRI

Initiating Frequency: 3.80E-04

Y / N

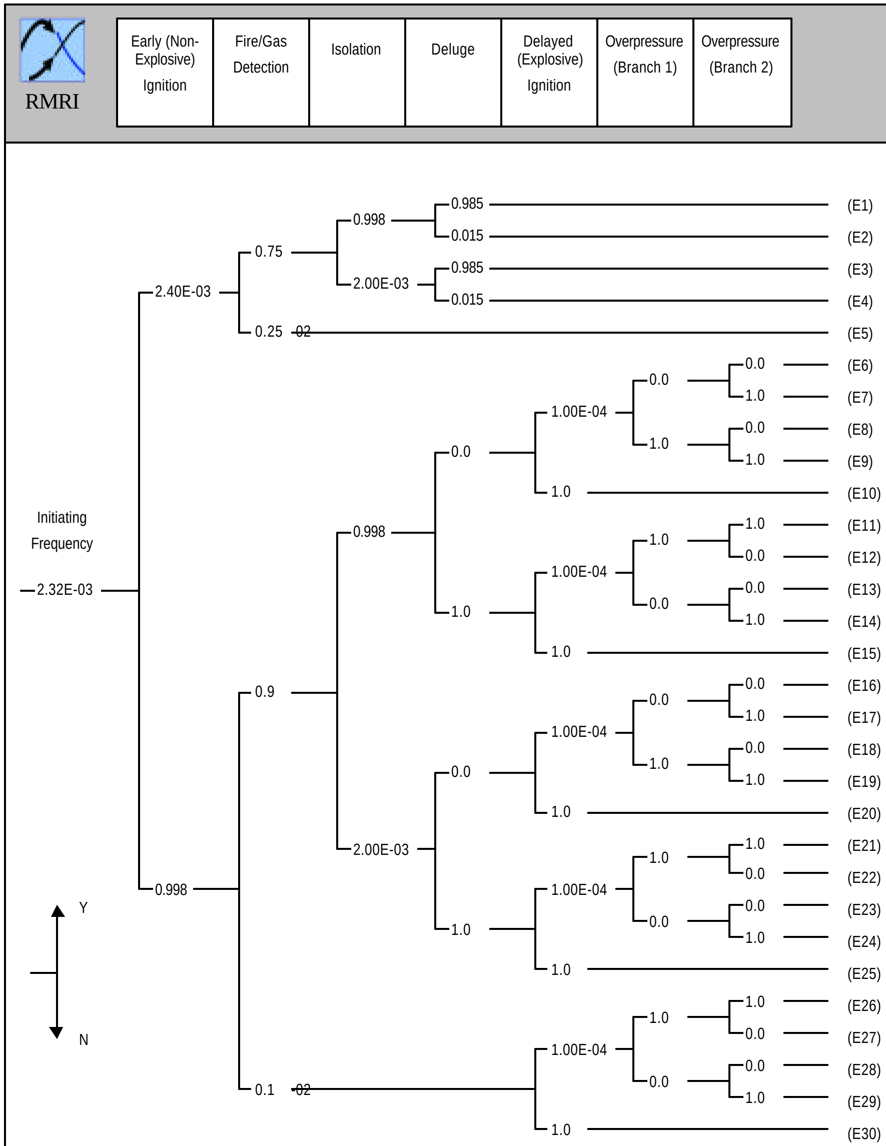
Failure to Disconnect	Severe Damage	Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
0.01	0.5	(E1)	1.90E-06	0.0	0.0	6.0	6.0	1.14E-05	3.00E+04	5.70E-02
	0.5	(E2)	1.90E-06	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
0.99		(E3)	3.76E-04	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
								1.14E-05		5.70E-02

Hazard : Ship Collision

Sub Category 1 : Passing Vessels

Project : FPSO4

RMRI

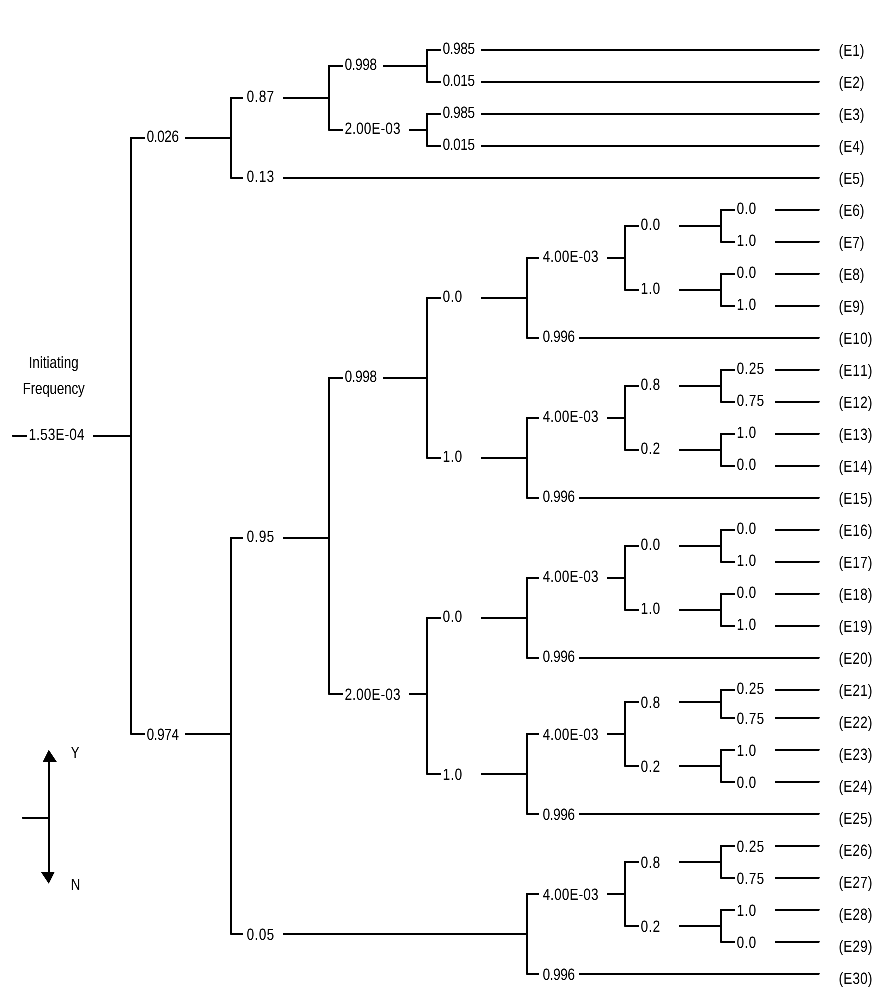


Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.11E-06	0.71	0.0	0.0	0.71	2.91E-06
(E2)	6.25E-08	0.71	0.0	0.0	0.71	4.44E-08
(E3)	8.23E-09	0.71	0.0	0.0	0.71	5.84E-09
(E4)	1.25E-10	0.71	0.0	0.0	0.71	8.89E-11
(E5)	1.39E-06	0.71	0.0	0.0	0.71	9.88E-07
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.08E-07	2.22	0.0	0.0	2.22	4.61E-07
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	2.08E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	4.17E-10	2.22	0.0	0.0	2.22	9.25E-10
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	4.17E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.31E-08	2.22	0.0	0.0	2.22	5.14E-08
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	2.31E-04	0.0	0.0	0.0	0.0	0.00E+00
						4.47E-06

Hazard : Process Loss of Containment	Sub Category 1 : Abovesea Gas Inj/n Risers Y 4+	Sub Category 2 : Small	Project : FPSO4

RMRI

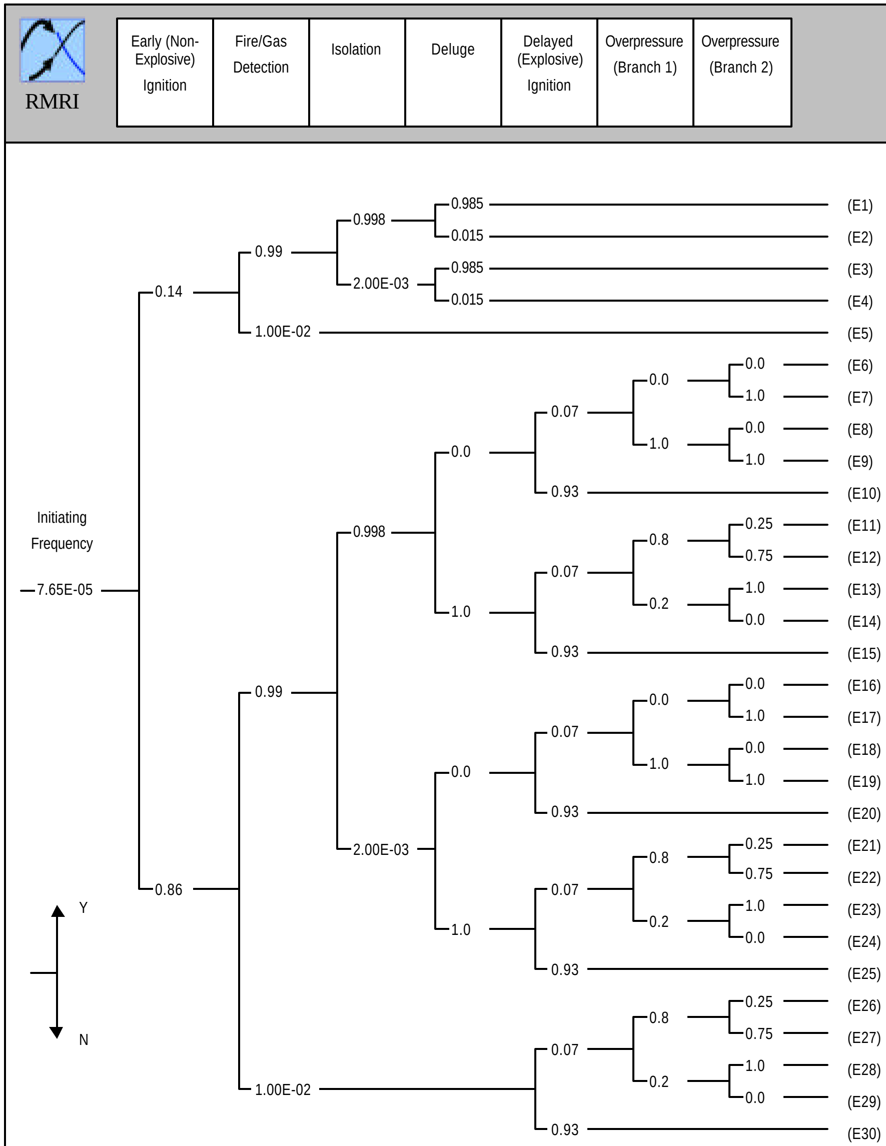
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.40E-06	4.44	0.0	0.0	4.44	1.51E-05
(E2)	5.18E-08	4.44	0.0	0.0	4.44	2.30E-07
(E3)	6.82E-09	4.44	0.0	0.0	4.44	3.03E-08
(E4)	1.04E-10	4.44	0.0	0.0	4.44	4.61E-10
(E5)	5.17E-07	4.44	0.0	0.0	4.44	2.30E-06
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.13E-07	2.22	0.0	0.0	2.22	2.51E-07
(E12)	3.39E-07	4.44	1.125	0.0	5.565	1.89E-06
(E13)	1.13E-07	4.44	2.955	0.5261	7.9211	8.95E-07
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.41E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.27E-10	2.22	0.0	0.0	2.22	5.03E-10
(E22)	6.80E-10	4.44	1.125	0.0	5.565	3.78E-09
(E23)	2.27E-10	4.44	2.955	0.5261	7.9211	1.79E-09
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	2.82E-07	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.96E-09	2.22	0.0	0.0	2.22	1.32E-08
(E27)	1.79E-08	4.44	1.125	0.0	5.565	9.95E-08
(E28)	5.96E-09	4.44	2.955	0.5261	7.9211	4.72E-08
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	7.42E-06	0.0	0.0	0.0	0.0	0.00E+00
						2.09E-05

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Abovesea Gas Inj/n Risers Y 4+	Medium	

RMRI

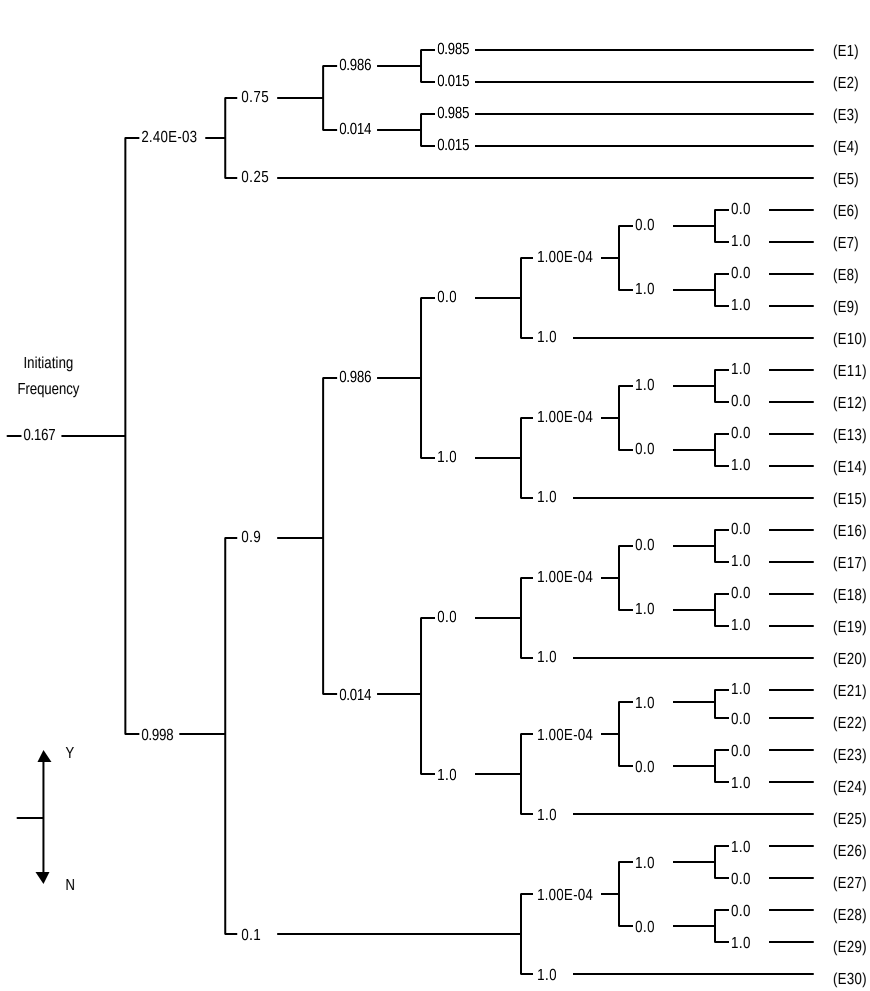


Event	Event Frequency	Fatalities: Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.04E-05	4.44	0.0	0.0	4.44	4.63E-05
(E2)	1.59E-07	4.44	0.0	0.0	4.44	7.05E-07
(E3)	2.09E-08	4.44	0.0	0.6	5.04	1.05E-07
(E4)	3.18E-10	4.44	0.0	0.6	5.04	1.60E-09
(E5)	1.07E-07	4.44	0.0	0.6	5.04	5.40E-07
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.10E-07	2.22	0.0	0.0	2.22	2.02E-06
(E12)	2.73E-06	4.44	1.125	0.0	5.565	1.52E-05
(E13)	9.10E-07	4.44	2.955	0.5261	7.9211	7.21E-06
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	6.05E-05	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.6	2.82	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.6	6.165	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	1.82E-09	2.22	0.0	0.6	2.82	5.14E-09
(E22)	5.47E-09	4.44	1.125	0.6	6.165	3.37E-08
(E23)	1.82E-09	4.44	2.955	0.5261	7.9211	1.44E-08
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.21E-07	0.0	0.0	0.6	0.6	7.27E-08
(E26)	9.21E-09	2.22	0.0	0.6	2.82	2.60E-08
(E27)	2.76E-08	4.44	1.125	0.6	6.165	1.70E-07
(E28)	9.21E-09	4.44	2.955	0.5261	7.9211	7.30E-08
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	6.12E-07	0.0	0.0	0.6	0.6	3.67E-07
						7.28E-05

Hazard : Process Loss of Containment	Sub Category 1 : Abovesea Gas Inj/n Risers Y 4+	Sub Category 2 : Large	Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.92E-04	0.52	0.0	0.0	0.52	1.52E-04
(E2)	4.45E-06	0.52	0.0	0.0	0.52	2.31E-06
(E3)	4.15E-06	0.52	0.0	0.0	0.52	2.16E-06
(E4)	6.31E-08	0.52	0.0	0.0	0.52	3.28E-08
(E5)	1.00E-04	0.52	0.0	0.0	0.52	5.21E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.48E-05	2.22	0.0	0.0	2.22	3.28E-05
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.48E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.10E-07	2.22	0.0	0.0	2.22	4.66E-07
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	2.10E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.67E-06	2.22	0.0	0.0	2.22	3.70E-06
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	1.67E-02	0.0	0.0	0.0	0.0	0.00E+00
						2.45E-04

Hazard : Process Loss of Containment

Sub Category 1 : Pr. Man/Flow (Yr 4+) - 2 Ph

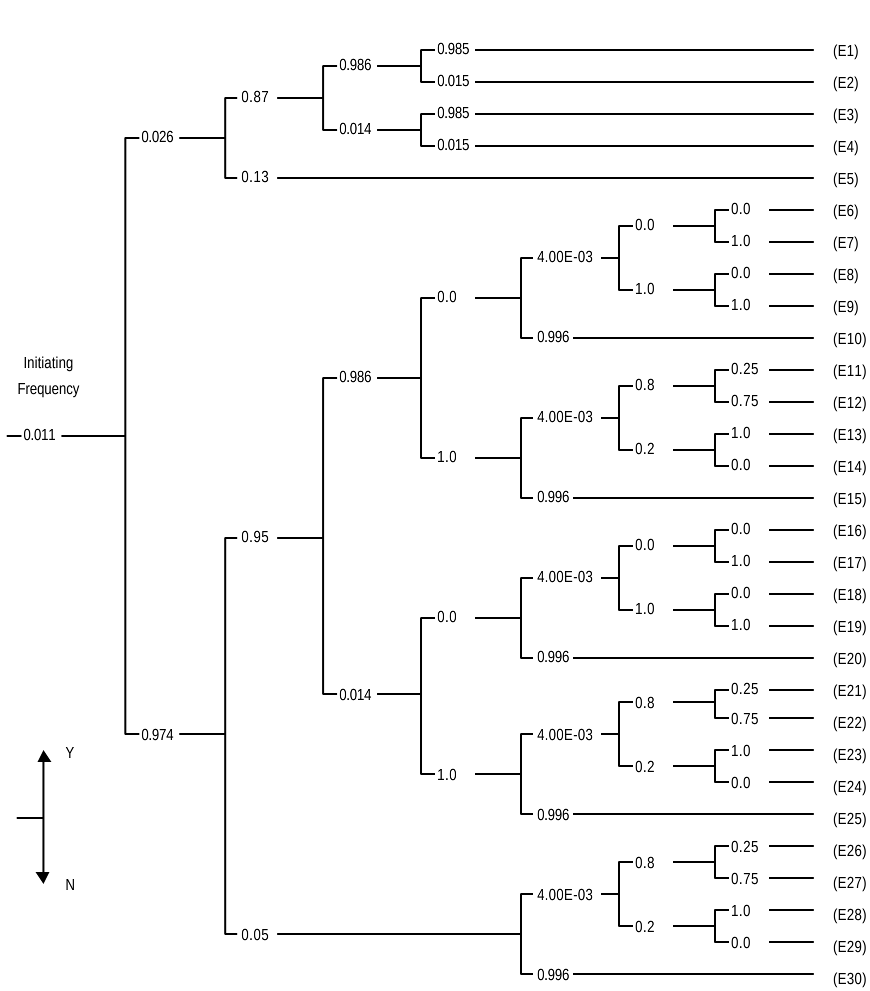
Sub Category 2 : Small

Project : FPSO4

RMRI

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

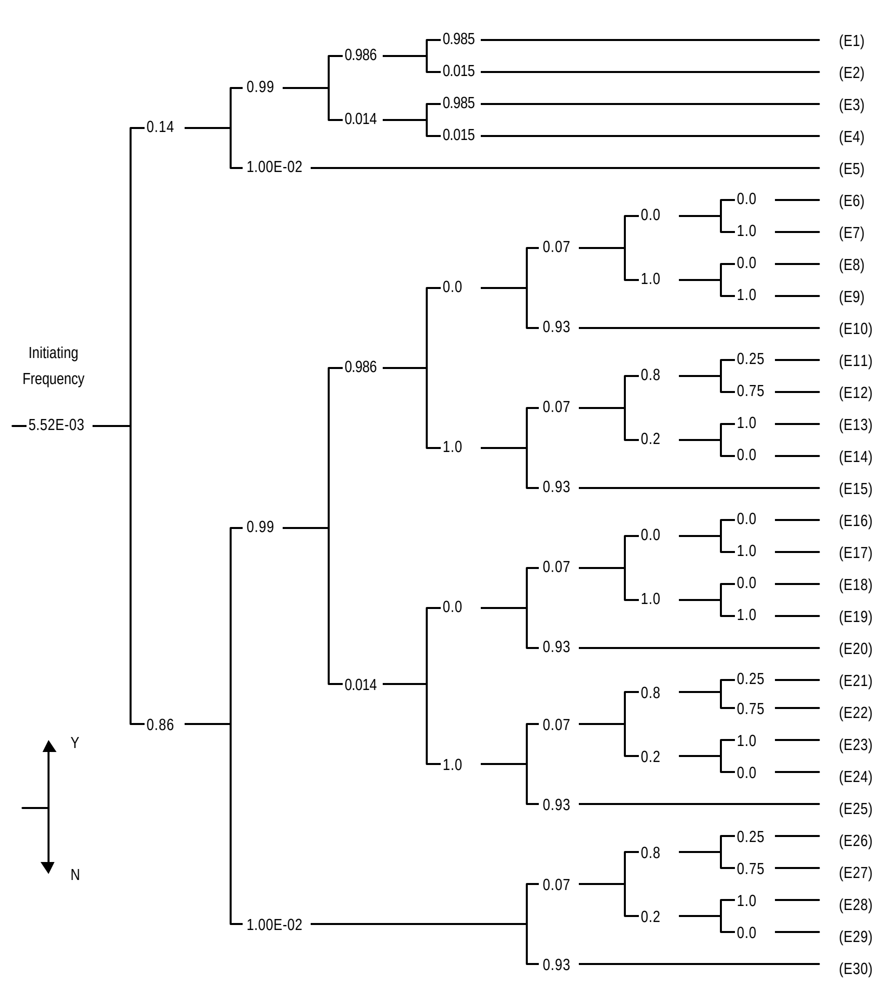


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.42E-04	4.44	0.0	0.0	4.44	1.07E-03
(E2)	3.68E-06	4.44	0.0	0.0	4.44	1.63E-05
(E3)	3.43E-06	4.44	0.0	0.0	4.44	1.52E-05
(E4)	5.23E-08	4.44	0.0	0.0	4.44	2.32E-07
(E5)	3.72E-05	4.44	0.0	0.0	4.44	1.65E-04
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	8.03E-06	2.22	0.0	0.0	2.22	1.78E-05
(E12)	2.41E-05	4.44	1.125	0.0	5.565	1.34E-04
(E13)	8.03E-06	4.44	2.955	0.5261	7.9211	6.36E-05
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.00E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.14E-07	2.22	0.0	0.0	2.22	2.53E-07
(E22)	3.42E-07	4.44	1.125	0.0	5.565	1.90E-06
(E23)	1.14E-07	4.44	2.955	0.5261	7.9211	9.03E-07
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.42E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	4.29E-07	2.22	0.0	0.0	2.22	9.51E-07
(E27)	1.29E-06	4.44	1.125	0.0	5.565	7.15E-06
(E28)	4.29E-07	4.44	2.955	0.5261	7.9211	3.39E-06
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	5.34E-04	0.0	0.0	0.0	0.0	0.00E+00
						1.50E-03

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Pr. Man/Flow (Yr 4+) - 2 Ph	Medium	

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

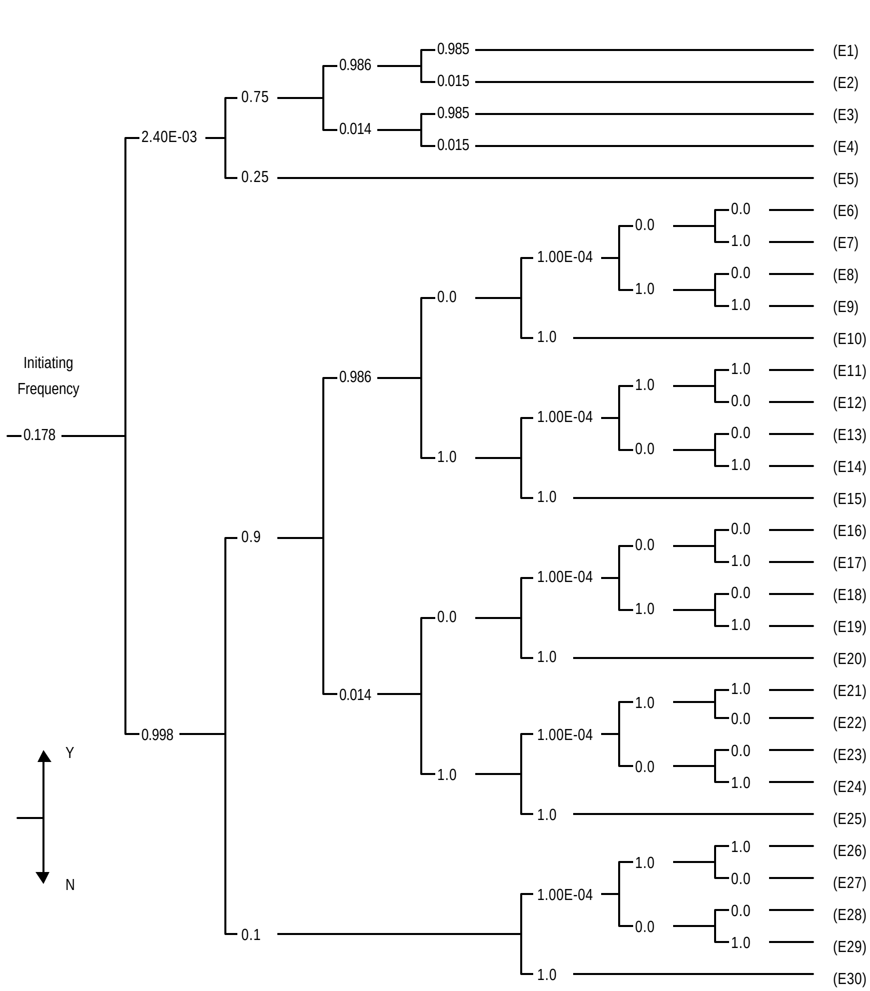


Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	7.43E-04	4.44	0.0	0.0	4.44	3.30E-03
(E2)	1.13E-05	4.44	0.0	0.0	4.44	5.02E-05
(E3)	1.06E-05	4.44	0.0	0.6	5.04	5.32E-05
(E4)	1.61E-07	4.44	0.0	0.6	5.04	8.10E-07
(E5)	7.73E-06	4.44	0.0	0.6	5.04	3.89E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	6.49E-05	2.22	0.0	0.0	2.22	1.44E-04
(E12)	1.95E-04	4.44	1.125	0.0	5.565	1.08E-03
(E13)	6.49E-05	4.44	2.955	0.5261	7.9211	5.14E-04
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	4.31E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.6	2.82	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.6	6.165	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	9.21E-07	2.22	0.0	0.6	2.82	2.60E-06
(E22)	2.76E-06	4.44	1.125	0.6	6.165	1.70E-05
(E23)	9.21E-07	4.44	2.955	0.5261	7.9211	7.30E-06
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	6.12E-05	0.0	0.0	0.6	0.6	3.67E-05
(E26)	6.65E-07	2.22	0.0	0.6	2.82	1.87E-06
(E27)	1.99E-06	4.44	1.125	0.6	6.165	1.23E-05
(E28)	6.65E-07	4.44	2.955	0.5261	7.9211	5.26E-06
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	4.41E-05	0.0	0.0	0.6	0.6	2.65E-05
						5.29E-03

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Pr. Man/Flow (Yr 4+) - 2 Ph	Large	

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.11E-04	0.52	0.0	0.0	0.52	1.62E-04
(E2)	4.74E-06	0.52	0.0	0.0	0.52	2.46E-06
(E3)	4.42E-06	0.52	0.0	0.0	0.52	2.30E-06
(E4)	6.73E-08	0.52	0.0	0.0	0.52	3.50E-08
(E5)	1.07E-04	0.52	0.0	0.0	0.52	5.55E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.58E-05	2.22	0.0	0.0	2.22	3.50E-05
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.58E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.24E-07	2.22	0.0	0.0	2.22	4.97E-07
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	2.24E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.78E-06	2.22	0.0	0.0	2.22	3.94E-06
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	1.78E-02	0.0	0.0	0.0	0.0	0.00E+00
						2.62E-04

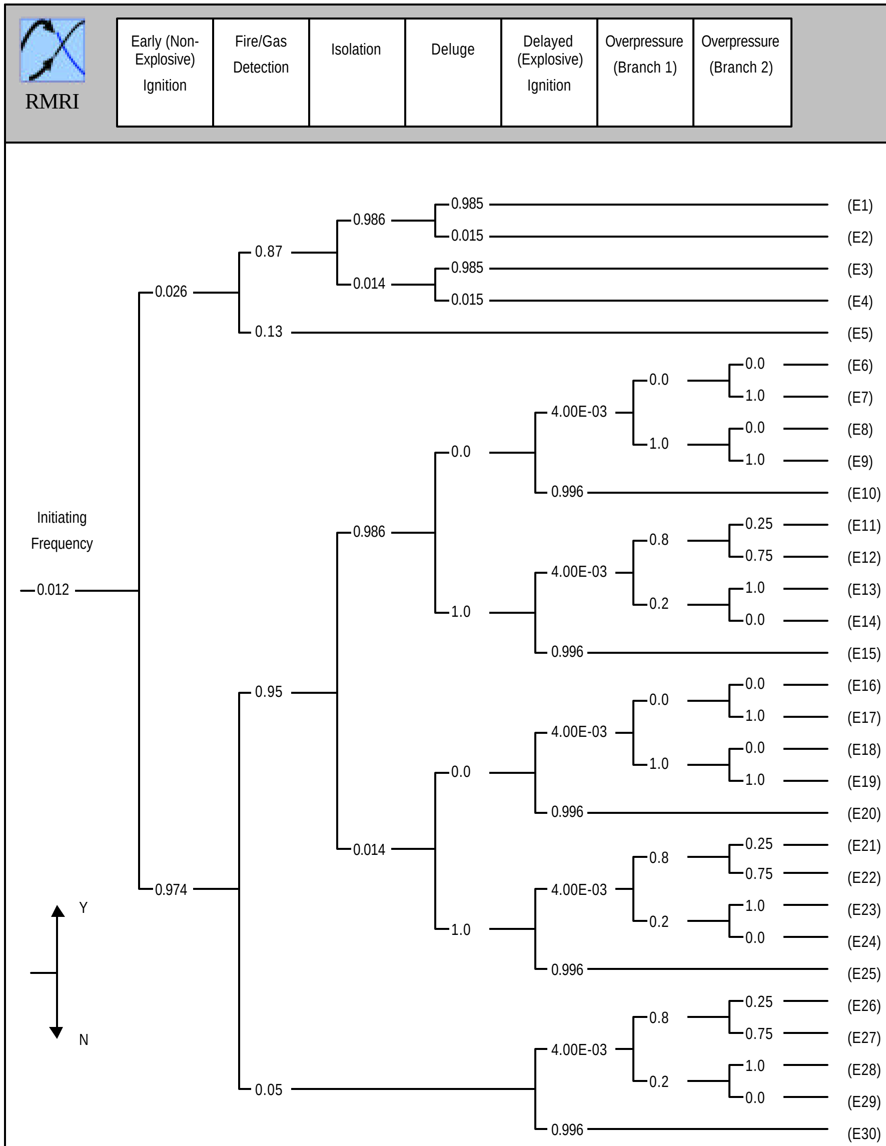
Hazard : Process Loss of Containment

Sub Category 1 : Test Man/Flow (Yr 4+) - 2 Ph

Sub Category 2 : Small

Project : FPSO4

RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.59E-04	4.44	0.0	0.0	4.44	1.15E-03
(E2)	3.95E-06	4.44	0.0	0.0	4.44	1.75E-05
(E3)	3.68E-06	4.44	0.0	0.0	4.44	1.63E-05
(E4)	5.61E-08	4.44	0.0	0.0	4.44	2.49E-07
(E5)	3.99E-05	4.44	0.0	0.0	4.44	1.77E-04
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	8.61E-06	2.22	0.0	0.0	2.22	1.91E-05
(E12)	2.58E-05	4.44	1.125	0.0	5.565	1.44E-04
(E13)	8.61E-06	4.44	2.955	0.5261	7.9211	6.82E-05
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.07E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.22E-07	2.22	0.0	0.0	2.22	2.71E-07
(E22)	3.67E-07	4.44	1.125	0.0	5.565	2.04E-06
(E23)	1.22E-07	4.44	2.955	0.5261	7.9211	9.69E-07
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.52E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	4.60E-07	2.22	0.0	0.0	2.22	1.02E-06
(E27)	1.38E-06	4.44	1.125	0.0	5.565	7.68E-06
(E28)	4.60E-07	4.44	2.955	0.5261	7.9211	3.64E-06
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	5.72E-04	0.0	0.0	0.0	0.0	0.00E+00
						1.61E-03

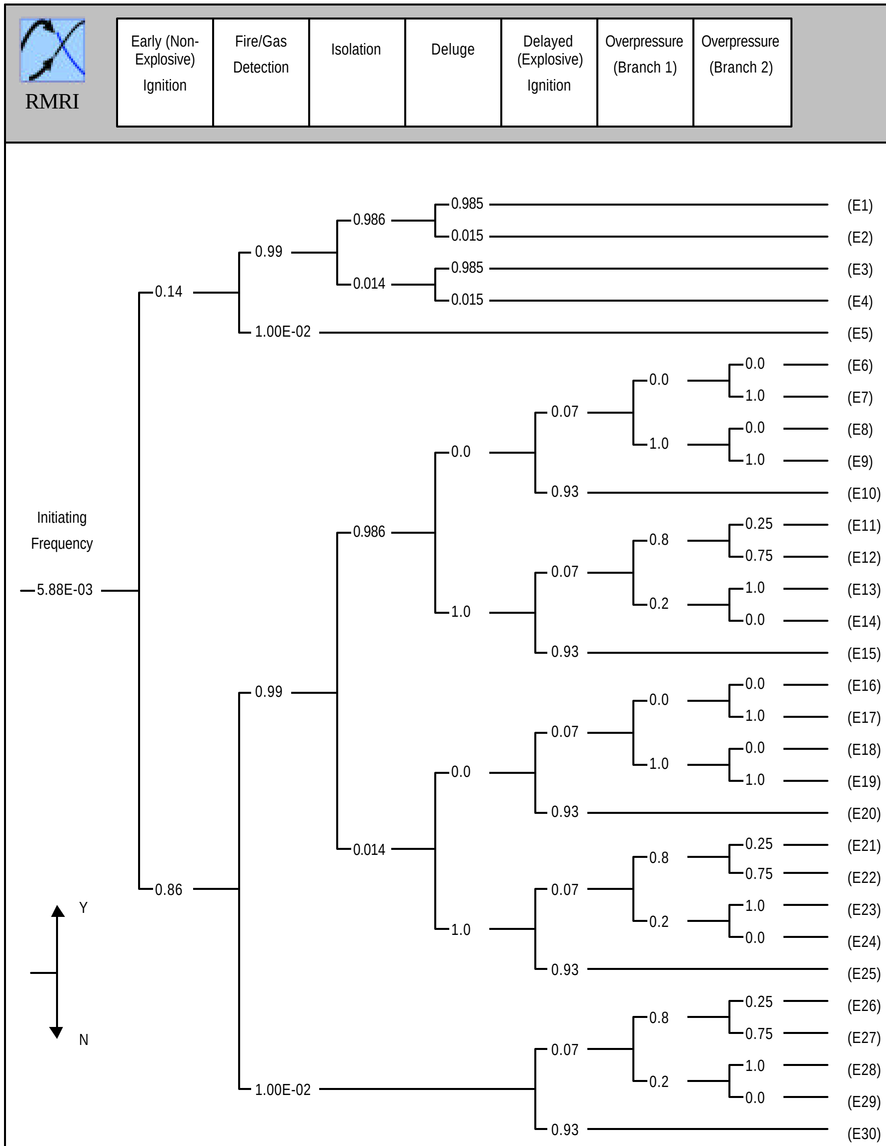
Hazard : Process Loss of Containment

Sub Category 1 : Test Man/Flow (Yr 4+) - 2 Ph

Sub Category 2 : Medium

Project : FPSO4

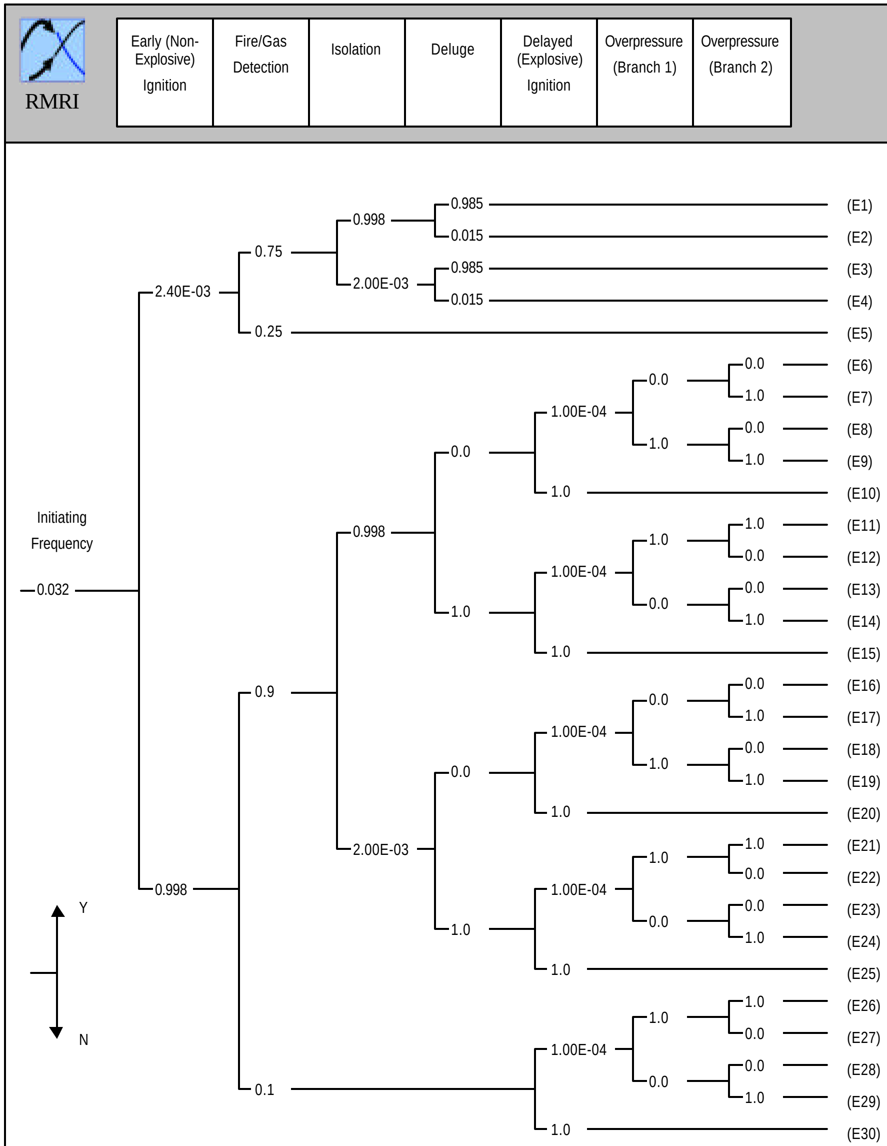
RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	7.92E-04	4.44	0.0	0.0	4.44	3.51E-03
(E2)	1.21E-05	4.44	0.0	0.0	4.44	5.35E-05
(E3)	1.12E-05	4.44	0.0	0.6	5.04	5.66E-05
(E4)	1.71E-07	4.44	0.0	0.6	5.04	8.63E-07
(E5)	8.23E-06	4.44	0.0	0.6	5.04	4.15E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	6.91E-05	2.22	0.0	0.0	2.22	1.53E-04
(E12)	2.07E-04	4.44	1.125	0.0	5.565	1.15E-03
(E13)	6.91E-05	4.44	2.955	0.5261	7.9211	5.47E-04
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	4.59E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.6	2.82	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.6	6.165	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	9.81E-07	2.22	0.0	0.6	2.82	2.77E-06
(E22)	2.94E-06	4.44	1.125	0.6	6.165	1.81E-05
(E23)	9.81E-07	4.44	2.955	0.5261	7.9211	7.77E-06
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	6.52E-05	0.0	0.0	0.6	0.6	3.91E-05
(E26)	7.08E-07	2.22	0.0	0.6	2.82	2.00E-06
(E27)	2.12E-06	4.44	1.125	0.6	6.165	1.31E-05
(E28)	7.08E-07	4.44	2.955	0.5261	7.9211	5.61E-06
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	4.70E-05	0.0	0.0	0.6	0.6	2.82E-05
						5.64E-03

Hazard : Process Loss of Containment	Sub Category 1 : Test Man/Flow (Yr 4+) - 2 Ph	Sub Category 2 : Large	Project : FPSO4

RMRI



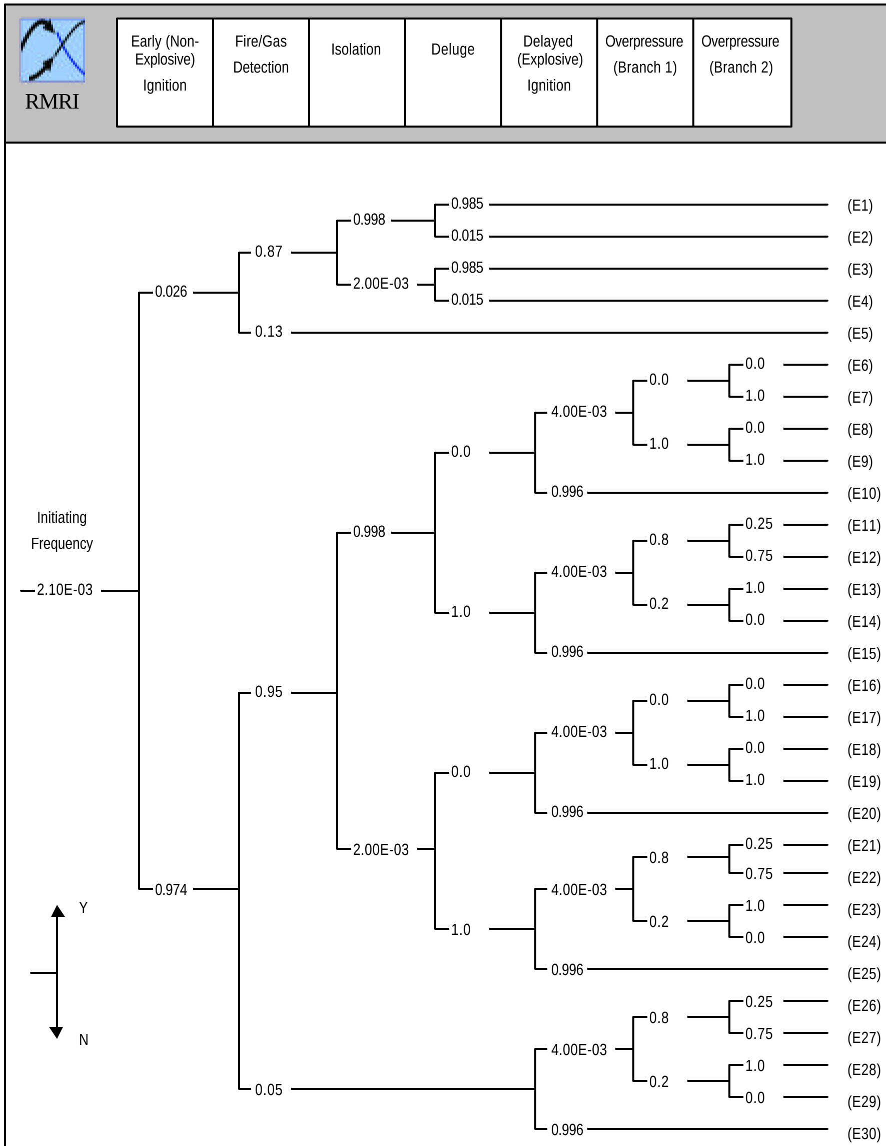
Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	5.64E-05	0.71	0.0	0.0	0.71	4.01E-05
(E2)	8.60E-07	0.71	0.0	0.0	0.71	6.10E-07
(E3)	1.13E-07	0.71	0.0	0.0	0.71	8.03E-08
(E4)	1.72E-09	0.71	0.0	0.0	0.71	1.22E-09
(E5)	1.91E-05	0.71	0.0	0.0	0.71	1.36E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.86E-06	2.22	0.0	0.0	2.22	6.35E-06
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	2.86E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	5.73E-09	2.22	0.0	0.0	2.22	1.27E-08
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	5.73E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	3.18E-07	2.22	0.0	0.0	2.22	7.06E-07
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	3.18E-03	0.0	0.0	0.0	0.0	0.00E+00
						6.14E-05

Hazard : Process Loss of Containment

Sub Category 1 : Gas Inj. Man/Flow (Yr 4+)

Sub Category 2 : Small

Project : FPSO4



	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.67E-05	4.44	0.0	0.0	4.44	2.07E-04
(E2)	7.11E-07	4.44	0.0	0.0	4.44	3.16E-06
(E3)	9.36E-08	4.44	0.0	0.0	4.44	4.15E-07
(E4)	1.43E-09	4.44	0.0	0.0	4.44	6.33E-09
(E5)	7.10E-06	4.44	0.0	0.0	4.44	3.15E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.55E-06	2.22	0.0	0.0	2.22	3.44E-06
(E12)	4.65E-06	4.44	1.125	0.0	5.565	2.59E-05
(E13)	1.55E-06	4.44	2.955	0.5261	7.9211	1.23E-05
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.93E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	3.11E-09	2.22	0.0	0.0	2.22	6.90E-09
(E22)	9.33E-09	4.44	1.125	0.0	5.565	5.19E-08
(E23)	3.11E-09	4.44	2.955	0.5261	7.9211	2.46E-08
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	3.87E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	8.18E-08	2.22	0.0	0.0	2.22	1.82E-07
(E27)	2.45E-07	4.44	1.125	0.0	5.565	1.37E-06
(E28)	8.18E-08	4.44	2.955	0.5261	7.9211	6.48E-07
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	1.02E-04	0.0	0.0	0.0	0.0	0.00E+00
						2.86E-04

Hazard : Process Loss of Containment

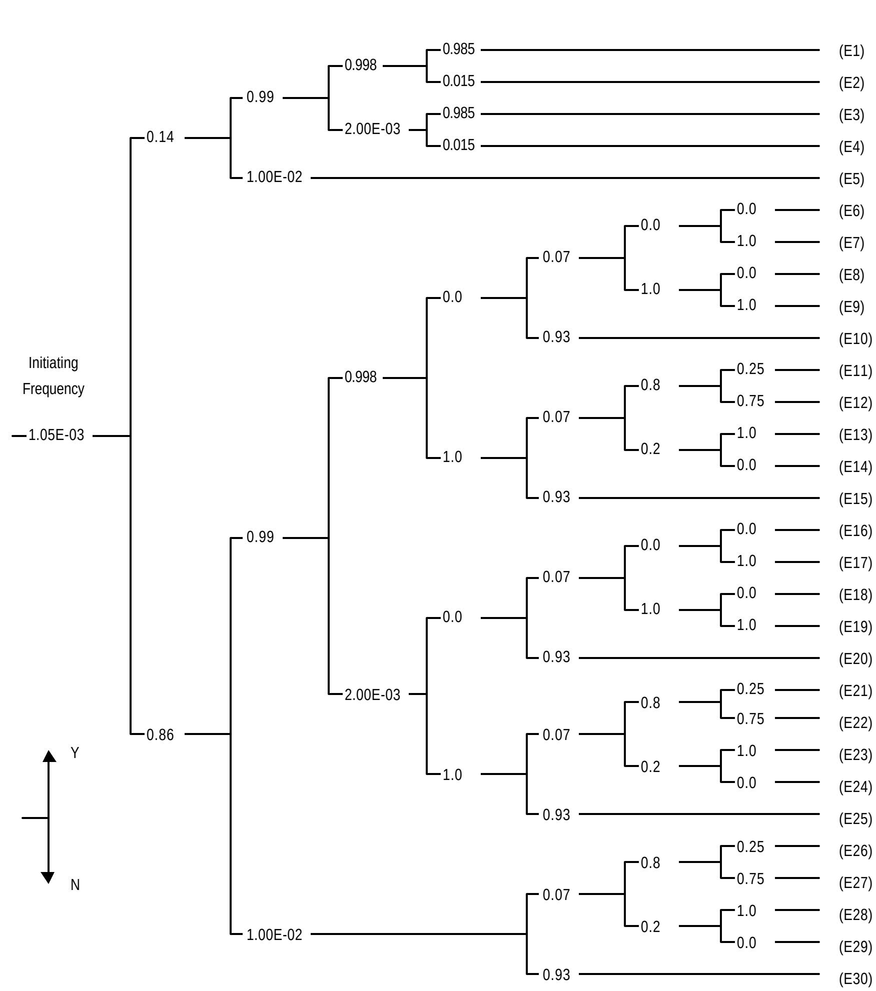
Sub Category 1 : Gas Inj. Man/Flow (Yr 4+)

Sub Category 2 : Medium

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.43E-04	4.44	0.0	0.0	4.44	6.35E-04
(E2)	2.18E-06	4.44	0.0	0.0	4.44	9.67E-06
(E3)	2.87E-07	4.44	0.0	0.6	5.04	1.44E-06
(E4)	4.37E-09	4.44	0.0	0.6	5.04	2.20E-08
(E5)	1.47E-06	4.44	0.0	0.6	5.04	7.41E-06
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.25E-05	2.22	0.0	0.0	2.22	2.77E-05
(E12)	3.75E-05	4.44	1.125	0.0	5.565	2.09E-04
(E13)	1.25E-05	4.44	2.955	0.5261	7.9211	9.89E-05
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	8.30E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.6	2.82	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.6	6.165	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	2.50E-08	2.22	0.0	0.6	2.82	7.06E-08
(E22)	7.51E-08	4.44	1.125	0.6	6.165	4.63E-07
(E23)	2.50E-08	4.44	2.955	0.5261	7.9211	1.98E-07
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.66E-06	0.0	0.0	0.6	0.6	9.98E-07
(E26)	1.26E-07	2.22	0.0	0.6	2.82	3.57E-07
(E27)	3.79E-07	4.44	1.125	0.6	6.165	2.34E-06
(E28)	1.26E-07	4.44	2.955	0.5261	7.9211	1.00E-06
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	8.40E-06	0.0	0.0	0.6	0.6	5.04E-06
						9.99E-04

Hazard : Process Loss of Containment

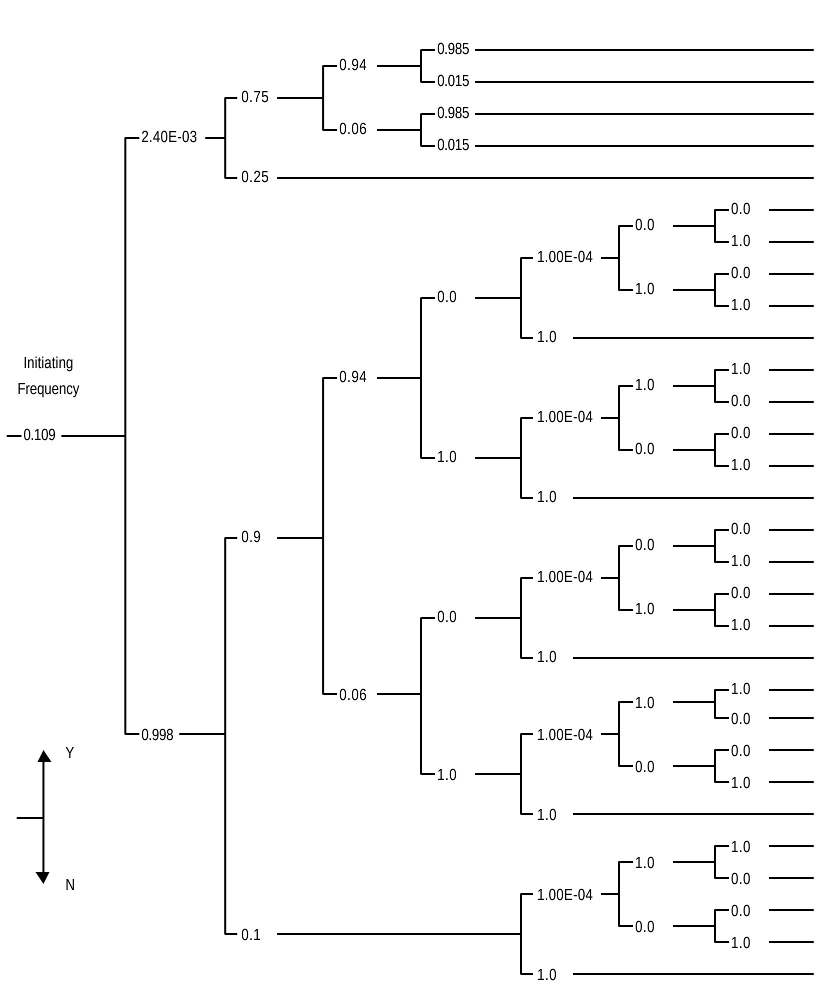
Sub Category 1 : Gas Inj. Man/Flow (Yr 4+)

Sub Category 2 : Large

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.82E-04	0.03	0.0	0.0	0.03	5.45E-06
(E2)	2.77E-06	0.03	0.0	0.0	0.03	8.30E-08
(E3)	1.16E-05	0.03	0.0	0.0	0.03	3.48E-07
(E4)	1.77E-07	0.03	0.0	0.0	0.03	5.30E-09
(E5)	6.54E-05	0.03	0.0	0.0	0.03	1.96E-06
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.20E-06	0.81	0.0	0.0	0.81	7.45E-06
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	9.20E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	5.87E-07	0.81	0.0	0.0	0.81	4.76E-07
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	5.87E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.09E-06	0.81	0.0	0.0	0.81	8.81E-07
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.09E-02	0.0	0.0	0.0	0.0	0.00E+00
						1.67E-05

Hazard : Process Loss of Containment

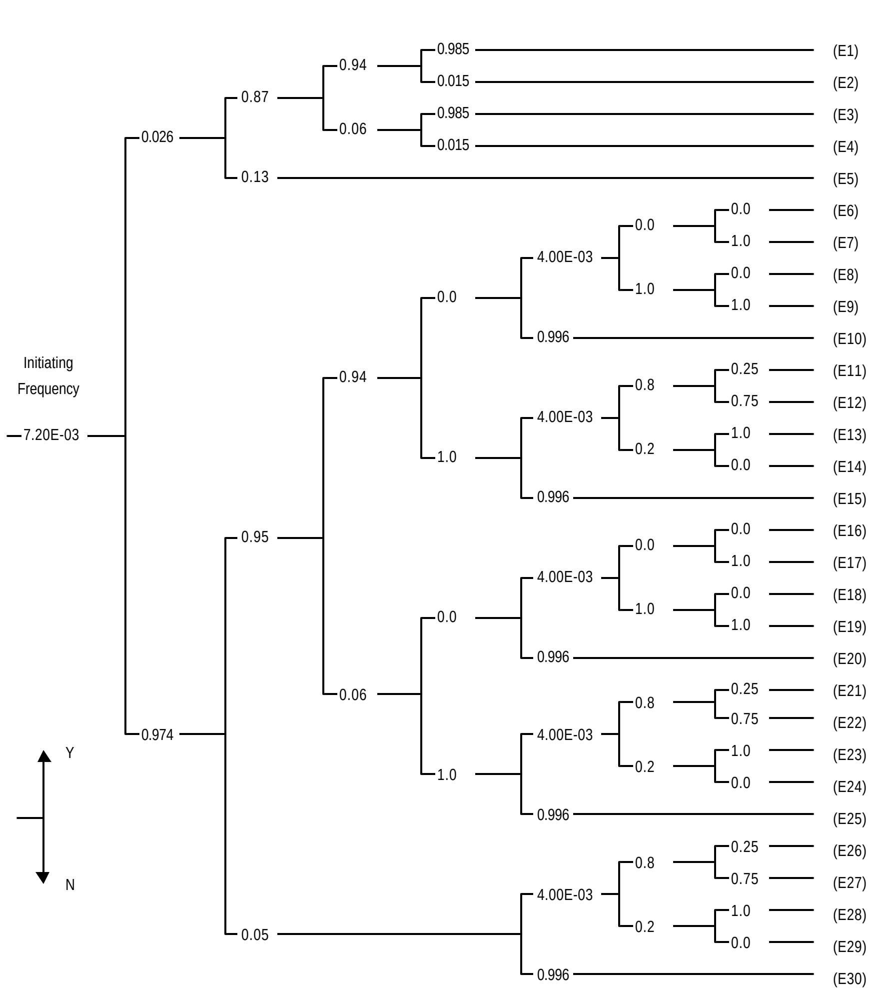
Sub Category 1 : 1st Stage Separator (Gas)

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

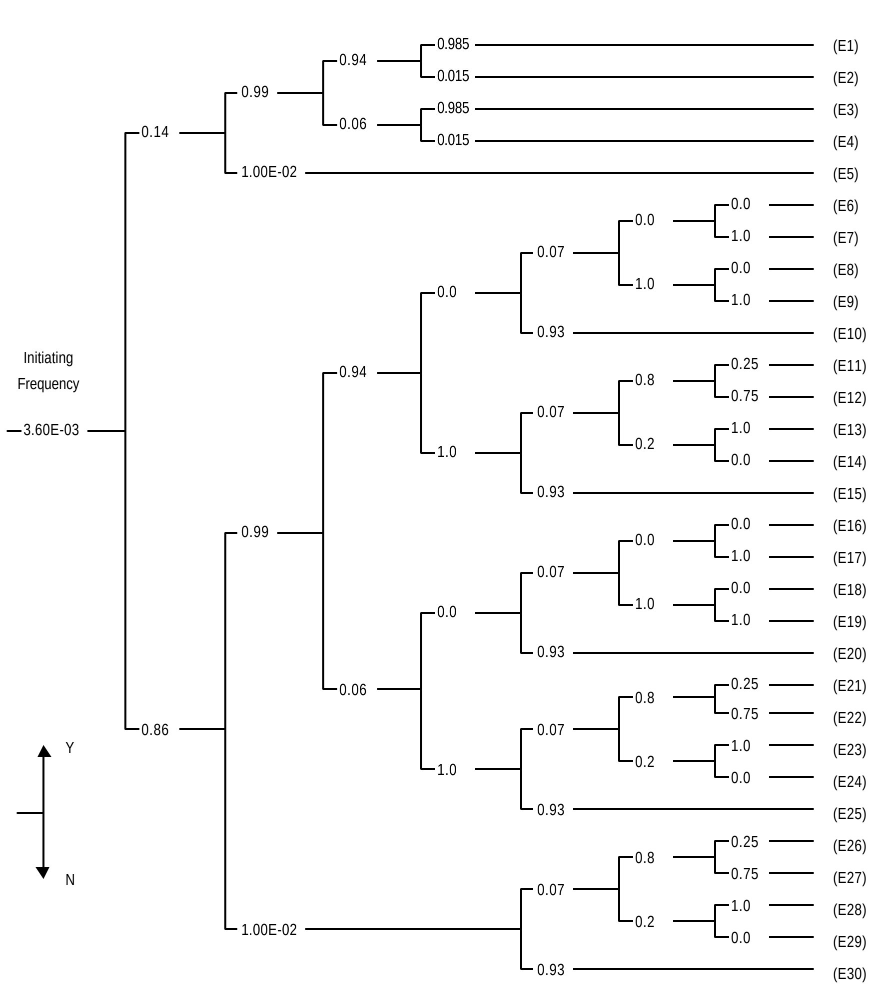


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.51E-04	0.5	0.0	0.0	0.5	7.54E-05
(E2)	2.30E-06	0.5	0.0	0.0	0.5	1.15E-06
(E3)	9.63E-06	0.5	0.0	0.0	0.5	4.81E-06
(E4)	1.47E-07	0.5	0.0	0.0	0.5	7.33E-08
(E5)	2.43E-05	0.5	0.0	0.0	0.5	1.22E-05
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	5.01E-06	0.81	0.0	0.0	0.81	4.06E-06
(E12)	1.50E-05	1.62	1.41	0.0	3.03	4.55E-05
(E13)	5.01E-06	1.62	4.755	0.5363	6.9113	3.46E-05
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	6.24E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	3.20E-07	0.81	0.0	0.0	0.81	2.59E-07
(E22)	9.59E-07	1.62	1.41	0.0	3.03	2.91E-06
(E23)	3.20E-07	1.62	4.755	0.5363	6.9113	2.21E-06
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	3.98E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.81E-07	0.81	0.0	0.0	0.81	2.27E-07
(E27)	8.42E-07	1.62	1.41	0.0	3.03	2.55E-06
(E28)	2.81E-07	1.62	4.755	0.5363	6.9113	1.94E-06
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	3.49E-04	0.0	0.0	0.0	0.0	0.00E+00
						1.88E-04

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage Separator (Gas)	Medium	

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



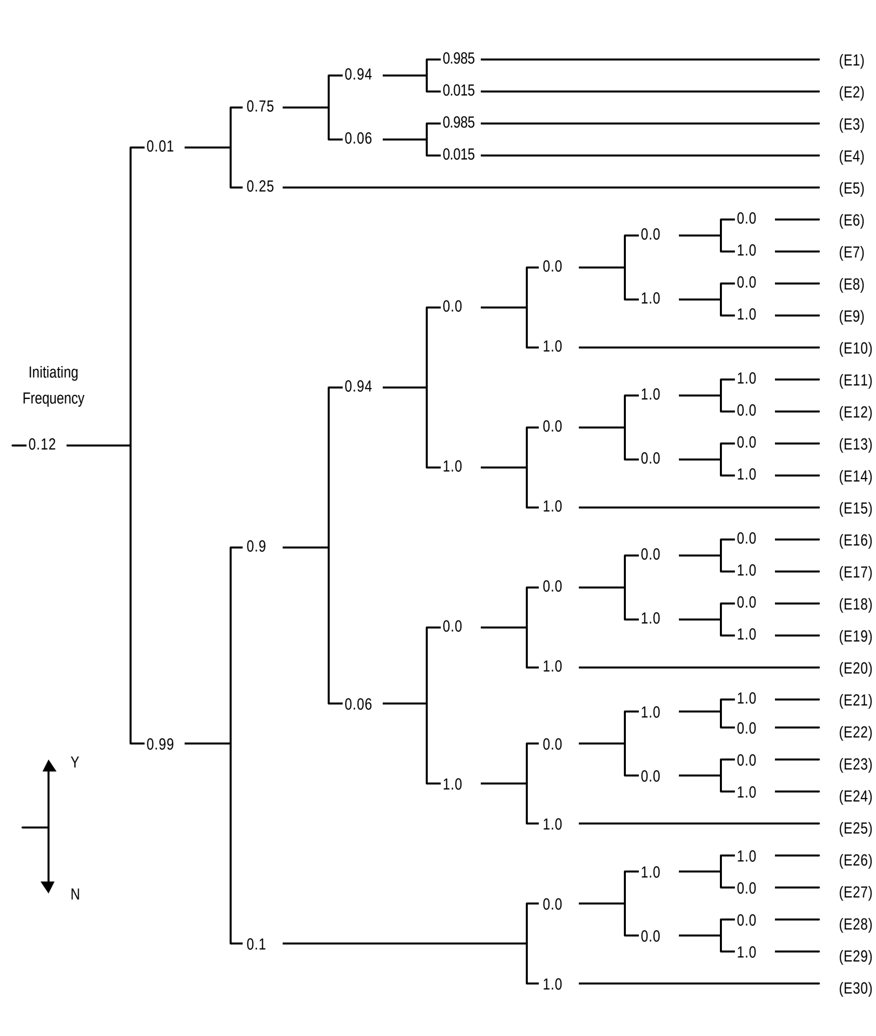
Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.62E-04	1.62	0.0	0.0	1.62	7.48E-04
(E2)	7.04E-06	1.62	0.0	0.0	1.62	1.14E-05
(E3)	2.95E-05	1.62	0.0	0.6	2.22	6.55E-05
(E4)	4.49E-07	1.62	0.0	0.6	2.22	9.97E-07
(E5)	5.04E-06	1.62	0.0	0.6	2.22	1.12E-05
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	4.03E-05	0.81	0.0	0.0	0.81	3.27E-05
(E12)	1.21E-04	1.62	1.41	0.0	3.03	3.67E-04
(E13)	4.03E-05	1.62	4.755	0.5363	6.9113	2.79E-04
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	2.68E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.6	1.41	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.6	3.63	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	2.57E-06	0.81	0.0	0.6	1.41	3.63E-06
(E22)	7.72E-06	1.62	1.41	0.6	3.63	2.80E-05
(E23)	2.57E-06	1.62	4.755	0.5363	6.9113	1.78E-05
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.71E-04	0.0	0.0	0.6	0.6	1.03E-04
(E26)	4.33E-07	0.81	0.0	0.6	1.41	6.11E-07
(E27)	1.30E-06	1.62	1.41	0.6	3.63	4.72E-06
(E28)	4.33E-07	1.62	4.755	0.5363	6.9113	3.00E-06
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	2.88E-05	0.0	0.0	0.6	0.6	1.73E-05
						1.69E-03

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage Separator (Gas)	Large	

RMRI

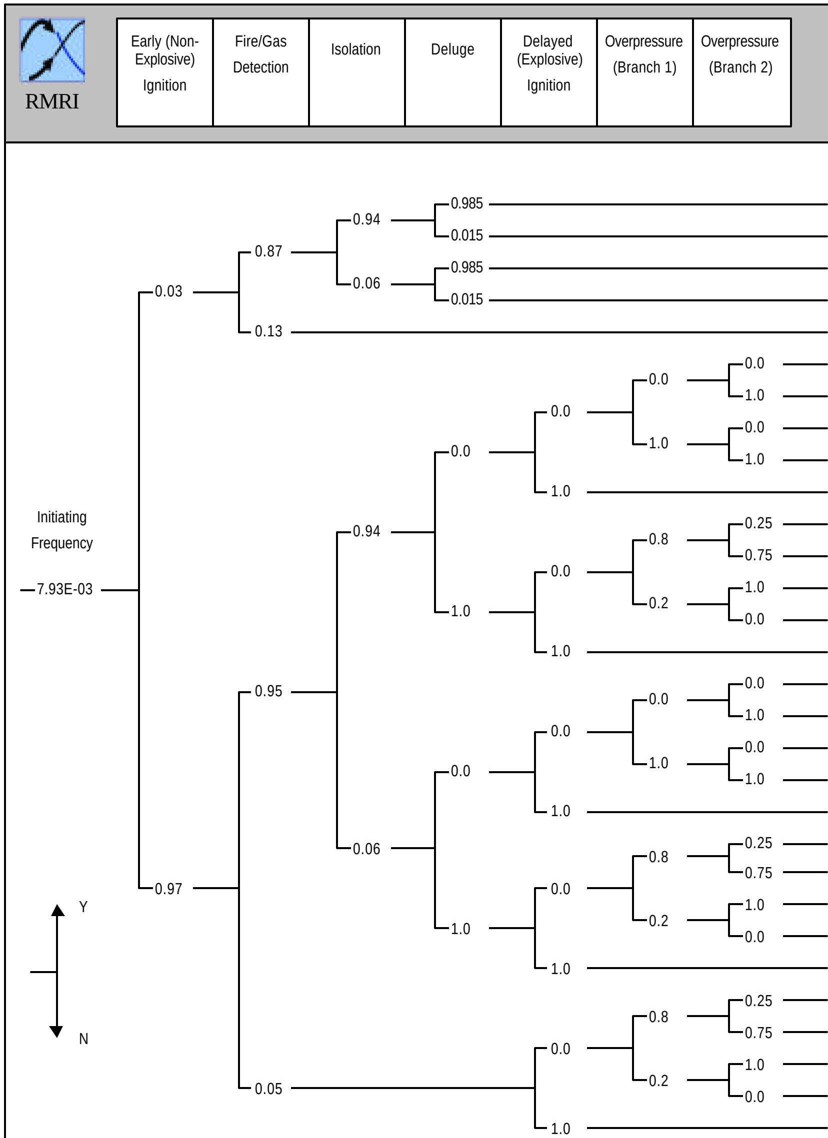
RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.33E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.27E-05	0.0	0.0	0.0	0.0	0.00E+00
(E3)	5.32E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	8.10E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.00E-04	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.01E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	6.42E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.19E-02	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage Separator (Liquid)	Small	

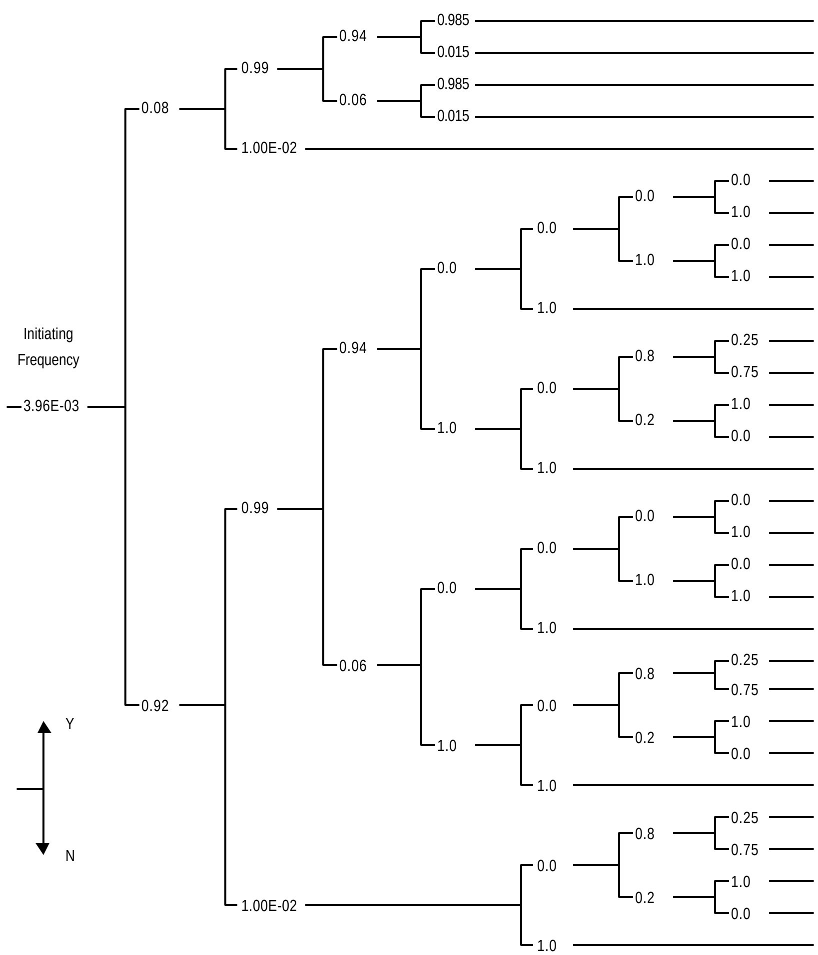


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.92E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	2.92E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	1.22E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	1.86E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.09E-05	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	6.87E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	4.38E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	3.85E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment	Sub Category 1 : 1st Stage Separator (Liquid)	Sub Category 2 : Medium	Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

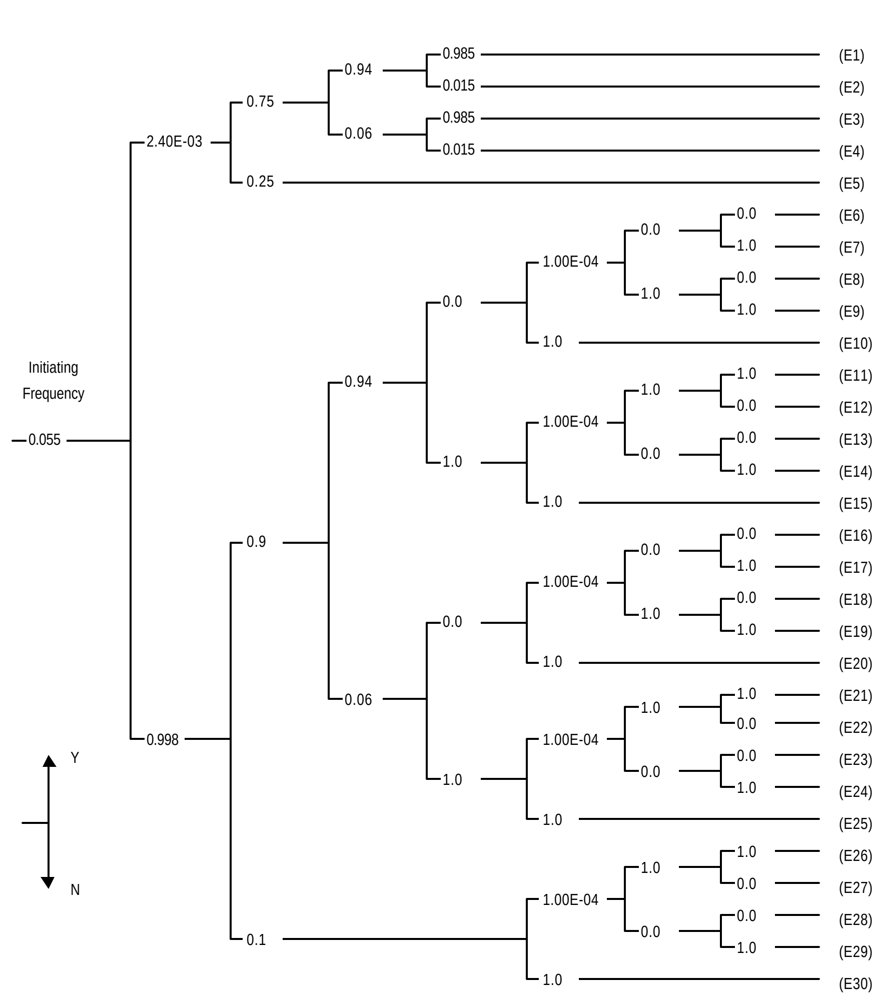


Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.90E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	4.42E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	1.85E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	2.82E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.17E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	3.39E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	2.16E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	3.64E-05	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage Separator (Liquid)	Large	

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	9.10E-05	0.03	0.0	0.0	0.03	2.73E-06
(E2)	1.39E-06	0.03	0.0	0.0	0.03	4.16E-08
(E3)	5.81E-06	0.03	0.0	0.0	0.03	1.74E-07
(E4)	8.85E-08	0.03	0.0	0.0	0.03	2.65E-09
(E5)	3.28E-05	0.03	0.0	0.0	0.03	9.83E-07
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	4.61E-06	0.81	0.0	0.0	0.81	3.73E-06
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	4.61E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.94E-07	0.81	0.0	0.0	0.81	2.38E-07
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	2.94E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.45E-07	0.81	0.0	0.0	0.81	4.41E-07
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	5.45E-03	0.0	0.0	0.0	0.0	0.00E+00
						8.34E-06

Hazard : Process Loss of Containment

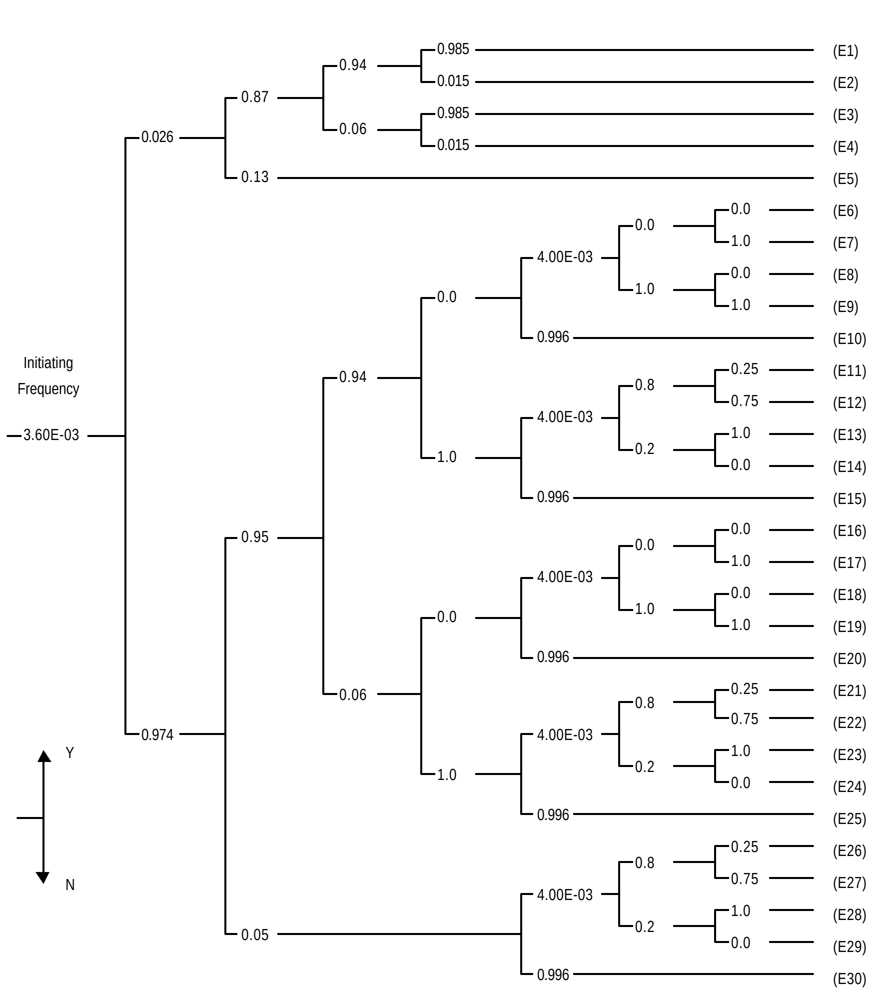
Sub Category 1 : Test Separator (Gas)

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	7.54E-05	0.5	0.0	0.0	0.5	3.77E-05
(E2)	1.15E-06	0.5	0.0	0.0	0.5	5.74E-07
(E3)	4.81E-06	0.5	0.0	0.0	0.5	2.41E-06
(E4)	7.33E-08	0.5	0.0	0.0	0.5	3.66E-08
(E5)	1.22E-05	0.5	0.0	0.0	0.5	6.08E-06
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.50E-06	0.81	0.0	0.0	0.81	2.03E-06
(E12)	7.51E-06	1.62	1.41	0.0	3.03	2.28E-05
(E13)	2.50E-06	1.62	4.755	0.5363	6.9113	1.73E-05
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	3.12E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.60E-07	0.81	0.0	0.0	0.81	1.30E-07
(E22)	4.80E-07	1.62	1.41	0.0	3.03	1.45E-06
(E23)	1.60E-07	1.62	4.755	0.5363	6.9113	1.11E-06
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.99E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.40E-07	0.81	0.0	0.0	0.81	1.14E-07
(E27)	4.21E-07	1.62	1.41	0.0	3.03	1.27E-06
(E28)	1.40E-07	1.62	4.755	0.5363	6.9113	9.69E-07
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.75E-04	0.0	0.0	0.0	0.0	0.00E+00
						9.40E-05

Hazard : Process Loss of Containment

Sub Category 1 : Test Separator (Gas)

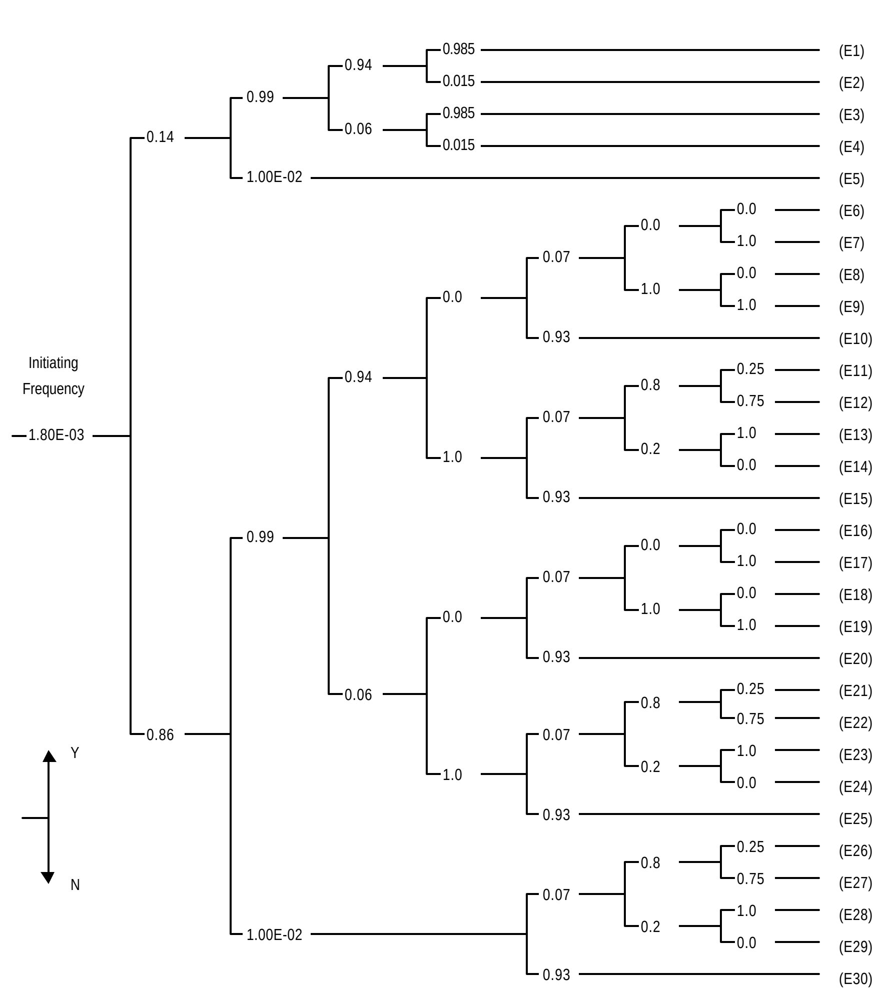
Sub Category 2 : Medium

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

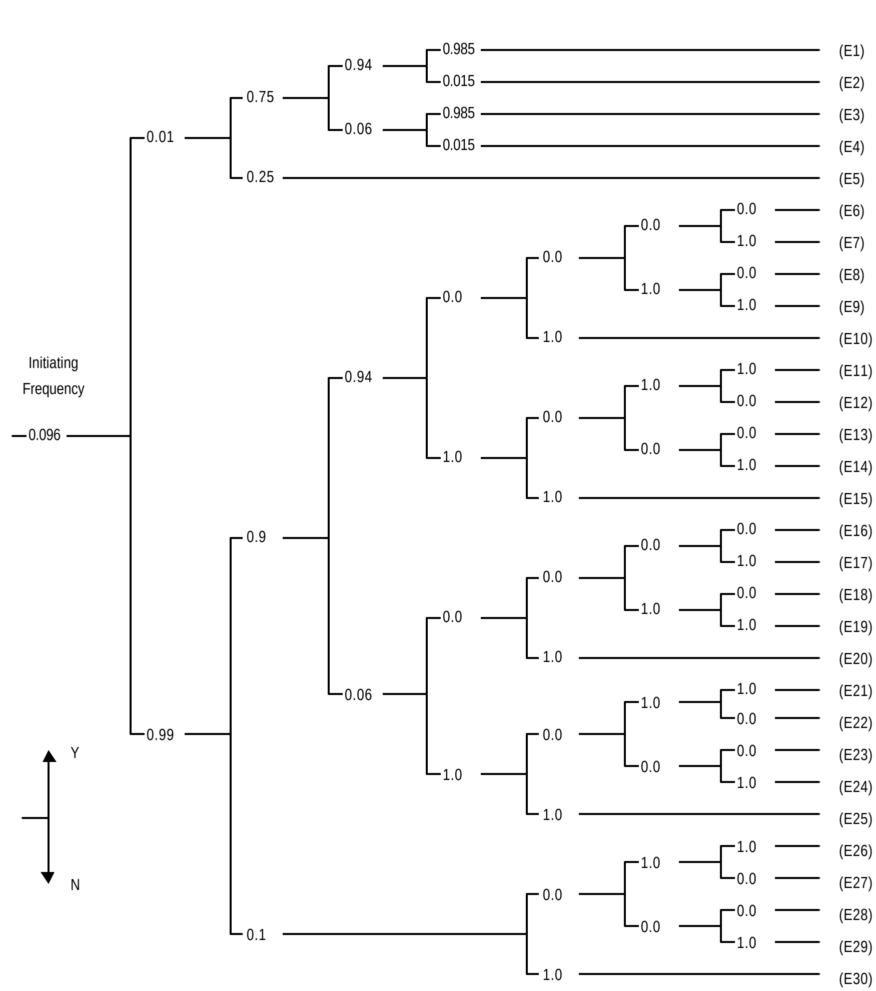
Initiating Frequency



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.31E-04	1.62	0.0	0.0	1.62	3.74E-04
(E2)	3.52E-06	1.62	0.0	0.0	1.62	5.70E-06
(E3)	1.47E-05	1.62	0.0	0.6	2.22	3.27E-05
(E4)	2.25E-07	1.62	0.0	0.6	2.22	4.98E-07
(E5)	2.52E-06	1.62	0.0	0.6	2.22	5.59E-06
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.02E-05	0.81	0.0	0.0	0.81	1.63E-05
(E12)	6.05E-05	1.62	1.41	0.0	3.03	1.83E-04
(E13)	2.02E-05	1.62	4.755	0.5363	6.9113	1.39E-04
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.34E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.6	1.41	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.6	3.63	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	1.29E-06	0.81	0.0	0.6	1.41	1.82E-06
(E22)	3.86E-06	1.62	1.41	0.6	3.63	1.40E-05
(E23)	1.29E-06	1.62	4.755	0.5363	6.9113	8.90E-06
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00 5
(E25)	8.55E-05	0.0	0.0	0.6	0.6	.
(E26)	2.17E-07	0.81	0.0	0.6	1.41	1 3
(E27)	6.50E-07	1.62	1.41	0.6	3.63	E -
(E28)	2.17E-07	1.62	4.755	0.5363	6.9113	0 5
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	
(E30)	1.44E-05	0.0	0.0	0.6	0.6	3
						8

Hazard : Process Loss of Containment	Sub Category 1 : Test Separator (Gas)	Sub Category 2 : Large	Project : FPSO4

RMRI

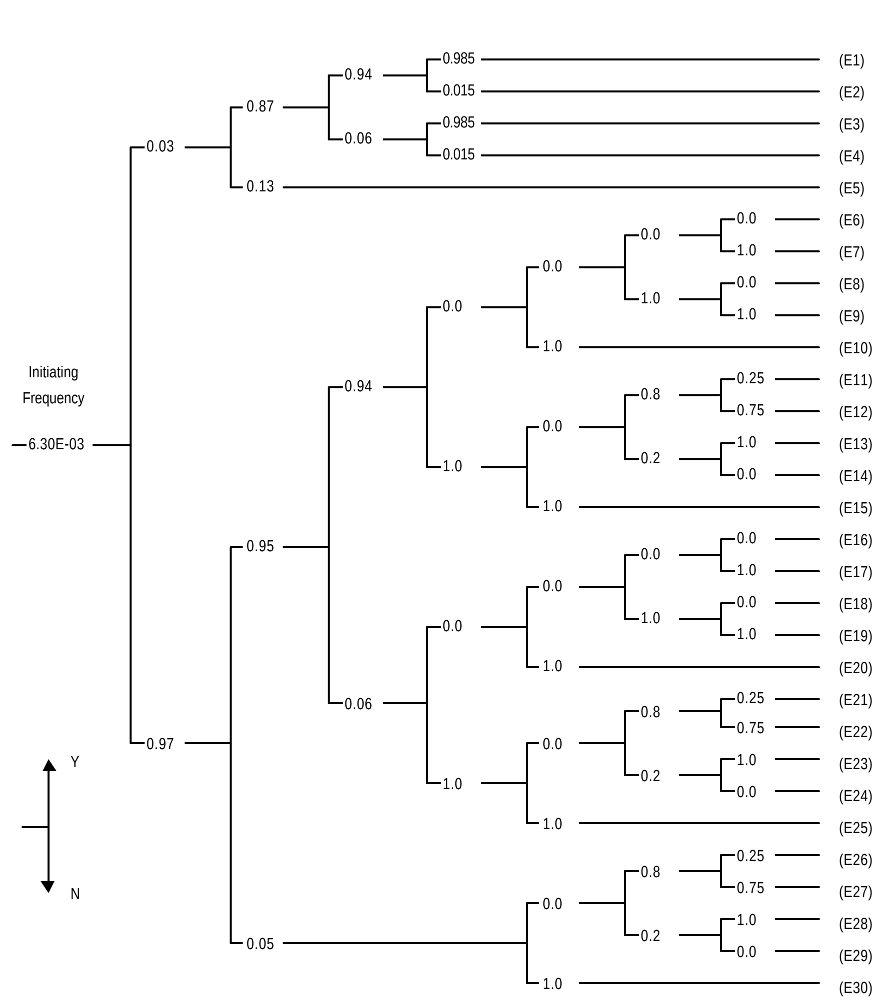


Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	6.67E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.02E-05	0.0	0.0	0.0	0.0	0.00E+00
(E3)	4.26E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	6.48E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	2.40E-04	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	8.04E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	5.13E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	9.50E-03	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Test Separator (Liquid)	Small	

RMRI

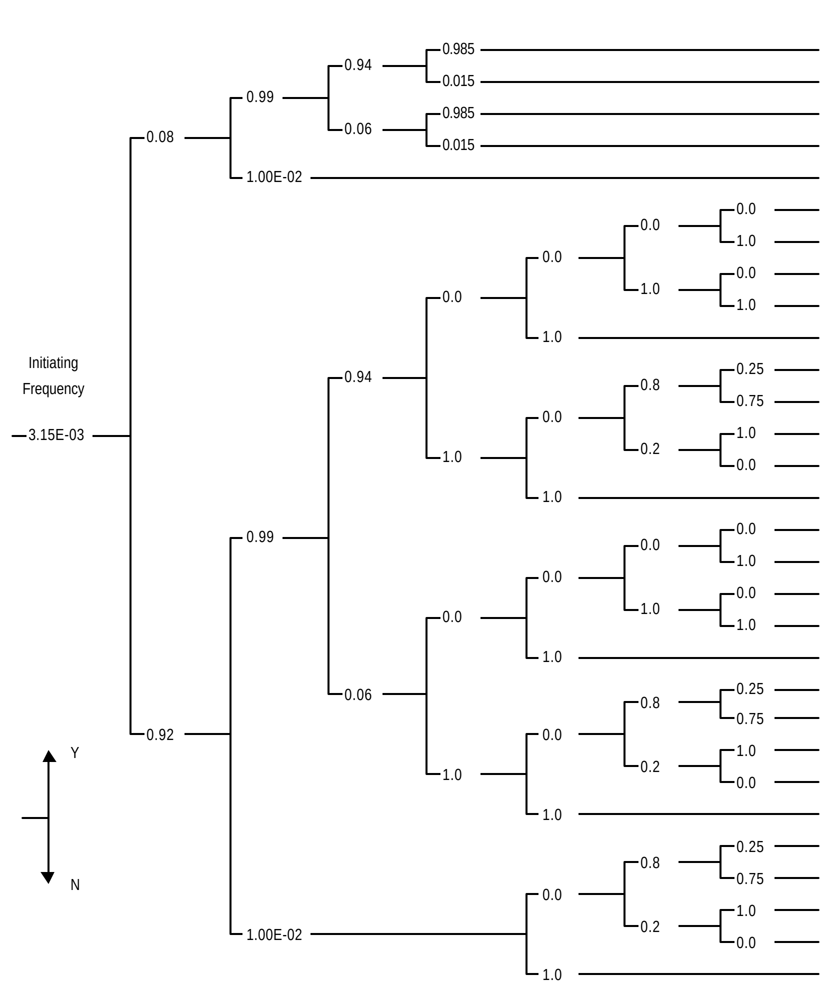
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.52E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	2.32E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	9.72E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	1.48E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	2.46E-05	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	5.46E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	3.48E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	3.06E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Test Separator (Liquid)	Medium	

RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.31E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	3.52E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	1.47E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	2.25E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	2.52E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	2.70E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.72E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	2.90E-05	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

Sub Category 1 : Test Separator (Liquid)

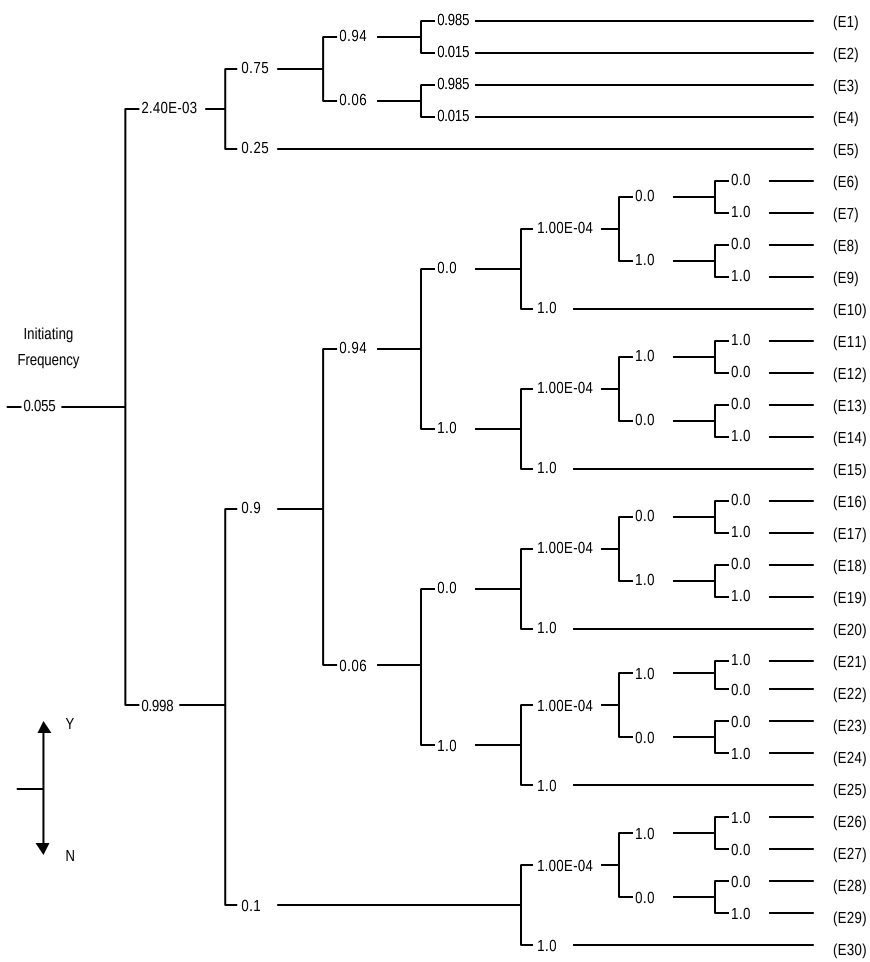
Sub Category 2 : Large

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

Initiating Frequency



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	9.10E-05	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.39E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	5.81E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	8.85E-08	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.28E-05	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	4.61E-06	0.81	0.0	0.0	0.81	3.73E-06
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	4.61E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.94E-07	0.81	0.0	0.0	0.81	2.38E-07
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	2.94E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.45E-07	0.81	0.0	0.0	0.81	4.41E-07
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	5.45E-03	0.0	0.0	0.0	0.0	0.00E+00
						4.41E-06

Hazard : Process Loss of Containment

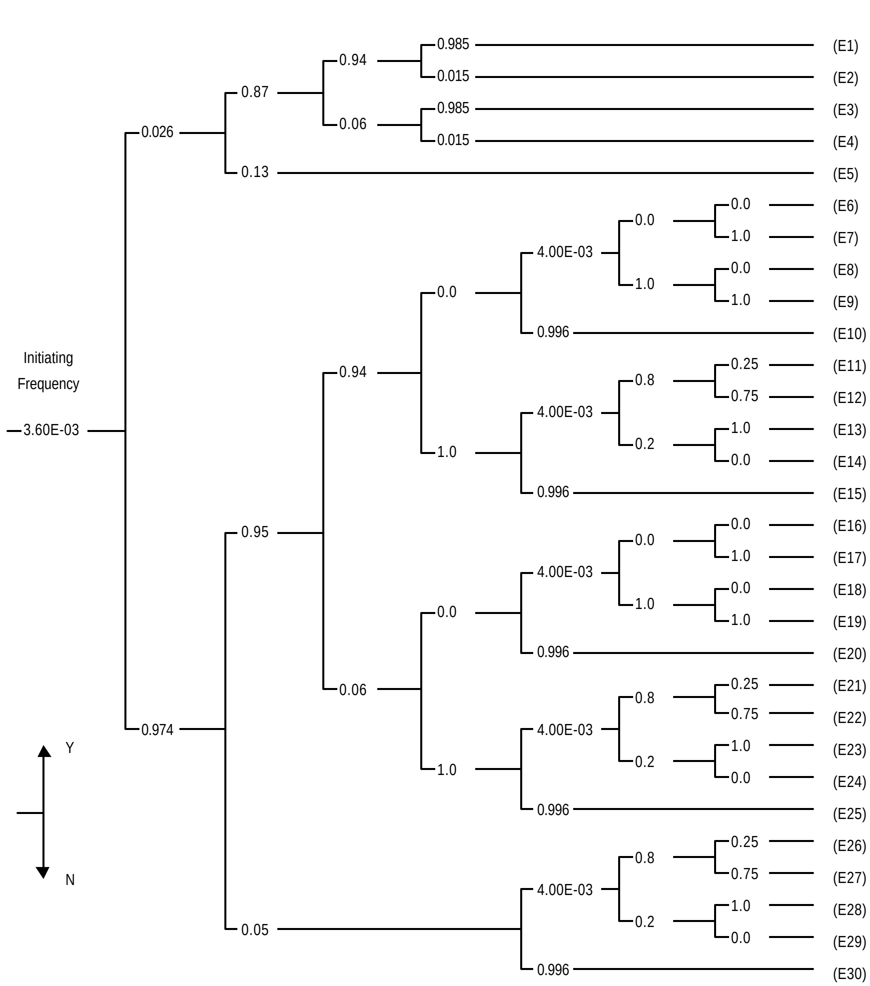
Sub Category 1 : 2nd Stage Separator (Gas)

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

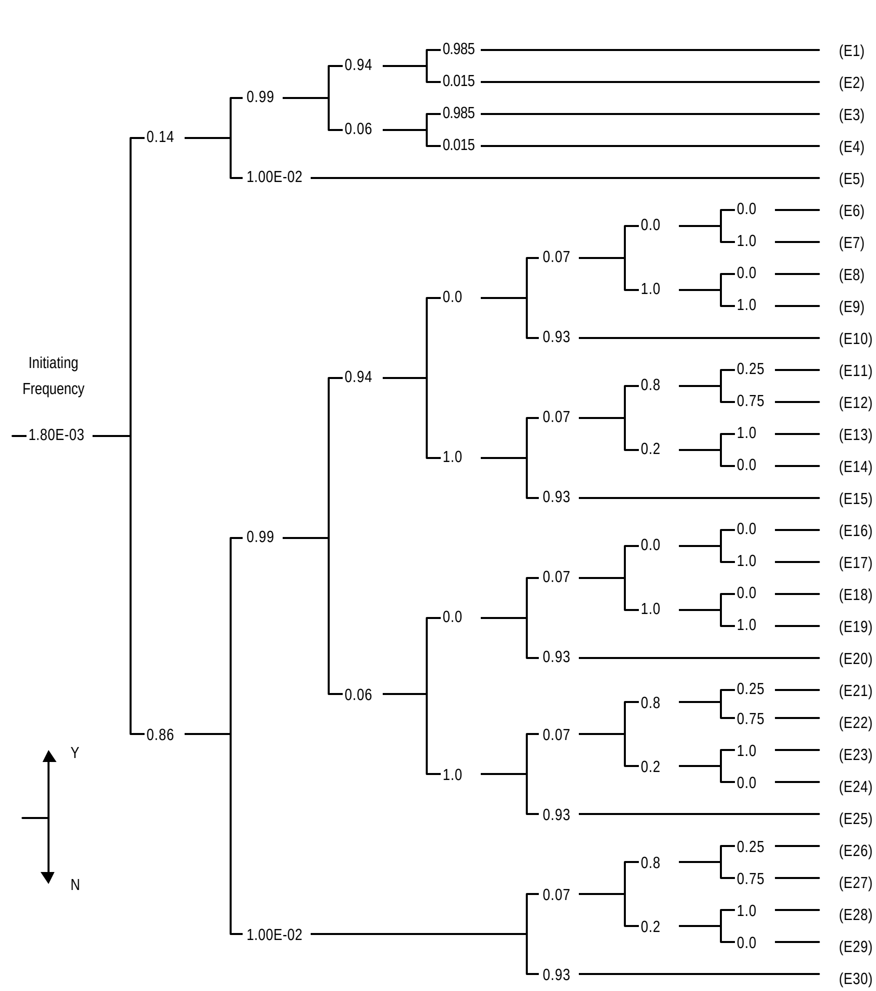


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	7.54E-05	0.04	0.0	0.0	0.04	3.02E-06
(E2)	1.15E-06	0.04	0.0	0.0	0.04	4.59E-08
(E3)	4.81E-06	0.04	0.0	0.0	0.04	1.93E-07
(E4)	7.33E-08	0.04	0.0	0.0	0.04	2.93E-09
(E5)	1.22E-05	0.04	0.0	0.0	0.04	4.87E-07
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.50E-06	0.81	0.0	0.0	0.81	2.03E-06
(E12)	7.51E-06	1.62	1.41	0.0	3.03	2.28E-05
(E13)	2.50E-06	1.62	4.755	0.5363	6.9113	1.73E-05
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	3.12E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.60E-07	0.81	0.0	0.0	0.81	1.30E-07
(E22)	4.80E-07	1.62	1.41	0.0	3.03	1.45E-06
(E23)	1.60E-07	1.62	4.755	0.5363	6.9113	1.11E-06
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.99E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.40E-07	0.81	0.0	0.0	0.81	1.14E-07
(E27)	4.21E-07	1.62	1.41	0.0	3.03	1.27E-06
(E28)	1.40E-07	1.62	4.755	0.5363	6.9113	9.69E-07
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.75E-04	0.0	0.0	0.0	0.0	0.00E+00
						5.09E-05

Hazard : Process Loss of Containment	Sub Category 1 : 2nd Stage Separator (Gas)	Sub Category 2 : Medium	Project : FPSO4

RMRI

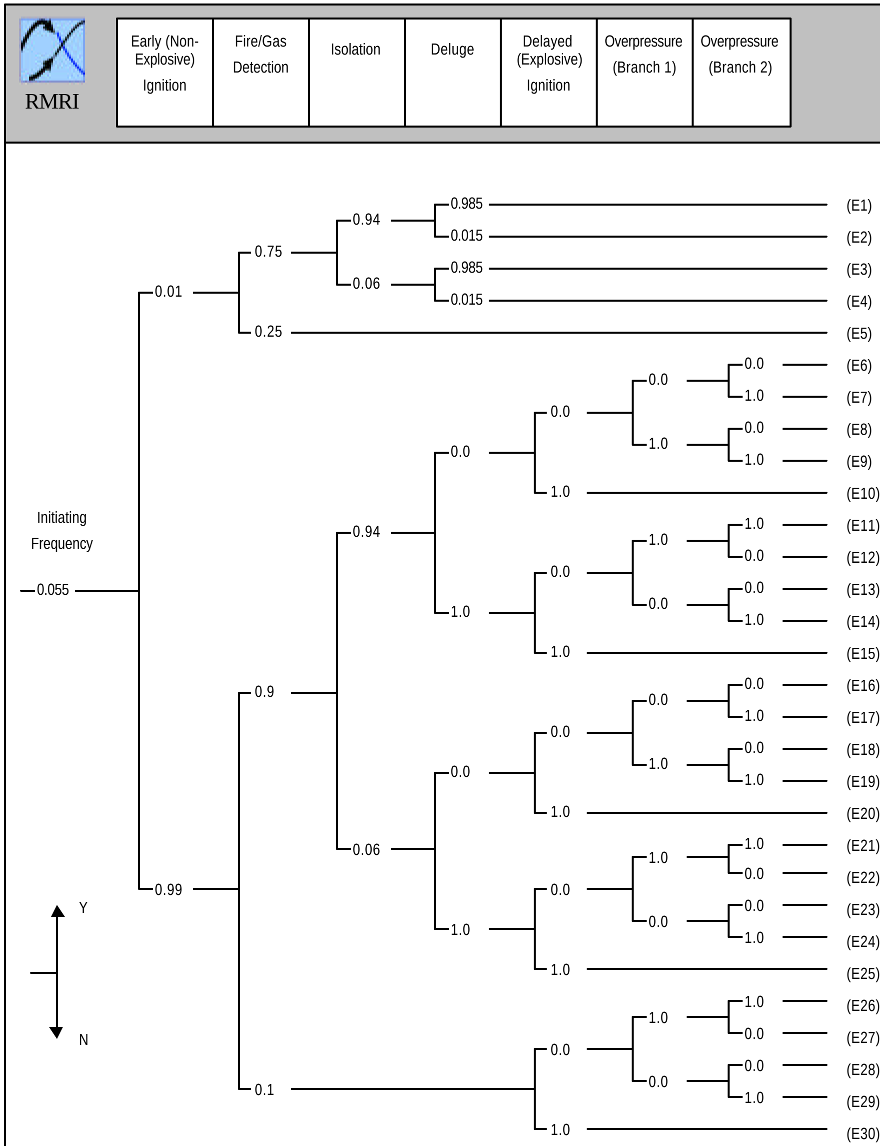
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.31E-04	0.16	0.0	0.0	0.16	3.70E-05
(E2)	3.52E-06	0.16	0.0	0.0	0.16	5.63E-07
(E3)	1.47E-05	0.16	0.0	0.6	0.76	1.12E-05
(E4)	2.25E-07	0.16	0.0	0.6	0.76	1.71E-07
(E5)	2.52E-06	0.16	0.0	0.6	0.76	1.92E-06
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.02E-05	0.81	0.0	0.0	0.81	1.63E-05
(E12)	6.05E-05	1.62	1.41	0.0	3.03	1.83E-04
(E13)	2.02E-05	1.62	4.755	0.5363	6.9113	1.39E-04
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.34E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.6	1.41	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.6	3.63	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	1.29E-06	0.81	0.0	0.6	1.41	1.82E-06
(E22)	3.86E-06	1.62	1.41	0.6	3.63	1.40E-05
(E23)	1.29E-06	1.62	4.755	0.5363	6.9113	8.90E-06
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	8.55E-05	0.0	0.0	0.6	0.6	5.13E-05
(E26)	2.17E-07	0.81	0.0	0.6	1.41	3.06E-07
(E27)	6.50E-07	1.62	1.41	0.6	3.63	2.36E-06
(E28)	2.17E-07	1.62	4.755	0.5363	6.9113	1.50E-06
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.44E-05	0.0	0.0	0.6	0.6	8.64E-06
						4.79E-04

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	2nd Stage Separator (Gas)	Large	

RMRI



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.79E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	5.77E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	2.42E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	3.69E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.36E-04	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	4.57E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	2.92E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	5.41E-03	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

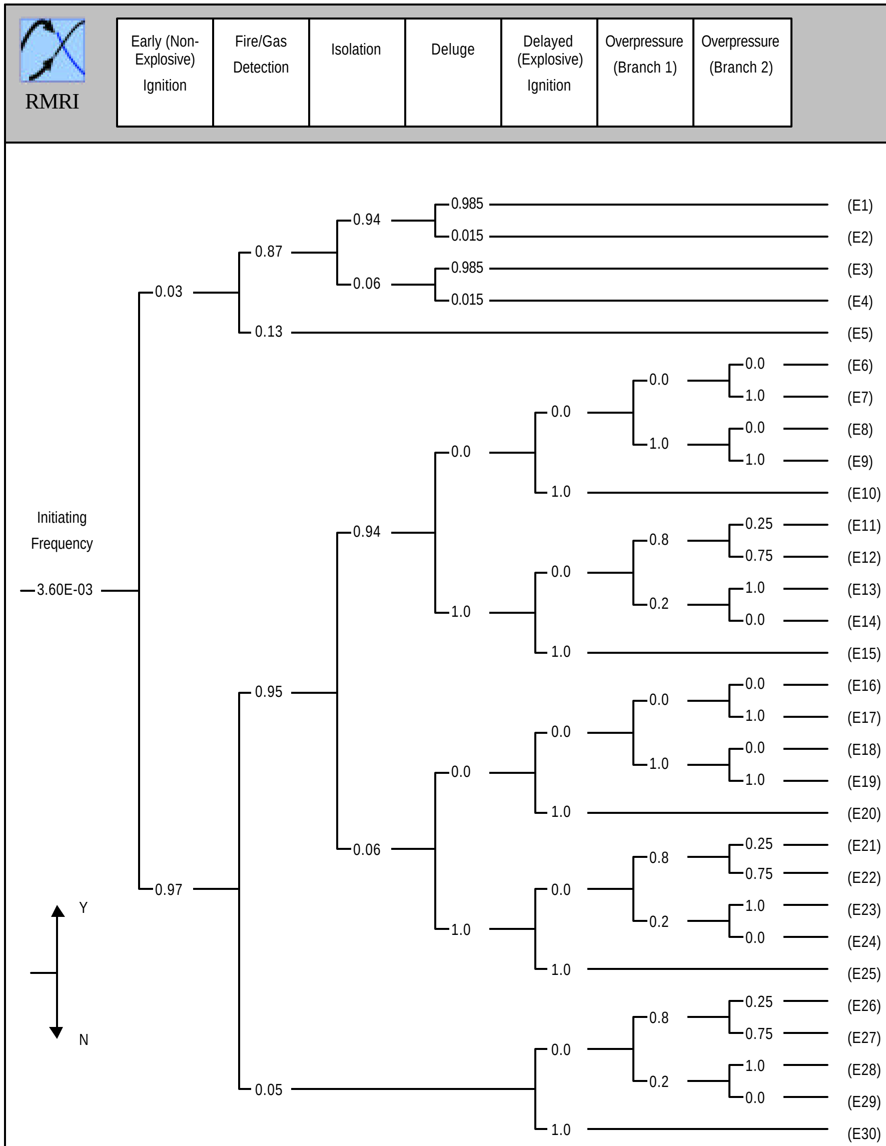
Hazard : Process Loss of Containment

Sub Category 1 : 2nd Stage Separator (Liquid)

Sub Category 2 : Small

Project : FPSO4

RMRI



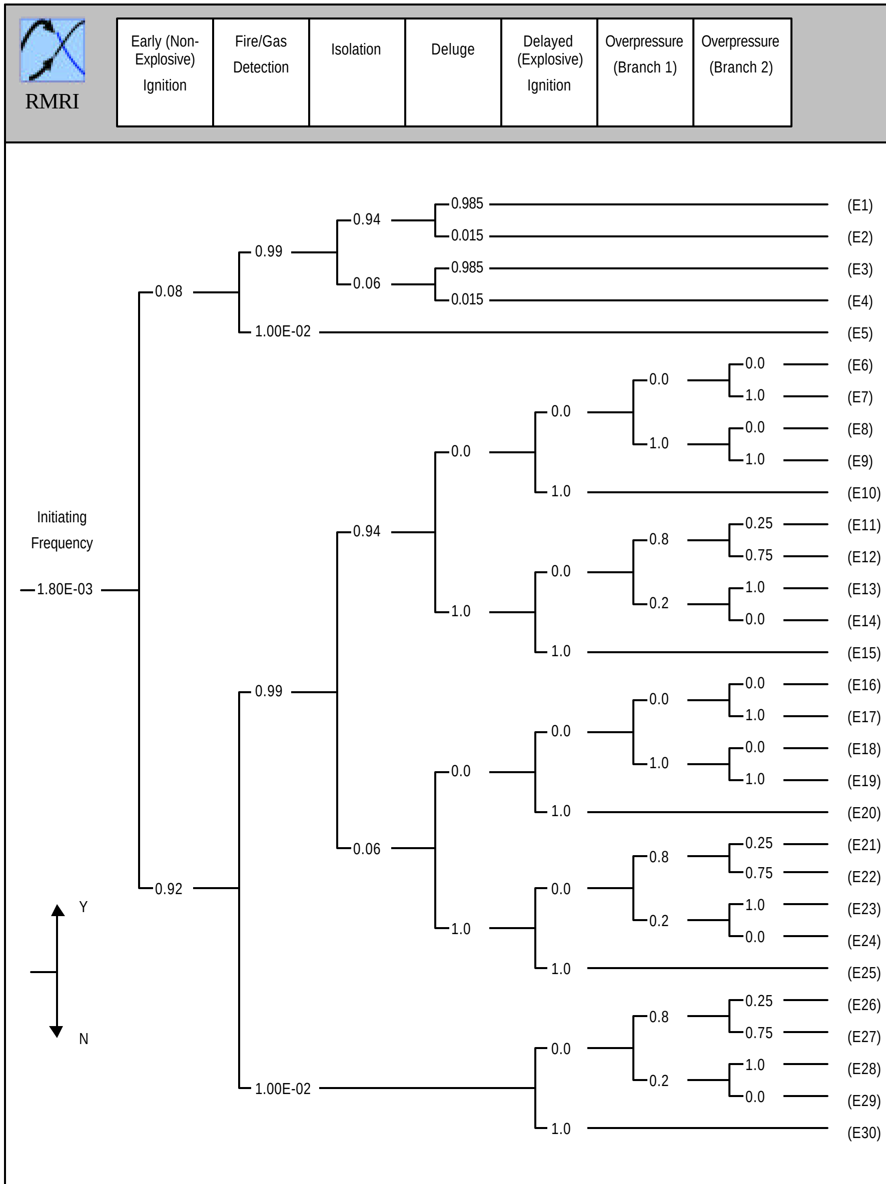
	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.70E-05	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.32E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	5.55E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	8.46E-08	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.40E-05	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	3.12E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.99E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.75E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

Sub Category 1 : 2nd Stage Separator (Liquid)

Sub Category 2 : Medium

Project : FPSO4



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.32E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	2.01E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	8.43E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	1.28E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.44E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.54E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	9.84E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.66E-05	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

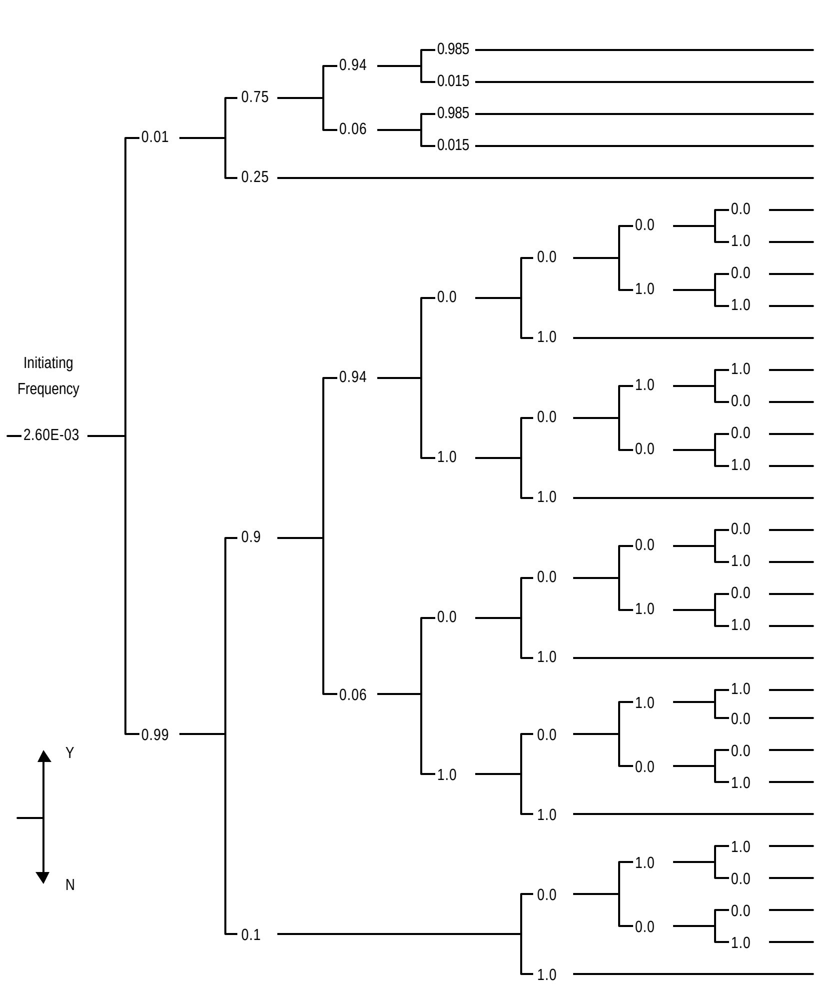
Sub Category 1 : 2nd Stage Separator (Liquid)

Sub Category 2 : Large

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.81E-05	0.0	0.0	0.0	0.0	0.00E+00
(E2)	2.75E-07	0.0	0.0	0.0	0.0	0.00E+00
(E3)	1.15E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	1.75E-08	0.0	0.0	0.0	0.0	0.00E+00
(E5)	6.50E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	2.18E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.39E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	2.57E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

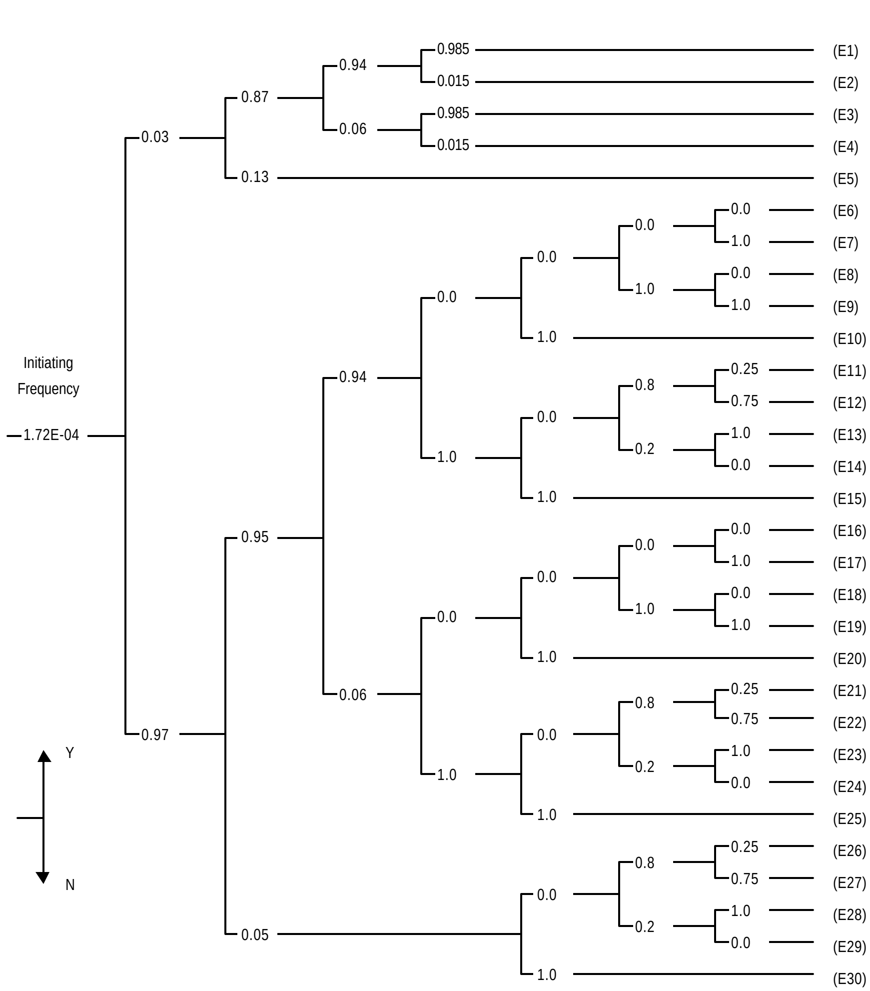
Sub Category 1 : Crude Oil Electrost. Coalescer

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.16E-06	0.0	0.0	0.0	0.0	0.00E+00
(E2)	6.33E-08	0.0	0.0	0.0	0.0	0.00E+00
(E3)	2.65E-07	0.0	0.0	0.0	0.0	0.00E+00
(E4)	4.04E-09	0.0	0.0	0.0	0.0	0.00E+00
(E5)	6.71E-07	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.49E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	9.51E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	8.34E-06	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

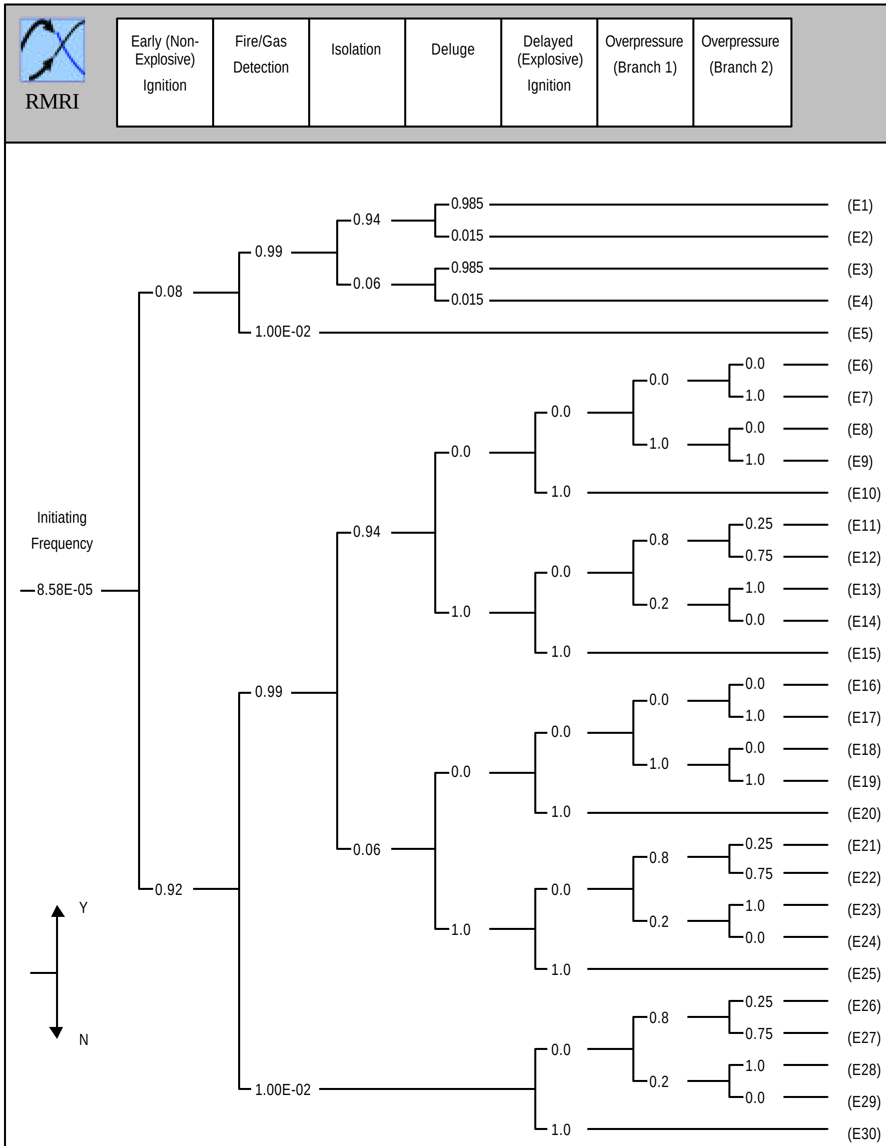
Hazard : Process Loss of Containment

Sub Category 1 : Crude Oil Electrost. Coalescer

Sub Category 2 : Medium

Project : FPSO4

RMRI



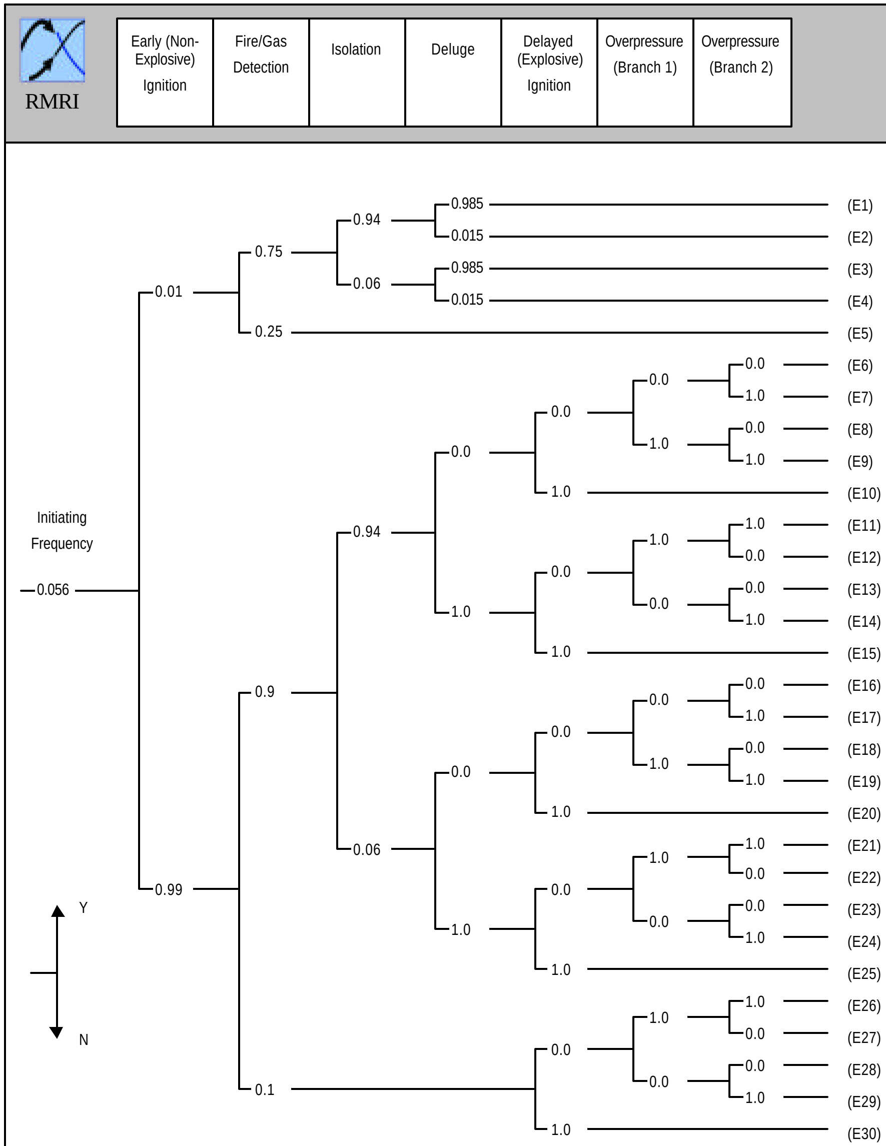
Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	6.29E-06	0.0	0.0	0.0	0.0	0.00E+00
(E2)	9.58E-08	0.0	0.0	0.0	0.0	0.00E+00
(E3)	4.02E-07	0.0	0.0	0.0	0.0	0.00E+00
(E4)	6.12E-09	0.0	0.0	0.0	0.0	0.00E+00
(E5)	6.86E-08	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	7.35E-05	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	4.69E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	7.89E-07	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

Sub Category 1 : Crude Oil Electrost Coalescer

Sub Category 2 : Large

Project : FPSO4



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.90E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	5.93E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	2.49E-05	0.0	0.0	0.0	0.0	0.00E+00
(E4)	3.79E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.40E-04	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	4.70E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	3.00E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	5.55E-03	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

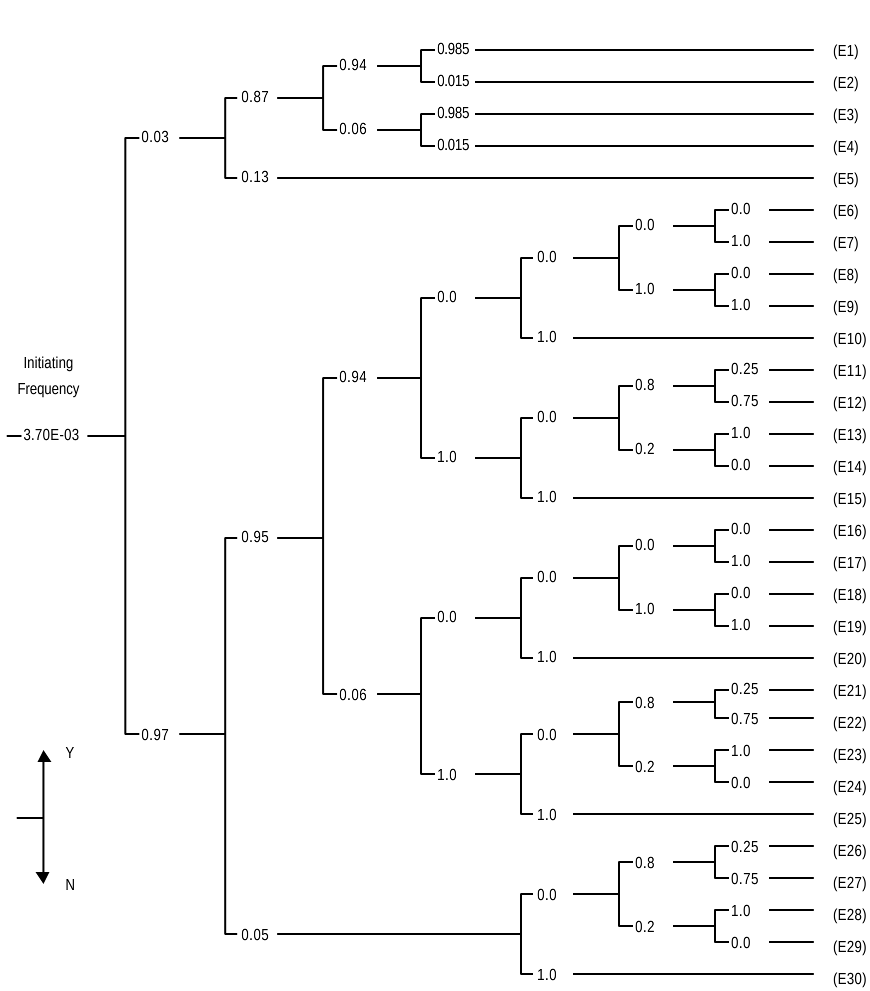
Sub Category 1 : Crude Oil Storage

Sub Category 2 : Small

Project : FPSO4

RMRI

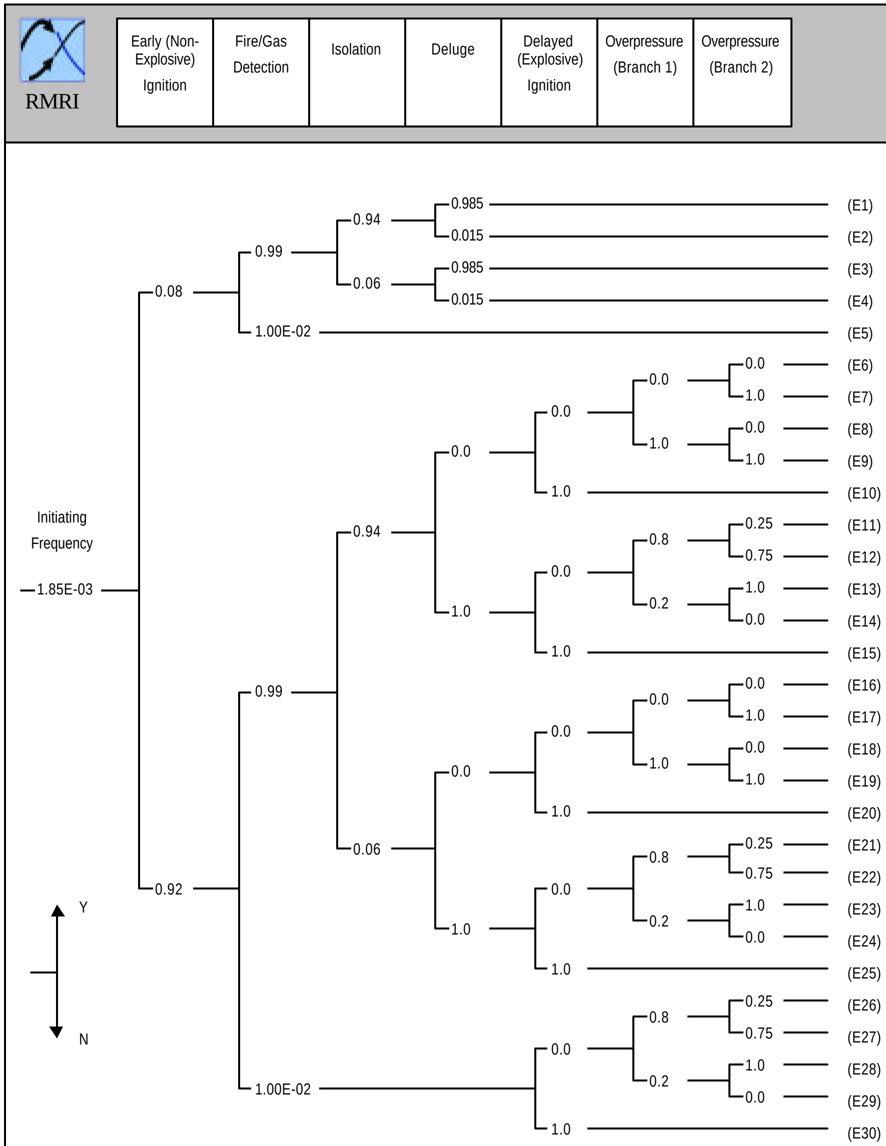
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.94E-05	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.36E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	5.71E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	8.69E-08	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.44E-05	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	3.20E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	2.05E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.79E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Crude Oil Storage	Medium	

RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.36E-04	0.0	0.0	0.0	0.0	0.00E+00
(E2)	2.07E-06	0.0	0.0	0.0	0.0	0.00E+00
(E3)	8.66E-06	0.0	0.0	0.0	0.0	0.00E+00
(E4)	1.32E-07	0.0	0.0	0.0	0.0	0.00E+00
(E5)	1.48E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E7)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E8)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E9)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E12)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E13)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E14)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E15)	1.58E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E17)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E18)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E19)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E22)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E23)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E24)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E25)	1.01E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.81	0.0	0.0	0.81	0.00E+00
(E27)	0.00E+00	1.62	1.41	0.0	3.03	0.00E+00
(E28)	0.00E+00	1.62	4.755	0.5363	6.9113	0.00E+00
(E29)	0.00E+00	1.62	6.165	2.6108	10.3958	0.00E+00
(E30)	1.70E-05	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

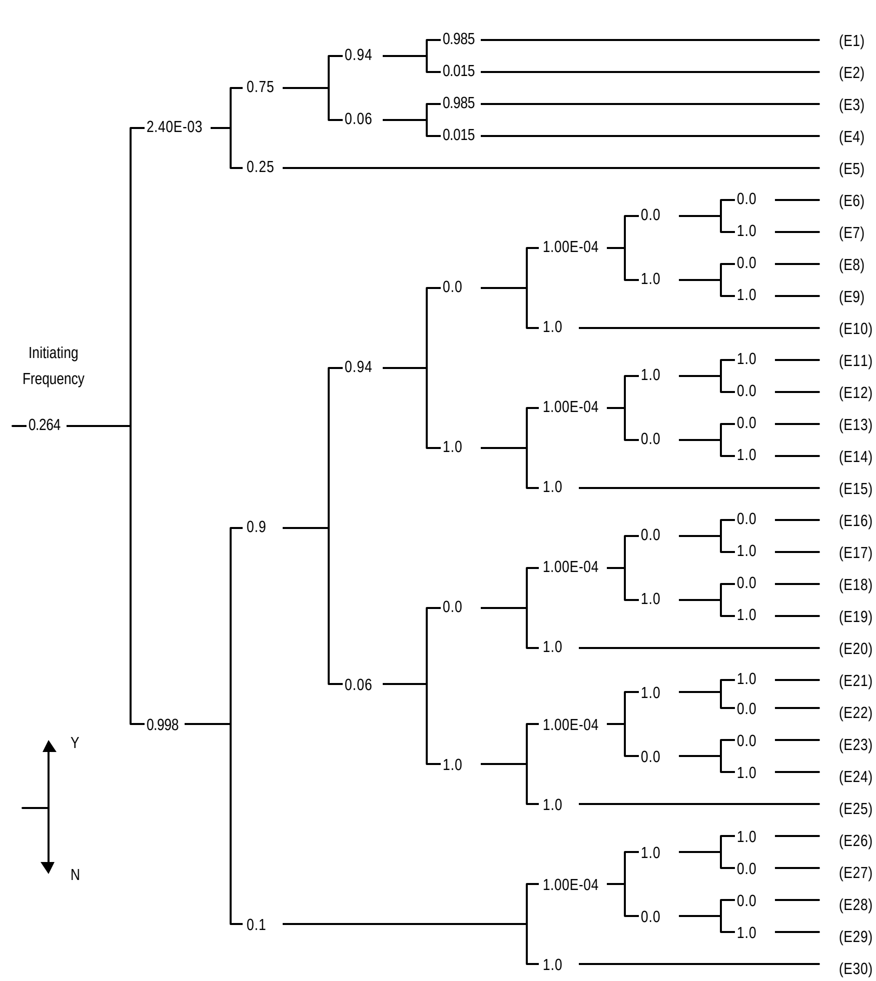
Sub Category 1 : Crude Oil Storage

Sub Category 2 : Large

Project : FPSO4

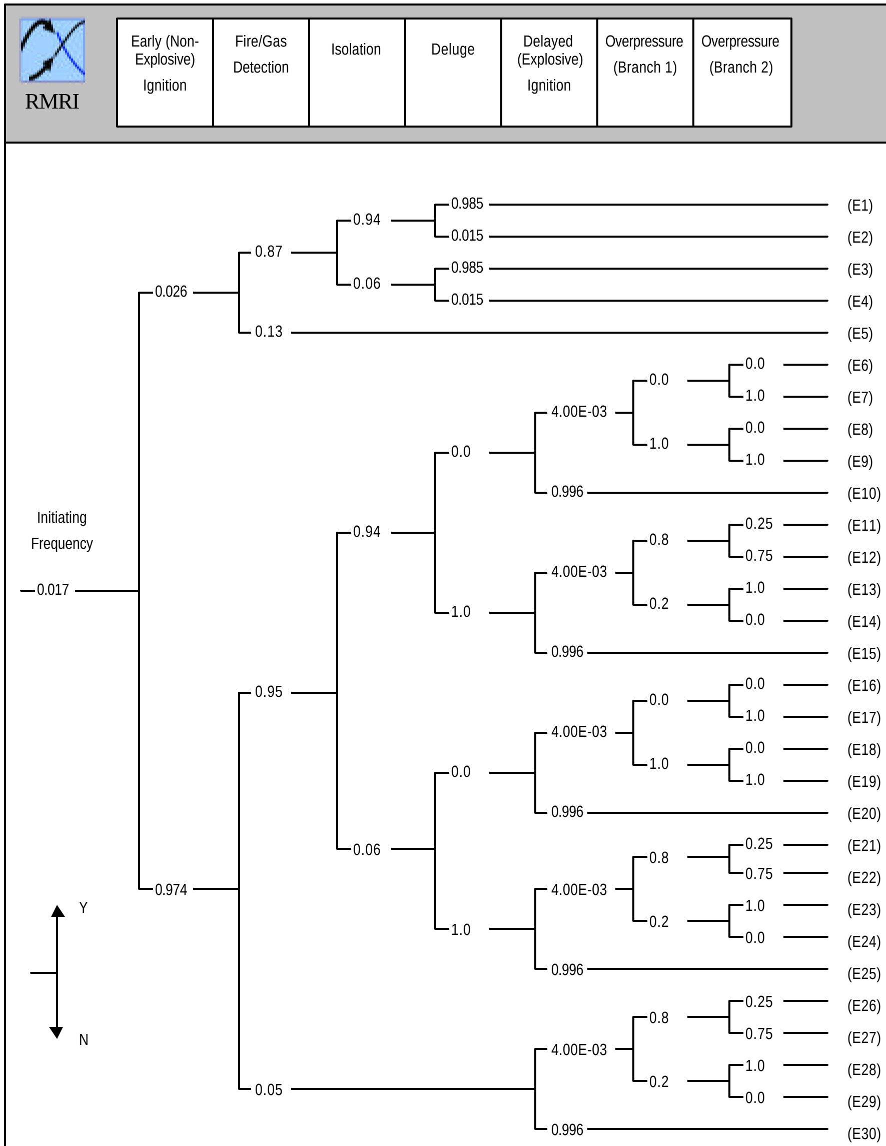
RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.40E-04	0.01	0.0	0.0	0.01	4.40E-06
(E2)	6.70E-06	0.01	0.0	0.0	0.01	6.70E-08
(E3)	2.81E-05	0.01	0.0	0.0	0.01	2.81E-07
(E4)	4.28E-07	0.01	0.0	0.0	0.01	4.28E-09
(E5)	1.58E-04	0.01	0.0	0.0	0.01	1.58E-06
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.23E-05	0.705	0.0	0.0	0.705	1.57E-05
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	2.23E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.42E-06	0.705	0.0	0.0	0.705	1.00E-06
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	1.42E-02	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.63E-06	0.705	0.0	0.0	0.705	1.86E-06
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	2.63E-02	0.0	0.0	0.0	0.0	0.00E+00
						2.49E-05

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage FG Compression	Small	



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.64E-04	0.23	0.0	0.0	0.23	8.38E-05
(E2)	5.55E-06	0.23	0.0	0.0	0.23	1.28E-06
(E3)	2.33E-05	0.23	0.0	0.0	0.23	5.35E-06
(E4)	3.54E-07	0.23	0.0	0.0	0.23	8.15E-08
(E5)	5.88E-05	0.23	0.0	0.0	0.23	1.35E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.21E-05	0.705	0.0	0.0	0.705	8.54E-06
(E12)	3.63E-05	1.41	0.705	0.0	2.115	7.68E-05
(E13)	1.21E-05	1.41	3.84	0.5475	5.7975	7.02E-05
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.51E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	7.73E-07	0.705	0.0	0.0	0.705	5.45E-07
(E22)	2.32E-06	1.41	0.705	0.0	2.115	4.90E-06
(E23)	7.73E-07	1.41	3.84	0.5475	5.7975	4.48E-06
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	9.62E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	6.78E-07	0.705	0.0	0.0	0.705	4.78E-07
(E27)	2.03E-06	1.41	0.705	0.0	2.115	4.30E-06
(E28)	6.78E-07	1.41	3.84	0.5475	5.7975	3.93E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	8.44E-04	0.0	0.0	0.0	0.0	0.00E+00
						2.78E-04

Hazard : Process Loss of Containment

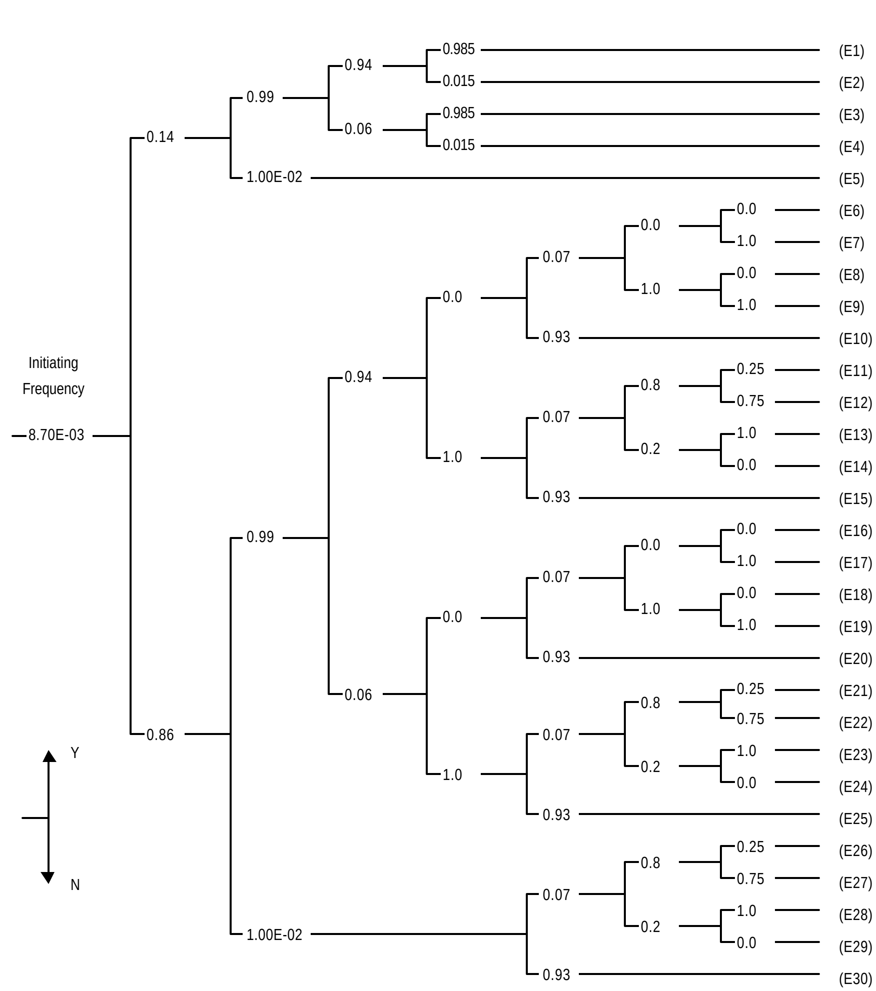
Sub Category 1 : 1st Stage FG Compression

Sub Category 2 : Medium

Project : FPSO4

RMRI

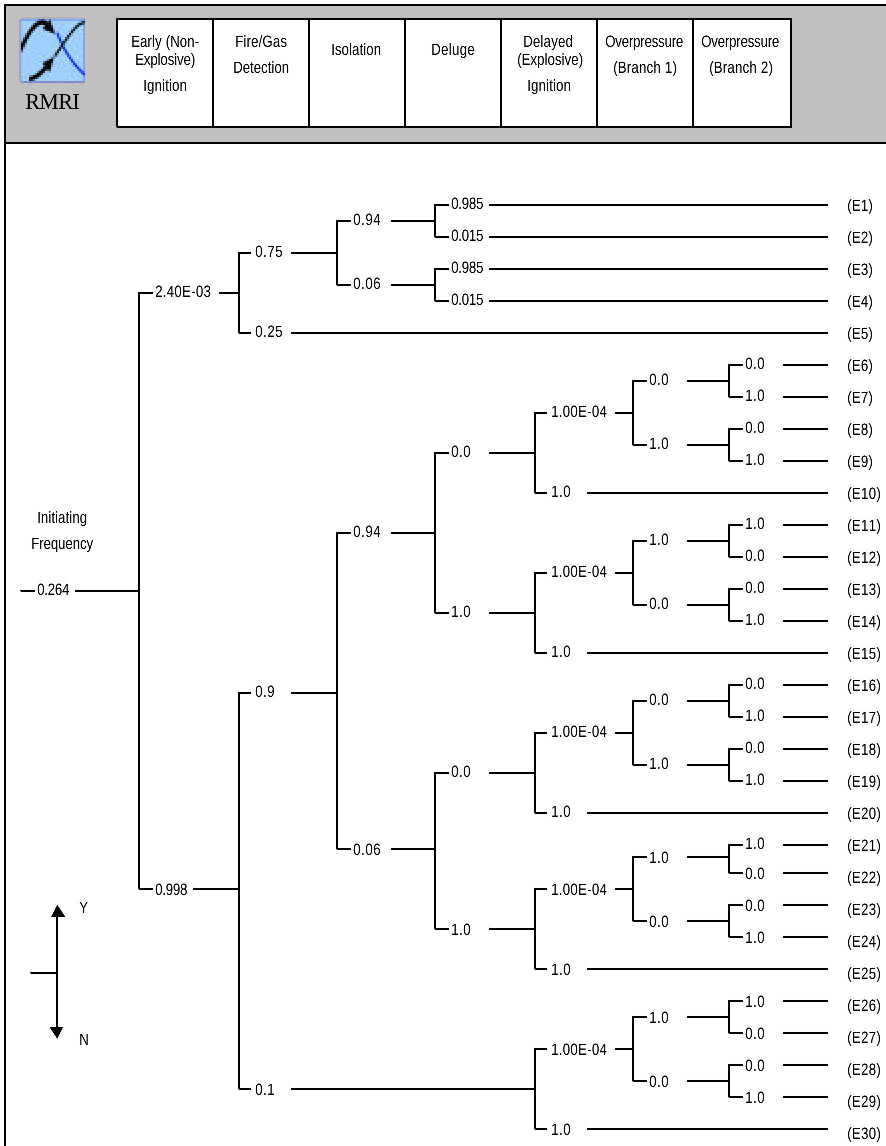
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.12E-03	1.01	0.0	0.0	1.01	1.13E-03
(E2)	1.70E-05	1.01	0.0	0.0	1.01	1.72E-05
(E3)	7.13E-05	1.01	0.0	0.6	1.61	1.15E-04
(E4)	1.09E-06	1.01	0.0	0.6	1.61	1.75E-06
(E5)	1.22E-05	1.01	0.0	0.6	1.61	1.96E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.75E-05	0.705	0.0	0.0	0.705	6.87E-05
(E12)	2.92E-04	1.41	0.705	0.0	2.115	6.19E-04
(E13)	9.75E-05	1.41	3.84	0.5475	5.7975	5.65E-04
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	6.48E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.6	2.715	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	6.22E-06	0.705	0.0	0.6	1.305	8.12E-06
(E22)	1.87E-05	1.41	0.705	0.6	2.715	5.07E-05
(E23)	6.22E-06	1.41	3.84	0.5475	5.7975	3.61E-05
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	4.13E-04	0.0	0.0	0.6	0.6	2.48E-04
(E26)	1.05E-06	0.705	0.0	0.6	1.305	1.37E-06
(E27)	3.14E-06	1.41	0.705	0.6	2.715	8.53E-06
(E28)	1.05E-06	1.41	3.84	0.5475	5.7975	6.07E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	6.96E-05	0.0	0.0	0.6	0.6	4.17E-05
						2.93E-03

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st Stage FG Compression	Large	

RMRI



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.40E-04	0.05	0.0	0.0	0.05	2.20E-05
(E2)	6.70E-06	0.05	0.0	0.0	0.05	3.35E-07
(E3)	2.81E-05	0.05	0.0	0.0	0.05	1.40E-06
(E4)	4.28E-07	0.05	0.0	0.0	0.05	2.14E-08
(E5)	1.58E-04	0.05	0.0	0.0	0.05	7.92E-06
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.23E-05	0.705	0.0	0.0	0.705	1.57E-05
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	2.23E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.42E-06	0.705	0.0	0.0	0.705	1.00E-06
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	1.42E-02	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.63E-06	0.705	0.0	0.0	0.705	1.86E-06
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	2.63E-02	0.0	0.0	0.0	0.0	0.00E+00
						5.02E-05

Hazard : Process Loss of Containment

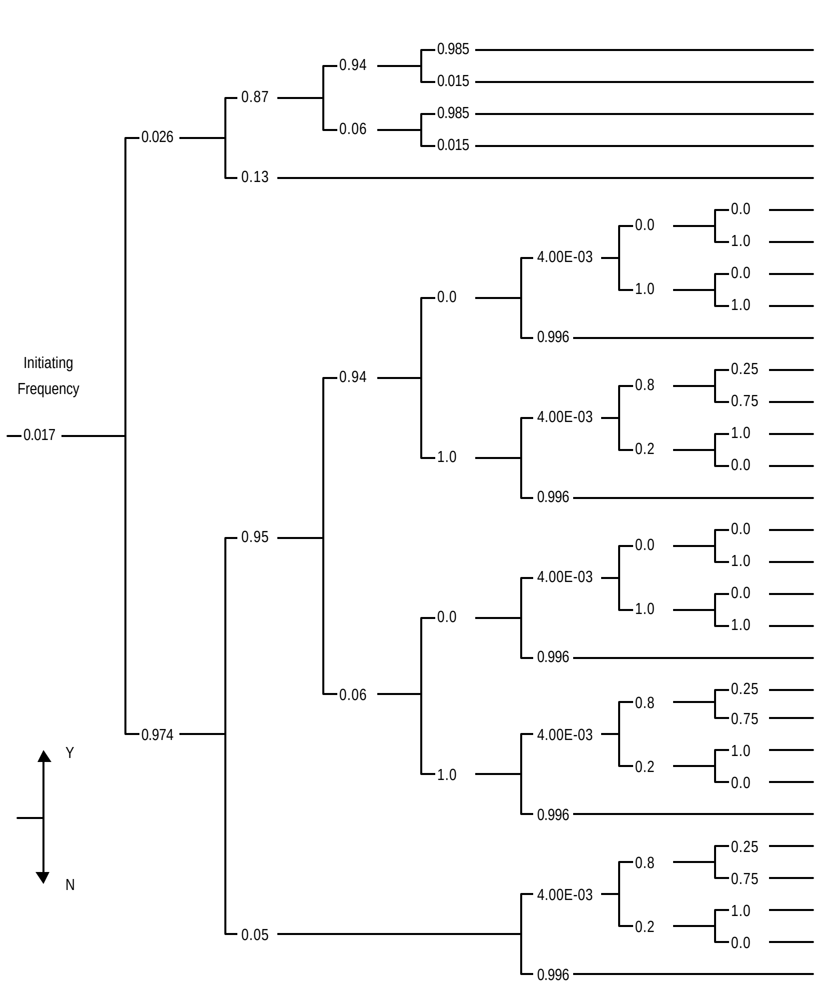
Sub Category 1 : 2nd Stage FG Compression

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

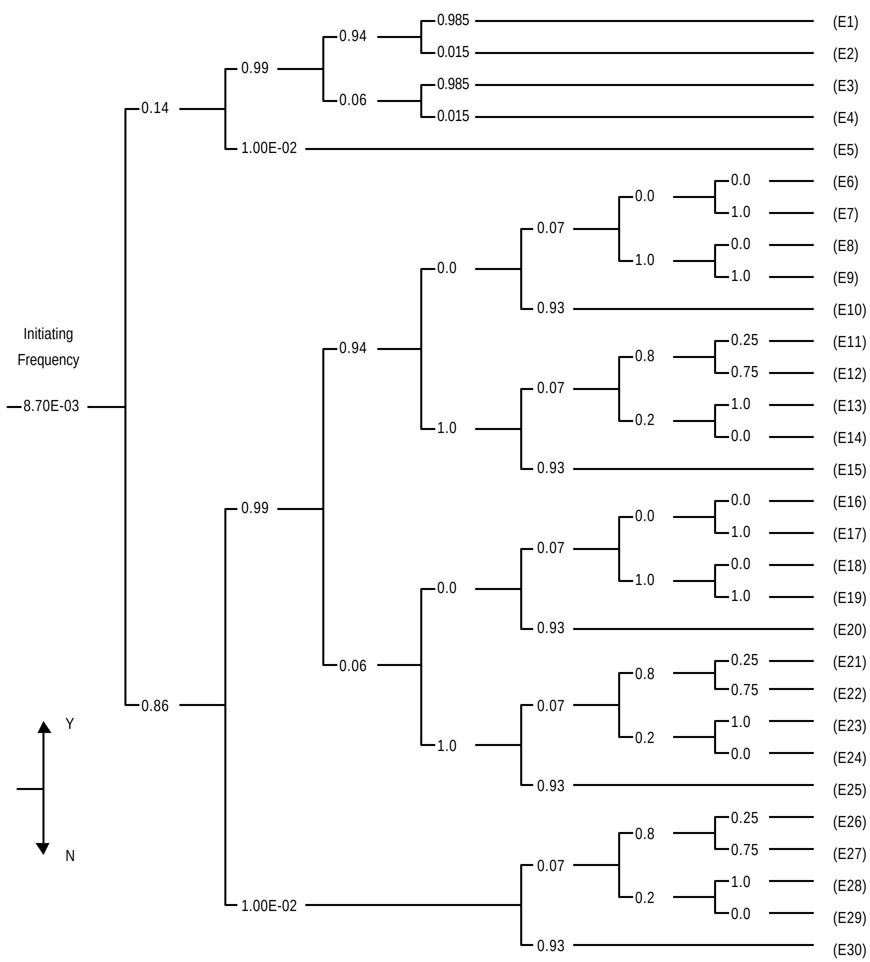


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.64E-04	0.83	0.0	0.0	0.83	3.02E-04
(E2)	5.55E-06	0.83	0.0	0.0	0.83	4.61E-06
(E3)	2.33E-05	0.83	0.0	0.0	0.83	1.93E-05
(E4)	3.54E-07	0.83	0.0	0.0	0.83	2.94E-07
(E5)	5.88E-05	0.83	0.0	0.0	0.83	4.88E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.21E-05	0.705	0.0	0.0	0.705	8.54E-06
(E12)	3.63E-05	1.41	0.705	0.0	2.115	7.68E-05
(E13)	1.21E-05	1.41	3.84	0.5475	5.7975	7.02E-05
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.51E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	7.73E-07	0.705	0.0	0.0	0.705	5.45E-07
(E22)	2.32E-06	1.41	0.705	0.0	2.115	4.90E-06
(E23)	7.73E-07	1.41	3.84	0.5475	5.7975	4.48E-06
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	9.62E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	6.78E-07	0.705	0.0	0.0	0.705	4.78E-07
(E27)	2.03E-06	1.41	0.705	0.0	2.115	4.30E-06
(E28)	6.78E-07	1.41	3.84	0.5475	5.7975	3.93E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	8.44E-04	0.0	0.0	0.0	0.0	0.00E+00
						5.50E-04

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	2nd Stage FG Compression	Medium	

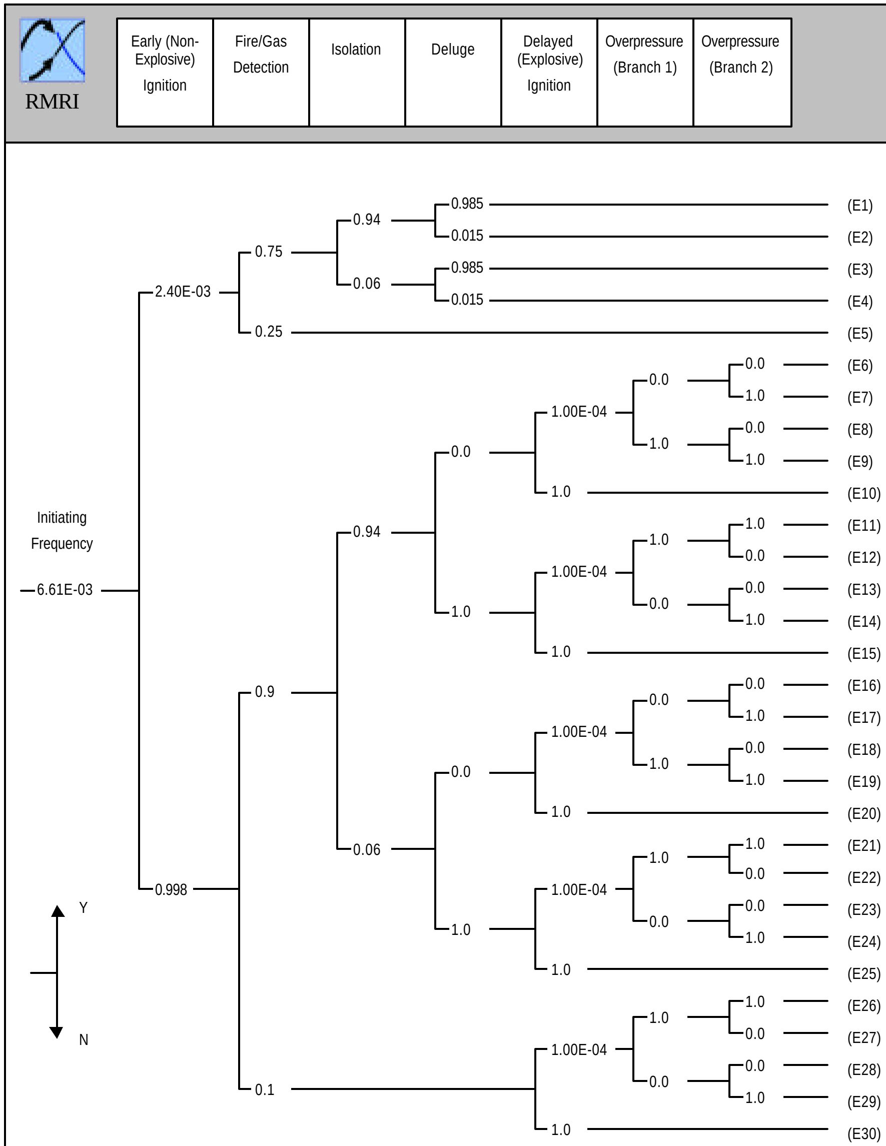
RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.12E-03	1.41	0.0	0.0	1.41	1.57E-03
(E2)	1.70E-05	1.41	0.0	0.0	1.41	2.40E-05
(E3)	7.13E-05	1.41	0.0	0.6	2.01	1.43E-04
(E4)	1.09E-06	1.41	0.0	0.6	2.01	2.18E-06
(E5)	1.22E-05	1.41	0.0	0.6	2.01	2.45E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.75E-05	0.705	0.0	0.0	0.705	6.87E-05
(E12)	2.92E-04	1.41	0.705	0.0	2.115	6.19E-04
(E13)	9.75E-05	1.41	3.84	0.5475	5.7975	5.65E-04
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	6.48E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.6	2.715	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	6.22E-06	0.705	0.0	0.6	1.305	8.12E-06
(E22)	1.87E-05	1.41	0.705	0.6	2.715	5.07E-05
(E23)	6.22E-06	1.41	3.84	0.5475	5.7975	3.61E-05
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	4.13E-04	0.0	0.0	0.6	0.6	2.48E-04
(E26)	1.05E-06	0.705	0.0	0.6	1.305	1.37E-06
(E27)	3.14E-06	1.41	0.705	0.6	2.715	8.53E-06
(E28)	1.05E-06	1.41	3.84	0.5475	5.7975	6.07E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	6.96E-05	0.0	0.0	0.6	0.6	4.17E-05
						3.42E-03

Hazard : Process Loss of Containment	Sub Category 1 : 2nd Stage FG Compression	Sub Category 2 : Large	Project : FPSO4

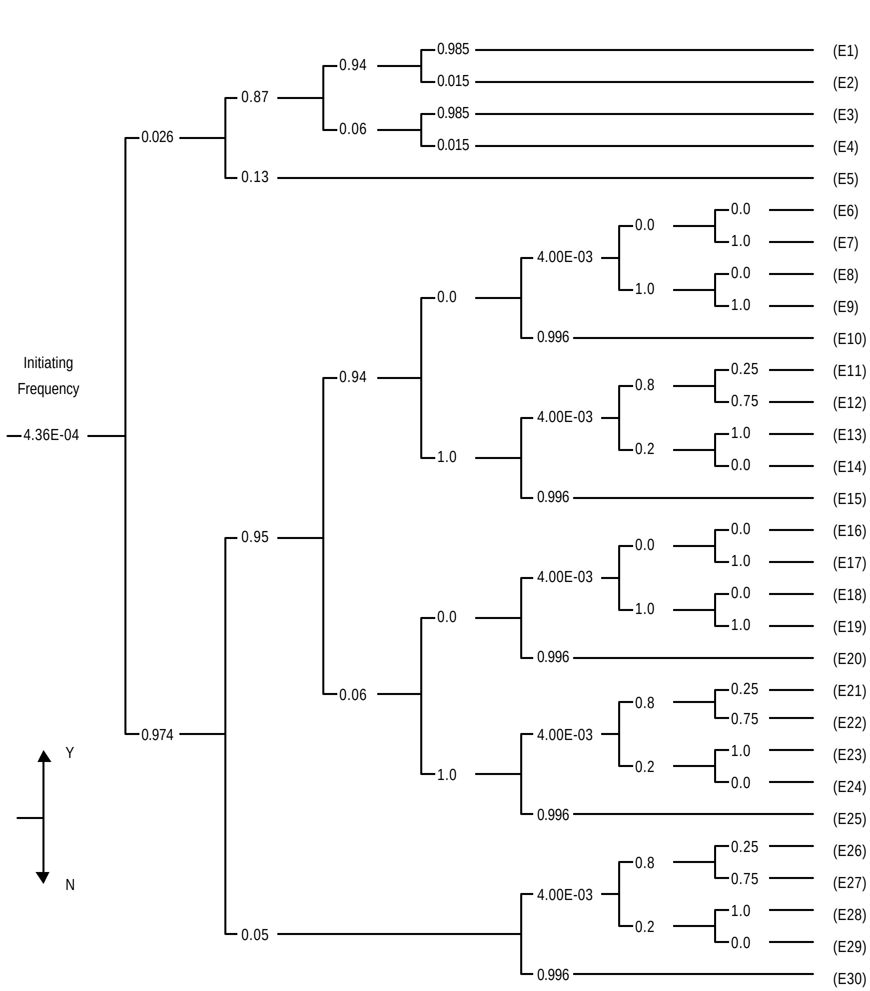


	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.10E-05	0.06	0.0	0.0	0.06	6.61E-07
(E2)	1.68E-07	0.06	0.0	0.0	0.06	1.01E-08
(E3)	7.03E-07	0.06	0.0	0.0	0.06	4.22E-08
(E4)	1.07E-08	0.06	0.0	0.0	0.06	6.42E-10
(E5)	3.97E-06	0.06	0.0	0.0	0.06	2.38E-07
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	5.58E-07	0.705	0.0	0.0	0.705	3.93E-07
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	5.58E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	3.56E-08	0.705	0.0	0.0	0.705	2.51E-08
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	3.56E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	6.59E-08	0.705	0.0	0.0	0.705	4.65E-08
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	6.59E-04	0.0	0.0	0.0	0.0	0.00E+00
						1.42E-06

Hazard : Process Loss of Containment	Sub Category 1 : 2nd St. FG Discharge (Gas)	Sub Category 2 : Small	Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	9.13E-06	0.91	0.0	0.0	0.91	8.31E-06
(E2)	1.39E-07	0.91	0.0	0.0	0.91	1.27E-07
(E3)	5.83E-07	0.91	0.0	0.0	0.91	5.30E-07
(E4)	8.88E-09	0.91	0.0	0.0	0.91	8.08E-09
(E5)	1.47E-06	0.91	0.0	0.0	0.91	1.34E-06
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	3.03E-07	0.705	0.0	0.0	0.705	2.14E-07
(E12)	9.10E-07	1.41	0.705	0.0	2.115	1.92E-06
(E13)	3.03E-07	1.41	3.84	0.5475	5.7975	1.76E-06
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	3.78E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.94E-08	0.705	0.0	0.0	0.705	1.37E-08
(E22)	5.81E-08	1.41	0.705	0.0	2.115	1.23E-07
(E23)	1.94E-08	1.41	3.84	0.5475	5.7975	1.12E-07
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	2.41E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.70E-08	0.705	0.0	0.0	0.705	1.20E-08
(E27)	5.10E-08	1.41	0.705	0.0	2.115	1.08E-07
(E28)	1.70E-08	1.41	3.84	0.5475	5.7975	9.85E-08
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	2.11E-05	0.0	0.0	0.0	0.0	0.00E+00
						1.47E-05

Hazard : Process Loss of Containment

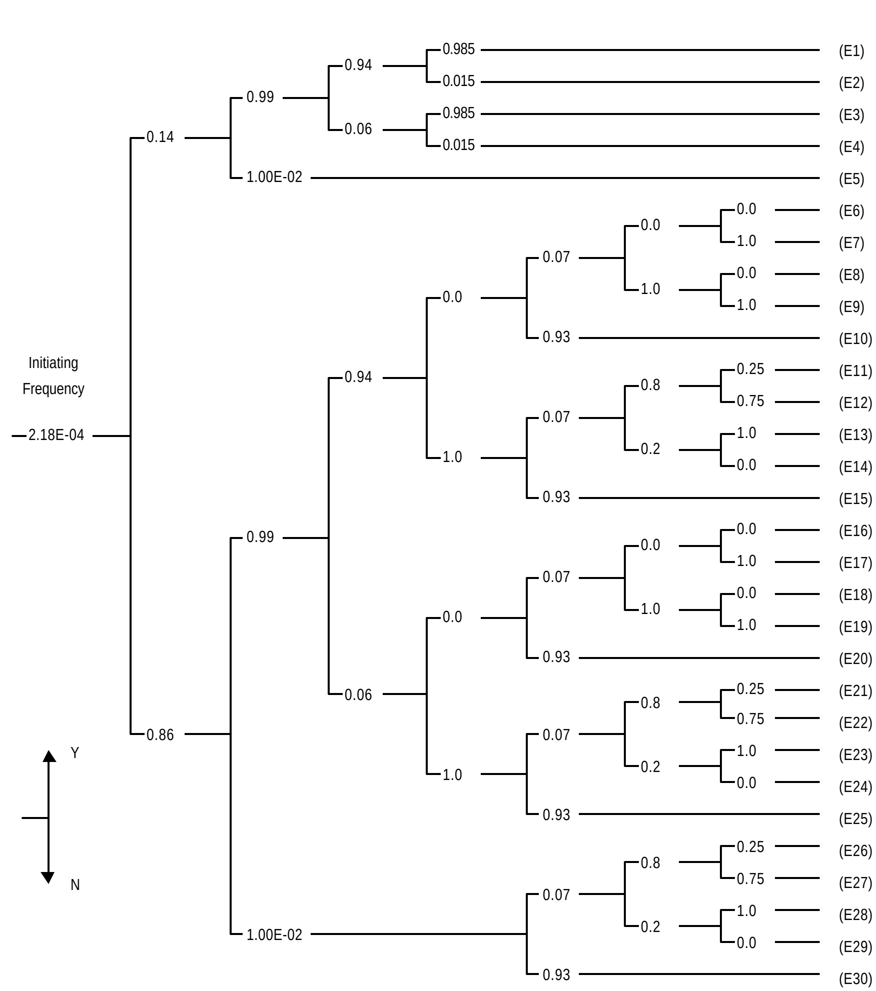
Sub Category 1 : 2nd St. FG Discharge (Gas)

Sub Category 2 : Medium

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.80E-05	1.41	0.0	0.0	1.41	3.94E-05
(E2)	4.26E-07	1.41	0.0	0.0	1.41	6.01E-07
(E3)	1.79E-06	1.41	0.0	0.6	2.01	3.59E-06
(E4)	2.72E-08	1.41	0.0	0.6	2.01	5.47E-08
(E5)	3.05E-07	1.41	0.0	0.6	2.01	6.13E-07
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.44E-06	0.705	0.0	0.0	0.705	1.72E-06
(E12)	7.33E-06	1.41	0.705	0.0	2.115	1.55E-05
(E13)	2.44E-06	1.41	3.84	0.5475	5.7975	1.42E-05
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.62E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.6	2.715	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	1.56E-07	0.705	0.0	0.6	1.305	2.03E-07
(E22)	4.68E-07	1.41	0.705	0.6	2.715	1.27E-06
(E23)	1.56E-07	1.41	3.84	0.5475	5.7975	9.04E-07
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	1.04E-05	0.0	0.0	0.6	0.6	6.21E-06
(E26)	2.62E-08	0.705	0.0	0.6	1.305	3.43E-08
(E27)	7.87E-08	1.41	0.705	0.6	2.715	2.14E-07
(E28)	2.62E-08	1.41	3.84	0.5475	5.7975	1.52E-07
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	1.74E-06	0.0	0.0	0.6	0.6	1.05E-06
						8.57E-05

Hazard : Process Loss of Containment

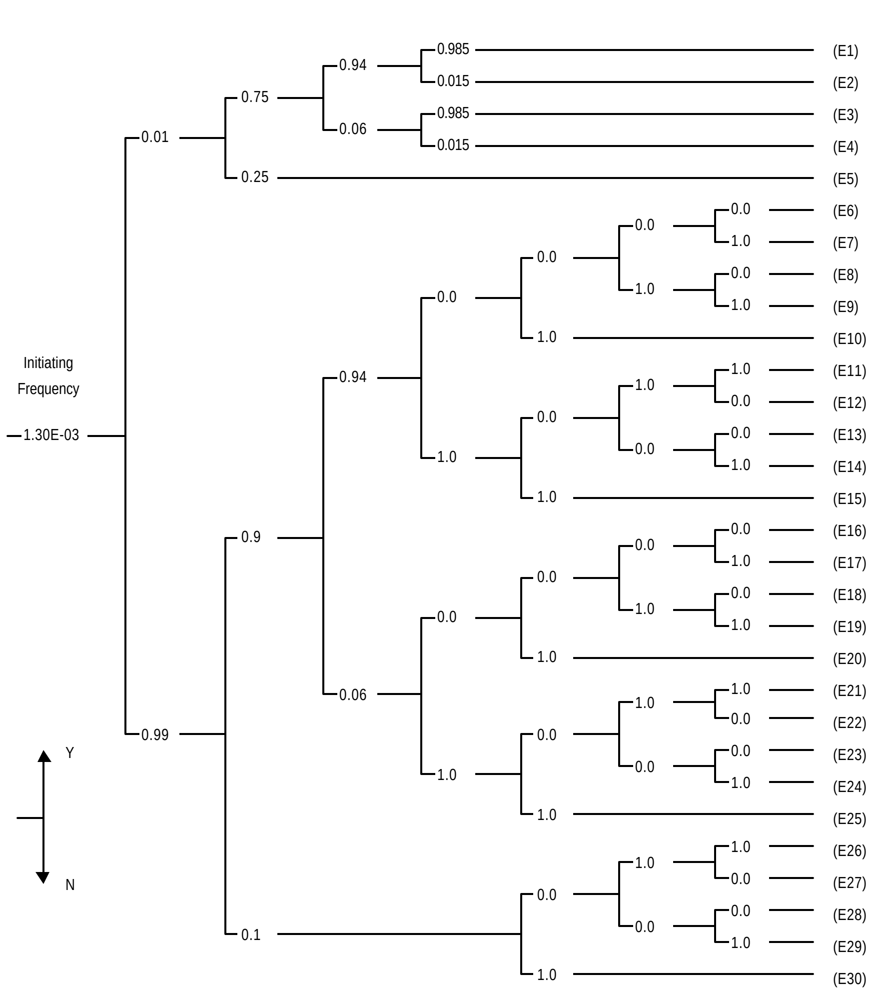
Sub Category 1 : 2nd St. FG Discharge (Gas)

Sub Category 2 : Large

Project : FPSO4

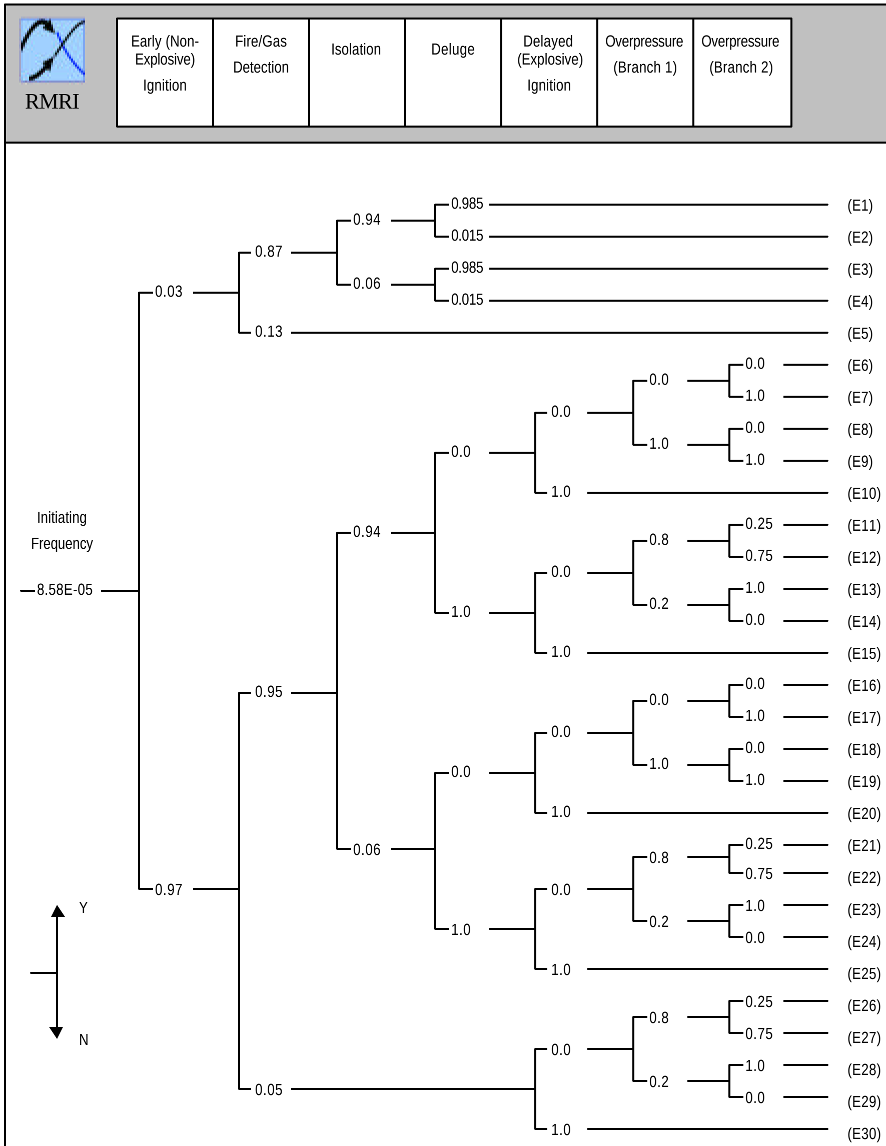
RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	9.03E-06	0.0	0.0	0.0	0.0	0.00E+00
(E2)	1.37E-07	0.0	0.0	0.0	0.0	0.00E+00
(E3)	5.76E-07	0.0	0.0	0.0	0.0	0.00E+00
(E4)	8.77E-09	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.25E-06	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.09E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	6.95E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	1.29E-04	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	2nd St. FG Discharge (Liquid)	Small	



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.07E-06	0.0	0.0	0.0	0.0	0.00E+00
(E2)	3.16E-08	0.0	0.0	0.0	0.0	0.00E+00
(E3)	1.32E-07	0.0	0.0	0.0	0.0	0.00E+00
(E4)	2.02E-09	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.35E-07	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	7.43E-05	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	4.74E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	4.16E-06	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard : Process Loss of Containment

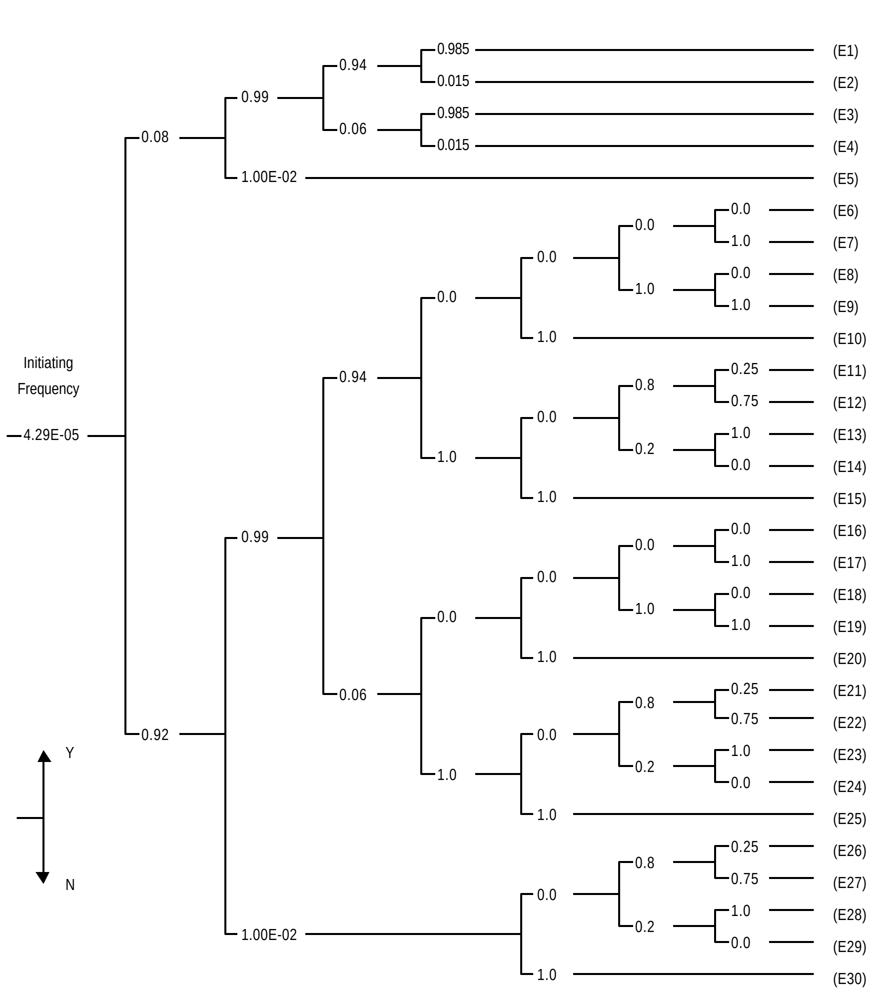
Sub Category 1 : 2nd St. FG Discharge (Liquid)

Sub Category 2 : Medium

Project : FPSO4

RMRI

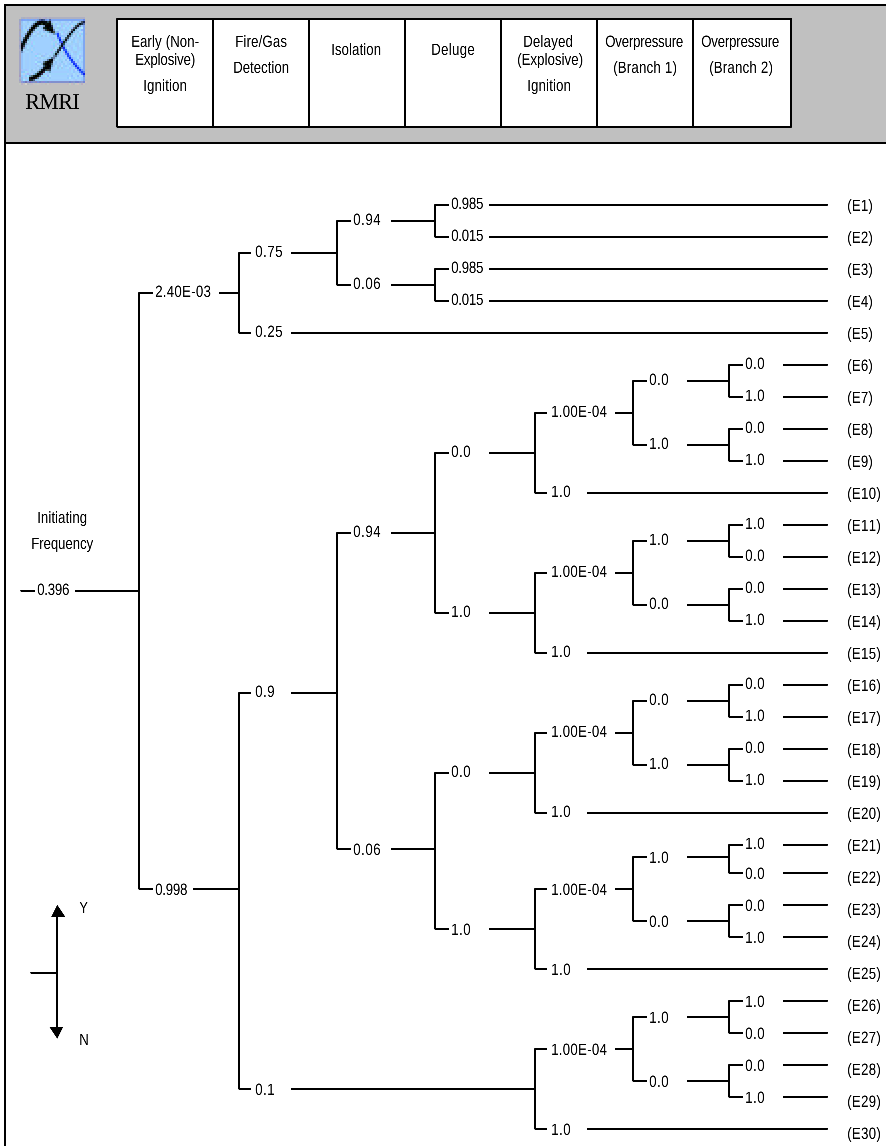
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.15E-06	0.0	0.0	0.0	0.0	0.00E+00
(E2)	4.79E-08	0.0	0.0	0.0	0.0	0.00E+00
(E3)	2.01E-07	0.0	0.0	0.0	0.0	0.00E+00
(E4)	3.06E-09	0.0	0.0	0.0	0.0	0.00E+00
(E5)	3.43E-08	0.0	0.0	0.0	0.0	0.00E+00
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E8)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E12)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E13)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	3.67E-05	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E18)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E22)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E23)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	2.34E-06	0.0	0.0	0.0	0.0	0.00E+00
(E26)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E27)	0.00E+00	1.41	0.705	0.0	2.115	0.00E+00
(E28)	0.00E+00	1.41	3.84	0.5475	5.7975	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	3.95E-07	0.0	0.0	0.0	0.0	0.00E+00
						0.00E+00

Hazard	Sub Category 1	Sub Category 2	Project
Process Loss of Containment	2nd St. FG Discharge (Liquid)	Large	FPSO4

RMRI



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	6.60E-04	0.08	0.0	0.0	0.08	5.28E-05
(E2)	1.01E-05	0.08	0.0	0.0	0.08	8.04E-07
(E3)	4.21E-05	0.08	0.0	0.0	0.08	3.37E-06
(E4)	6.42E-07	0.08	0.0	0.0	0.08	5.13E-08
(E5)	2.38E-04	0.08	0.0	0.0	0.08	1.90E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	3.34E-05	0.705	0.0	0.0	0.705	2.36E-05
(E12)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E13)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	3.34E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.13E-06	0.705	0.0	0.0	0.705	1.50E-06
(E22)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E23)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	2.13E-02	0.0	0.0	0.0	0.0	0.00E+00
(E26)	3.95E-06	0.705	0.0	0.0	0.705	2.79E-06
(E27)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E28)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	3.95E-02	0.0	0.0	0.0	0.0	0.00E+00
						1.04E-04

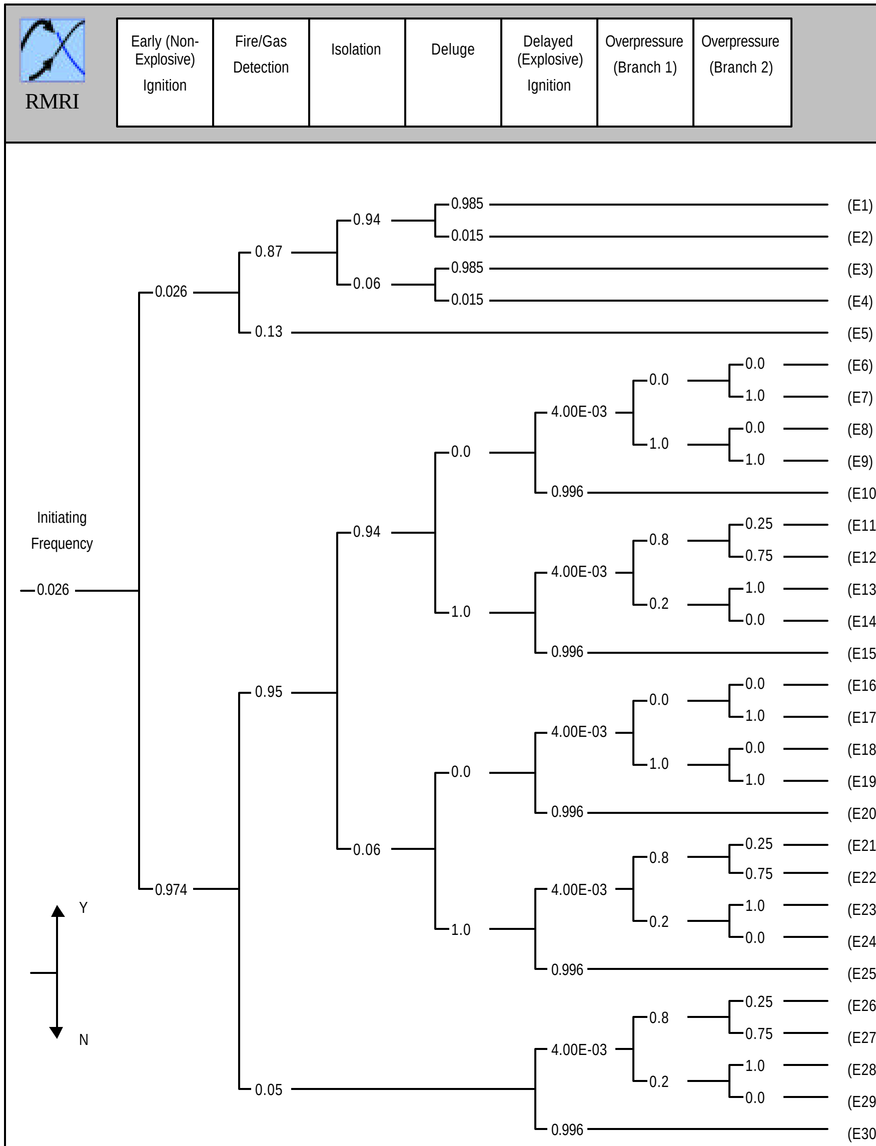
Hazard : Process Loss of Containment

Sub Category 1 : 1st St. Injection Compression

Sub Category 2 : Small

Project : FPSO4

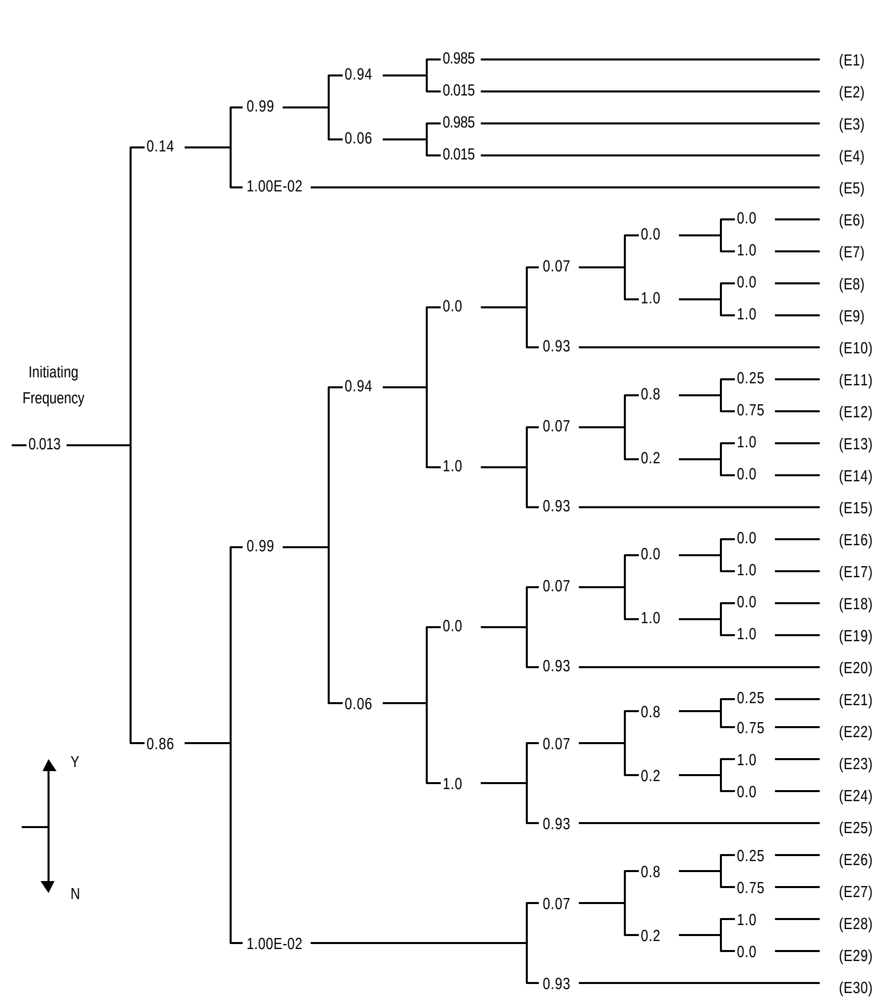
RMRI



	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	5.47E-04	1.2	0.0	0.0	1.2	6.56E-04
(E2)	8.32E-06	1.2	0.0	0.0	1.2	9.99E-06
(E3)	3.49E-05	1.2	0.0	0.0	1.2	4.19E-05
(E4)	5.31E-07	1.2	0.0	0.0	1.2	6.38E-07
(E5)	8.82E-05	1.2	0.0	0.0	1.2	1.06E-04
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.82E-05	0.705	0.0	0.0	0.705	1.28E-05
(E12)	5.45E-05	1.41	2.33	0.0	3.74	2.04E-04
(E13)	1.82E-05	1.41	5.25	0.53	7.19	1.31E-04
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	2.26E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.16E-06	0.705	0.0	0.0	0.705	8.17E-07
(E22)	3.48E-06	1.41	2.33	0.0	3.74	1.30E-05
(E23)	1.16E-06	1.41	5.25	0.53	7.19	8.33E-06
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	1.44E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.02E-06	0.705	0.0	0.0	0.705	7.17E-07
(E27)	3.05E-06	1.41	2.33	0.0	3.74	1.14E-05
(E28)	1.02E-06	1.41	5.25	0.53	7.19	7.31E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	1.27E-03	0.0	0.0	0.0	0.0	0.00E+00
						1.20E-03

Hazard : Process Loss of Containment	Sub Category 1 : 1st St. Injection Compression	Sub Category 2 : Medium	Project : FPSO4

RMRI



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.68E-03	1.41	0.0	0.0	1.41	2.37E-03
(E2)	2.56E-05	1.41	0.0	0.0	1.41	3.61E-05
(E3)	1.07E-04	1.41	0.0	0.6	2.01	2.16E-04
(E4)	1.63E-06	1.41	0.0	0.6	2.01	3.28E-06
(E5)	1.83E-05	1.41	0.0	0.6	2.01	3.69E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.47E-04	0.705	0.0	0.0	0.705	1.03E-04
(E12)	4.40E-04	1.41	2.33	0.0	3.74	1.65E-03
(E13)	1.47E-04	1.41	5.25	0.53	7.19	1.06E-03
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	9.75E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.6	4.34	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	9.37E-06	0.705	0.0	0.6	1.305	1.22E-05
(E22)	2.81E-05	1.41	2.33	0.6	4.34	1.22E-04
(E23)	9.37E-06	1.41	5.25	0.53	7.19	6.74E-05
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	6.22E-04	0.0	0.0	0.6	0.6	3.73E-04
(E26)	1.58E-06	0.705	0.0	0.6	1.305	2.06E-06
(E27)	4.73E-06	1.41	2.33	0.6	4.34	2.05E-05
(E28)	1.58E-06	1.41	5.25	0.53	7.19	1.13E-05
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	1.05E-04	0.0	0.0	0.6	0.6	6.29E-05
						6.14E-03

Hazard : Process Loss of Containment

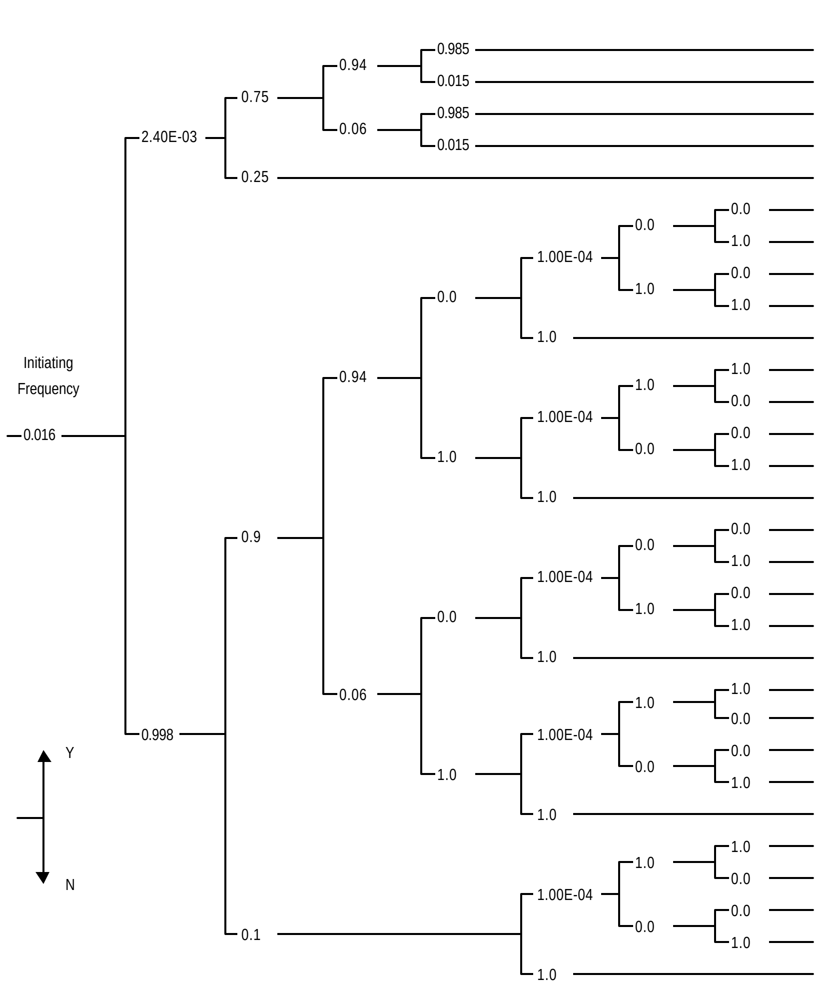
Sub Category 1 : 1st St. Injection Compression

Sub Category 2 : Large

Project : FPSO4

RMRI

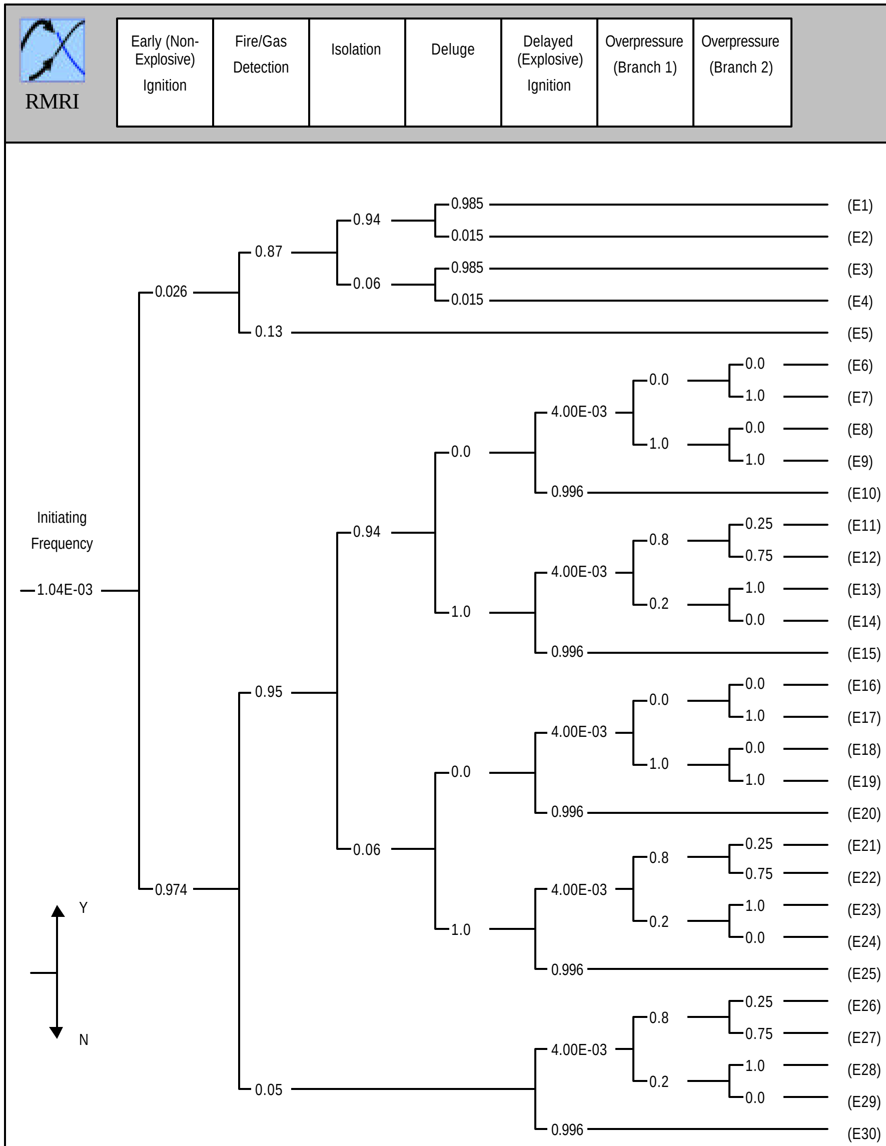
Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.63E-05	0.09	0.0	0.0	0.09	2.37E-06
(E2)	4.01E-07	0.09	0.0	0.0	0.09	3.61E-08
(E3)	1.68E-06	0.09	0.0	0.0	0.09	1.51E-07
(E4)	2.56E-08	0.09	0.0	0.0	0.09	2.30E-09
(E5)	9.48E-06	0.09	0.0	0.0	0.09	8.53E-07
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.33E-06	0.705	0.0	0.0	0.705	9.40E-07
(E12)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E13)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.33E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	8.51E-08	0.705	0.0	0.0	0.705	6.00E-08
(E22)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E23)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	8.51E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.58E-07	0.705	0.0	0.0	0.705	1.11E-07
(E27)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E28)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	1.58E-03	0.0	0.0	0.0	0.0	0.00E+00
						4.52E-06

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	1st St. Inj. Gas Discharge	Small	

RMRI



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.18E-05	1.39	0.0	0.0	1.39	3.03E-05
(E2)	3.32E-07	1.39	0.0	0.0	1.39	4.61E-07
(E3)	1.39E-06	1.39	0.0	0.0	1.39	1.93E-06
(E4)	2.12E-08	1.39	0.0	0.0	1.39	2.94E-08
(E5)	3.52E-06	1.39	0.0	0.0	1.39	4.89E-06
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	7.24E-07	0.705	0.0	0.0	0.705	5.10E-07
(E12)	2.17E-06	1.41	2.33	0.0	3.74	8.12E-06
(E13)	7.24E-07	1.41	5.25	0.53	7.19	5.20E-06
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	9.01E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	4.62E-08	0.705	0.0	0.0	0.705	3.26E-08
(E22)	1.39E-07	1.41	2.33	0.0	3.74	5.18E-07
(E23)	4.62E-08	1.41	5.25	0.53	7.19	3.32E-07
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	5.75E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	4.05E-08	0.705	0.0	0.0	0.705	2.86E-08
(E27)	1.22E-07	1.41	2.33	0.0	3.74	4.55E-07
(E28)	4.05E-08	1.41	5.25	0.53	7.19	2.91E-07
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	5.04E-05	0.0	0.0	0.0	0.0	0.00E+00
						5.31E-05

Hazard : Process Loss of Containment

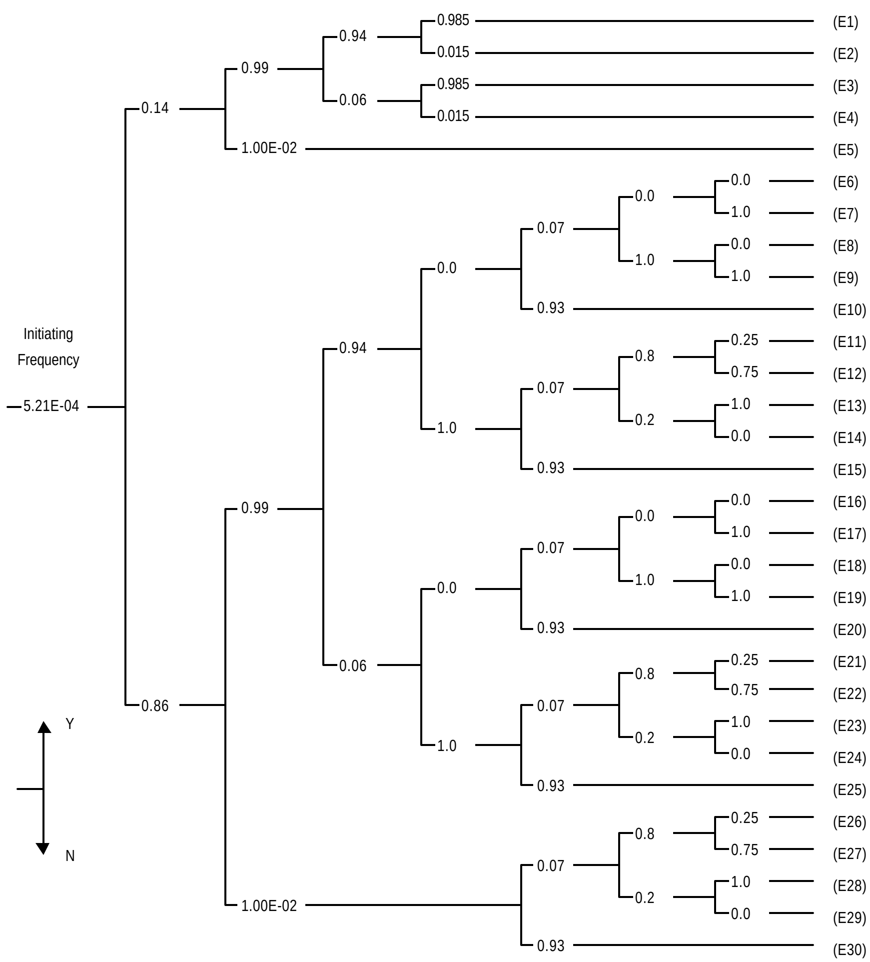
Sub Category 1 : 1st St. Inj. Gas Discharge

Sub Category 2 : Medium

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	6.69E-05	1.41	0.0	0.0	1.41	9.43E-05
(E2)	1.02E-06	1.41	0.0	0.0	1.41	1.44E-06
(E3)	4.27E-06	1.41	0.0	0.6	2.01	8.58E-06
(E4)	6.50E-08	1.41	0.0	0.6	2.01	1.31E-07
(E5)	7.29E-07	1.41	0.0	0.6	2.01	1.47E-06
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	5.84E-06	0.705	0.0	0.0	0.705	4.12E-06
(E12)	1.75E-05	1.41	2.33	0.0	3.74	6.55E-05
(E13)	5.84E-06	1.41	5.25	0.53	7.19	4.20E-05
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	3.88E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.6	4.34	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	3.73E-07	0.705	0.0	0.6	1.305	4.86E-07
(E22)	1.12E-06	1.41	2.33	0.6	4.34	4.85E-06
(E23)	3.73E-07	1.41	5.25	0.53	7.19	2.68E-06
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	2.48E-05	0.0	0.0	0.6	0.6	1.49E-05
(E26)	6.27E-08	0.705	0.0	0.6	1.305	8.19E-08
(E27)	1.88E-07	1.41	2.33	0.6	4.34	8.17E-07
(E28)	6.27E-08	1.41	5.25	0.53	7.19	4.51E-07
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	4.17E-06	0.0	0.0	0.6	0.6	2.50E-06
						2.44E-04

Hazard : Process Loss of Containment

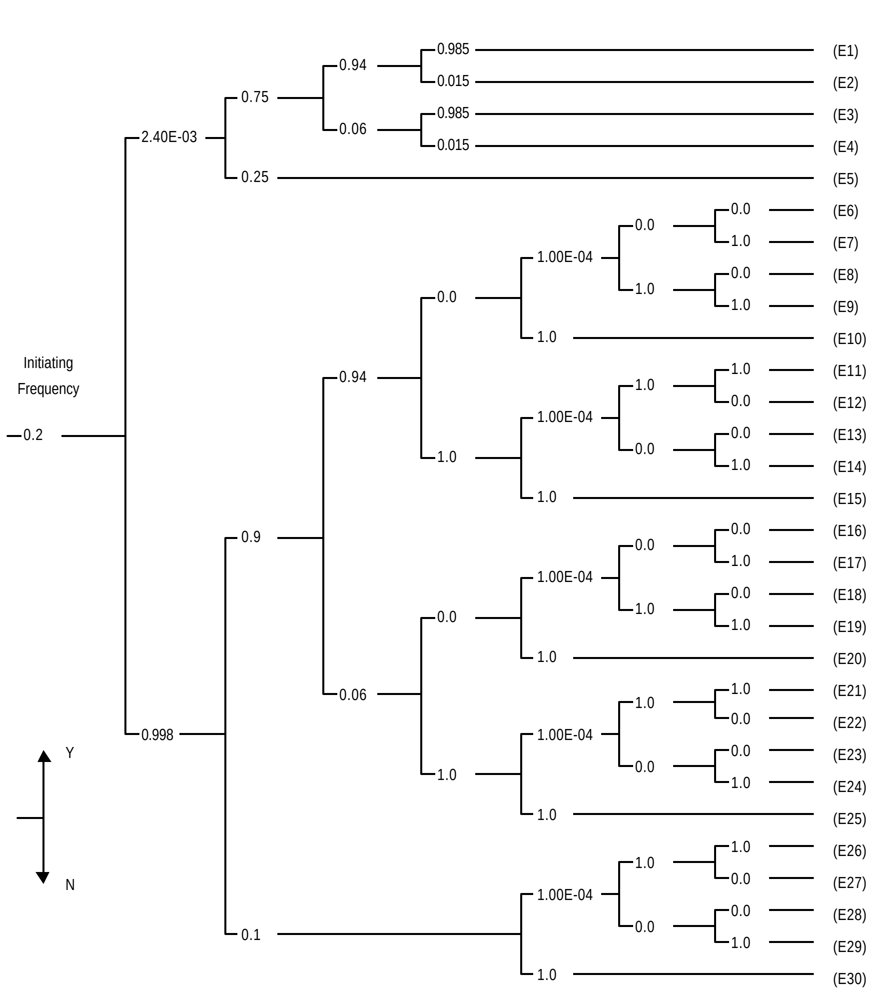
Sub Category 1 : 1st St. Inj. Gas Discharge

Sub Category 2 : Large

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.33E-04	0.26	0.0	0.0	0.26	8.67E-05
(E2)	5.08E-06	0.26	0.0	0.0	0.26	1.32E-06
(E3)	2.13E-05	0.26	0.0	0.0	0.26	5.53E-06
(E4)	3.24E-07	0.26	0.0	0.0	0.26	8.42E-08
(E5)	1.20E-04	0.26	0.0	0.0	0.26	3.12E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.69E-05	0.705	0.0	0.0	0.705	1.19E-05
(E12)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E13)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.69E-01	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.08E-06	0.705	0.0	0.0	0.705	7.60E-07
(E22)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E23)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	1.08E-02	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.00E-06	0.705	0.0	0.0	0.705	1.41E-06
(E27)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E28)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	2.00E-02	0.0	0.0	0.0	0.0	0.00E+00
						1.39E-04

Hazard : Process Loss of Containment

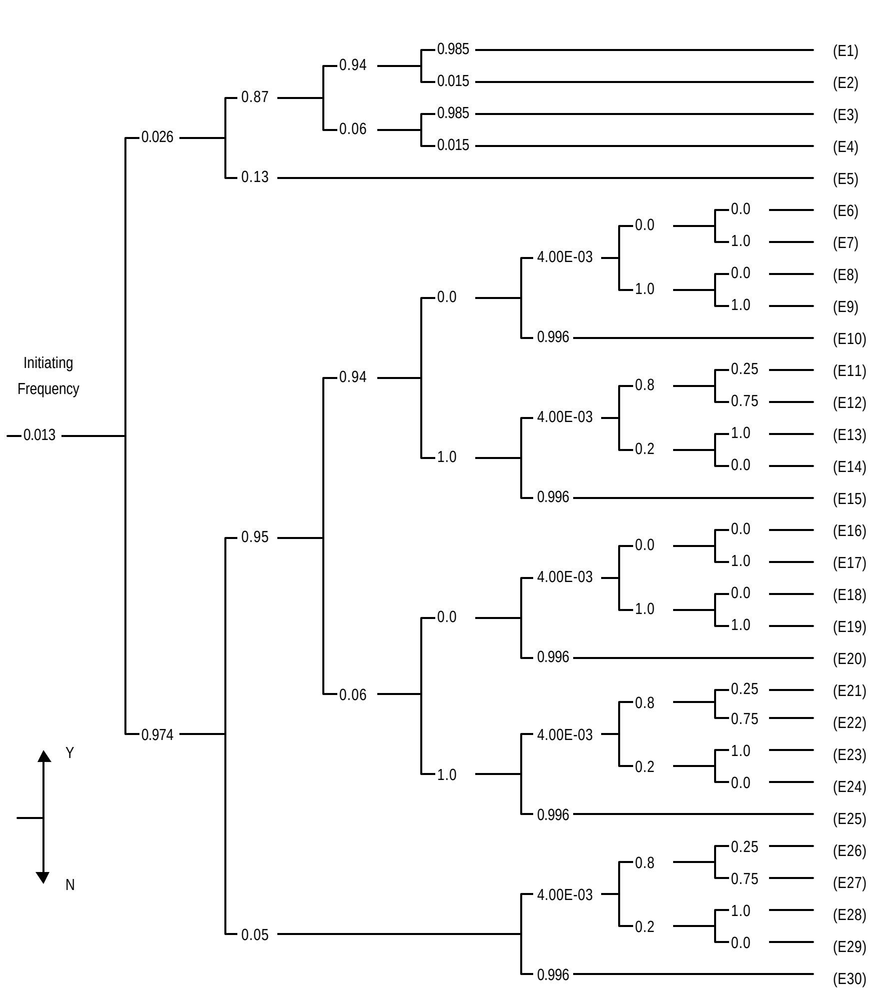
Sub Category 1 : 2nd St. Injection Compression

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.74E-04	1.41	0.0	0.0	1.41	3.87E-04
(E2)	4.18E-06	1.41	0.0	0.0	1.41	5.89E-06
(E3)	1.75E-05	1.41	0.0	0.0	1.41	2.47E-05
(E4)	2.67E-07	1.41	0.0	0.0	1.41	3.76E-07
(E5)	4.43E-05	1.41	0.0	0.0	1.41	6.24E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.12E-06	0.705	0.0	0.0	0.705	6.43E-06
(E12)	2.73E-05	1.41	2.33	0.0	3.74	1.02E-04
(E13)	9.12E-06	1.41	5.25	0.53	7.19	6.55E-05
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	1.13E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	5.82E-07	0.705	0.0	0.0	0.705	4.10E-07
(E22)	1.75E-06	1.41	2.33	0.0	3.74	6.53E-06
(E23)	5.82E-07	1.41	5.25	0.53	7.19	4.18E-06
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	7.24E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.10E-07	0.705	0.0	0.0	0.705	3.60E-07
(E27)	1.53E-06	1.41	2.33	0.0	3.74	5.73E-06
(E28)	5.10E-07	1.41	5.25	0.53	7.19	3.67E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	6.35E-04	0.0	0.0	0.0	0.0	0.00E+00
						6.75E-04

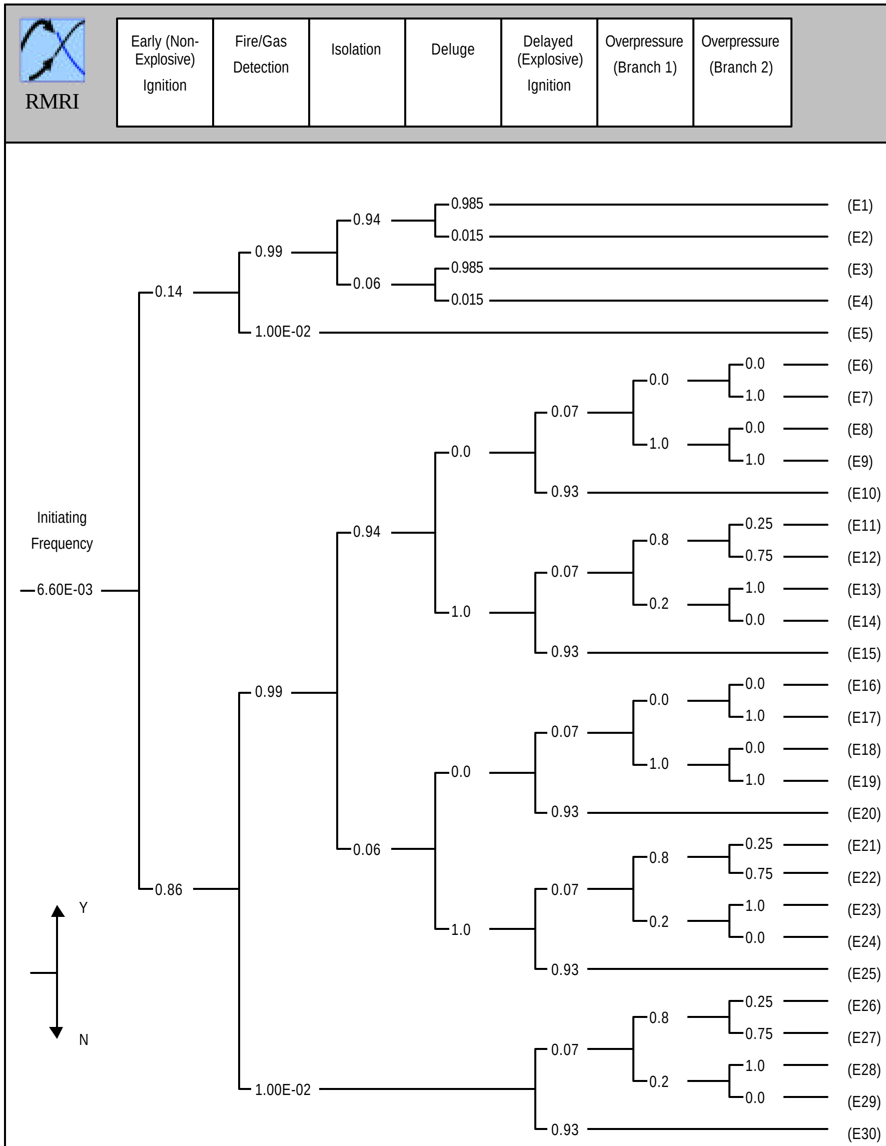
Hazard : Process Loss of Containment

Sub Category 1 : 2nd St. Injection Compression

Sub Category 2 : Medium

Project : FPSO4

RMRI



	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.47E-04	1.41	0.0	0.0	1.41	1.19E-03
(E2)	1.29E-05	1.41	0.0	0.0	1.41	1.82E-05
(E3)	5.41E-05	1.41	0.0	0.6	2.01	1.09E-04
(E4)	8.23E-07	1.41	0.0	0.6	2.01	1.65E-06
(E5)	9.24E-06	1.41	0.0	0.6	2.01	1.86E-05
(E6)	0.00E+00	0.705	0.0	0.0	0.705	0.00E+00
(E7)	0.00E+00	1.41	2.33	0.0	3.74	0.00E+00
(E8)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E9)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	7.39E-05	0.705	0.0	0.0	0.705	5.21E-05
(E12)	2.22E-04	1.41	2.33	0.0	3.74	8.30E-04
(E13)	7.39E-05	1.41	5.25	0.53	7.19	5.32E-04
(E14)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E15)	4.91E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.705	0.0	0.6	1.305	0.00E+00
(E17)	0.00E+00	1.41	2.33	0.6	4.34	0.00E+00
(E18)	0.00E+00	1.41	5.25	0.53	7.19	0.00E+00
(E19)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	4.72E-06	0.705	0.0	0.6	1.305	6.16E-06
(E22)	1.42E-05	1.41	2.33	0.6	4.34	6.15E-05
(E23)	4.72E-06	1.41	5.25	0.53	7.19	3.39E-05
(E24)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E25)	3.14E-04	0.0	0.0	0.6	0.6	1.88E-04
(E26)	7.95E-07	0.705	0.0	0.6	1.305	1.04E-06
(E27)	2.38E-06	1.41	2.33	0.6	4.34	1.03E-05
(E28)	7.95E-07	1.41	5.25	0.53	7.19	5.71E-06
(E29)	0.00E+00	1.41	6.06	2.6265	10.0965	0.00E+00
(E30)	5.28E-05	0.0	0.0	0.6	0.6	3.17E-05
						3.09E-03

Hazard : Process Loss of Containment

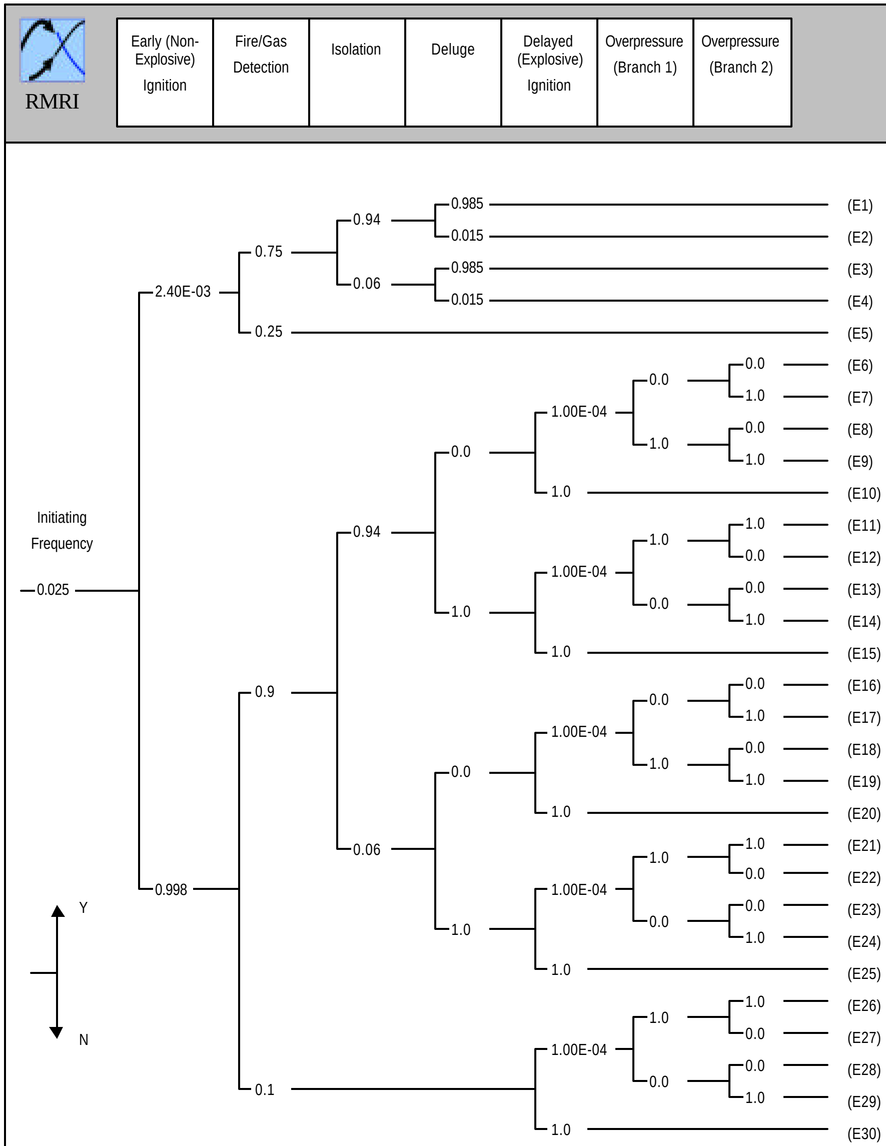
Sub Category 1 : 2nd St. Injection Compression

Sub Category 2 : Large

Project : FPSO4

RMRI

RMRI



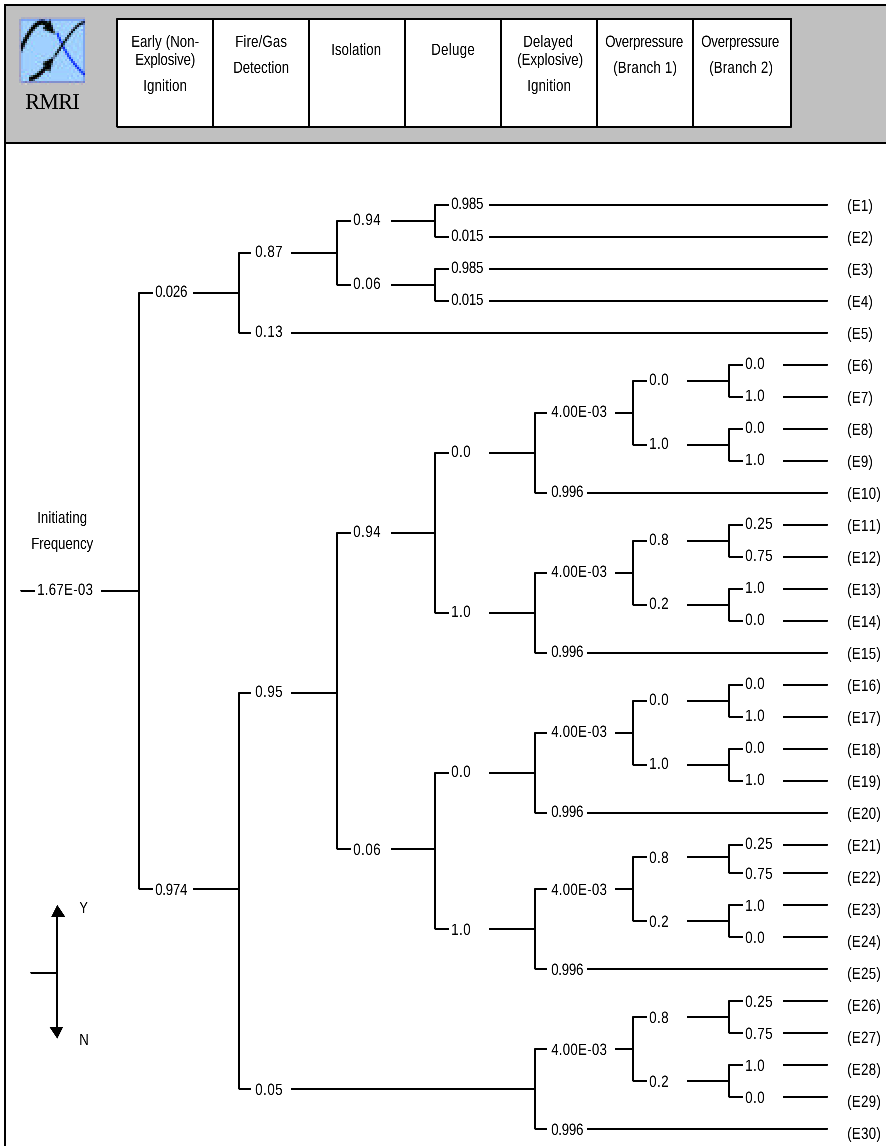
Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	4.22E-05	0.71	0.0	0.0	0.71	2.99E-05
(E2)	6.42E-07	0.71	0.0	0.0	0.71	4.56E-07
(E3)	2.69E-06	0.71	0.0	0.0	0.71	1.91E-06
(E4)	4.10E-08	0.71	0.0	0.0	0.71	2.91E-08
(E5)	1.52E-05	0.71	0.0	0.0	0.71	1.08E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.14E-06	2.22	0.0	0.0	2.22	4.74E-06
(E12)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E13)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	2.14E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.36E-07	2.22	0.0	0.0	2.22	3.03E-07
(E22)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E23)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	1.36E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.52E-07	2.22	0.0	0.0	2.22	5.60E-07
(E27)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E28)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	2.52E-03	0.0	0.0	0.0	0.0	0.00E+00
						4.87E-05

Hazard : Process Loss of Containment

Sub Category 1 : Deck, Re-Inj. Wells

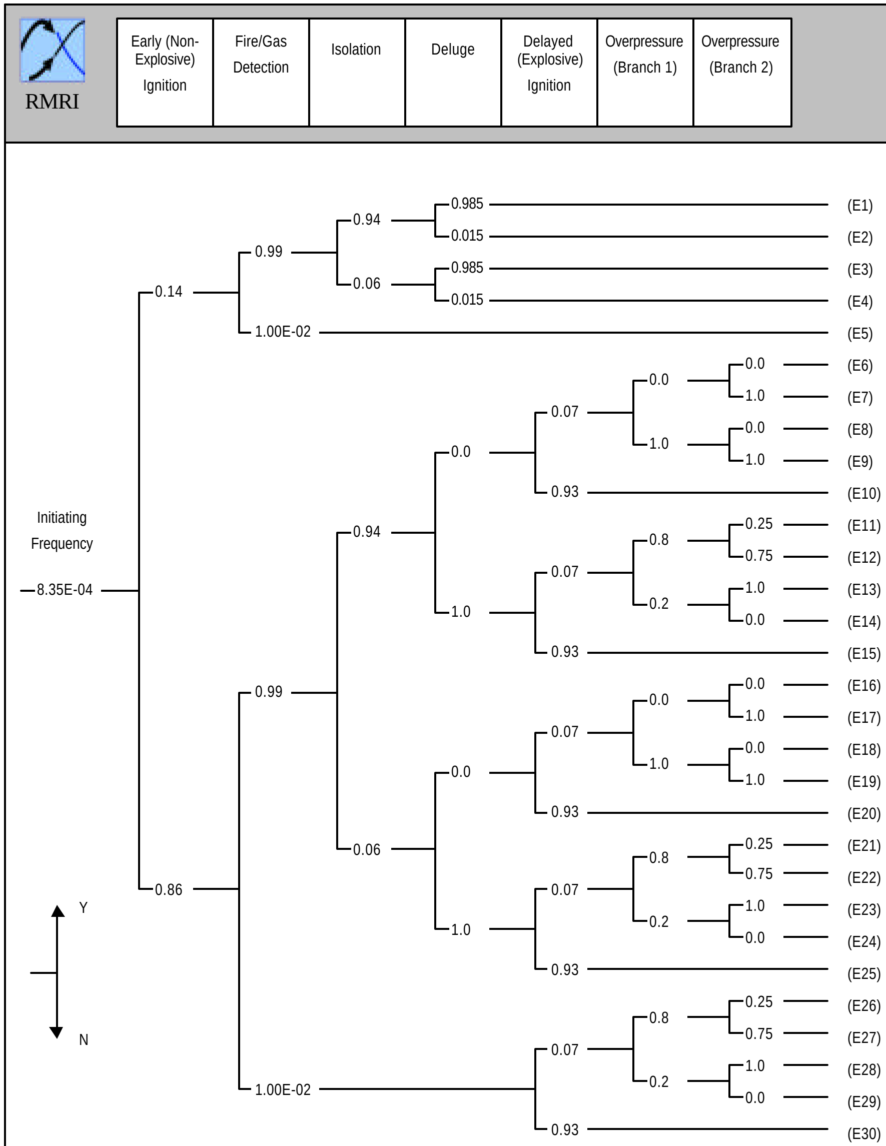
Sub Category 2 : Small

Project : FPSO4



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.50E-05	4.44	0.0	0.0	4.44	1.55E-04
(E2)	5.33E-07	4.44	0.0	0.0	4.44	2.36E-06
(E3)	2.23E-06	4.44	0.0	0.0	4.44	9.91E-06
(E4)	3.40E-08	4.44	0.0	0.0	4.44	1.51E-07
(E5)	5.64E-06	4.44	0.0	0.0	4.44	2.51E-05
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.16E-06	2.22	0.0	0.0	2.22	2.58E-06
(E12)	3.49E-06	4.44	1.125	0.0	5.565	1.94E-05
(E13)	1.16E-06	4.44	2.955	0.5261	7.9211	9.20E-06
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	1.45E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	7.42E-08	2.22	0.0	0.0	2.22	1.65E-07
(E22)	2.23E-07	4.44	1.125	0.0	5.565	1.24E-06
(E23)	7.42E-08	4.44	2.955	0.5261	7.9211	5.88E-07
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	9.23E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	6.51E-08	2.22	0.0	0.0	2.22	1.44E-07
(E27)	1.95E-07	4.44	1.125	0.0	5.565	1.09E-06
(E28)	6.51E-08	4.44	2.955	0.5261	7.9211	5.15E-07
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	8.10E-05	0.0	0.0	0.0	0.0	0.00E+00
						2.28E-04

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Deck, Re-Inj. Wells	Medium	



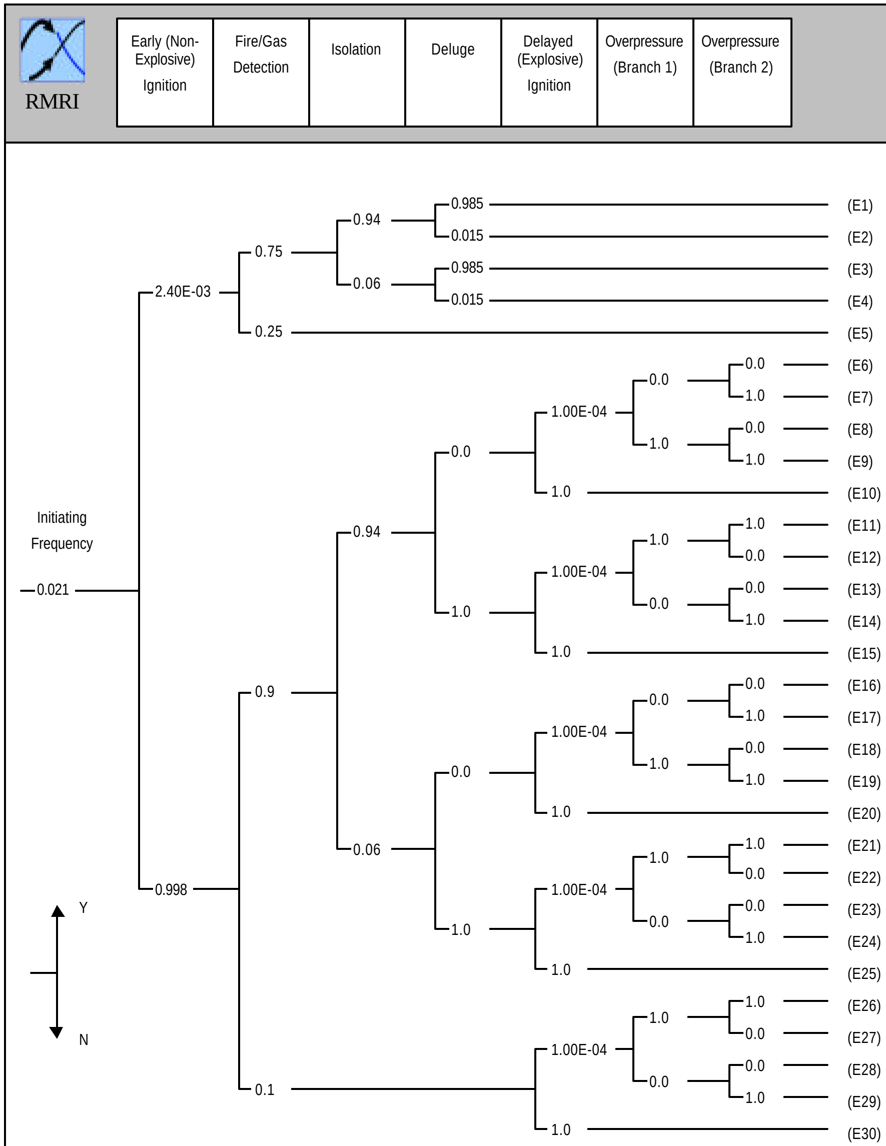
Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	1.07E-04	4.44	0.0	0.0	4.44	4.76E-04
(E2)	1.63E-06	4.44	0.0	0.0	4.44	7.25E-06
(E3)	6.84E-06	4.44	0.0	0.6	5.04	3.45E-05
(E4)	1.04E-07	4.44	0.0	0.6	5.04	5.25E-07
(E5)	1.17E-06	4.44	0.0	0.6	5.04	5.89E-06
(E6)	0.00E+00	2.22	0.0	0.0	2.22	0.00E+00
(E7)	0.00E+00	4.44	1.125	0.0	5.565	0.00E+00
(E8)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E9)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.36E-06	2.22	0.0	0.0	2.22	2.08E-05
(E12)	2.81E-05	4.44	1.125	0.0	5.565	1.56E-04
(E13)	9.36E-06	4.44	2.955	0.5261	7.9211	7.41E-05
(E14)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E15)	6.21E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	2.22	0.0	0.6	2.82	0.00E+00
(E17)	0.00E+00	4.44	1.125	0.6	6.165	0.00E+00
(E18)	0.00E+00	4.44	2.955	0.5261	7.9211	0.00E+00
(E19)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	5.97E-07	2.22	0.0	0.6	2.82	1.68E-06
(E22)	1.79E-06	4.44	1.125	0.6	6.165	1.10E-05
(E23)	5.97E-07	4.44	2.955	0.5261	7.9211	4.73E-06
(E24)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E25)	3.97E-05	0.0	0.0	0.6	0.6	2.38E-05
(E26)	1.01E-07	2.22	0.0	0.6	2.82	2.84E-07
(E27)	3.02E-07	4.44	1.125	0.6	6.165	1.86E-06
(E28)	1.01E-07	4.44	2.955	0.5261	7.9211	7.96E-07
(E29)	0.00E+00	4.44	2.955	2.6303	10.0253	0.00E+00
(E30)	6.68E-06	0.0	0.0	0.6	0.6	4.01E-06
						8.23E-04

Hazard : Process Loss of Containment

Sub Category 1 : Deck, Re-Inj. Wells

Sub Category 2 : Large

Project : FPSO4

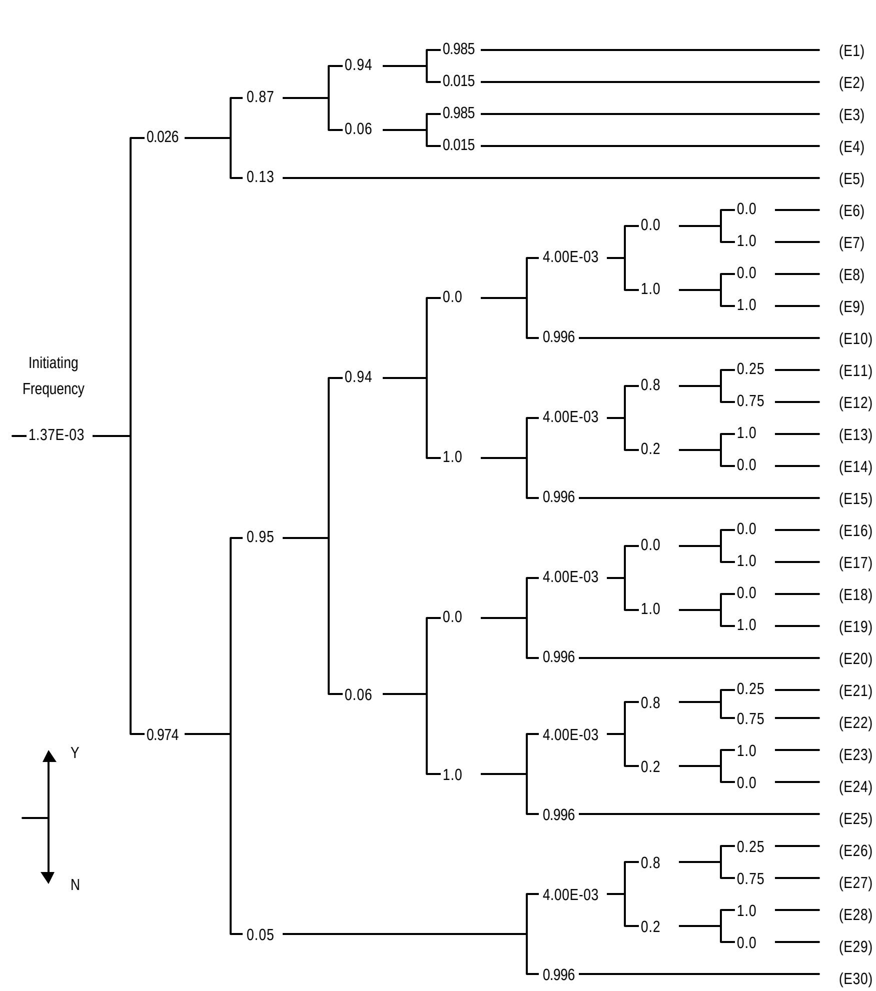


Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.47E-05	0.1	0.0	0.0	0.1	3.47E-06
(E2)	5.28E-07	0.1	0.0	0.0	0.1	5.28E-08
(E3)	2.21E-06	0.1	0.0	0.0	0.1	2.21E-07
(E4)	3.37E-08	0.1	0.0	0.0	0.1	3.37E-09
(E5)	1.25E-05	0.1	0.0	0.0	0.1	1.25E-06
(E6)	0.00E+00	1.41	0.0	0.0	1.41	0.00E+00
(E7)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E8)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E9)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.76E-06	1.41	0.0	0.0	1.41	2.48E-06
(E12)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E13)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E14)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E15)	1.76E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.41	0.0	0.0	1.41	0.00E+00
(E17)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E18)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E19)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.12E-07	1.41	0.0	0.0	1.41	1.58E-07
(E22)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E23)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E24)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E25)	1.12E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	2.08E-07	1.41	0.0	0.0	1.41	2.93E-07
(E27)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E28)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E29)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E30)	2.07E-03	0.0	0.0	0.0	0.0	0.00E+00
						7.92E-06

Hazard : Process Loss of Containment	Sub Category 1 : Fuel Gas System	Sub Category 2 : Small	Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.87E-05	1.63	0.0	0.0	1.63	4.68E-05
(E2)	4.37E-07	1.63	0.0	0.0	1.63	7.12E-07
(E3)	1.83E-06	1.63	0.0	0.0	1.63	2.99E-06
(E4)	2.79E-08	1.63	0.0	0.0	1.63	4.55E-08
(E5)	4.63E-06	1.63	0.0	0.0	1.63	7.55E-06
(E6)	0.00E+00	1.41	0.0	0.0	1.41	0.00E+00
(E7)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E8)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E9)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.53E-07	1.41	0.0	0.0	1.41	1.34E-06
(E12)	2.86E-06	2.82	2.04	0.0	4.86	1.39E-05
(E13)	9.53E-07	2.82	4.08	0.531	7.431	7.08E-06
(E14)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E15)	1.19E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.41	0.0	0.0	1.41	0.00E+00
(E17)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E18)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E19)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	6.08E-08	1.41	0.0	0.0	1.41	8.58E-08
(E22)	1.83E-07	2.82	2.04	0.0	4.86	8.87E-07
(E23)	6.08E-08	2.82	4.08	0.531	7.431	4.52E-07
(E24)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E25)	7.58E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.34E-08	1.41	0.0	0.0	1.41	7.53E-08
(E27)	1.60E-07	2.82	2.04	0.0	4.86	7.78E-07
(E28)	5.34E-08	2.82	4.08	0.531	7.431	3.97E-07
(E29)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E30)	6.65E-05	0.0	0.0	0.0	0.0	0.00E+00
						8.31E-05

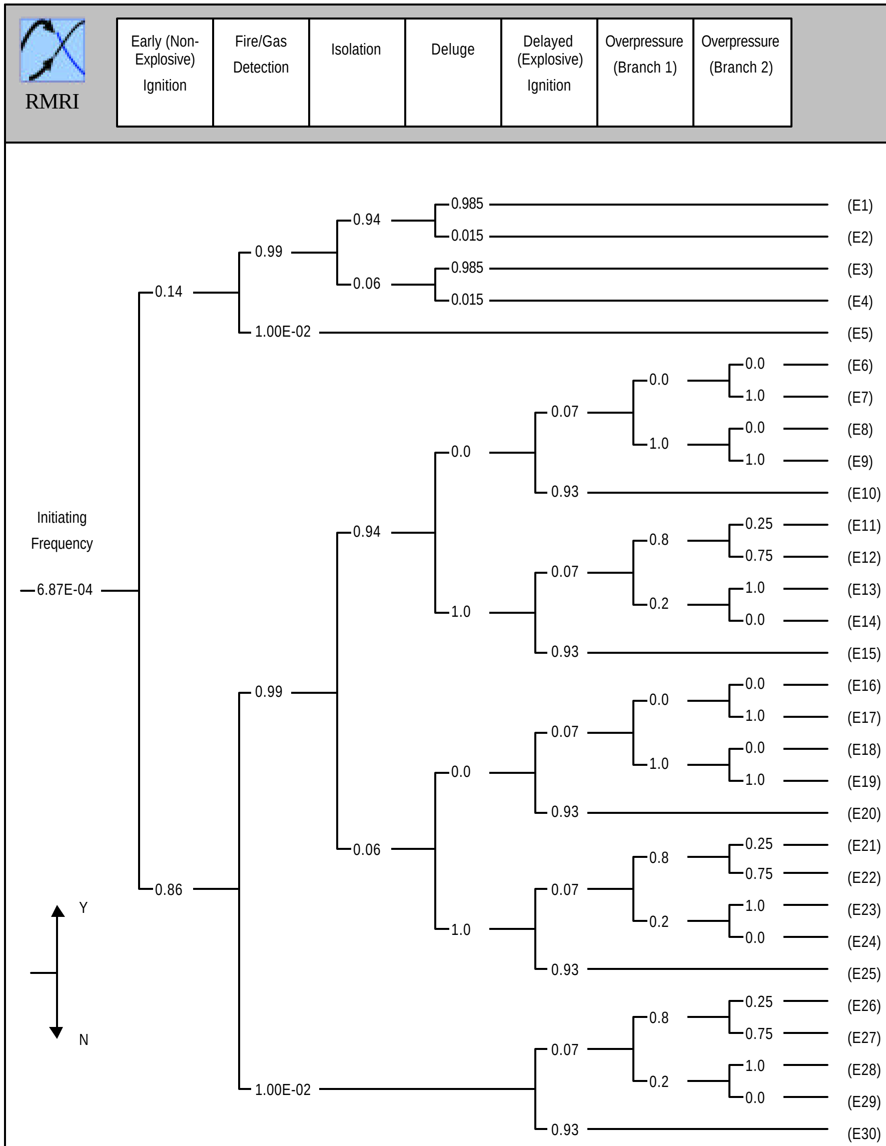
Hazard : Process Loss of Containment

Sub Category 1 : Fuel Gas System

Sub Category 2 : Medium

Project : FPSO4

RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.82E-05	2.82	0.0	0.0	2.82	2.49E-04
(E2)	1.34E-06	2.82	0.0	0.0	2.82	3.79E-06
(E3)	5.63E-06	2.82	0.0	0.6	3.42	1.92E-05
(E4)	8.57E-08	2.82	0.0	0.6	3.42	2.93E-07
(E5)	9.62E-07	2.82	0.0	0.6	3.42	3.29E-06
(E6)	0.00E+00	1.41	0.0	0.0	1.41	0.00E+00
(E7)	0.00E+00	2.82	2.04	0.0	4.86	0.00E+00
(E8)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E9)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	7.70E-06	1.41	0.0	0.0	1.41	1.09E-05
(E12)	2.31E-05	2.82	2.04	0.0	4.86	1.12E-04
(E13)	7.70E-06	2.82	4.08	0.531	7.431	5.72E-05
(E14)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E15)	5.11E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.41	0.0	0.6	2.01	0.00E+00
(E17)	0.00E+00	2.82	2.04	0.6	5.46	0.00E+00
(E18)	0.00E+00	2.82	4.08	0.531	7.431	0.00E+00
(E19)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	4.91E-07	1.41	0.0	0.6	2.01	9.88E-07
(E22)	1.47E-06	2.82	2.04	0.6	5.46	8.05E-06
(E23)	4.91E-07	2.82	4.08	0.531	7.431	3.65E-06
(E24)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E25)	3.26E-05	0.0	0.0	0.6	0.6	1.96E-05
(E26)	8.27E-08	1.41	0.0	0.6	2.01	1.66E-07
(E27)	2.48E-07	2.82	2.04	0.6	5.46	1.35E-06
(E28)	8.27E-08	2.82	4.08	0.531	7.431	6.15E-07
(E29)	0.00E+00	2.82	4.785	2.6198	10.2248	0.00E+00
(E30)	5.49E-06	0.0	0.0	0.6	0.6	3.30E-06
						4.93E-04

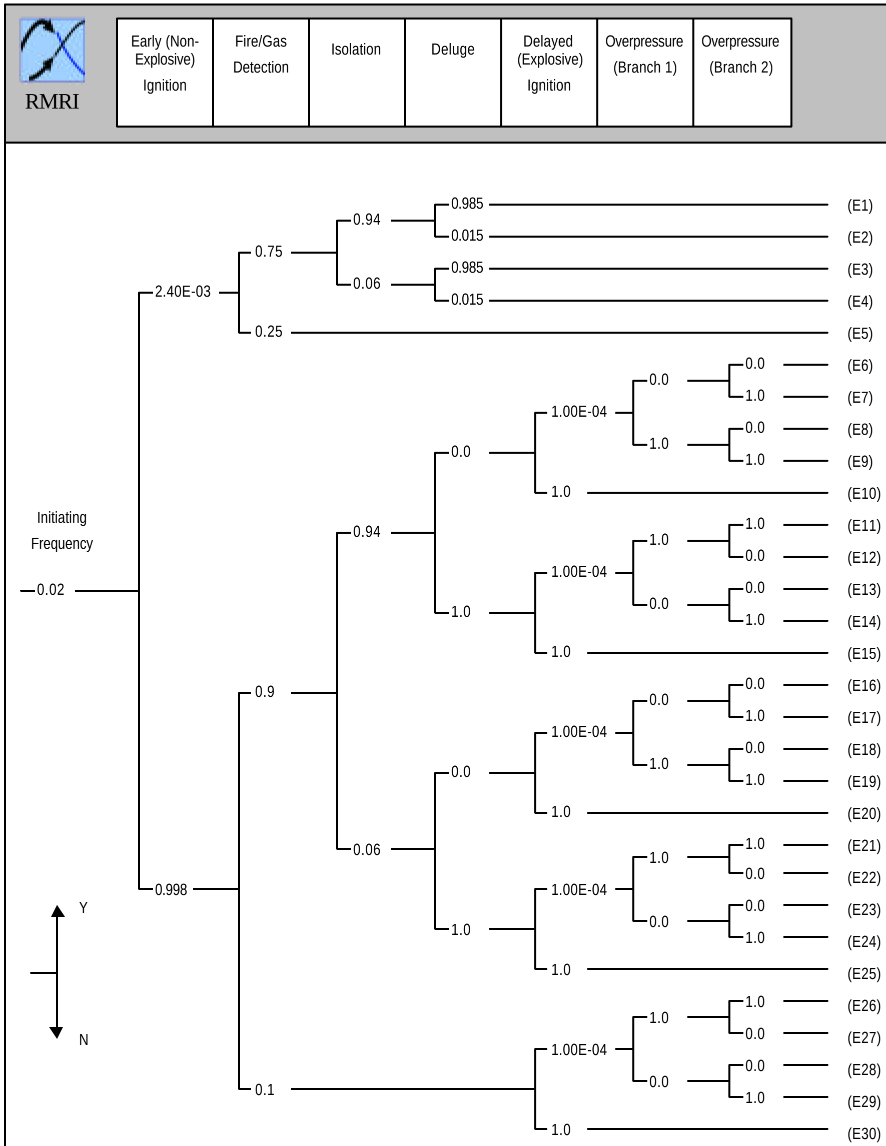
Hazard : Process Loss of Containment

Sub Category 1 : Fuel Gas System

Sub Category 2 : Large

Project : FPSO4

RMRI



Event	Event Frequency	Fatalities: Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	3.30E-05	0.14	0.0	0.0	0.14	4.62E-06
(E2)	5.03E-07	0.14	0.0	0.0	0.14	7.04E-08
(E3)	2.11E-06	0.14	0.0	0.0	0.14	2.95E-07
(E4)	3.21E-08	0.14	0.0	0.0	0.14	4.49E-09
(E5)	1.19E-05	0.14	0.0	0.0	0.14	1.66E-06
(E6)	0.00E+00	0.42	0.0	0.0	0.42	0.00E+00
(E7)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E8)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E9)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.67E-06	0.42	0.0	0.0	0.42	7.02E-07
(E12)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E13)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E14)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E15)	1.67E-02	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.42	0.0	0.0	0.42	0.00E+00
(E17)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E18)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E19)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.07E-07	0.42	0.0	0.0	0.42	4.48E-08
(E22)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E23)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E24)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E25)	1.07E-03	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.98E-07	0.42	0.0	0.0	0.42	8.30E-08
(E27)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E28)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E29)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E30)	1.98E-03	0.0	0.0	0.0	0.0	0.00E+00
						7.48E-06

Hazard : Process Loss of Containment

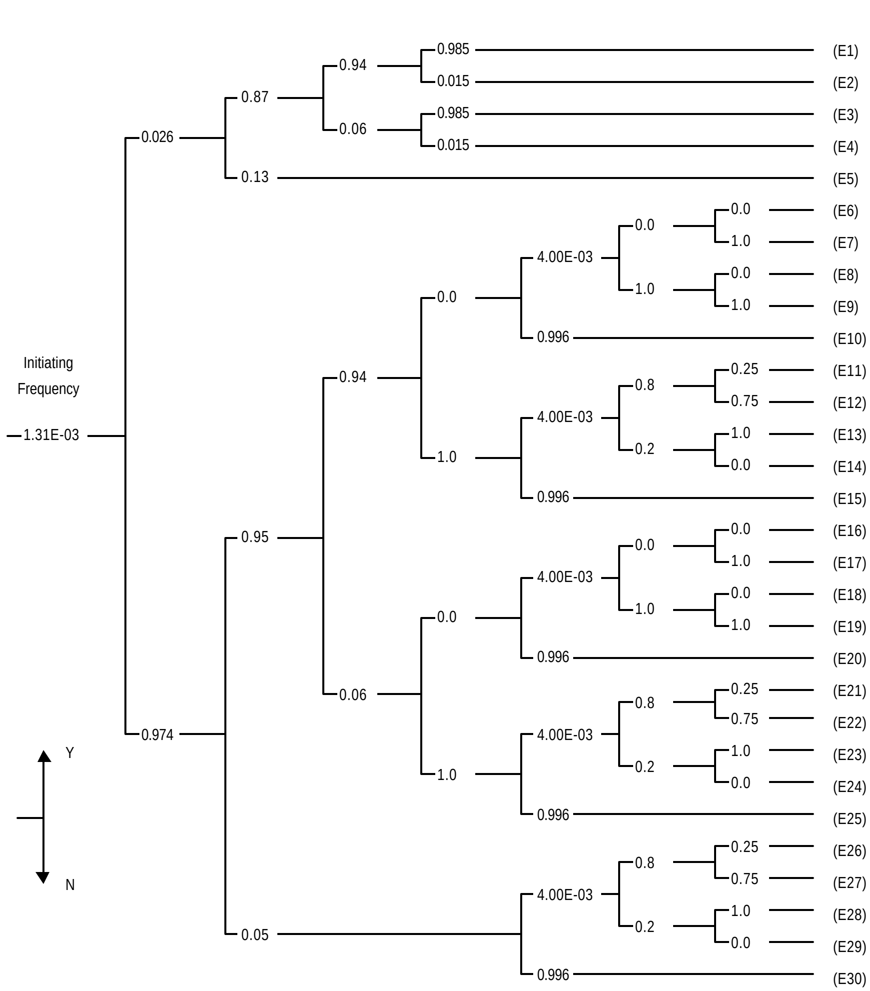
Sub Category 1 : Flare and Vent System

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.74E-05	0.84	0.0	0.0	0.84	2.30E-05
(E2)	4.18E-07	0.84	0.0	0.0	0.84	3.51E-07
(E3)	1.75E-06	0.84	0.0	0.0	0.84	1.47E-06
(E4)	2.67E-08	0.84	0.0	0.0	0.84	2.24E-08
(E5)	4.43E-06	0.84	0.0	0.0	0.84	3.72E-06
(E6)	0.00E+00	0.42	0.0	0.0	0.42	0.00E+00
(E7)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E8)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E9)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	9.12E-07	0.42	0.0	0.0	0.42	3.83E-07
(E12)	2.73E-06	0.84	0.6	0.0	1.44	3.94E-06
(E13)	9.12E-07	0.84	2.82	0.5634	4.2234	3.85E-06
(E14)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E15)	1.13E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.42	0.0	0.0	0.42	0.00E+00
(E17)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E18)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E19)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	5.82E-08	0.42	0.0	0.0	0.42	2.44E-08
(E22)	1.75E-07	0.84	0.6	0.0	1.44	2.51E-07
(E23)	5.82E-08	0.84	2.82	0.5634	4.2234	2.46E-07
(E24)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E25)	7.24E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.10E-08	0.42	0.0	0.0	0.42	2.14E-08
(E27)	1.53E-07	0.84	0.6	0.0	1.44	2.20E-07
(E28)	5.10E-08	0.84	2.82	0.5634	4.2234	2.16E-07
(E29)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E30)	6.35E-05	0.0	0.0	0.0	0.0	0.00E+00
						3.78E-05

Hazard : Process Loss of Containment

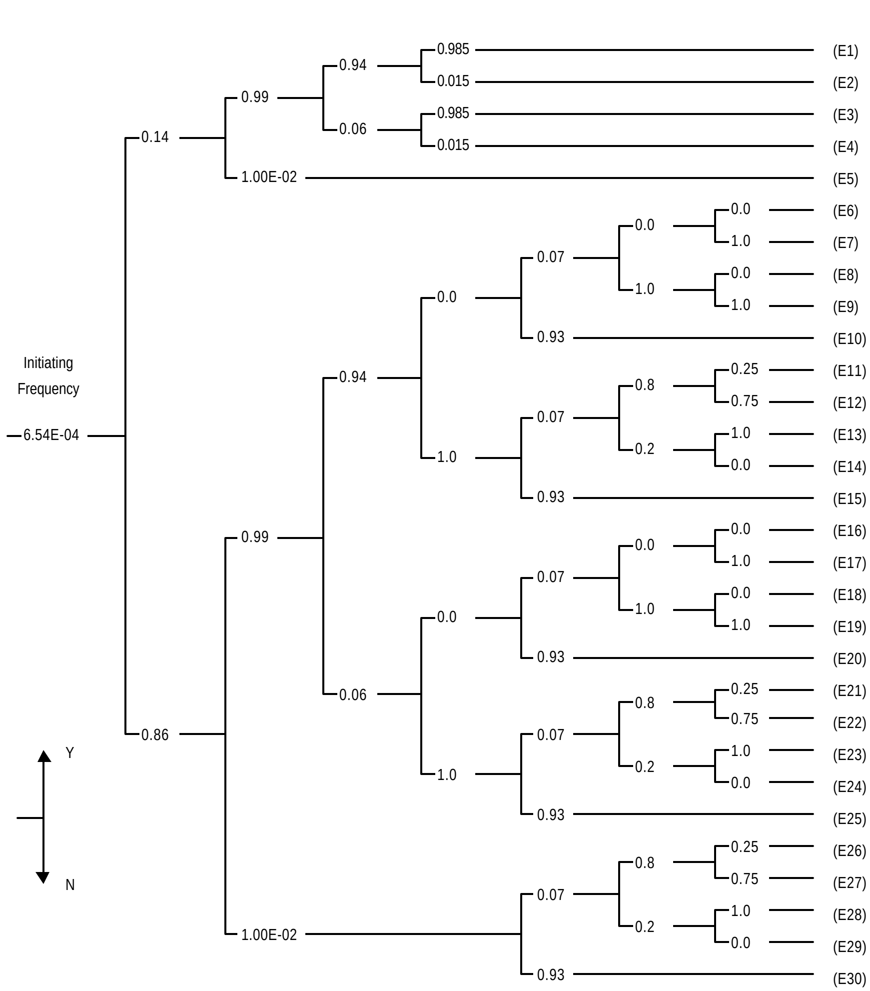
Sub Category 1 : Flare and Vent System

Sub Category 2 : Medium

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



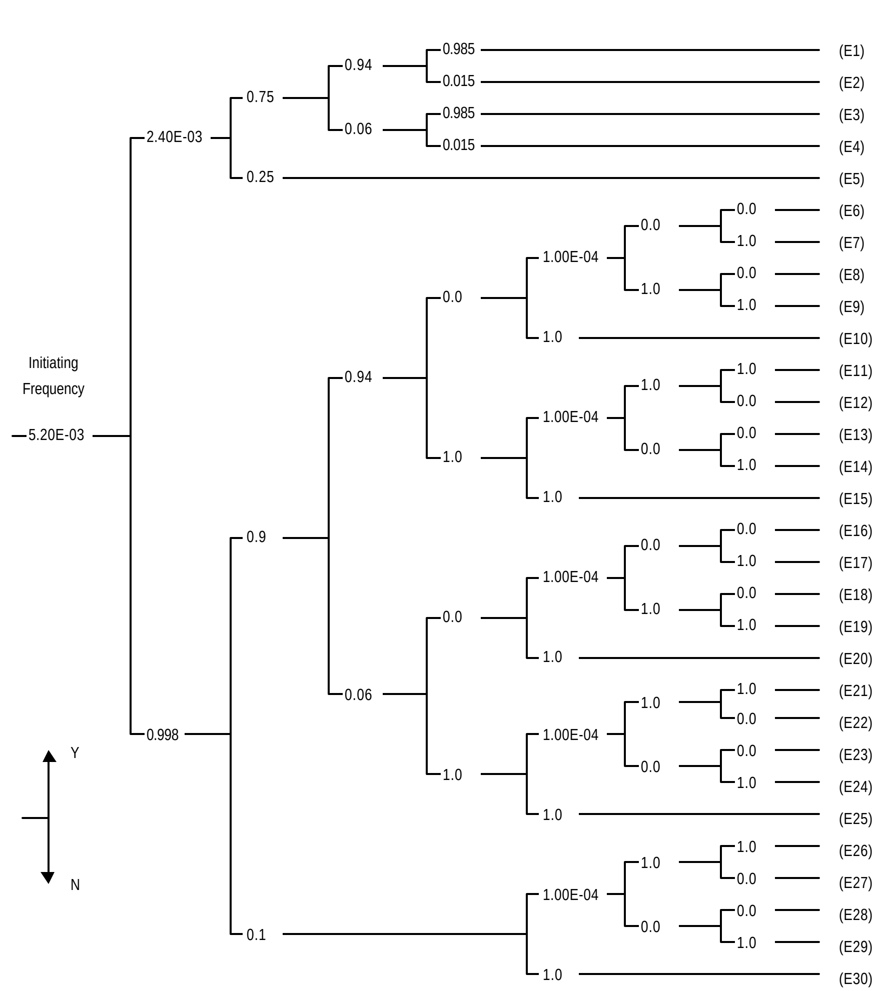
Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.39E-05	0.84	0.0	0.0	0.84	7.05E-05
(E2)	1.28E-06	0.84	0.0	0.0	0.84	1.07E-06
(E3)	5.36E-06	0.84	0.0	0.6	1.44	7.71E-06
(E4)	8.16E-08	0.84	0.0	0.6	1.44	1.17E-07
(E5)	9.16E-07	0.84	0.0	0.6	1.44	1.32E-06
(E6)	0.00E+00	0.42	0.0	0.0	0.42	0.00E+00
(E7)	0.00E+00	0.84	0.6	0.0	1.44	0.00E+00
(E8)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E9)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	7.33E-06	0.42	0.0	0.0	0.42	3.08E-06
(E12)	2.20E-05	0.84	0.6	0.0	1.44	3.17E-05
(E13)	7.33E-06	0.84	2.82	0.5634	4.2234	3.09E-05
(E14)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E15)	4.87E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	0.42	0.0	0.6	1.02	0.00E+00
(E17)	0.00E+00	0.84	0.6	0.6	2.04	0.00E+00
(E18)	0.00E+00	0.84	2.82	0.5634	4.2234	0.00E+00
(E19)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	4.68E-07	0.42	0.0	0.6	1.02	4.77E-07
(E22)	1.40E-06	0.84	0.6	0.6	2.04	2.86E-06
(E23)	4.68E-07	0.84	2.82	0.5634	4.2234	1.98E-06
(E24)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E25)	3.11E-05	0.0	0.0	0.6	0.6	1.86E-05
(E26)	7.87E-08	0.42	0.0	0.6	1.02	8.03E-08
(E27)	2.36E-07	0.84	0.6	0.6	2.04	4.82E-07
(E28)	7.87E-08	0.84	2.82	0.5634	4.2234	3.33E-07
(E29)	0.00E+00	0.84	2.82	2.817	6.477	0.00E+00
(E30)	5.23E-06	0.0	0.0	0.6	0.6	3.14E-06
						1.74E-04

Hazard :
Process Loss of Containment

Sub Category 1 :
Flare and Vent System

Sub Category 2 :
Large

Project : FPSO4



Event	Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	8.67E-06	0.12	0.0	0.0	0.12	1.04E-06
(E2)	1.32E-07	0.12	0.0	0.0	0.12	1.58E-08
(E3)	5.53E-07	0.12	0.0	0.0	0.12	6.64E-08
(E4)	8.42E-09	0.12	0.0	0.0	0.12	1.01E-09
(E5)	3.12E-06	0.12	0.0	0.0	0.12	3.74E-07
(E6)	0.00E+00	1.23	0.0	0.0	1.23	0.00E+00
(E7)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E8)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E9)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	4.39E-07	1.23	0.0	0.0	1.23	5.40E-07
(E12)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E13)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E14)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E15)	4.39E-03	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.23	0.0	0.0	1.23	0.00E+00
(E17)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E18)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E19)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	2.80E-08	1.23	0.0	0.0	1.23	3.45E-08
(E22)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E23)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E24)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E25)	2.80E-04	0.0	0.0	0.0	0.0	0.00E+00
(E26)	5.19E-08	1.23	0.0	0.0	1.23	6.38E-08
(E27)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E28)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E29)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E30)	5.19E-04	0.0	0.0	0.0	0.0	0.00E+00
						2.14E-06

Hazard : Process Loss of Containment

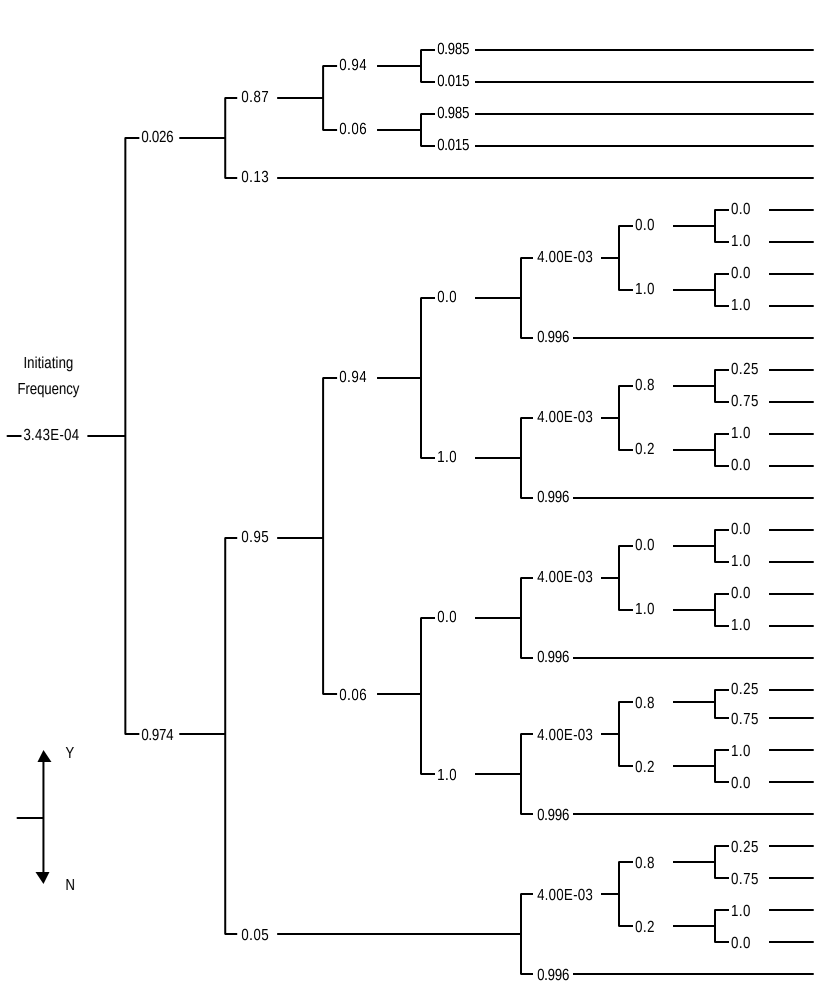
Sub Category 1 : Main Power Generators

Sub Category 2 : Small

Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)

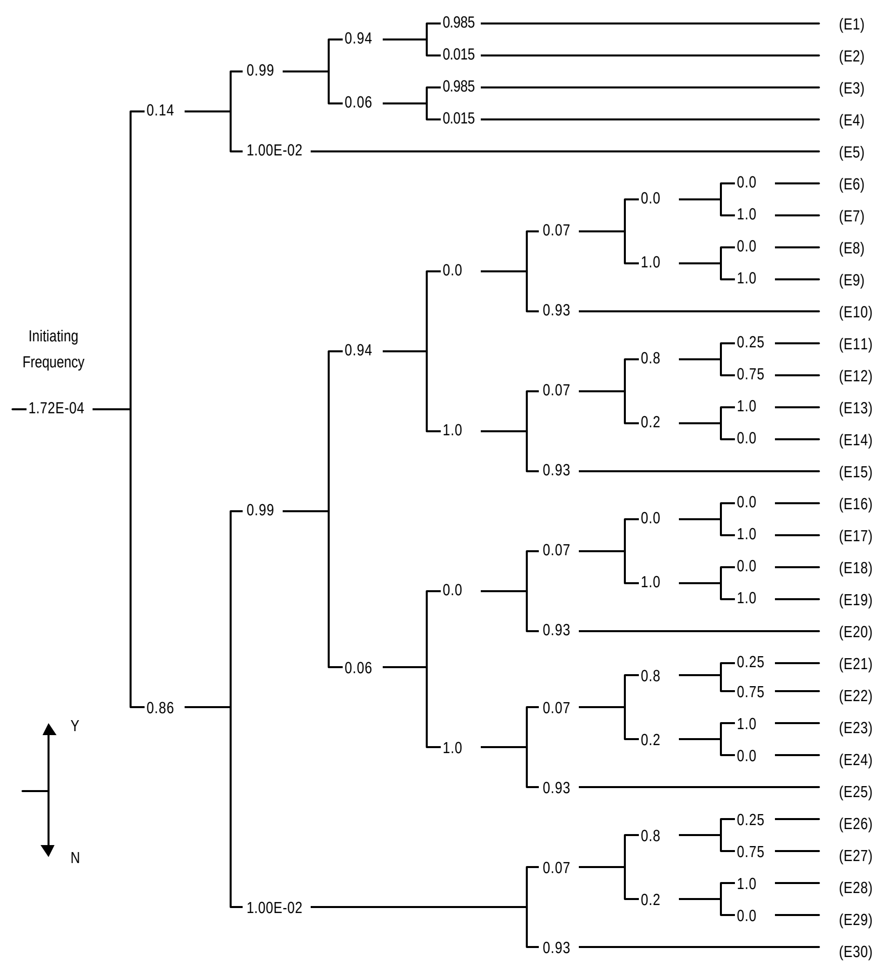


Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	7.18E-06	1.89	0.0	0.0	1.89	1.36E-05
(E2)	1.09E-07	1.89	0.0	0.0	1.89	2.07E-07
(E3)	4.59E-07	1.89	0.0	0.0	1.89	8.67E-07
(E4)	6.98E-09	1.89	0.0	0.0	1.89	1.32E-08
(E5)	1.16E-06	1.89	0.0	0.0	1.89	2.19E-06
(E6)	0.00E+00	1.23	0.0	0.0	1.23	0.00E+00
(E7)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E8)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E9)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	2.39E-07	1.23	0.0	0.0	1.23	2.94E-07
(E12)	7.16E-07	2.46	1.41	0.0	3.87	2.77E-06
(E13)	2.39E-07	2.46	3.63	0.5391	6.6291	1.58E-06
(E14)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E15)	2.97E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.23	0.0	0.0	1.23	0.00E+00
(E17)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E18)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E19)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E21)	1.52E-08	1.23	0.0	0.0	1.23	1.87E-08
(E22)	4.57E-08	2.46	1.41	0.0	3.87	1.77E-07
(E23)	1.52E-08	2.46	3.63	0.5391	6.6291	1.01E-07
(E24)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E25)	1.90E-05	0.0	0.0	0.0	0.0	0.00E+00
(E26)	1.34E-08	1.23	0.0	0.0	1.23	1.64E-08
(E27)	4.01E-08	2.46	1.41	0.0	3.87	1.55E-07
(E28)	1.34E-08	2.46	3.63	0.5391	6.6291	8.86E-08
(E29)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E30)	1.66E-05	0.0	0.0	0.0	0.0	0.00E+00
						2.21E-05

Hazard : Process Loss of Containment
Sub Category 1 : Main Power Generators
Sub Category 2 : Medium
Project : FPSO4

RMRI

Early (Non-Explosive) Ignition	Fire/Gas Detection	Isolation	Deluge	Delayed (Explosive) Ignition	Overpressure (Branch 1)	Overpressure (Branch 2)



Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution
(E1)	2.21E-05	2.46	0.0	0.0	2.46	5.43E-05
(E2)	3.36E-07	2.46	0.0	0.0	2.46	8.27E-07
(E3)	1.41E-06	2.46	0.0	0.6	3.06	4.31E-06
(E4)	2.15E-08	2.46	0.0	0.6	3.06	6.57E-08
(E5)	2.41E-07	2.46	0.0	0.6	3.06	7.37E-07
(E6)	0.00E+00	1.23	0.0	0.0	1.23	0.00E+00
(E7)	0.00E+00	2.46	1.41	0.0	3.87	0.00E+00
(E8)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E9)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E10)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00
(E11)	1.93E-06	1.23	0.0	0.0	1.23	2.37E-06
(E12)	5.78E-06	2.46	1.41	0.0	3.87	2.24E-05
(E13)	1.93E-06	2.46	3.63	0.5391	6.6291	1.28E-05
(E14)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E15)	1.28E-04	0.0	0.0	0.0	0.0	0.00E+00
(E16)	0.00E+00	1.23	0.0	0.6	1.83	0.00E+00
(E17)	0.00E+00	2.46	1.41	0.6	4.47	0.00E+00
(E18)	0.00E+00	2.46	3.63	0.5391	6.6291	0.00E+00
(E19)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E20)	0.00E+00	0.0	0.0	0.6	0.6	0.00E+00
(E21)	1.23E-07	1.23	0.0	0.6	1.83	2.25E-07
(E22)	3.69E-07	2.46	1.41	0.6	4.47	1.65E-06
(E23)	1.23E-07	2.46	3.63	0.5391	6.6291	8.15E-07
(E24)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E25)	8.17E-06	0.0	0.0	0.6	0.6	4.90E-06
(E26)	2.07E-08	1.23	0.0	0.6	1.83	3.79E-08
(E27)	6.21E-08	2.46	1.41	0.6	4.47	2.78E-07
(E28)	2.07E-08	2.46	3.63	0.5391	6.6291	1.37E-07
(E29)	0.00E+00	2.46	26.13	1.5705	30.1605	0.00E+00
(E30)	1.38E-06	0.0	0.0	0.6	0.6	8.25E-07
						1.07E-04

Hazard :	Sub Category 1 :	Sub Category 2 :	Project : FPSO4
Process Loss of Containment	Main Power Generators	Large	

APPENDIX I

Other Major Hazard Event Trees for FPSO

RMRI

RMRI

Y / N

Initiating Frequency: 1.83E-03

Event	Oil Released?	Oil ignited?	Severe list?	Event Frequency	Fatalities: Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
(E1)	0.1	0.3	0.1	5.49E-06	1.5	0.0	3.0	4.5	2.47E-05	1.00E+04	5.49E-02
(E2)	0.1	0.3	0.9	4.94E-05	1.5	0.0	3.0	4.5	2.22E-04	1.00E+04	4.94E-01
(E3)	0.1	0.7	0.1	1.28E-05	0.0	0.0	1.8	1.8	2.31E-05	1.00E+04	1.28E-01
(E4)	0.1	0.7	0.9	1.15E-04	0.0	0.0	0.6	0.6	6.92E-05	1.00E+04	1.15E+00
(E5)	0.9		0.1	1.65E-04	0.0	0.0	1.8	1.8	2.96E-04	0.0	0.00E+00
(E6)	0.9		0.9	1.48E-03	0.0	0.0	0.6	0.6	8.89E-04	0.0	0.00E+00
									1.53E-03		1.83E+00

Hazard :
Ship Collision

Sub Category 1 :
Attend.vessels imp. 30-100MJ

Project : FPSO4

RMRI

Initiating Frequency: 4.77E-04

Oil Released?	Oil ignited?	Severe list?	Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
0.5	0.5	0.1	(E1)	1.19E-05	1.5	0.0	3.0	4.5	5.37E-05	3.00E+04	3.58E-01
		0.9	(E2)	1.07E-04	1.5	0.0	3.0	4.5	4.83E-04	3.00E+04	3.22E+00
	0.5	0.1	(E3)	1.19E-05	0.0	0.0	1.8	1.8	2.15E-05	3.00E+04	3.58E-01
		0.9	(E4)	1.07E-04	0.0	0.0	0.6	0.6	6.44E-05	3.00E+04	3.22E+00
0.5		0.1	(E5)	2.38E-05	0.0	0.0	1.8	1.8	4.29E-05	0.0	0.00E+00
		0.9	(E6)	2.15E-04	0.0	0.0	0.6	0.6	1.29E-04	0.0	0.00E+00
									7.94E-04		7.15E+00

Hazard : Ship Collision

Sub Category 1 : Attend. vessels impact >100MJ

Project : FPSO4

RMRI

Initiating Frequency	Failure to Disconnect	Severe Damage		Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
3.80E-04	0.01	0.5	(E1)	1.90E-06	0.0	0.0	6.0	6.0	1.14E-05	3.00E+04	5.70E-02
		0.5	(E2)	1.90E-06	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
	0.99		(E3)	3.76E-04	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
									1.14E-05		5.70E-02

Y / N

Hazard : Ship Collision

Sub Category 1 : Passing Vessels

Project : FPSO4

RMRI

Initiating Frequency: 1.28E-05

Oil Released?	Oil ignited?	Severe list?	Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
0.05	0.05	0.1	(E1)	3.20E-09	0.0	0.0	0.6	0.6	1.92E-09	1.00E+04	3.20E-05
		0.9	(E2)	2.88E-08	0.0	0.0	0.6	0.6	1.73E-08	1.00E+04	2.88E-04
	0.95	0.1	(E3)	6.08E-08	0.0	0.0	0.6	0.6	3.65E-08	1.00E+04	6.08E-04
		0.9	(E4)	5.47E-07	0.0	0.0	0.6	0.6	3.28E-07	1.00E+04	5.47E-03
0.95		0.1	(E5)	1.22E-06	0.0	0.0	0.6	0.6	7.30E-07	0.0	0.00E+00
		0.9	(E6)	1.09E-05	0.0	0.0	0.6	0.6	6.57E-06	0.0	0.00E+00
									7.68E-06		6.40E-03

Y / N

Hazard : Iceberg Collision

Sub Category 1 : impact: 30-100MJ

Project : FPSO4

RMRI

Initiating Frequency: 4.70E-06 (Y / N)

Oil Released?	Oil ignited?	Severe list?		Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
0.3	0.1	0.1	(E1)	1.41E-08	0.0	0.0	0.6	0.6	8.46E-09	3.00E+04	4.23E-04
		0.9	(E2)	1.27E-07	0.0	0.0	0.6	0.6	7.61E-08	3.00E+04	3.81E-03
	0.9	0.1	(E3)	1.27E-07	0.0	0.0	0.6	0.6	7.61E-08	3.00E+04	3.81E-03
		0.9	(E4)	1.14E-06	0.0	0.0	0.6	0.6	6.85E-07	3.00E+04	3.43E-02
0.7		0.1	(E5)	3.29E-07	0.0	0.0	0.6	0.6	1.97E-07	0.0	0.00E+00
		0.9	(E6)	2.96E-06	0.0	0.0	0.6	0.6	1.78E-06	0.0	0.00E+00
									2.82E-06		4.23E-02

Hazard :
Iceberg Collision

Sub Category 1 :
impact > 100MJ

Project : FPSO4

RMRI

RMRI

Initiating Frequency	Pipeline Damaged	Isolation failure		Event Frequency	Immediate Fatalities	Escape+Escalation fatal.	Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
7.08E-03	0.0	0.05	(E1)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00	2.25E+04	0.00E+00
		0.95	(E2)	0.00E+00	0.0	0.0	0.0	0.0	0.00E+00	53.0	0.00E+00
	1.0		(E3)	7.08E-03	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
									0.00E+00		0.00E+00

Y
N

Hazard :
Iceberg Impact on pipelines

Project : FPSO4

RMRI

Initiating Frequency: 0.049

Y / N

Ignition	Isolation failure	Event	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
1.00E-03	0.02	(E1)	9.80E-07	0.0	0.0	0.15	0.15	1.47E-07	0.0	0.00E+00
	0.98	(E2)	4.80E-05	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
0.999		(E3)	4.90E-02	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
								1.47E-07		0.00E+00

Hazard :
Riser Releases subsea

Project : FPSO4

RMRI

Initiating Frequency: 4.59E-03

Y / N

Injury accident		Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
0.15	(E1)	6.89E-04	9.84	0.0	0.0	9.84	6.77E-03	0.0	0.00E+00
0.85	(E2)	3.90E-03	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
							6.77E-03		0.00E+00

Hazard :
Helicopter Crash

Sub Category 1 :
During flight

Project : FPSO4

RMRI

Initiating Frequency	Injury accident (Y / N)		Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
2.52E-03	0.35	(E1)	8.81E-04	5.76	0.0	0.0	5.76	5.07E-03	0.0	0.00E+00
	0.65	(E2)	1.64E-03	0.0	0.0	0.0	0.0	0.00E+00	0.0	0.00E+00
								5.07E-03		0.00E+00

Hazard :
Helicopter Crash

Sub Category 1 :
During Take-off/Landing

Project : FPSO4

RMRI

RMRI

Initiating Frequency	Total loss?		Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Total Fatalities	PLL Contribution	Environmental Damage	Expctd Environmental Dmg
4.80E-05	Y: 0.5	(E1)	2.40E-05	0.0	0.0	50.4	50.4	1.21E-03	3.00E+04	7.20E-01
	N: 0.5	(E2)	2.40E-05	0.0	0.0	3.0	3.0	7.20E-05	1.00E+04	2.40E-01
								1.28E-03		9.60E-01

Hazard :
Structural failure

Project : FPSO4

RMRI

RMRI

Null Event Trees
(No Branches)

	Hazard	Sub Category 1	Sub Category 2	Sub Category 3	Event Frequency	Fatalities: Immediate Fatalities	Fatalities: Escape+Escalation fatal.	Fatalities: Evacuation+Rescue fatal.	Fatalities: Total	PLL Contribution
1	Blowouts (Subsea Well)	Production			1.48E-04	0.0	0.0	0.0	0.00E+00	0.00E+00
2		Wirelining			2.94E-05	0.0	0.0	0.0	0.00E+00	0.00E+00

Project : FPSO4

RMRI

RMRI

	Event Frequency	Environmental Damage	Expctd Environmental Dmg
1	1.48E-04	1.42E+04	2.10E+00
2	2.94E-05	1.42E+04	4.17E-01

Project : FPSO4

GLOSSARY

10^3. Abbreviation for thousand.

10^6. Abbreviation for million.

10^9. Abbreviation for billion.

abandonment. The decommissioning of facilities and removal of offshore structures following exhaustion of reserves.

AERP. Acronym for Alert and Emergency Response Plan.

AFP. Acronym for active fire protection.

ALARP. Acronym for as low as reasonably practicable.

ANSI. Acronym for American National Standards Institute.

API. Acronym for American Petroleum Institute.

avg. Abbreviation for average.

bbl. The abbreviation for barrel.

BDV. Acronym for blow down valve.

bergy bit. A piece of floating glacier having a sail greater than 1.5 m but less than 5 m and a water plane area greater than 20 m^2 but less than 300 m^2. Size approximates that of a small house and mass is between 120 and 5,400 t.

BOP. Acronym for blowout preventer.

BVD. Acronym for blow down valve.

CCG. Acronym for Canadian Coast Guard.

C-CORE. Acronym for Centre for Cold Ocean Resources Engineering.

CCR. Acronym for central control room.

CEAA. Acronym for *Canadian Environmental Assessment Act*.

CERT. Acronym for Corporate Emergency Response Team.

christmas tree. Arrangement of valves and fittings attached to the tubing head to control flow and provide access to the tubing string.

CIS. Acronym for Canada Ice Sevices.

cluster. Wells grouped together to minimize infield flowlines.

CMG. Acronym for course made good.

C-NOPB. Acronym for Canada-Newfoundland Offshore Petroleum Board.

COT. Acronym for cargo oil tank.

CPA. Acronym for closest point of approach.

crude oil. Unrefined petroleum.

CSA. Acronym for Concept Safety Assessment.

d. Abbreviation for day.

DA. Acronym for Development Application.

DCS. Acronym for distributed control system.

DDMT. Acronym for Data and Decision Management Tool.

Development (White Rose Oilfield Development). "Development" refers to all phases of the project, from the decision to go ahead with construction through to abandonment of the field.

Development Application. The official title of the documentation submitted in support of the White Rose oilfield development. The Development Application includes: Project Summary; Canada-Newfoundland benefits Plan (Volume 1); Development Plan (Volume 2): Environmental Impact Statement (Volume 3 - Comprehensive Study Part One); Socio-Economic Impact Statement (Volume 4 - Comprehensive Study Part Two); and Concept Safety Analysis/Safety Plan (Volume 5).

DFO. Acronym for federal Department of Fisheries and Oceans.

DND. Acronym for Department of National Defence.

DNV. Acronym for Det Norske Veritas.

DP. Acronym for dynamically positioned.

drill centre. Location at which a group of wells is drilled.

drilling platform. An offshore structure from which a number of wells are drilled. The legs of the platform are anchored to the seabed and the platform is built on a large-diameter pipe frame.

drilling rig. A ship-shaped or semi-submersible vessel, or a jackup platform, with equipment suitable for offshore drilling.

DTI. Acronym for UK Department of Trade and Industry.

DWT. Dead weight tonnage.

EAT. Acronym for Emergency Action Teams.

ECERT. Acronym for East Coast Emergency Response Team.

ECM. Acronym for environmental compliance monitoring.

ECRC. Acronym for Eastern Canada Response Corporation.

ECS. Acronym for emergency control system.

EEM. Acronym for environmental effects monitoring.

Environmental Impact Statement (EIS). A document that attempts to predict the effects of a major development might have on the human and natural environments of a given geographic area. An EIS is prepared to enable industry, government and the public to consider the environmental costs and benefits of a development project. Based on the information contained in the EIS, decisions an be made on whether to proceed with the development project.

ERP. Acronym for Emergency Response Plan.

ERT. Acronym for Emergency Response Team.

ESD. Acronym for emergency shut down.

ESDV. Acronym for emergency shut down valve.

FGD. Acronym for fire and gas detection.

FGS. Acronym for fire and gas detection system.

First Oil. Milestone achieved when the first shuttle tanker has been filled with oil from the White Rose production system and the shuttle tanker disconnects from the offloading system. The entire production system is handed over to operations personnel at this point. This is the first quantity of oil to be delivered from the reservoir through the complete production and offloading system, including fiscal metering.

flaring. Disposal of surplus combustible vapours by burning at the discharge of the flare tower.

floating production system. A monohull or semi-submersible vessel with equipment suitable for producing hydrocarbons.

flowline. Pipe which conveys crude oil from the well to the riser, or mud, water or gas from the riser to the well.

FPF. Acronym for floating production facility.

FPSO. Acronym for floating production, storage and offloading facility.

FRC. Acronym for fast rescue craft.

FSU. Acronym for floating storage unit.

FTO. Acronym for failure to operate.

glory hole. Hole, excavated in the seabed, in which wellhead facilities are placed for protection from iceberg scour.

h. The abbreviation for hour.

H_2S. Abbreviation for hydrogen sulphide.

HAZID. Acronym for Hazard Identification.

HMDC. Acronym for Hibernia Management and Development Company.

HS&E. Acronym for Health, Safety and Environment.

Husky Oil. Abbreviation for Husky Oil Operations Limited.

HVAC. Acronym for heating, ventilation and air conditioning.

iceberg scour. Seafloor trench caused by the ploughing motion of an iceberg grounding on the ocean floor.

ICS. Acronym for Incident Command System.

IDNS. Acronym for Ice Data Network System.

IIF. Acronym for input initiating frequency.

IIP. Acronym for International Ice Patrol.

IMO. Acronym for International Maritime Organization.

IR. Acronym for individual risk.

ISM. Acronym for International Safety Management.

km. The abbreviation for kilometre.

km^2. The abbreviation for square kilometre.

kPa. Abbreviation for kiloPascal.

KSLO. Acronym for Kvaerner-SNC Lavelin Offshore.

kV. The abbreviation for kilovolts.

kts. The abbreviation for knots.

kW. The abbreviation for kilowatts.

L. The abbreviation for litre.

m. The abbreviation for a) metre or b) earthquake magnitude.

m^2 . The abbreviation for square metre.

m^3. The abbreviation for cubic metre.

MANMAR. Acronym for Manual of Marine Weather Observing.

MARPOL. International Convention for the Prevention of Pollution from Ships.

MFPSV. Acronym for Multifunctional Platform Support Vessel.

min. Abbreviation for minute.

mm. The abbreviation for millimetre.

MODU. Acronym for mobile offshore drilling units.

monohull. A ship-shaped vessel.

MRSC. Acronym for Marine Rescue Sub Centre.

MSDS. Acronym for Material Safety Data Sheets.

OCMS. Acronym for Offshore Chemical Management System.

OEC. Acronym for overpressure exceedance curve.

OERT. Acronym for Offshore Emergency Response Team.

OIM. Acronym for offshore installation manager.

On-shore/at-shore hook-op. The installation, testing and commissioning of topsides modules at a designated hook-up site.

Operations Phase. The period following First Oil until cessation of all oil production from the White Rose oilfield. Includes post-First Oil development drilling, offshore installation activities, production, operations, maintenance, well abandonment, decommissioning and removal from the White Rose oilfield of all facilities, equipment and vessels used in the production system.

Operator. When capitalized in the Development Application, refers to Husky Oil.

OSC. Acronym for On-Scene Commander.

OSRL. Acronym for Oil Spill Response Limited.

overpressured. A subsurface formation that exerts an abnormally high formation pressure on a wellbore drilled into it.

Owner/Operator. When capitalized in the Development Application, refers to Husky Oil.

pack ice. Any area of sea ice, except fast ice, composed of a heterogeneous mixture of ice of varying ages and sizes, and formed by packing together of pieces of floating ice.

PAL. Acronym for Provincial Airlines Limited.

petroleum. Oil and natural gas.

PFD. Acronym for process flow diagrams.

PFP. Acronym for passive fire detection.

PLL. Acronym for probable loss of life.

POB. Acronym for persons on board.

ppb. The abbreviation for parts per billion.

PPE. Acronym for personal protective equipment.

ppm. The abbreviation for parts per million.

PPSD. Acronym for partial process shutdown system.

Pre-Engineering. All of the engineering work undertaken before the Project Phase to determine the preferred floating production system for White Rose. Begins with the invitation to submit alliance qualification proposals through selection of the three alliance groups, through selection of the preferred production system and alliance. Includes further definition engineering work with the preferred alliance up to the commencement of the Project Phase.

Project Phase. The period beginning with regulatory approval of the Development Application and the Proponent's authorization to execute the White Rose oilfield development, up to the production and offloading of First Oil. Includes detail engineering, procurement, construction, commissioning, installation and development drilling up to First Oil. Does not include development drilling after First Oil.

PSD. Acronym for process shutdown system.

PTW. Acronym for Permit to Work.

QA/QC. Acronym for quality assurance/quality control.

QRA. Acronym for quantified risk analysis.

R&D. Acronym for Research and Development.

RBDM. Acronym for Risk-Based Decision Management.

RCC. Acronym for Rescue Coordination Centre.

RCM. Acronym for reliability centred maintenance.

RCMP. Acronym for Royal Canadian Mounted Police.

REET. Acronym for Regional Environmental Emergency Team.

Regulatory Phase. The period and activities associated with the regulatory review of the Development Application. Commences with the filing of the Development Application and ends upon receipt of approval.

reserves. That part of an identified resource from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination.

reservoir. A subsurface, porous, permeable rock body in which oil or gas has accumulated; most reservoir rocks are limestones, dolomites, sandstones, or a combination of these.

resource. An initial volume of oil and gas that is estimated to be contained in a reservoir.

RNC. Acronym for Royal Newfoundland Constabulary.

ROV. Acronym for remotely operated vehicle.

RV. Acronym for research vessel.

SAR. Acronym for a) search and rescue; b) synthetic aperture radar.

SAWRS. Acronym for Supplementary Aviation Weather Reporting Station.

SBM. Acronym for a) synthetic-based mud or b) Single Buoy Mooring.

scour. (a) Seafloor trench caused by the ploughing motion of an iceberg grounding on the ocean floor. (b) Seafloor erosion caused by strong currents, resulting in the redeployment of bottom sediments and formation of holes and channels.

SCSSV. Acronym for surface controlled sub-surface controlled safety valve.

sea ice. Any ice floating in the sea.

semi-submersible. A drilling or production vessel that has the main buoyancy chambers (pontoons) below the active wave zone to provide enhanced vessel stability.

shuttle tanker. A ship with large tanks in the hull for carrying oil or water back and forth over a short route.

SOP. Acronym for Search and Rescue Region.

spider buoy. Disconnectable interface between the risers and the FPSO.

SPM. Acronym for Single Point Mooring.

SRD. Acronym for Search and Rescue Design.

SRR. Acronym for Search and Rescue Region.

t. The abbreviation for tonne (a metric ton).

TCPA. Acronym for time to closest point of approach.

td. Abbreviation for total depth.

template. Device through which a group of wells is drilled and produced.

TEMPSC. Acronym for Totally Enclosed Motor Propelled Survival Craft.

TIF. Acronym for test independent failure.

TLS. Acronym for target levels of safety.

topside (or topsides) facilities. The oil- and gas-producing and support equipment located on the top of an offshore structure.

tree. (a) An arrangement of valves placed on top of a well to control flow from the well. (b) An arrangement of valves and fittings attached to the tubing head to control flow and provide access to the tubing string.

TSR. Acronym for temporary safe refuge.

T-time. The total time required to suspend operations, secure the subsea facilities and prepare the installation to move off location. This time is determined and updated continuously by the OIM and ice observer.

turret. A low, tower-like structure capable of revolving horizontally within the hull of a ship and connected to a number of mooring lines and risers. It allows the ship to rotate with the weather while maintaining a fixed mooring system.

umbilical. Device through which control of subsea instrumentation is maintained from the FPSO.

UPS. Acronym for uninterruptible power supply.

USD. Acronym for unit shutdown system.

VCS. Acronym for vessel control system.

VHF. Acronym for very high frequency.

water-based mud. A drilling mud in which the continuous phase is water.

White Rose Development. “Development” refers to all phases of the project, from the decision to go ahead with construction through to abandonment of the field.

WHMIS. Acronym for Workplace Hazardous Materials Information Systems.

WMO. Acronym for World Meteorological Organization.