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Nuclear Generation Group

February 20, 2008

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant; Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Independent Spent Fuel Storage Installation; Docket No. 72-8
Revision to Hazards Analysis Related to Liquefied Natural Gas Plant Operations at Cove Point

REFERENCES:

(a) Letter from Mr. G. S. Vissing (NRC) to Mr. G. Vanderheyen (CCNPP), dated January 20, 2004, Safety Evaluation Regarding Effect of Modification of Liquefied Natural Gas Facility on Safety on Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 (TAC Nos. MC0188 and MC0189)

(b) Letter from Mr. L. B. Marsh (NRC) to Mr. R. E. Denton (BGE), dated August 31, 1995, Liquefied Natural Gas Analysis – Calvert Cliffs Nuclear Power Plant, Unit No. 1 (TAC No. M86704) and Unit No. 2 (TAC No. M86705)

(c) Letter from Mr. R. E. Denton (BGE) to Document Control Desk (NRC), dated June 7, 1993, Liquefied Natural Gas Hazards Analysis

(d) Letter from Mr. R. E. Denton (BGE) to Document Control Desk (NRC), dated May 31, 1995, Response to NRC's Request for Additional Information; Liquefied Natural Gas Hazards Analysis (TAC Nos. M86704; M86705)

By Reference (a), the Nuclear Regulatory Commission issued a safety evaluation concluding that modifications proposed in 2003 to the Liquified Natural Gas (LNG) Facility at Cove Point, Maryland (Cove Point) would not invalidate the conclusions of their existing safety evaluation (Reference b), which was issued in 1995. Since that time, Dominion Cove Point LNG, LP, current owner and operator of the Cove Point LNG terminal, has received approval from State and Federal authorities for an additional expansion to the Cove Point facility. This submittal provides notice to the Nuclear Regulatory Commission of the expected expansion of storage capacities and LNG shipments to Dominion Cove Point LNG beginning in the Fall of 2008.

The current Cove Point LNG facility expansion includes an increase from approximately 90 shipments per year to 200 shipments per year. It also includes the addition of two LNG storage tanks with a

NMSS01

capacity of 1,000,000 barrels each. Dominion Cove Point LNG plans to place the additional storage tanks in service in the fall of 2008, with increased shipments to follow. The Maryland Department of Natural Resources Power Plant Research Program (PPRP) has released a risk analysis performed by Environmental Resources Management on this expansion (Enclosure 1). The Maryland Department of Natural Resources, acting through the PPRP, identified the need for an independent and comprehensive evaluation of potential human health risks to nearby communities and risk to Calvert Cliffs Nuclear Power Plant (CCNPP). Constellation Energy Nuclear Group's probabilistic risk assessment group participated in a review of this analysis.

In June 1993, Baltimore Gas and Electric submitted an analysis (Reference c) done by Arthur D. Little on the re-opening of the Cove Point LNG facility. Baltimore Gas and Electric supplemented this analysis in May 1995 in response to a Nuclear Regulatory Commission request for additional information (Reference d). The PPRP study (Enclosure 1) evaluates the risk of the expansion and compares this to the Arthur D. Little report (Reference c). The new report is a more detailed analysis which uses more current evaluation techniques. The PPRP study concludes that the risk of expanded operations at the Cove Point LNG facility to CCNPP is well within Nuclear Regulatory Commission acceptable limits. We have reviewed the PPRP study and also concluded that the risk to CCNPP, from the Cove Point LNG facility, is well within the criteria set by NUREG-1407 for external events.

Should you have questions regarding this matter, please contact Mr. Jay S. Gaines at (410) 495-5219.

Very truly yours,

JAS/MJY/bjd

Enclosure: (1) Cove Point LNG Terminal Expansion Project Risk Study, dated June 28, 2006

cc: D. V. Pickett, NRC
S. J. Collins, NRC
Resident Inspector, NRC
R. I. McLean, DNR
M. E. Gardner, Dominion

ENCLOSURE (1)

Cove Point LNG Terminal Expansion Project Risk Study,

dated June 28, 2006

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

DNR 12-7312006-147
PPRP-CPT-01

PPRP

Cove Point LNG Terminal Expansion Project Risk Study

28 June 2006

MARYLAND POWER PLANT RESEARCH PROGRAM

Robert L. Ehrlich, Jr., Governor ♦ Michael S. Steele, Lt. Governor

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%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
=	equals
°C	degrees Celsius
°F	degrees Fahrenheit
ALARP	as low as reasonably practicable; measuring risk to the threshold to where any further reductions in risk would involve costs grossly disproportionate to the benefits
bara	barometric pressure
BCF	billion cubic feet
BCFD	billion cubic feet dry
BP Cirrus	a suite of consequence models developed by BP International Limited, London, and others
Btu	British thermal unit
bund	an embankment or dike
CCNPP	Calvert Cliffs Nuclear Power Plant
CDF	core damage frequency
CFR	Code of Federal Regulations
DCS	distributed control system
EPA	Environmental Protection Agency
explosion	combustion of a flammable gas where the flame or confinement velocities are sufficient to result in damaging overpressures
FERC	Federal Energy Regulatory Commission
FF	flash fire; combustion of a flammable gas where the flame propagates at a velocity insufficient to result in damaging overpressures
FN curve	a curve that shows the frequency that N or more fatalities will occur as a result of the considered facilities
ft	feet
g	gram
HAZID	Hazard Identification & Analysis
hr	hour
HSE	Health and Safety Executive
in	inch
J	Joule
JF	jet fire; combustion of a high pressure gas or liquid
k (prefix)	kilo-; multiplied 1,000 times (e.g. 2 kJ equals 2,000 J)
LERF	large early release frequency

LFL	lower flammable limit; lowest concentration of a fuel by volume mixed with air that is flammable
LNG	liquefied natural gas; natural gas that has been cooled to a temperature such that the natural gas becomes a liquid
LSIR	location specific individual risk
m	meter
min	minute
m (prefix)	milli-; divided 1,000 times (e.g. 1 mm equals 1/1000 m)
mol	mole
N	Newton
NFPA	National Fire Protection Agency
NRC	Nuclear Regulatory Commission
NUREG	US Nuclear Regulatory Commission Regulation
OPS	Office of Pipeline Safety
Pa	Pascal
PCAG	Planning Consequence Assessment Guidelines
PF	pool fire; combustion of a flammable liquid pool
PLL	potential loss of life
PPRP	Power Plant Research Program
psig	pounds per square inch gauge
QRA	quantitative risk analysis
s	second
SRI	societal risk index
SSRRC	Santa Barbara County System Safety and Reliability Review Committee
UFL	upper flammable limit; highest concentration of a fuel by volume mixed with air that is flammable
UK	United Kingdom
US	United States
USCG	United States Coast Guard
USDOT	United States Department of Transportation
VCE	vapor cloud explosion
vol	volume
W	watt
yr	year

FOREWORD

This technical study utilizes information pertinent solely to the Cove Point LNG facility in the assessment of risks associated with the expansion of the project to nearby residential communities and the Calvert Cliffs Nuclear Power Plant. Parameters utilized as inputs to the risk models employed in the study are unique to this facility and its location. Conclusions reached in this assessment are likewise site and facility specific and are not transferable or applicable to any other facility or location.

This report was prepared under the direction of Mr. Richard McLean of the Maryland Department of Natural Resources, Power Plant Research Program (PPRP). The report was prepared by Environmental Resources Management, Inc. (ERM) under the direction of PPRP. The work that is described in this report reflects the collective efforts of a core project team comprised of representatives from PPRP and several groups within ERM.

Substantial efforts were required by the project team and other staff from those organizations. We further acknowledge Constellation Energy, Inc., Dominion Cove Point LNG, L.P., and Dominion Transmission, Inc. for providing information necessary for completion as well as their critical reviews in finalizing the report.

ABSTRACT

The owners of the Cove Point LNG facility located in Calvert County, Maryland, Dominion Cove Point LNG, L.P. (Dominion), filed an application with the Federal Energy Regulatory Commission (FERC) in April 2005 to expand operations at the Cove Point facility. The proposed expansion would add two new on-shore LNG storage tanks and increase LNG imports from approximately 90 shipments per year to 200 shipments per year, thereby essentially doubling the operating capacity of the facility. The Maryland Department of Natural Resources, acting through the Power Plant Research Program (PPRP), is an intervening party in the FERC licensing proceedings for the proposed expansion.

FERC evaluated the environmental impacts related to the proposed expansion and issued its draft Environmental Impact Statement (EIS) in October 2005. After reviewing the draft EIS, PPRP identified the need for an independent and comprehensive evaluation of potential human health risks to nearby communities and risk to the Calvert Cliffs Nuclear Power Plant that would result from the proposed expansion. PPRP, in comment to FERC, indicated its intention to conduct such a study. This report presents the scope, methods and findings from PPRP's risk study.

In summary, the study concludes that the quantified risks to populations and facilities, including Calvert Cliffs Nuclear Power Plant, fall within a range considered acceptable relative to available industry criteria, including the U.S. Nuclear Regulatory Commission regulatory standards. The report further notes that although the incremental risks associated with the expanded facility relative to the existing licensed facility are minimal, all measures that might further reduce those risks to as low as reasonably achievable should be considered by the regulatory agency, and where appropriate incorporated into the license.

Conclusions reached in this study are site and facility specific and are not transferable or applicable to any other facility or location.

Background

The Maryland Department of Natural Resources, Power Plant Research Program (PPRP) has completed a risk assessment of the proposed expansion of the Cove Point Liquefied Natural Gas (LNG) facility in Lusby, Calvert County, Maryland. The current Cove Point facility stores 7.8 billion cubic feet of LNG and has an export capacity of 1 billion cubic feet per day. The expansion project would introduce two new storage tanks and increase LNG imports from approximately 90 to 200 shipments per year, thereby increasing storage and export capacities to 14.6 billion cubic feet and 1.8 billion cubic feet per day, respectively.

The risk study identifies plausible large-scale hazard scenarios that have the potential to cause injury or property damage off site, and estimates the probabilities and consequences of those scenarios using quantitative risk assessment techniques. A range of risk scenarios was considered, including tanker releases, process pipe rupture, and storage tank breaches. The study quantified risks based on probability of occurrence and frequency for each scenario. Specific causes of, and controls for, the major hazard scenarios are not explicitly considered; rather, event frequencies are estimated using generic historical failure data for each equipment component. Consequently, the scope of study effectively includes events caused by hazards internal to the facility (such as operator error) and external hazards (such as impact damage or sabotage).

The total risk profile for the facility before and after the expansion project was determined by summing the risks from the individual scenarios. Risks posed to the nearby Calvert Cliffs Nuclear Power Plant (CCNPP) were a focus of the study, as well as risks posed to the nearest residential area (to the south of the terminal).

Estimated Risk Levels for Existing Facility

The risk of fatality at CCNPP from all hazardous events associated with the existing LNG facility is estimated to be slightly more than 2 in a billion (2.3×10^{-9}) per year, an extremely low risk level. The risk of physical damage to CCNPP is estimated to be lower still.

The risk of fatality in the immediate vicinity of the existing Cove Point facility is in the range of 1 in 100,000 to 1 in 10 million per year depending on the exact location, with the maximum risk level over the most exposed residential area (opposite the terminal entrance) being 1 in a million per year.

To place these risk figures in context, the average individual fatality risk from all accidents (motor vehicle accidents, falls, drowning, fires, etc.) is about 3 in 10,000

(3.1×10^{-4}) per year in the US. Hence, the risk from the existing facility to the most exposed residential location is approximately 0.3 percent of the total fatality risk that an individual faces from all accidents.

Effect of Expansion Project on Risk Levels

The fatality risk determined for the proposed expansion of the Cove Point facility is between 6 and 7 in a billion (6.6×10^{-9}) per year at CCNPP. This reflects the increased frequency of ships visiting the terminal in the expansion case. These risks are well within the threshold of acceptable risk defined by the U.S. Nuclear Regulatory Commission (NRC) for nuclear power facilities.

With respect to the nearest residential area, the risk from the expanded facility is approximately 2 ½ fatalities in a population of one million (2.4×10^{-6}) per year. This equates to 0.8 percent of the total fatality risk that an individual faces from all accidents.

Summary of Findings

The NRC has established an acceptable risk threshold level of 1 in a million (10^{-6}) per year for Core Damage Frequency and 0.1 in a million (10^{-7}) per year for Large Early Release Frequency. PPRP's risk study estimates the risk of fatalities at CCNPP to be 6.6×10^{-9} per year, given the expanded operations at Cove Point. The risk of physical damage to the power plant is even smaller, and therefore would be well within the NRC's acceptable limits.

With respect to broader societal risk, there are relatively few sets of quantitative criteria available with which to compare the risk estimates developed in this study to determine acceptability of the risk levels. In the absence of publicly available risk guideline that would be directly applicable to the Cove Point facility, the study team compared the risks to established risk evaluation criteria used in the UK and other countries. On the basis of this evaluation, the risks from the expanded facility are within the range of acceptability or "tolerability" as defined in those criteria, as long as the risks have been reduced to the greatest extent practicable through engineering design and construction of the proposed expansion.

It is important to note that these conclusions are based upon unique facility and site specific information and are not transferable or applicable to any other facility or location.

1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Maryland Department of Natural Resources, Power Plant Research Program (PPRP) has commissioned an independent risk (or hazard) study of the proposed expansion of the Cove Point Liquefied Natural Gas (LNG) facility and associated pipeline in Lusby, Calvert County, Maryland. The study was conducted by Environmental Resources Management (ERM).

The purpose of the risk study is to evaluate the effects of the proposed expansion project on risks to people and property in the vicinity of the terminal, pipeline and marine operations and to compare those risks to industry standards and 'everyday' risks.

In particular the risk study also examines the effects, if any, the proposed expansion project will have on the Calvert Cliffs Nuclear Power Plant (CCNPP) 3.6 miles north of the Cove Point terminal and the nearest local community, located ½ mile south of the terminal.

Similar studies of the Cove Point LNG facility have previously been conducted on two occasions:

- In 1992, when Cove Point was proposed to be re-opened and a liquefaction unit constructed. The Arthur D. Little (ADL) hazard study was performed as a requirement of the operating license issued by the Nuclear Regulatory Commission (NRC) for the CCNPP. This license requires any development proposal in the vicinity of the CCNPP to evaluate the potential threats that the development may pose to the CCNPP.
- In 2001, as part of its application to the Federal Energy Regulatory Commission (FERC) for the proposed reactivation and expansion of the facility, a hazard study was performed by the Williams Company, a prior owner of the Cove Point LNG facility.

The current study describes the input information and methodology used in the hazard and risk study, as well as all results and conclusions. The approach is based on ERM experience in LNG risk studies around the world.

In carrying out this study, ERM reviewed the previous Cove Point hazard studies, reports on major incidents involving LNG and a range of recent background documents from the United States (US) and United Kingdom (UK). This review was carried out in order to provide an objective analysis of LNG risks.

1.2 *SCOPE*

The scope of this study is limited to assessment of major hazard scenarios involving LNG that may have the potential to cause property damage or adverse impacts on human health offsite. Smaller scale events with direct effects limited to onsite populations are not included except in relation to their potential to cause an escalation to a more severe event.

The proposed expansion project may be implemented in stages; for example, the south pier is expected to be in use well before the expansion project is completed, the new processing and storage equipment is expected to go into service in August 2008, and LNG shipping could reach a maximum of 200 vessels per year in 2009. However these intermediate stages are not considered within this study; risks are calculated only for the current (effectively pre-2004) baseline and the fully completed expansion project.

The geographical scope of the study, shown in ***Figure 1.1***, covers the area around Cove Point and CCNPP. The risk study is limited to LNG operations contained within this area, e.g., LNG ships en route within the area, berthing of ships and cargo transfer, onshore storage and processing and pipeline export within the study area. There are several additional downstream developments such as further transmission system pipelines and compressor stations, which are outside the scope of this project.

The study does not evaluate construction phase risks, any future modifications to the facility or surrounding areas, or risks to the environment.

1.3 *REPORT ORGANIZATION*

In the remaining chapters of this report we present the following information:

Chapter 2 - Description and discussion of the existing facility and the proposed expansion, as well as the surrounding environment (i.e., physical features and demographics);

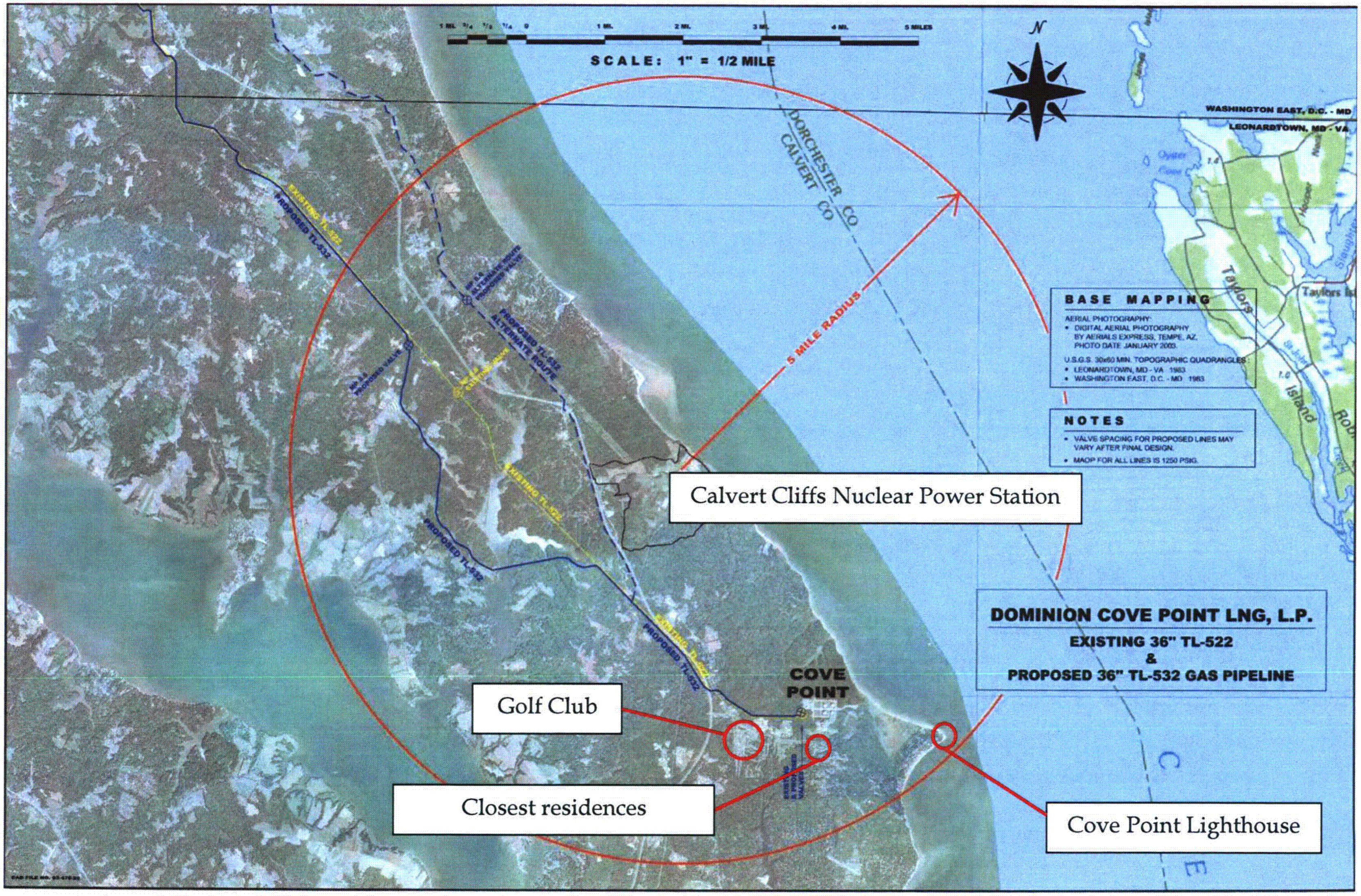
Chapter 3 - Discussion of relevant risk criteria for evaluating and providing context for studies of this nature;

Chapter 4 - Discussion of the methods employed in performing the risk study;

Chapter 5 - Presentation of the results from the current study; and

Chapter 6 - Discussion of the results from the study and especially what they mean relative to relevant risk criteria and other benchmarks.

Figure 1.1 Area Map



Source: Base Map Provided by Dominion Cove Point LNG, L.P.

2 LNG OPERATIONS AND SURROUNDING ENVIRONMENT

2.1 CURRENT AND PROPOSED LNG OPERATIONS

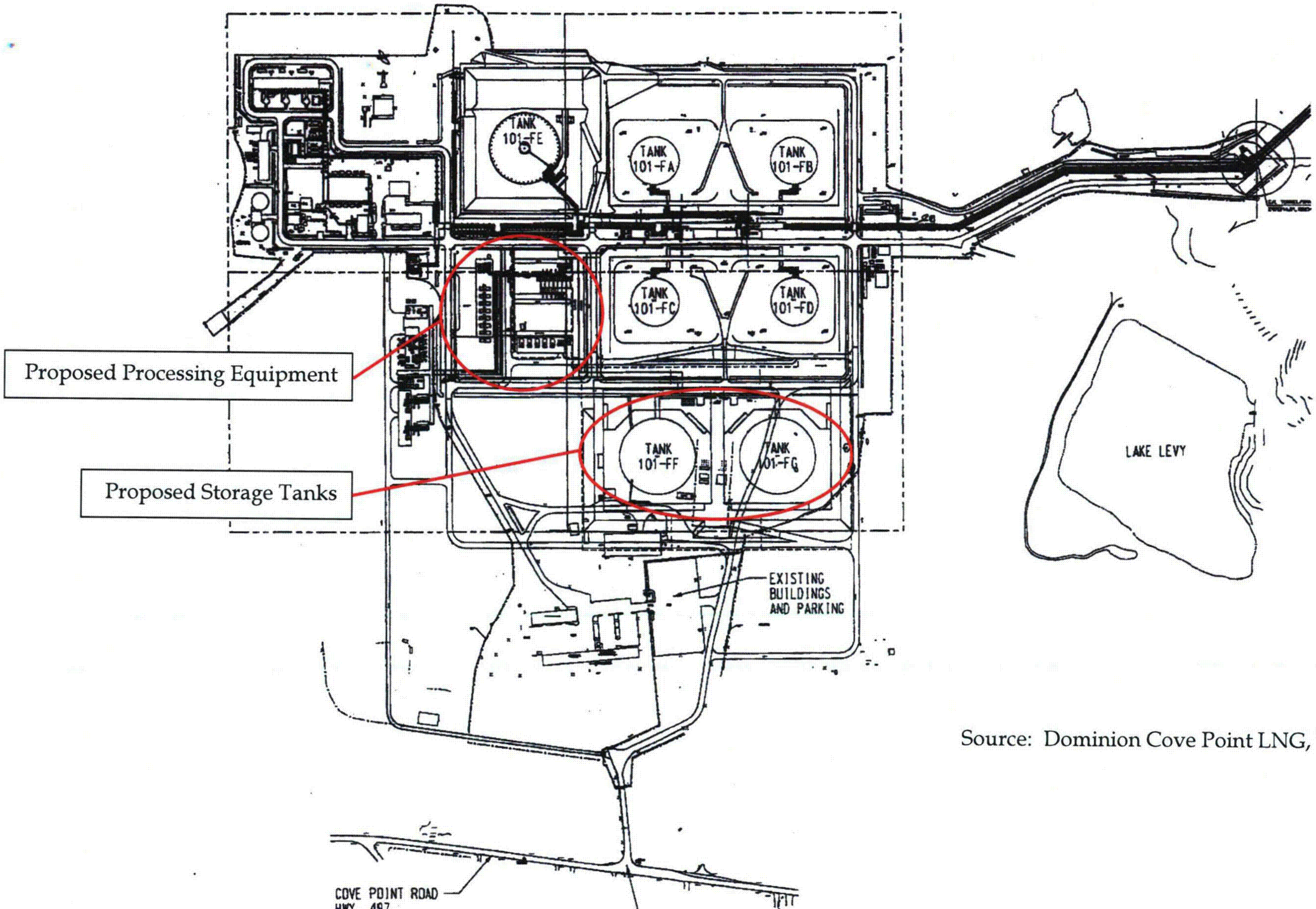
The current and proposed Cove Point LNG facilities are summarized in ***Table 2.1***; site layout is shown in ***Figure** 2.1*. The current terminal provides a total of 1 billion ft^3/day peak export capacity and 7.8 billion ft^3 storage capacity. The expansion project will increase these to 1.8 billion ft^3/day and 14.6 billion ft^3 respectively.

Table 2.1 *Cove Point LNG Operations*

Area	Existing Operations	Expanded Operations
LNG shipping	90+ ships per year to north pier of offshore LNG unloading platform; typical ship capacity 70-140,000 m^3	200 ships per year to both north and south piers of unloading platform; typical ship capacity same as current
Transfer to onshore facilities	6400 ft submerged/buried pipeline tunnel carrying 2x32" liquid lines and 2x14" vapor return lines	No change
Onshore LNG storage	5 (1 x 850,000 plus 4 x 230,000 barrels) double walled insulated LNG storage tanks at -260 °F and 2 psig	2 additional 1,000,000 barrel double walled insulated LNG storage tanks
Processing equipment	LNG vaporizing and liquefaction equipment (liquefaction equipment not in operation)	Additional vaporization capacity and improvements/additions to existing equipment
Pipeline export	88 mile 36" pipeline from the terminal to interconnections with LNG distribution and transmission systems	Additional 47 miles of 36" pipeline to connections with other interstate pipelines; 36 miles of the 47-mile length will run alongside the existing pipeline corridor

The expansion project is designed to meet federal regulations and National Fire Protection Agency (NFPA) standards. The expanded terminal will incorporate a new distributed control system (DCS) which will fully integrate the operation of the existing and new facilities.

Figure 2.1 Site Layout Showing Expanded Terminal Layout



Source: Dominion Cove Point LNG, L.P.

2.2 *SURROUNDING ENVIRONMENT*

The Cove Point LNG terminal is located directly south of the Calvert Cliffs State Park and Cove Point Park. The land is forested to within a few hundred feet of the terminal to the north and west.

Calvert Cliffs Nuclear Power Plant (CCNPP) is 3.6 miles to the north of the LNG terminal. CCNPP and the LNG terminal are therefore separated by thickly forested parkland.

Chesapeake Hills Golf Club is immediately to the west of the terminal, and the town of Lusby is approximately 1 mile to the south, with the nearest residential areas about ½ mile from the terminal. The population of Lusby is approximately 1700 (based on year 2000 data). The nearest main road is Route 497 (Cove Point Road), which lies between the terminal and Lusby.

To the east of the terminal is the offshore unloading platform, Cove Point Lighthouse and Chesapeake Bay. LNG ships enter Chesapeake Bay near Norfolk, approximately 100 miles south of the terminal, and travel directly north to the terminal. Therefore, they do not pass by CCNPP. The closest distance between the route taken by the LNG ships and populated areas is at Cove Point Lighthouse, which is approximately 1 mile from the route taken by the LNG ships approaching the unloading platform.

2.3 *COVE POINT EXPANSION PROJECT DOCUMENTATION*

Dominion has submitted extensive application documents to FERC relating to the proposed LNG terminal expansion project, including separate resource reports on the pipeline and terminal facilities.

PPRP has reviewed this documentation in order to obtain background information necessary for this risk study. In addition, PPRP has received detailed engineering information relating to the proposed modifications to the facility and further details on the pipeline and marine operations. This information has been taken into account in developing the risk model.

3 CRITERIA RELATING TO SAFETY/RISK ACCEPTANCE OF FACILITIES

There are specific engineering and regulatory criteria which can be used to gauge the acceptability of proposed industrial facilities; in the case of the LNG terminal, these are defined in the NFPA 59A[1] and United States Department of Transportation (USDOT)[2] and United States Coast Guard (USCG)[3] code of federal regulations (CFR) relating to LNG. The submissions by Dominion state that the facilities will comply fully with these standards and requirements.

In addition to the above, the acceptability of a facility may be gauged by reference to risk acceptance criteria. These are well established in several countries including the UK, Holland and Australia, and similar risk acceptance criteria have been used in the US in the past. However it is not known if there are any current widely recognized and routinely applied risk criteria in the US. Hence the approach taken here is to compare the predicted risks against a combination of US and international risk criteria. These are described below.

3.1 *US RISK CRITERIA*

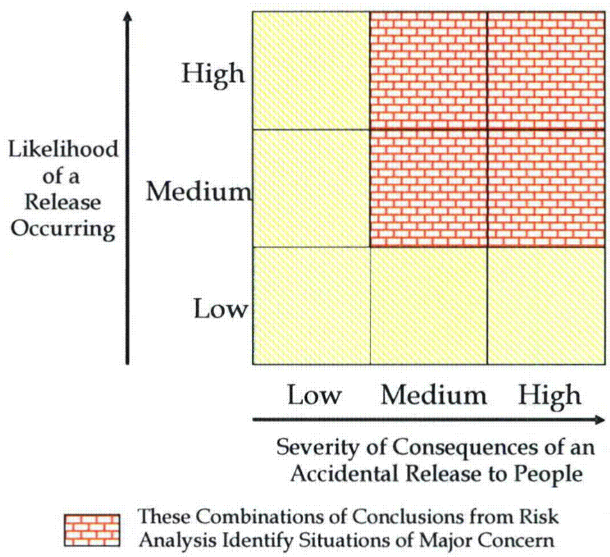
In its guidance document for hazard analysis[4], EPA provides some insight (although largely qualitative in nature) on *'unacceptable risk'*. A matrix of EPA classifications on incident frequency and incident severity are shown in ***Figure 3.1***. EPA suggests that the shaded areas attributable to medium to high combination of classes may be of concern and require further assessment.

The EPA definition of "low likelihood" is that the event is unlikely to occur during the expected lifetime of the facility assuming normal operation and maintenance (for example, an event with a frequency of 1:10,000 per year at a facility with a 50 year lifetime gives a likelihood of occurrence of 0.5% over the facility lifetime). The EPA definition of "medium consequence" is any release that could cause serious injuries or fatalities.

Thus, any event that has a likelihood that is higher than "low" and a consequence that is higher than "medium" as defined above, may require further assessment and risk management effort. There are two main difficulties with these criteria: the exact numerical equivalent of "low" likelihood is not clear; and the definition of an event is not clear. Many individual hazardous release events (e.g. failure of a storage tank) may have a frequency in the "low" range. However, the event frequency for a group of scenarios may exceed the "low" range.

[1] NFPA Standard for the Production, Storage and Handling of Liquefied Natural Gas LNG (NFPA 59A, 2001)
[2] 40 CFR 192 (Transportation of Natural and other gases by pipeline) and 40 CFR 193 (LNG Terminal Federal Safety Standards).
[3] 33 CFR 127 (Waterfront Facilities Handling LNG Liquefied Hazardous Gas).
[4] Environmental Protection Agency, Guidance Document for Hazard Analysis, 1987.

Figure 3.1 *Risk Analysis Matrix (EPA, 1987)*



The Santa Barbara County System Safety and Reliability Review Committee (SSRRC), consisting of members from several mainly California-based government organizations, was formed in the 1980s to establish criteria for tolerability of risk from oil and gas facilities. An article published by Vrat and Almy[5] gives details of the guidelines established for hazardous facility siting. A summary of the societal risk criteria suggested by the SSRRC for existing facilities is given in ***Table 3.1***. It is not known if these criteria are still in use in California; however, to our knowledge they are the clearest risk acceptance criteria relevant to an LNG facility that have been developed in the US and are in the public domain.

Table 3.1 ***Offsite Risk Regulation Criteria for Severe Events (SSRRC Criteria)***

De Manifestis	**'Grey Region'**	**De Minimis**
(Risk reduction required at any cost)	(Economic risk reduction methods only) < \$1.5 million - Yes > \$2.0 million - No	(No risk reduction required)
> 10^{-5} (1 in 100,000) per year	10^{-5} to 10^{-7} (1 in 100,000 to 1 in 10,00,000 per yr)	< 10^{-7} (1 in 10,000,000) per year

[5] Vrat and Almy, 1990

Another relevant set of criteria are those established by the Nuclear Regulatory Commission (NRC) for acceptability of risks to communities located near nuclear power facilities. The NRC's Societal Risk Index (SRI) represents *De Manifestis* and *De Minimis* risk criteria. These SRI levels are 10 cancers/year and 0.03 cancers/year, respectively, but they represent chronic risk to health. The NRC equates a single, acute fatality with 30 delayed fatalities from chronic risk. Application of this concept leads to a *De Manifestis* level of 0.3 fatalities per year and a *De Minimis* level of 0.001 fatalities per year from acute risks.

With respect to the risk of damage to a nuclear power plant itself as a result of external events, the NRC also has defined limits of acceptability[6]. The acceptable risk to a nuclear plant due to an external impact is 1.0 in a million (10^{-6}) per year for Core Damage Frequency (CDF) and 0.1 in a million (10^{-7}) per year for Large Early Release Frequency (LERF). Cases which exceed these criteria require further analysis and potential design changes to the plant to minimize the risk.

Although the nuclear industry has established risk acceptance criteria via NRC regulations (see discussion above), risk criteria are not widely adopted by industrial facilities (e.g. the chemical industry) in the US. There are several companies that refer to risk criteria, but these are not within the public domain. The criteria generally lie between, and are based on, Dutch and UK government risk criteria, depending on the company's level of "risk tolerance." The tolerable frequency of catastrophic events (causing 10 or more fatalities) is generally in the region of 0.01 to 100 in a million (10^{-3} to 10^{-4}) per year for a medium sized facility. The typical individual risk tolerable limit is around 1.0 to 10 in a million (10^{-6} to 10^{-5}) per year. Some companies aim to ensure the maximum range to potentially fatal effects is less than the distance to the nearest offsite population, and will only consider individual risk if this is not practicable.

3.2 *DUTCH GOVERNMENT RISK CRITERIA*

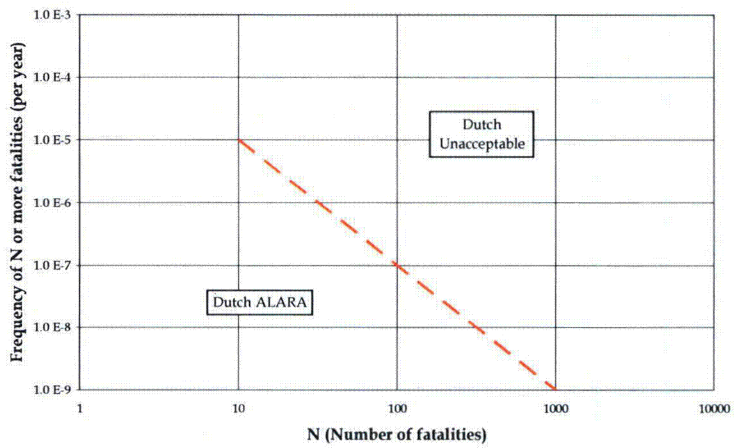
The Dutch government tolerable limit values for individual risk from industrial activities to residential areas[7] are 1.0 in a million (10^{-6}) per year and 10 in a million (10^{-5}) per year respectively for new and existing operations. These criteria are derived by assuming that in order to be tolerable, the risk from a facility to the public must be a small fraction of the total risk of death from all types of accidents in everyday life, which is estimated to be 100 per million (10^{-4}) each year. Thus an additional risk of 1.0 per million (10^{-6}) per year represents an incremental increase of 1% in the total risks to those exposed.

[6] NRC, NUREG 1407, SRP – 0800, and Reg. Guide 1.174

[7] Dutch National Environmental Policy Plan, Premises for Risk Management, Risk Limits in the Context of Environmental Policy, Directorate General for Environmental Protection at the Ministry of Housing, Physical Planning and Environment, Second Chamber of the States General Session 1988-1989, 21137, no 5.

The Dutch societal risk criteria are shown in ***Figure*** **3.2**. The Dutch criteria only use one line and below this the risks must be *"As Low As Reasonably Achievable"* (ALARA). The criteria established in the Dutch government policy only address the risk of events causing 10 or more fatalities.

Figure 3.2 ***Dutch Official Societal Risk Criteria for the Public***



3.3 *UK GOVERNMENT RISK CRITERIA*

The UK Health and Safety Executive (HSE) provides regulatory control of major industrial hazards in the UK, using the following concepts[8]:

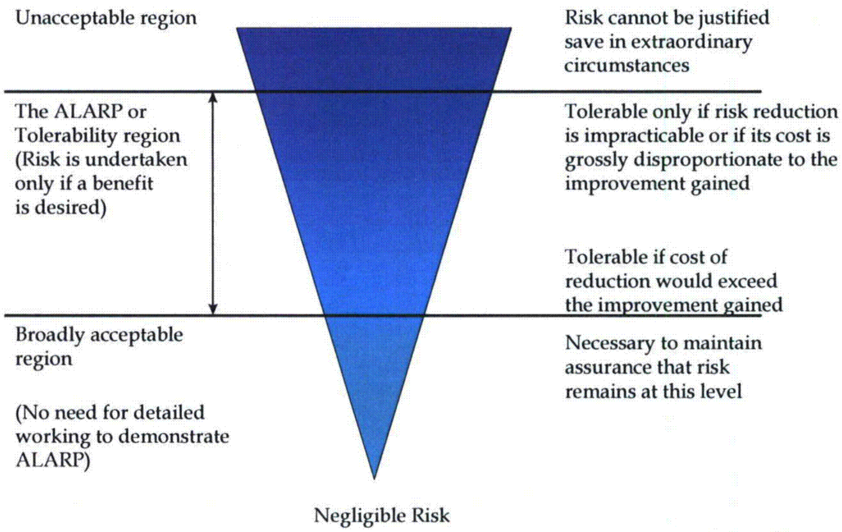
"The main tests that are applied in regulating industrial risks are very similar to those we apply in day to day life. They involve determining:

(a) whether a given risk is so great or the outcome so unacceptable that it must be refused altogether; or
(b) whether the risk is, or has been made, so small that no further precaution is necessary; or
(c) if a risk falls between these two states, that it has to be reduced to the lowest level practicable, bearing in mind the benefits flowing from its acceptance and taking into account the costs of any further reduction..."

These concepts translate into the decision making framework illustrated in ***Figure*** **3.3**. Risk is commonly measured in terms of individual and societal risk, and corresponding individual and societal risk criteria consistent with this framework are discussed below.

[8] UK HSE, Tolerability of Risk from Nuclear Power Stations, 1992

Figure 3.3 ***UK Risk Tolerability Decision Making Framework***



Individual risk in the context of a major industrial facility is the risk that a hypothetical individual continuously present at a given location in the vicinity of the facility will be seriously injured as a result of incidents occurring on that facility. Individual risk is very useful as it shows the geographical extent and scale of risk presented by a facility, regardless of how many people are exposed to that risk, and can be used relatively easily as a basis for comparing different risks.

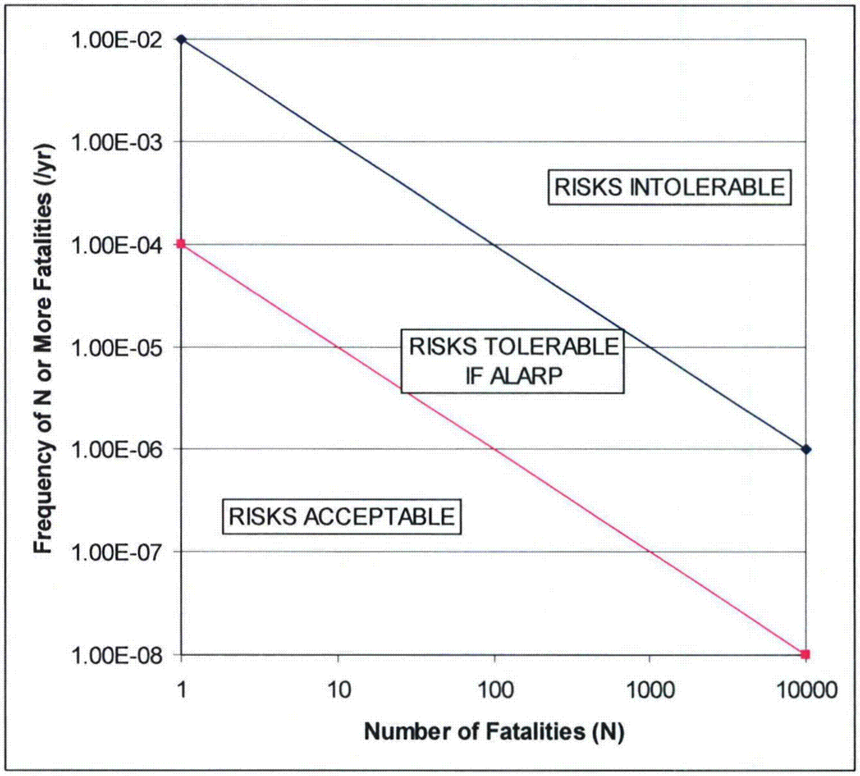
The HSE criteria for individual risk for a person not engaged in the industrial activity (i.e. an offsite member of the public) are as follows:

- Intolerable risk: greater than 1 in 10,000 (10^{-4}) per year.
- Broadly acceptable risk: less than 1 in 1,000,000 (10^{-6}) per year.
- Risk within the range of 1 in 10,000 (10^{-4}) to 1 in 1,000,000 (10^{-6}) per year is tolerable if it is reduced as low as reasonably practicable (ALARP) - i.e. any further reductions in risk would involve costs grossly disproportionate to the benefits.

Societal risk is a measure of the number of people that could be harmed at any one time as a result of a major accident. It reflects the consequences of the many different accidents that may occur and their frequencies, from the relatively high frequency small-scale incidents that may kill or injure one or two people, to the very rare multiple fatality incidents that are historically known to occur across the world but which may never happen at a particular facility given their low likelihood. Societal risk is useful to measure because society often displays particularly low levels of tolerance to multiple fatality incidents, out of proportion to their actual contribution to the total risk. Societal risk is complementary to individual risk, in that it reflects how many people are exposed to the risk and would change if more or less people lived or worked in the vicinity of the facility or if the facility changed, whereas individual risk does not change unless the facility itself changes.

Societal risk criteria can be derived as shown in ***Figure 3.4*** below.

Figure 3.4 *Societal Risk Criteria Lines Derived from UK HSE*



3.4 *AUSTRALIAN RISK CRITERIA*

Similar types of risk criteria have been developed by regulators in Australia. For example the Victorian safety regulator, WorkSafe, applies the following criteria as a guide to judging acceptability of risk from *new* major hazard facilities[9]:

- Individual risk must not exceed 10 in a million (10^{-5}) per year at the boundary of any new facility.
- If risk off-site is between 0.1 and 10 in a million (10^{-7} to 10^{-5}) per year, all practicable risk reduction measures are to be taken, and residential developments are to be restricted.
- Risk levels below 0.1 per million (10^{-7}) per year are broadly tolerable.

[9] State of Victoria, Major Hazard Facilities Regulations Guidance Note 16, MHD GN-16 Rev 0, 2001

The Victorian individual risk criteria are more stringent than the HSE criteria; however they are specifically for new facilities. Higher risk levels would be expected to be tolerable for existing facilities, in which case the Victorian and UK criteria would be broadly in agreement.

The Victorian societal risk criteria are also more stringent than their UK counterparts: they have the same values at N=1 (i.e. a total frequency of incidents causing 1 or more fatalities of 1.0 in 100 (10^{-2}) each year or above is intolerable, and below 1.0 in 10,000 (10^{-4}) each year it is acceptable), but the gradient of the lines is twice as steep to reflect a strong aversion to multiple fatality events. Hence, while in the UK a frequency of accidents involving 10 or more people of below 1.0 per thousand (10^{-3}) each year is "tolerable if ALARP", in Victoria the frequency of accidents involving 10 or more people must be below 1.0 per ten-thousand (10^{-4}) each year to be "tolerable if ALARP." Again this may be because the Victorian criteria are intended to apply to new facilities.

The HSE criteria are developed for a country with fairly limited space, and are similar to those used by the Dutch government, which also has limited space. It may be expected that criteria would be more stringent in a country with lower population densities and greater available space. Australia is probably more representative of the US in this respect.

4 *HAZARD AND RISK STUDY METHODOLOGY*

An overview of the methodology employed in our study is provided below. Details of the models used and consequence modeling input data and assumptions are provided in ***Appendix A*** (***Section*** 1 and ***Section*** 2 respectively). The previous hazard studies provided a substantial amount of useful information (PPRP's review of these studies and comparison to the current study can be found in ***Section*** 6.4). The current study goes into additional detail by addressing the following items:

1. Modeling impacts of the specific changes proposed for the expansion project on hazards and risks from the facility as a whole;
2. Consideration of delayed ignition case;
3. Carrying out risk calculations - existing work is purely consequence based - the main effect of the expansion project will be to increase frequency of incidents; and
4. Evaluation of the potential for escalation between the existing facilities and the new facilities introduced by the expansion project.

A Quantitative Risk Analysis (QRA) was carried out for major hazard scenarios associated with the shipping, terminal and pipeline facilities within the study area, reflecting both the current operations and the future operations. The QRA was carried out using ERM's *ViewRisk™* software, the results of which are presented in ***Section*** 5.3.

Consequence analysis was performed as an integral part of the study, using the BP Cirrus suite of consequence models. Consequences were modeled for the following Pasquill atmospheric stability conditions (A, D, E or F) and representative wind speeds :

- A, 3 m/s;
- D, 2 m/s and 4 m/s;
- E, 2 m/s and 4 m/s; and
- F, 2 m/s.

A summary of the weather data analysis is given in ***Appendix A, Section*** 3.

Impact criteria were derived from previous ERM hazard and risk studies, US requirements specified in NFPA59A and FERC codes, and UK HSE criteria.

4.1 *FIRE IMPACT CRITERIA*

Fires associated with LNG hazard scenarios are of three types: jet fire (in which gas or liquid at high pressure ignites, as may occur with a pipeline rupture); pool fire (in which a pool of flammable liquid ignites, as may occur with a tank spill);

and flash fire (in which combustible gas reaches a threshold level in air and ignites, as may occur with any type of LNG release). For jet fires and pool fires, the estimated thermal flux can be used to indicate level of impact. At a thermal flux of 37.5 kW m^{-2} (10,000 Btu/hr-ft^2), a high thermal dose is achieved rapidly, offering little chance of escape for an exposed individual, resulting in a high probability of fatality. At a thermal flux of 9.5 kW m^{-2} (3,000 Btu/hr-ft^2), the 1% fatality level is achieved in approximately 30 seconds, offering some chance of escape. However, a 50% fatality level will be reached in approximately 1 minute. For a thermal flux of 5 kW m^{-2} (1,600 Btu/hr-ft^2), an exposure of almost 1.5 minutes is required to achieve 1% fatality probability and 2.5 minutes to achieve 50% fatality probability, resulting in a low likelihood of fatality.

For flash fires, impact can be determined based on the extent and concentration of flammable vapors, expressed as the lower flammable limit (LFL). People outdoors within the flash fire envelope (LFL contour) are considered to be killed. Within the ½ LFL contour exposure to burning pockets of vapor is possible. A fatality probability of 0.05 is assigned to account for this. Impact criteria used in this study are summarized in ***Table 4.1***.

Table 4.1 *Impact Criteria from Thermal Radiation (Pool or Jet Fires)*

Impact	**Fatality Probability**
Jet or Pool Fire	
Flux > 37.5 kW m^{-2}	1.0
37.5 kW m^{-2} < Flux > 9.5 kW m^{-2}	0.5
9.5 kW m^{-2} < Flux > 5 kW m^{-2}	0.05
Flash Fire	
Within LFL contour	1.0
Within ½ LFL contour	0.05

4.2 *BLAST OVERPRESSURE IMPACT CRITERIA*

If a natural gas cloud is ignited within a confined or congested space damaging explosion overpressures may result. The open nature of the Cove Point Terminal site means that LNG releases from the main berth, or LNG storage tanks are unlikely to generate any significant overpressures if ignited. However, dispersion of a vapor cloud into the terminal process areas, or surrounding woodlands may provide sufficient confinement/congestion to achieve a deflagration with associated overpressures. Lees[10] provides a considerable amount of data on blast injury. Some of this information is summarized in ***Table 4.2***.

[10] Loss Prevention in the Process Industries, Second Edition 2001, Frank P. Lees et al

Table 4.2 ***Direct Effects of Blast on People***

Blast Overpressure (kPa)	Effect
100 - 140	50% eardrum rupture among adults
80 - 100	Threshold for lung damage, long duration blast wave
275	Threshold lethality, long duration blast wave
430	50% lethality, long duration blast wave

Data concerning blast effects on structures are presented in *Table 4.3* (taken from Lees).

Table 4.3 ***Direct Effects of Blast on Structures***

Blast Overpressure (kPa)	Effect
0.2	Occasional breakage of large glass windows already under strain
0.7	Breakage of windows, small, under strain
1.0	Typical pressure for glass failure
4.8	Minor structural damage to house structures
6.9	Partial demolition of houses, made uninhabitable
17.3	50% destruction of brickwork of house
20.7 - 27.6	Steel frame building distorted and pulled away from foundations. Frameless, self-framing steel panel building demolished
34.5 - 48.3	Nearly complete destruction of houses

From these data it can be seen that the overpressure levels required to cause harm to people directly (i.e. the actual blast wave causing harm rather than flying debris or collapsing structures) are significantly greater than the levels required to damage structures (e.g., an overpressure of around 50kPa would be sufficient to destroy a house but would be below the threshold for lung damage). This means that the fatality probabilities for people outdoors and away from structures tend to be less than those for people within buildings, where secondary blast effects (the structure collapsing on to the occupants) may cause injury or fatality.

For the purposes of estimating risk from blasts it is necessary to develop some overpressure harm criteria that account for direct blast injuries and injuries from flying debris or collapsing structures (i.e. some compromise between the data presented in *Table 4.2* and *Table 4.3*). The fatality probabilities used in this study take consideration of the data shown above and are presented in *Table 4.4*.

Table 4.4 ***Impact Criteria from Blast Overpressure***

Impact	Fatality Probability
Overpressure ≥ 100kPa	1.0
100kPa > Overpressure ≥ 30kPa	0.6
30kPa > Overpressure ≥ 20kPa	0.15

4.3 *FREQUENCY ANALYSIS*

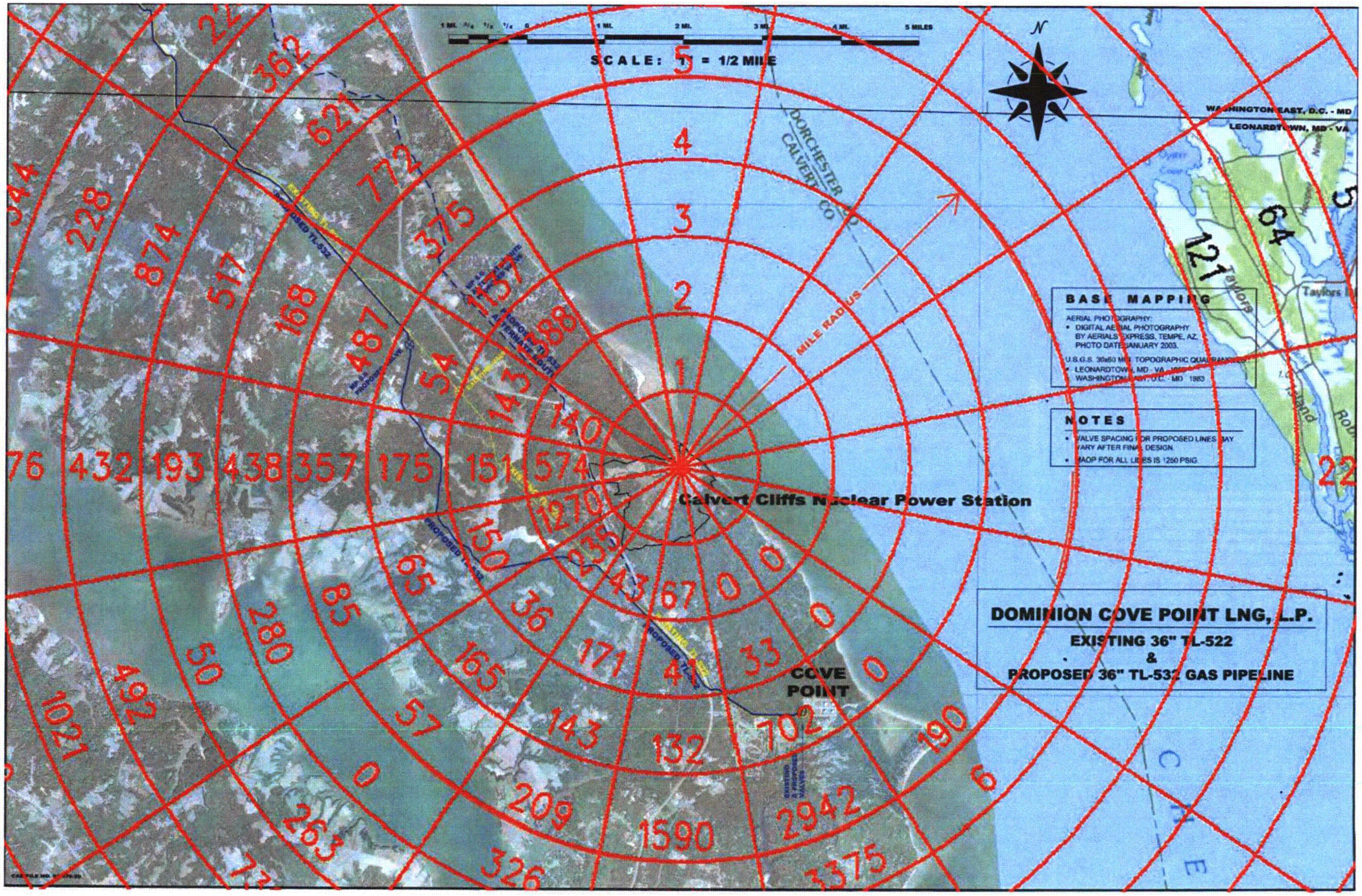
Frequency analysis was performed using predominantly the UK HSE Planning Consequence Assessment Guidelines (PCAG)[11] failure data – a data source of international credibility, and largely applicable throughout the global process industry. Other data sources were used for certain components of the process (for example, the gas export pipeline failure data was derived from gas transmission pipeline incident data for the State of Maryland[12]) and for comparison with others.

A summary of the frequency analysis is provided in ***Appendix A, Section 4,*** including main assumptions and data sources.

Population data used to estimate societal risk is shown in ***Figure 4.1*** below. This data was taken from the CCNPP Safety Report[13]. The figure divides the study area into sectors along a polar coordinate grid with spacing in 1-mile increments outward from CCNPP. For those sectors that are not entirely over water, the number printed within that sector on the figure indicates the residential population there.

[11] UK HSE, Planning Consequence Assessment Guidelines (PCAG).
[12] Office of Pipeline Safety (OPS), (http://primis.phmsa.dot.gov/comm/StagePages/htmGen/MD_detail1.html)
[13] CCNPP Emergency Planning Zones Evacuation Time Estimates Rev 6

Figure 4.1 Population Distribution around Calvert Cliffs Nuclear Power Station and Cove Point Terminal



Source: Base Map Provided by Dominion Cove Point LNG, L.P.
Notes: Grids denote population sectors in 1-mile radii outward from CCNPP. Numbers within grids represent population densities (except for radius distances which appear in the grids due north of CCNPP).

4.4 *ESCALATION STUDY*

As well as impacting people and the environment, released process fluids can result in damage to assets; either directly, from the initial event, or by a small event escalating into a much larger incident with more severe consequences.

The escalation of an event is dependent on several factors including initial event size, intensity, and duration. For example, a leaking flange may cause a small release of pressurized cryogenic, flammable material over a long period. This scenario, if ignited, may result in a jet fire lasting more than half an hour. Alternatively, a much larger release may result in a jet or pool fire, but may consume the fuel within a couple of minutes.

Failure frequencies used in the risk assessment inherently include a proportion of releases caused by escalation (e.g. caused by external fire). Two of the 'worst-case' scenarios we have modeled — (1) total loss of an LNG tanker, and (2) total loss of all storage tanks — can be considered the ultimate consequences of complete escalation; that is, it is very unlikely that any other consequence could be more devastating to an asset or surrounding populations than these.

Because escalation is dependent on the size of an event, one of the simplest methods of mitigation is increased equipment separation; if an event cannot impact other processing equipment, it will not escalate.

The current terminal layout can be split into eight distinct escalation zones: the jetty facility and transfer line, tank A, tank B, tank C, tank D, tank E, processing, and gas export pipeline. There are nine escalation routes — that is, nine points at which two escalation zones lie adjacent. Approximate separation distances between adjacent zones are given in ***Table 4.5***. The mean separation distance between adjacent zones for the current operations is approximately 90 m.

Table 4.5 ***Current Operation Terminal Area Separation between adjacent Escalation Zones***

Zone Separation (m)	Jetty & Transfer	Tank A	Tank B	Tank C	Tank D	Tank E	Process	Gas Export
Jetty & Transfer	-	-	97	-	125	-	-	-
Tank A	-	-	97	70	-	83	-	-
Tank B	97	97	-	-	97	-	-	-
Tank C	-	97	-	-	97	-	-	-
Tank D	125	-	97	97	-	-	-	-
Tank E	-	83	-	-	-	-	70	-
Process	-	-	-	-	-	70	-	83
Gas Export	-	-	-	-	-	-	83	-

Note: Blanks in the table indicate that those two escalation zones are not adjacent.

The expanded operations essentially add three additional zones to those presented above; tank F, tank G, and a new processing area. ***Table 4.6*** shows the separation distances between adjacent escalation zones for the expanded facility. The number of escalation routes has increased from 9 to 14. The mean separation distance for the expanded facilities is 75 m, a decrease of approximately 20%.

Table 4.6 ***Expanded Operation Terminal Area Separation between adjacent Escalation Zones***

Zone Separation (m)	Jetty & Transfer	Tank							P_{OLD}	P_{NEW}	Gas Export
		A	B	C	D	E	F	G			
Jetty & Transfer	-	-	97	-	125	-	-	-	-	-	-
Tank A	-	-	97	70	-	83	-	-	-	-	-
Tank B	97	97	-	-	97	-	-	-	-	-	-
Tank C	-	97	-	-	97	-	97	-	-	70	-
Tank D	125	-	97	97	-	-	-	97	-	-	-
Tank E	-	83	-	-	-	-	-	-	70	70	-
Tank F	-	-	-	97	-	-	-	42	-	-	-
Tank G	-	-	-	-	97	-	42	-	-	-	-
P_{OLD}	-	-	-	-	-	70			-	-	83
P_{NEW}	-	-	-	70	-	70	-	-	-	-	-
Gas Export	-	-	-	-	-	-	-	-	83	-	-

Inevitably, with more processing equipment in the expanded case there is an inherently greater risk of escalation than with the current facility. Moreover, given that the average separation between escalation sources and targets has reduced, the increase in escalation risk is greater than the actual increase in equipment. That is, a lesser event (with a higher frequency) may be able to cause escalation in the expanded facility, where it would not have done so in the current operations.

5 HAZARD AND RISK RESULTS

5.1 IDENTIFIED HAZARD SCENARIOS

The definition of a hazard scenario is as follows:

A sudden and uncontrolled incident, including an emission, loss of containment, escape, fire, explosion or release of energy, that poses a serious and immediate risk to health and safety of people or a serious and immediate risk of damage to property.

Potential hazard scenarios were identified using a 'desk-top' Hazard Identification & Analysis (HAZID) review in which each part of the operation from shipping to pipelines was analyzed for potential failure scenarios. This took into account the findings of the background review, including historical incidents and technical discussions regarding potential failure scenarios for LNG shipping and terminals.

The identified hazard scenarios and their estimated frequencies are shown in ***Table 5.1*** below. Event frequencies are estimated using generic historical failure data and are derived from a variety of sources including the UK Health and Safety Executive Commission's (HSE) *Planning Consequence Assessment Guidelines* (PCAG); US Department of Transportation, Office of Pipeline Safety data; and other failure data (data sources are identified in ***Appendix A, Table A 4-1,*** and complete references are provided in ***Appendix B***).

Specific causes of, and controls for, the major hazard scenarios are not explicitly considered within this study. However, the generic background frequencies are based on data compiled over the past 30 to 40 years that encompass an entire range of initiating events from unintentional but routine equipment failure (caused by external impact, corrosion, human error, etc.) to intentional sabotage and acts of war or terrorism. Although the current contribution from intentional causes (e.g., acts of terrorism) is likely to be higher than the historical average (and may increase or decrease in the future as a result of global conflicts and offsetting anti-terrorist measures), these intentional causes remain a very small component of the total incident frequency.

Table 5.1 Hazard Scenarios

Code	Scenario	Frequency (per year)	
		Existing	Expanded
SH-ER-S	Small hole in ship's tank en route	2.19×10^{-3}	4.88×10^{-3}
SH-ER-M	Medium hole in ship's tank en route	2.19×10^{-4}	4.88×10^{-4}
SH-ER-L	Large hole in ship's tank en route	2.19×10^{-5}	4.88×10^{-5}
SH-ER-T	Total loss of ship's tank en route	2.44×10^{-6}	5.42×10^{-6}

		Frequency (per year)	
SH-ER-SP	Small hole in ship's tank en route (off CCNPP)	1.96×10^{-4}	4.36×10^{-4}
SH-ER-MP	Medium hole in ship's tank en route (off CCNPP)	1.96×10^{-5}	4.36×10^{-5}
SH-ER-LP	Large hole in ship's tank en route (off CCNPP)	1.96×10^{-6}	4.36×10^{-6}
SH-ER-TP	Total loss of ship's tank en route (off CCNPP)	2.18×10^{-7}	4.84×10^{-7}
SH-AB-S	Small hole in ship's tank at berth or loading arm rupture	1.45×10^{-3}	3.28×10^{-3}
SH-AB-M	Medium hole in ship's tank at berth	1.36×10^{-3}	3.03×10^{-3}
SH-AB-L	Large hole in ship's tank at berth	9.66×10^{-7}	2.76×10^{-6}
SH-AB-T	Total loss of ship's tank at berth	1.07×10^{-7}	3.07×10^{-7}
TL-R	Rupture of transfer line	4.17×10^{-4}	8.30×10^{-4}
ST-S	Small hole in storage tank	4.00×10^{-4}	5.60×10^{-4}
ST-M	Medium hole in storage tank	5.00×10^{-4}	7.00×10^{-4}
ST-L	Large hole in storage tank	3.00×10^{-4}	4.20×10^{-4}
ST-T	Total loss of storage tank	2.00×10^{-4}	2.80×10^{-4}
ST-F	Loss of all storage tanks	4.00×10^{-6}	4.00×10^{-6}
PR-T	Process loss of containment	1.42×10^{-4}	2.81×10^{-4}
PL-R	Rupture of pipeline (total)	3.60×10^{-3} (1)	7.48×10^{-3} (2)

(1) Based on 21.2 km of existing gas export pipeline (visible length on map).
(2) Based on 21.2 km of existing and 22.8 km of new gas export pipeline (visible length on map).

5.2 *CONSEQUENCE ZONES*

A summary of the consequences of each identified scenario is provided in ***Table 5.2*** below. This shows the type of consequences and maximum downwind consequence range, measured as the distance to the LFL for a flash fire (FF) and the 37.5 kW/m^2 thermal radiation level for a pool fire (PF) or jet fire (JF) for each scenario. The consequence ranges are quoted for the existing case and are only quoted for the expanded case for those scenarios where the maximum consequence range has increased in the future; otherwise the existing scenario range remains the maximum range. As can be seen from this table, there are few cases where there is an increase in consequence range.

Consequence zones for the key hazard scenarios (identified as main contributors to current and expanded operations societal risk in ***Table 5.5*** and ***Table 5.6*** respectively) are shown in ***Figure 5.1*** to ***Figure 5.7***. These plots show hazard ranges to fatality levels described in ***Table 4.1*** and ***Table 4.4***. Note that the weather conditions vary per case.

Table 5.2 Consequences of Hazard Scenarios

Code	Scenario	Max. Range (m) to 37.5 kW m-2 (PF/JF), LFL (FF)	
		Existing	Expanded (if different)
SH-ER-S	Small hole in ship's tank en route	PF 68, FF 570	--
SH-ER-M	Medium hole in ship's tank en route	PF 154, FF 700	--
SH-ER-L	Large hole in ship's tank en route	PF 311, FF 600	--
SH-ER-T	Total loss of ship's tank en route	PF 475, FF 4250	--
SH-ER-SP	Small hole in ship's tank en route (off CCNPP)	PF 68, FF 570	--
SH-ER-MP	Medium hole in ship's tank enroute (off CCNPP)	PF 154, FF 700	--

Code	Scenario	Max. Range (m) to 37.5 kW m^{-2} (PF/JF), LFL (FF)	
		Existing	Expanded (if different)
SH-ER-L_P	Large hole in ship's tank en route (off CCNPP)	PF 311, FF 600	--
SH-ER-T_P	Total loss of ship's tank en route (off CCNPP)	PF 475, FF 4250	--
SH-AB-S	Small hole in ship's tank at berth or loading arm rupture	PF 68, FF 570	--
SH-AB-M	Medium hole in ship's tank at berth	PF 154, FF 700	--
SH-AB-L	Large hole in ship's tank at berth	PF 311, FF 600	--
SH-AB-T	Total loss of ship's tank at berth	PF 475, FF 4250	--
TL-R	Rupture of transfer line	PF 140, FF 725	--
ST-S	Small hole in storage tank	PF 180, FF 655	FF 770
ST-M	Medium hole in storage tank	PF 180, FF 810	FF 930
ST-L	Large hole in storage tank	PF 180, FF 670	FF 910
ST-T	Total loss of storage tank	PF 180, FF 1,300	--
ST-F	Loss of all storage tanks	PF 362, FF 1,650	FF 1,900
PR-T	Process loss of containment	PF 179, FF 290	--
PL-R	Rupture of pipeline (total)	JF 720, FF 220	--

Table 5.3 shows the hazard scenarios (and respective downwind impact zone distances) that impact on key receptors around the terminal. Note that the distances are quoted for 'hazard footprints' and not as terminal/receptor separations.

Table 5.3 *Hazard Scenarios and Ranges that Impact Key Receptors*

Receptor	Scenario	Distance to Impact Criterion		
		LFL or 37.5 kW m^{-2}	½ LFL or 9.5 kW m^{-2}	- 5 kW m^{-2}
CCNPP	SH-ER-T (Flash Fire)	6,000*	11,250*	-
Golf Course	PL-R (Jet Fire)	720	900	1050
Cove Point Light House	SH-AB-T (Flash Fire)	6,000*	11,250*	-
Nearest residential area – south of terminal opposite Cove Point Road	PL-R (Jet Fire)	720	900	1050

* Pasquill Stability Class E, 4 m/s

Figure 5.1 Hazard Scenario PL-R, Gas Export Line Jet Fire

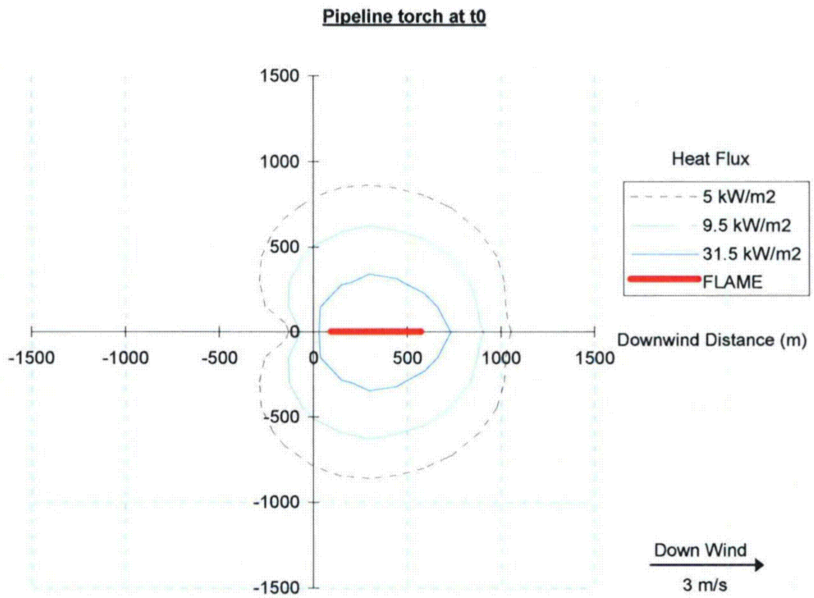


Figure 5.2 Hazard Scenario PL-R, Gas Export Line Flash Fire

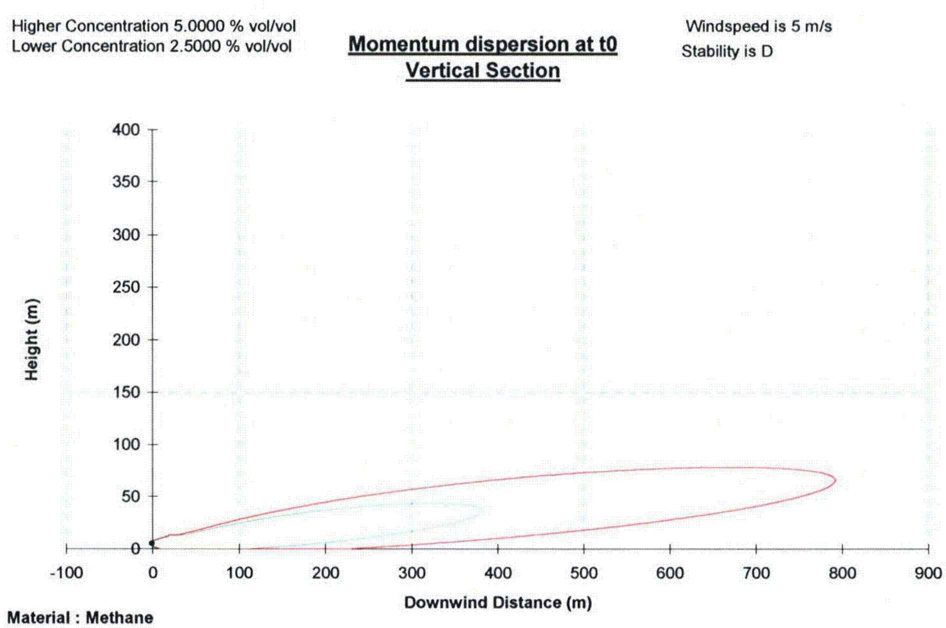
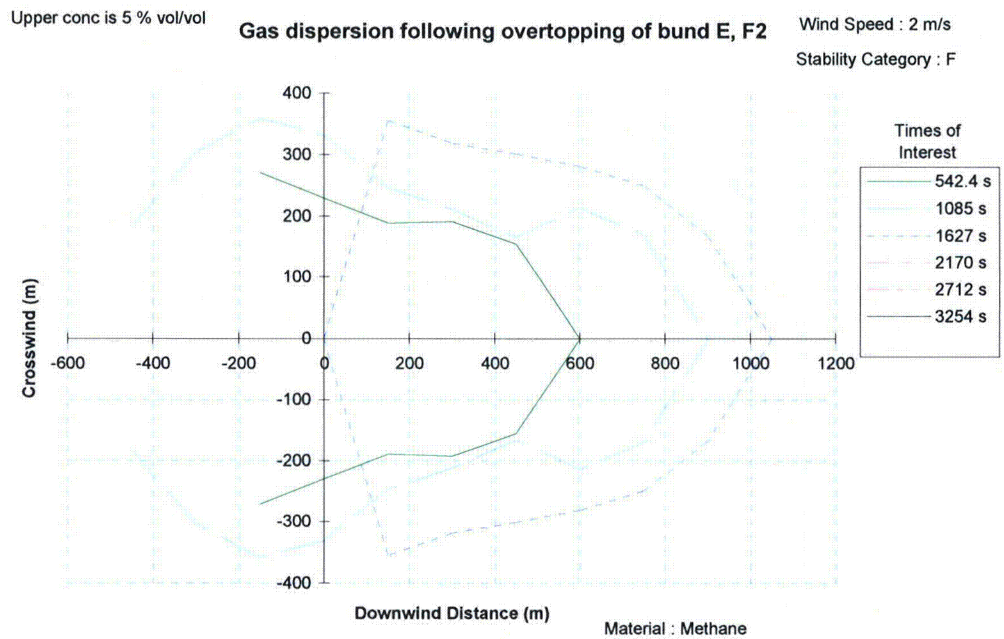


Figure 5.3 *Hazard Scenario ST-T_E, Total Loss of Storage Tank E (overtopping), LFL & ½ LFL*



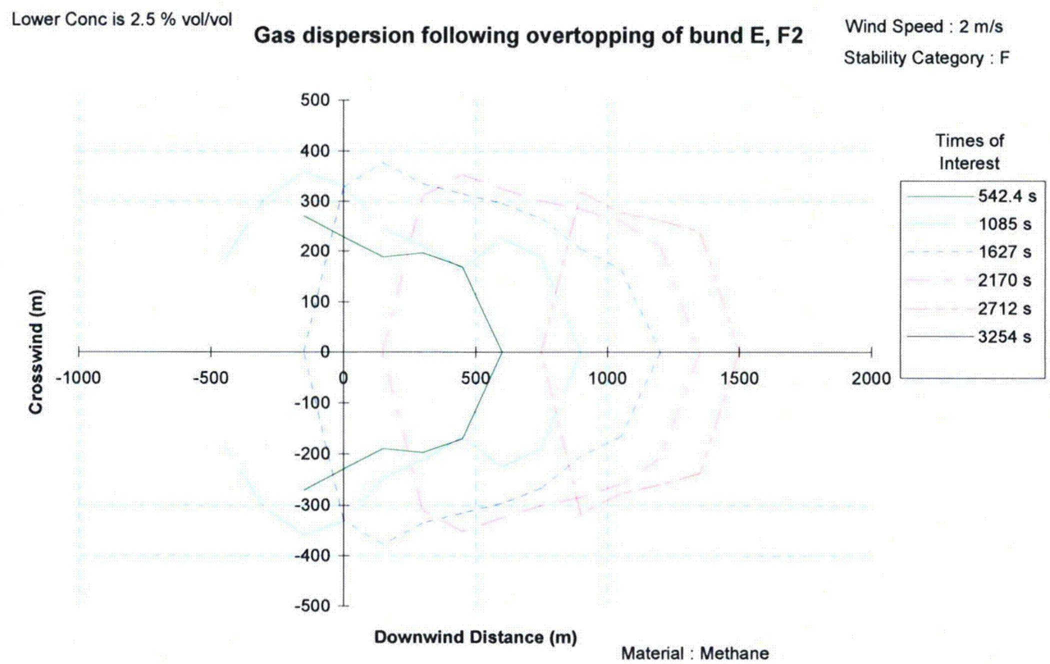


Figure 5.4 *Hazard Scenario ST-F, Failure of all Storage Tanks (Current Operations), LFL & ½ LFL*

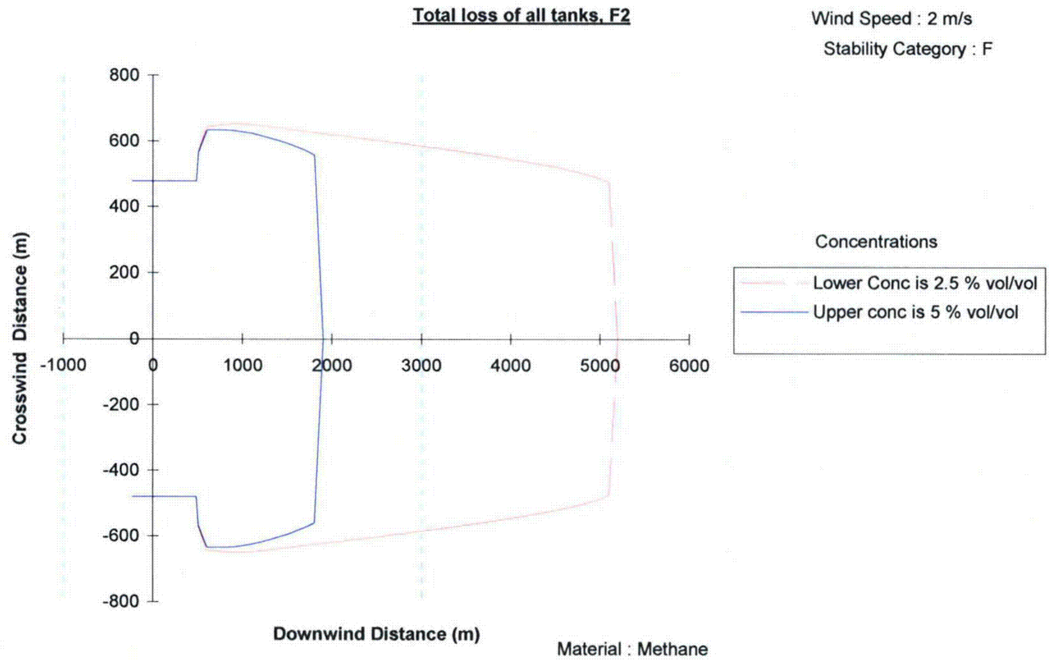
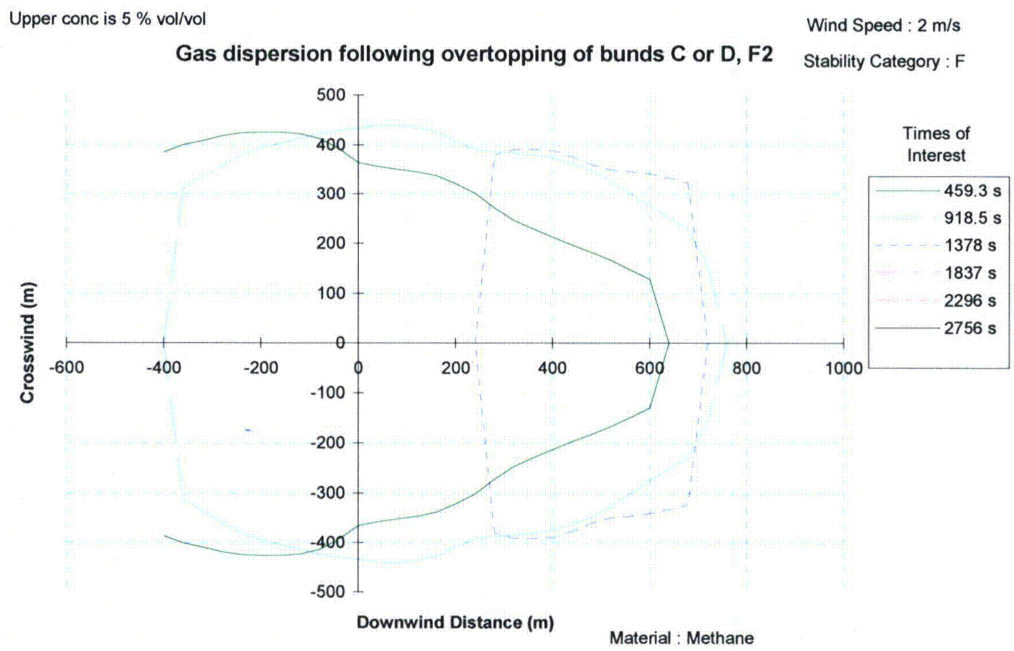


Figure 5.5 ***Hazard Scenario ST-T$_{CD}$, Total Loss of Storage Tank C or D (overtopping), LFL & ½ LFL***



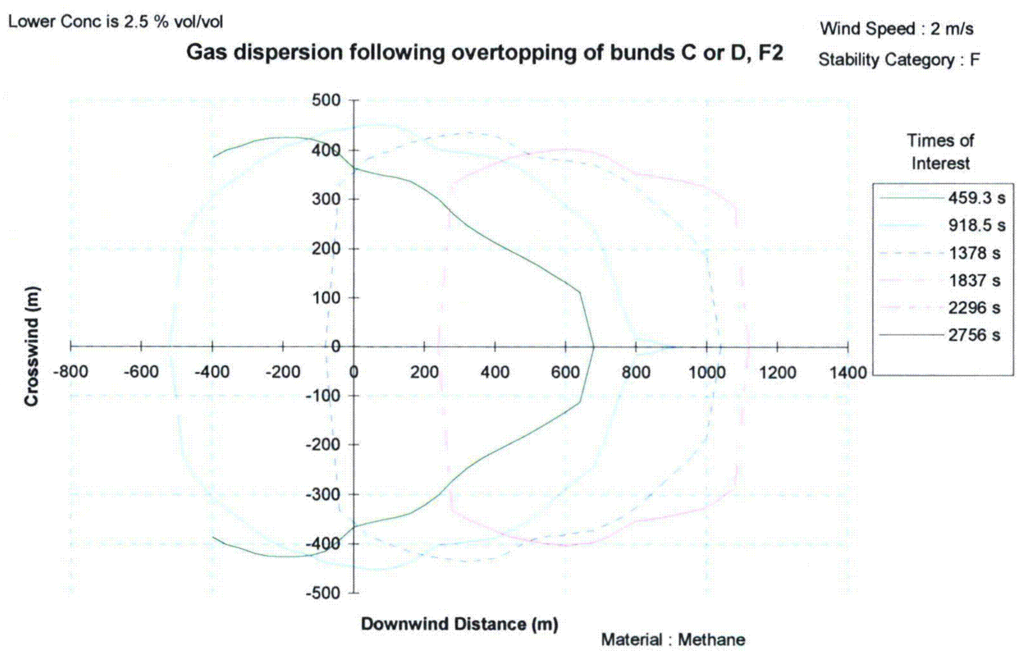
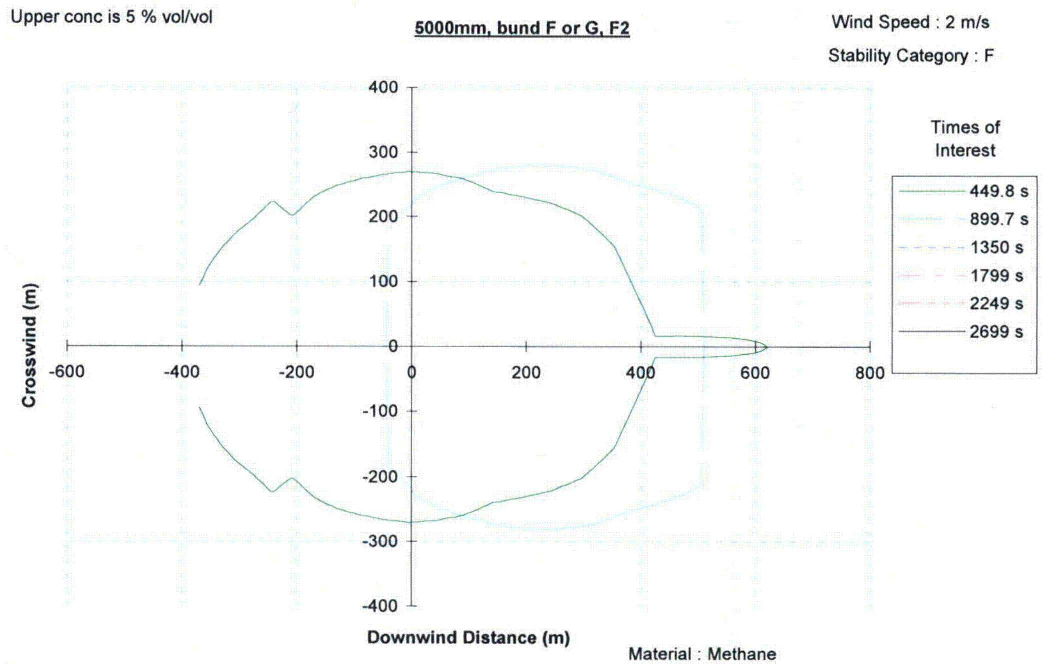


Figure 5.6 *Hazard Scenario ST-T_FG, Total Loss of Storage Tank F or G (overtopping), LFL & ½ LFL*



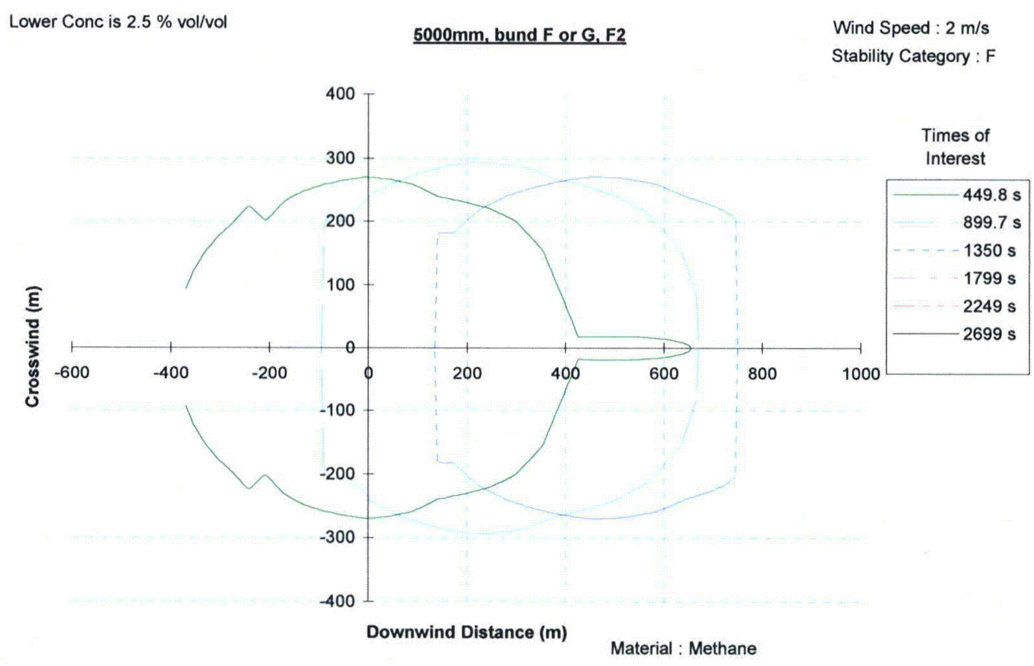
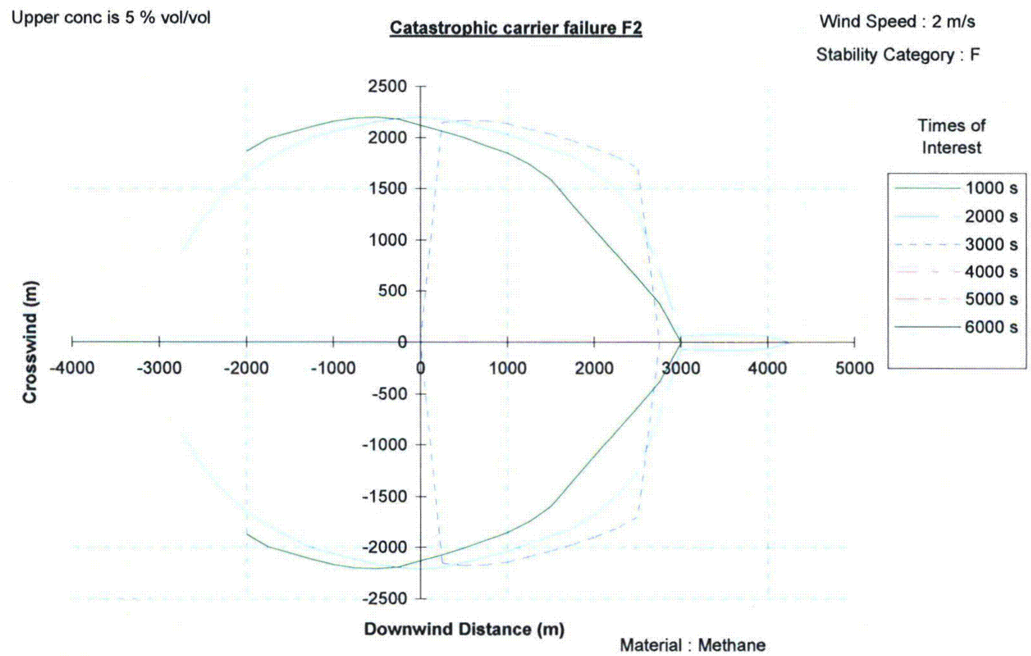
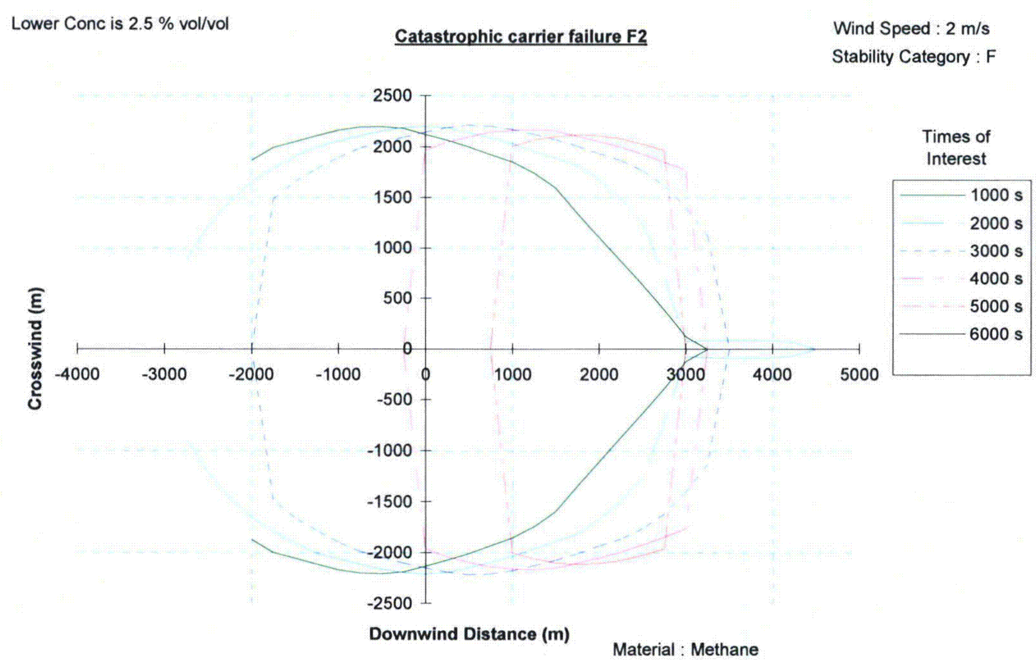


Figure 5.7 Hazard Scenario SH-ER-T, Total Loss LNG Tanker, LFL & ½ LFL





5.3 *RISK RESULTS*

The event frequency and hazard consequence data has been combined to produce estimates of risk using ViewRisk, ERM's risk calculation and contour plotting program.

Risk levels are calculated by considering each modeled scenario, and combining its frequency with the extent of its 'harm footprints'. For example, a pool fire may have a frequency of 1 per 10,000 (10^{-4}) per year, and thermal flux hazard ranges of 20, 40, and 55 meters to 37.5, 9.5 and 5 kW m^{-2} respectively (this corresponds to harm probabilities of 1, 0.5, and 0.05). In this example all points within 20 m radius of the pool source would have a risk of 1 per 10,000 (1×10^{-4}; i.e. $1 \times 10^{-4} \times 1$) each year, points between 20 and 40 m radius would have a risk of 5 per 100,000 (5×10^{-5}; $1 \times 10^{-4} \times 0.5$) each year, and points between 40 and 55 m would have a risk of 5 per one-million (5×10^{-6}; $1 \times 10^{-4} \times 0.05$) each year. ViewRisk considers all scenarios and sums their risk contributions across all points, and is then used to plot iso-risk contours (i.e. lines of constant risk).

Location specific individual risks (LSIR) to people are shown in *Figure 5.8* and *Figure 5.9* for the current and post-expansion operations respectively. These risk contours represent the total risk from the facility and associated operations, i.e. all identified hazard scenarios for marine operations, terminal, and the section of export pipeline included in the model. LSIR conservatively assumes that someone is present at a given location, outdoors all of the time, and takes no account of the individual occupancy of the area or the chance that people could escape or seek shelter indoors. In practice the actual risks to persons in these areas would be much lower, since people would only be present outdoors for a fraction of the time. The LSIR levels at the key receptor locations are shown in *Table 5.4.*

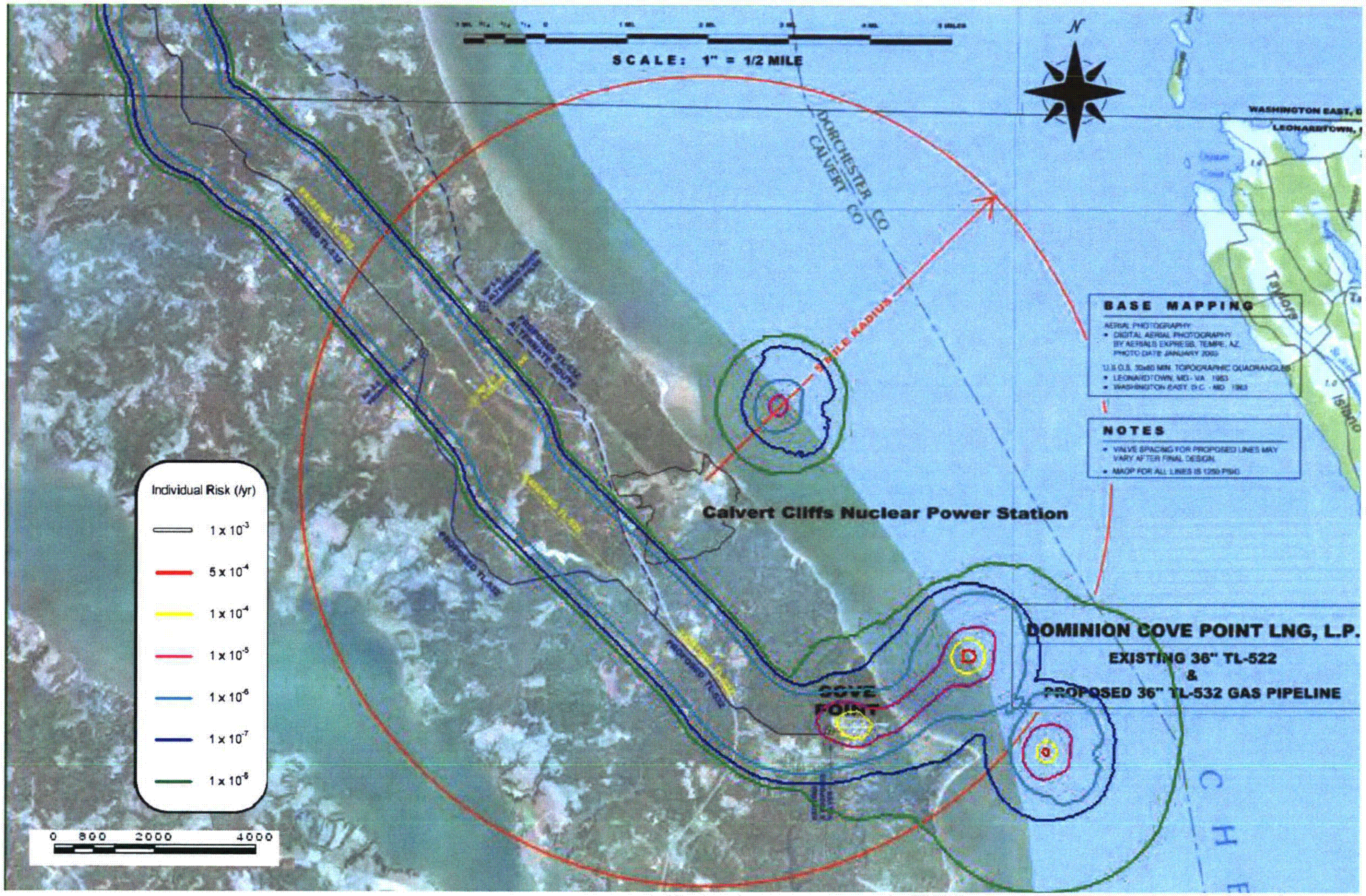
Table 5.4 ***Individual Risk Levels At Key Receptors***

Receptor	Individual Risk Level (Fatality Risk per Year)		Factorial
	Existing	Expanded	Increase
CCNPP	2.3×10^{-9}	6.6×10^{-9}	2.8
Golf Course	3.0×10^{-6}	5.6×10^{-6}	1.9
Cove Point Light House	6.8×10^{-8}	1.9×10^{-7}	2.8
Nearest residential area – south of terminal opposite Cove Point Road	1.0×10^{-6}	2.4×10^{-6}	2.3

Societal risk FN curves for the current and expanded operations are shown in *Figure 5.10* and *Figure 5.11* below. An FN curve shows the frequency with which it is estimated that N or more fatalities will occur as a result of the facilities considered.

Potential Loss of Life (PLL) is a single value measure of societal risk: it is the number of fatalities in each accident multiplied by the accident frequency, summed for all modeled accidents (essentially, the area under the FN curves in ***Figure 5.10*** and ***Figure** 5.11*). It is therefore the number of expected fatalities per year, averaged over all modeled accidents. The total offsite PLL for the current facility is about 0.0149 (or 1.49×10^{-2}) fatalities each year (including gas export pipeline). The total offsite PLL increases post expansion to about 0.0251 (or 2.51×10^{-2}) fatalities each year (including existing and proposed gas export pipelines). This is an increase of approximately 68% over the current facility.

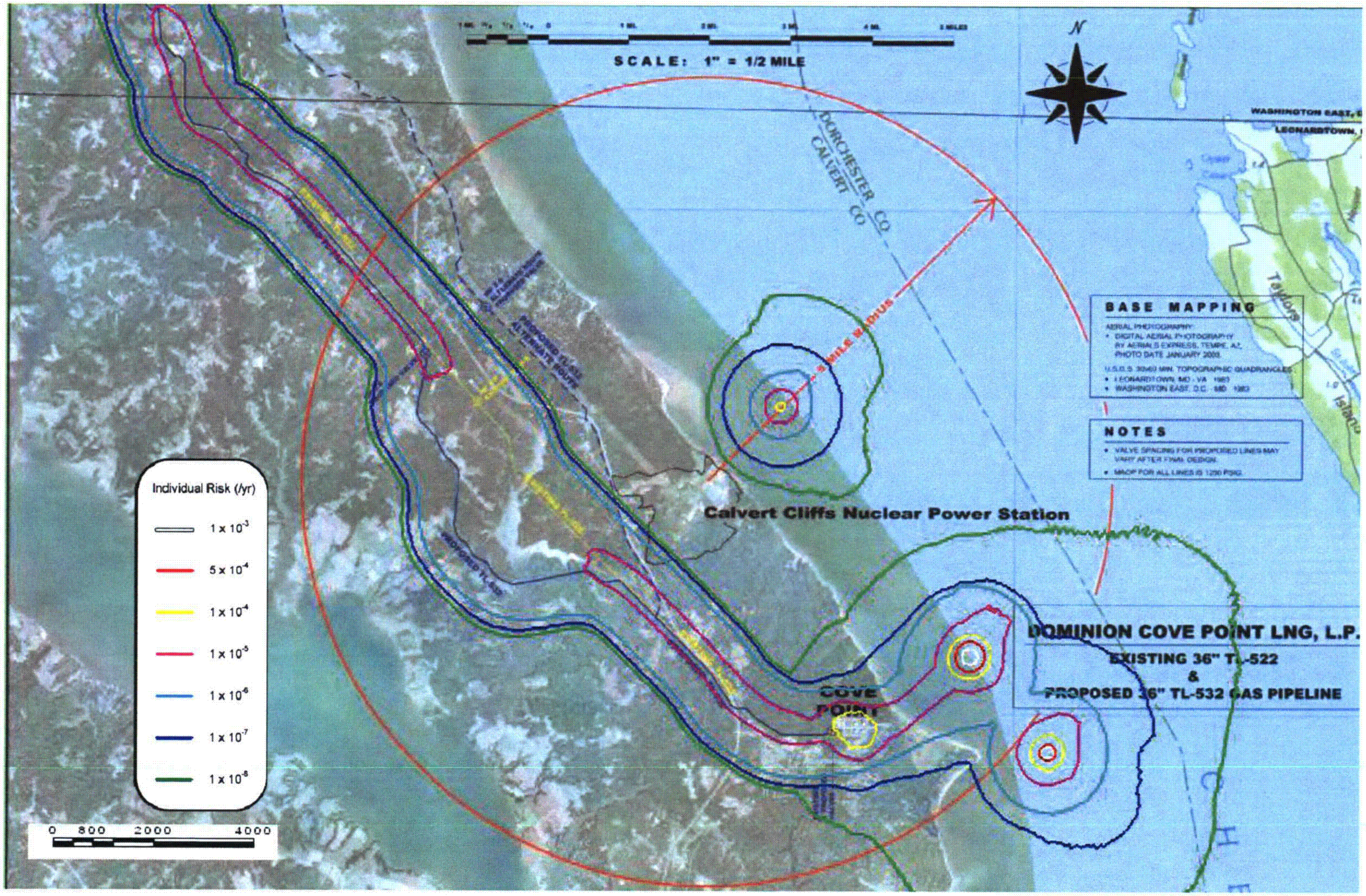
Figure 5.8 Location Specific Individual Risk from Existing Operations



Source: Base Map Provided by Dominion Cove Point LNG, L.P.

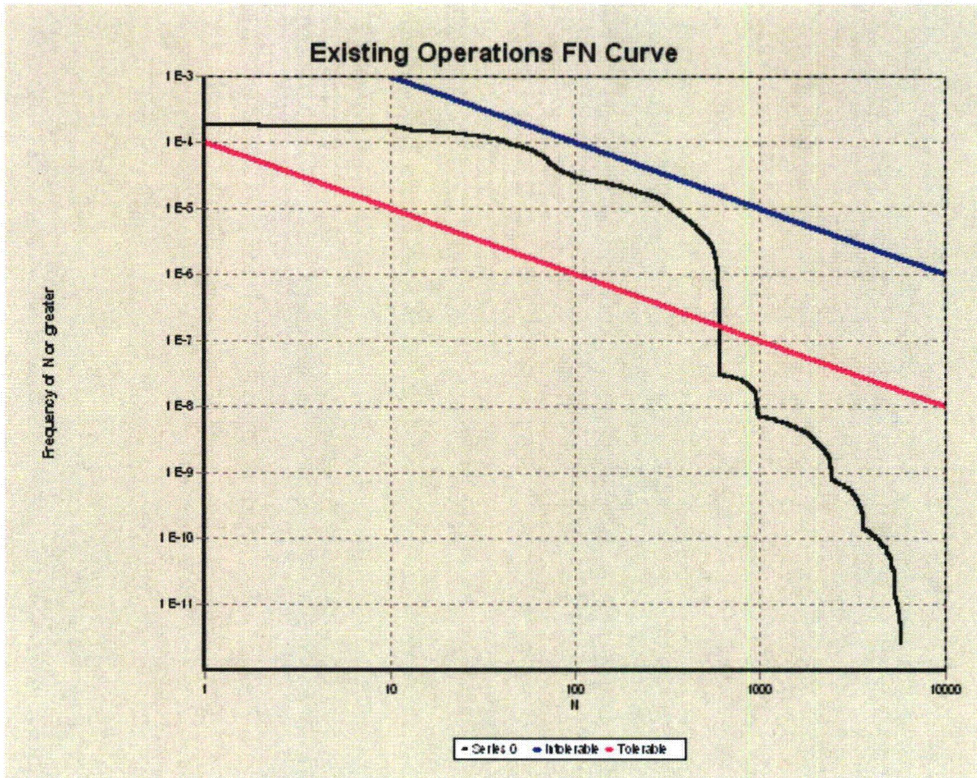
Note: Due to the scale of the map, the 1 x 10^{-3} risk contour is located exactly at the specified risk locations.

Figure 5.9 Location Specific Individual Risk from Expanded Operations



Source: Base Map Provided by Dominion Cove Point LNG, L.P.

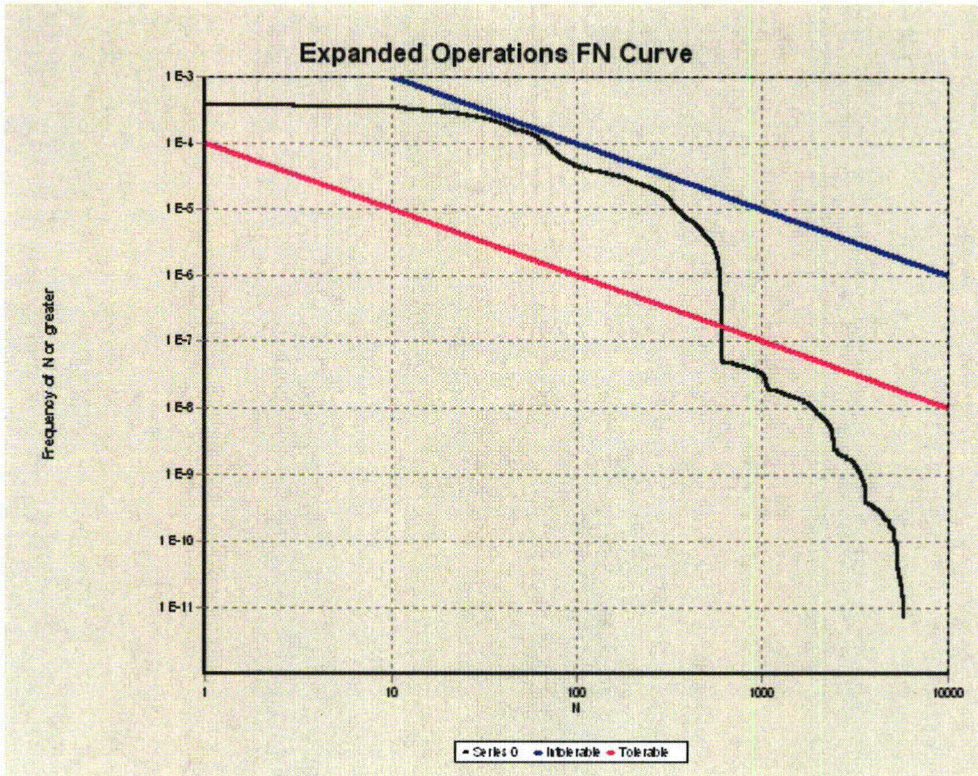
Figure 5.10 Societal Risk for Existing Operations showing UK HSE Risk Criteria



Note: No exclusion zones have been applied between the gas export pipeline and populations

The parallel lines in the above figure correspond to the UK Health and Safety Executive (HSE) criteria for tolerability and acceptability of risk. The curved line indicates, for existing Cove Point operations, the frequency with which it is estimated that N or more fatalities will occur (where N is shown along the x-axis). For instance, the graph shows that there is about a 0.02% chance (or 2×10^{-4}, or 2 in ten thousand) of an event occurring that results in 10 or more fatalities. Under the UK HSE criteria, as long as measures have been taken to reduce risk to as low as reasonably practicable, this is a tolerable risk level. for higher-fatality events, the expected frequency of occurrence drops off significantly, falling into the acceptable risk range.

Figure 5.11 *Societal Risk for Expanded Operations showing UK HSE Risk Criteria*



Note: No exclusion zones have been applied between gas export pipelines and populations

The hazard scenarios that dominate the risk profile and the contribution they make to overall risk levels are shown in ***Table 5.5*** and ***Table 5.6***.

Table 5.5 *Main Contributors to Current Operations Risk Profile*

Hazard Scenario		Contribution to PLL (%)
PL-R	Gas export line rupture (jet fire)	98.7
PL-R	Gas export line rupture (flash fire)	0.35
ST-T_E	Total loss of storage tank E	0.18
ST-F	Failure of all storage tanks	0.17
ST-T_C	Total loss of storage tank C (flash fire)	0.17
ST-T_D	Total loss of storage tank D (flash fire)	0.11

Table 5.6 *Main Contributors to Expanded Operations Risk Profile*

Hazard Scenario		Contribution to PLL (%)
PL-R	Existing gas export line rupture (jet fire)	58.6
PL-R	New gas export line rupture (jet fire)	39.8
ST-T_F	Total loss of storage tank F	0.25
PL-R	Existing gas export line rupture (flash fire)	0.20
ST-T_G	Total loss of storage tank G	0.19
SH-ER-T	Catastrophic loss of tanker (flash fire)	0.17

The population data supplied (***Figure** 4.1*) gives absolute values for sectors around Calvert Cliffs Nuclear Power Station. The existing and proposed gas export pipelines run directly through a number of these population sectors (totaling more than 6,000 people). Given that sector populations have been evenly spread across each sector, the results of the societal risk calculation will be skewed by more people being impacted than would be the case in reality. This will therefore result in a conservative assessment. In order to show the lower bound FN curves, ***Figure 5.12*** and ***Figure 5.13*** show the FN plots for existing and expanded operations without considering the gas export pipelines.

Without considering the gas export pipelines, the PLL of the existing operations is found to be less than 1 ½ per ten-thousand (1.4×10^{-4}) per year, increasing to between 3 and 3 ½ per ten-thousand (3.3×10^{-4}) per year for expanded operations. This equates to a factored increase of ~2.3. Comparison of the FN curves including and excluding the pipelines shows that the principal contributor to the PLL are the export gas pipelines.

The results which include the gas export pipelines should be considered as worst case upper limits of societal risk until more detailed population data along the pipeline routes can be used as an input to the societal risk calculations.

Figure 5.12 ***Societal Risk for Existing Operations showing UK HSE Risk Criteria (without gas export pipeline)***

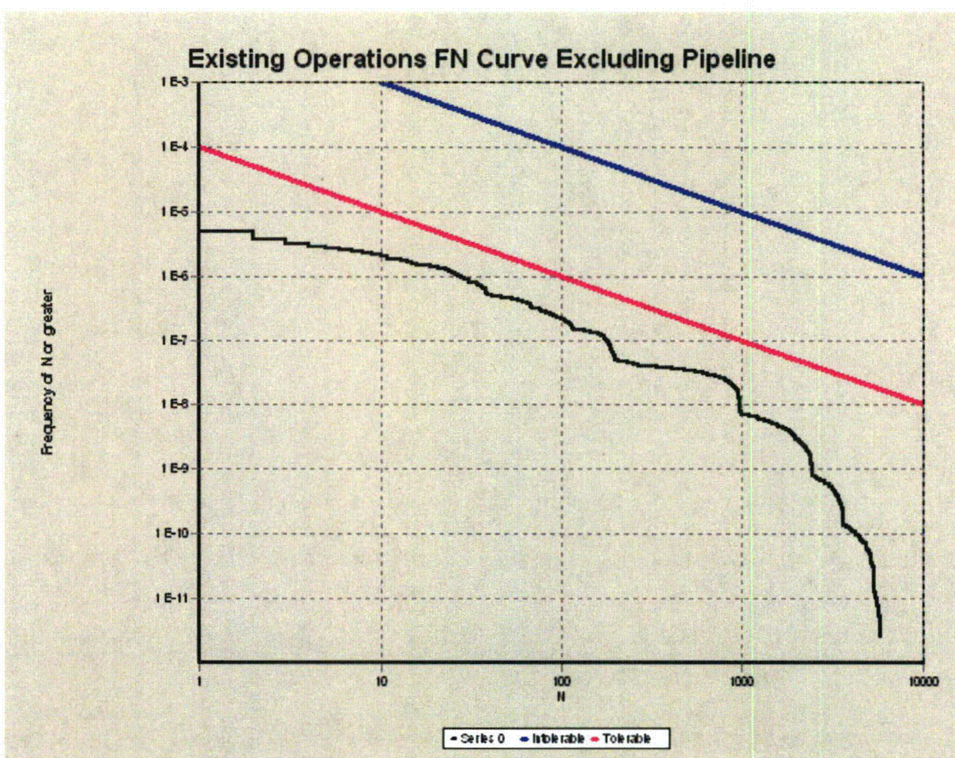
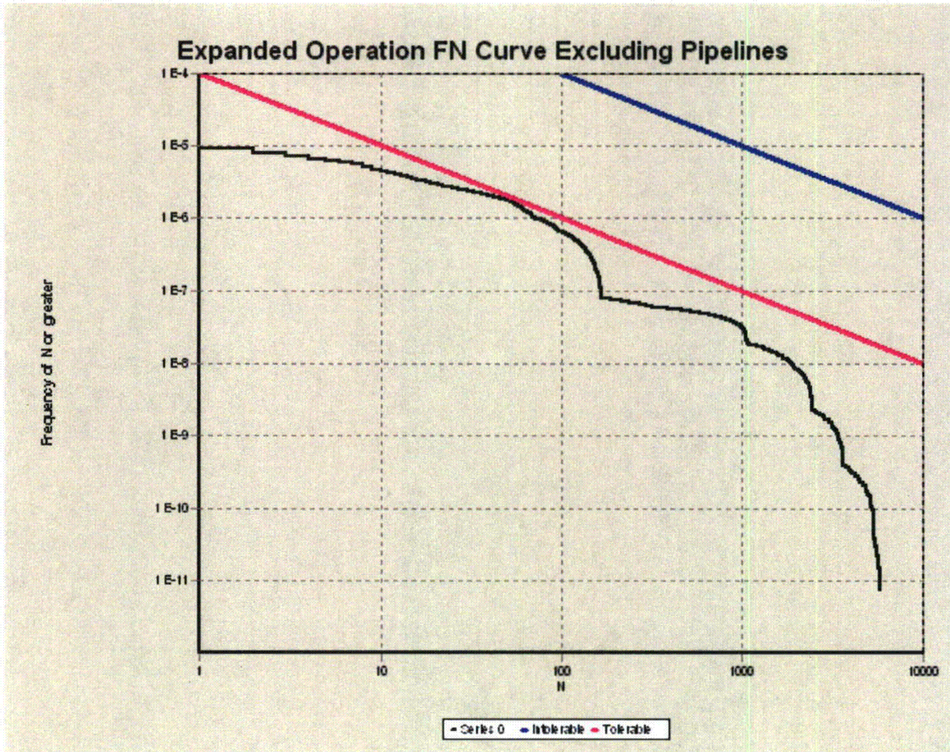


Figure 5.13 Societal Risk for Expanded Operations showing UK HSE Risk Criteria (without gas export pipeline)



6 DISCUSSION

6.1 COMPARISON WITH HISTORICAL AND CURRENT RISK LEVELS

The significance of the risk from the expanded facility may be judged from a number of perspectives. A straightforward and robust perspective may be gained from asking: what is the increase in risk associated with the expansion compared to the current, accepted risk of the existing licensed facility.

Comparing the individual risk contours for the current and expanded facilities (shown in ***Figure** 5.8* and ***Figure** 5.9*), it can be seen that the post expansion risk profile extends outwards slightly further from the terminal and loading platform, as a result of the new equipment and greater frequency of ship imports. Notably the contours around Cove Point Lighthouse are moved further outwards. However the risk contours have not altered dramatically.

Similarly the societal risk curve has moved upwards in the expanded facility case, largely due to the additional pipeline. The value of the PLL indicates in a single number how much the societal risk changes from the current to the expanded facility case. The 68% predicted increase in PLL (changing from 0.0149 to 0.025 per year) is not considered to be trivial but neither does it appear to be a major cause of concern given its small absolute value.

It is worth noting that the increases in inventory (87%), processing rate (80%) and ship movements (122%) are all considerably more than the increase in risk measured in PLL, individual risk or societal risk terms. The reason why the risk increase is more modest is because a significant proportion of the additional risk associated with the increased activity will have no impact on offsite populations, as the effects of the majority of incidents tend to remain onsite and present a risk only to the limited number of workers on site. In particular, much of the increased risk due to additional ship movements does not affect onshore populations. Although the total inventory increases by a significant amount, the more important parameter from a consequences perspective is the largest single isolatable inventory; this increases only by 18% going from the 850,000 barrel tank to the new 1 million barrel tanks in the expanded facility.

The individual risk contours show the estimated annual risk of fatality to an individual at each location around the facility (assuming a full 365 day/year exposure). To place these figures in context, the average individual risk of fatality from all accidents (motor vehicles, falls, drowning, fires etc.) is slightly greater than 3 per ten-thousand (3.1×10^{-4}) per year in the US, about 50% of which is due to motor vehicles[14]. The individual risk levels in the immediate vicinity of the

[14] FERC "Final Environmental Impact Statement, Sabine Pass LNG and Pipeline Project, CP04-47-00"

existing facility are in the range of 0.1 to 10 per million (10^{-7} to 10^{-5}) each year, with the maximum risk level over residential areas being 1.0 per million (10^{-6}) each year (opposite the terminal entrance). This increases to slightly less than 2 ½ per million (2.4×10^{-6}) each year for the expanded facility, an increase of 140%. **Hence the existing facility presents a risk to the most exposed offsite persons that is approximately 0.3% of the total risk of fatalities from all accidents, and this rises to approximately 0.8% for the expanded facility.**

The individual risk of fatality at CCNPP from all hazardous events associated with the existing LNG facility is estimated to be between 2 and 2 ½ per billion (2.3×10^{-9}) each year, an extremely low risk level. The risk of damage to CCNPP is likely to be lower still. The individual risk from the expanded facility is between 6 and 7 per billion (6.6×10^{-9}) each year at the CCNPP. **Although the expanded facility presents an increase in risk to CCNPP, the total risk of fatalities from all accidents is approximately 0.002%, an exceptionally low percentage.**

Societal risk reflects the total number of people exposed to the overall risk. For example, the societal risk from road accidents in the US is over 44,000 fatalities per year[15]. Societal risk for a facility can be estimated in terms of Potential Loss of Life (PLL), which is the sum of the product of the consequences and frequencies of all hazard scenarios, giving a predicted total number of fatalities per year. The PLL for the LNG operations is about 0.0149 fatality per year for the existing facility and 0.0251 fatality per year for the expanded facility, an increase of 68%.

Judging the acceptability of risk is always a complex matter. Different stakeholders may assess risk in different ways and arrive at different conclusions as to what is acceptable. The following overall approaches to judging the risk acceptability of a proposed development are applied here:

a) How does the proposed risk level compare with relevant well established risk acceptability criteria?
b) How do the consequences of accidents associated with the expanded facility compare with consequence criteria?
c) How does the proposed risk level compare with the risk from similar operations?
d) How does the proposed risk level compare with other unrelated activities that have well known and tolerated risks?

These questions are discussed in detail in the following subsections.

[15] Federal Energy Regulatory Commission. "Final Environmental Impact Statement, Sabine Pass LNG and Pipeline Project", CP04-4-00, 2004.

6.2 *COMPARISON OF RISK WITH ESTABLISHED RISK CRITERIA*

Comparing the risk contours and calculated societal risk levels in ***Section 5*** with the US risk criteria defined in ***Section 3***, the risk levels from the existing and expanded facility generally lie below the maximum tolerable risk criteria, with the exception that the 1980s SSRRC criteria are exceeded. However, we are not aware of any current and widely accepted criteria directly applicable to this facility.

The risks to CCNPP appear to be well within the NRC NUREG-1407 criteria for risk from external events to nuclear facilities. This is true for both the existing facility and the proposed expansion.

Comparing the current individual risk contours presented in ***Section*** 5 with the individual risk criteria from the UK for existing facilities (see ***Section*** 3), the current risk profile appears to be broadly tolerable: there are no residential areas within the intolerable risk area (i.e. within the 1.0 per ten-thousand (10^{-4}) contour), and there are few populated locations (mostly road and recreational areas) within the 1.0 per million (10^{-6}) contour. The risk at the nearest assumed residentially populated area (opposite Cove Point Terminal) is 1.0 per million (10^{-6}) per year. This may be considered acceptable for an existing facility.

If the Victorian individual risk criteria for a new facility are assumed to be applicable to the expanded facility, the 10 per million (10^{-5}) contour extends beyond the site boundary but does not appear to overlap any residential areas. The 0.1 per million (10^{-7}) contour overlaps a few populated areas to the south of the facility and in the vicinity of Cove Point Lighthouse. The risk at the most exposed location, opposite the terminal, is 2.4 per million (2.4×10^{-6}) per year, which is not intolerable, but falls into the "tolerable subject to ALARP" region.

Hence, overall it is concluded that the individual risk from the expanded facility, when compared with established risk criteria, is tolerable as long as it can be demonstrated that the risk has been reduced to a minimum practicable level.

Comparing the societal risk curves in ***Section*** 5 with the HSE societal risk criteria, the current and expanded facility societal risk levels are both within the "tolerable subject to ALARP " zone, although the expanded case sits very close to the limit of tolerability. When the export gas pipelines are excluded from the FN curve both cases lie within the "acceptable" zone (the expanded facility case is again very close to the limit of this zone). However, both the current and expanded facility societal risk levels fall within the "tolerable subject to ALARP" zone of the Victorian criteria, and are quite close to the intolerable zone in the range of 10-100 fatalities. Hence it is concluded that the societal risk from the expanded facility is tolerable subject to it being demonstrated to have been reduced to a minimum practicable level.

It must be emphasized that risk criteria are in the vast majority of cases not intended to be taken as precise, mandatory or inflexible; rather they are guidelines to assist decision-making. Precise determination of whether a risk is acceptable or unacceptable is impossible because risk estimates are themselves subject to considerable uncertainty, and furthermore the judgments about what level of risk is acceptable vary between societies or sections within a society, depending to a large extent on the perceived benefit accompanying the risk. What is acceptable risk also changes with time and how the activity is perceived (e.g. following a major accident the tolerance of the risk reduces). Thus it is best to assess the significance of risk from a number of different perspectives as well as by comparison with specific risk criteria.

6.3 COMPARISON WITH CONSEQUENCE CRITERIA

It is understood that FERC requires the vapor cloud dispersion range to the LFL and the range to a thermal radiation flux of 3000 Btu/hr-ft^2 (9.5 kW m^{-2}) to remain on the property. In addition, Dominion has volunteered to design the tank so that the thermal exclusion radius of 1600 Btu/ hr-ft^2 (5 kW m^{-2}) also remains within the property boundary (approximately 1,420 ft (430 m) from the centre of tank F or G). This provides a straightforward consequence-based method for judging the impacts of the expanded facility.

Pessimistic flammable gas dispersion ranges for releases of the order required by NFPA 59A (i.e. 24 in.) are shown in ***Table 6.1***.

Table 6.1 Flammable Gas Dispersion Ranges for LNG Release into Bund

Bund	Distance to LFL (m)
A, B, C or D	440 to 450
E	440 to 450
F or G	420 to 570

* Distances are given as ranges because 12" and 40" hole sizes were modeled

The ranges of distances to LFL presented in ***Table 6.1*** are of a similar order to the distance between tank F or G and the site boundary. However, consequence assessments assumptions were made to make pessimistic (i.e. worst case) estimates of hazard ranges for each hole size.

Consequence ranges for bund fires are shown in ***Table 6.2***.

Table 6.2 Thermal Radiation Hazard Ranges for Bund Fires

Bund	Distance to Thermal Flux Level (m)		
	37.5kW m^{-2}	9.5 kW m^{-2}	5 kW m^{-2}
A or B	124	249	341
C or D	128	255	348
E	176	336	454

Bund	Distance to Thermal Flux Level (m)		
	37.5kW m^{-2}	9.5 kW m^{-2}	5 kW m^{-2}
F or G	179	349	480

It is clear that all of the 9.5 kW m^{-2} hazard ranges are less than the distance to the site boundary, although the 5 kW m^{-2} hazard range for bund F or G is slightly longer. It is noteworthy that the results in ***Table 6.2*** are similar to those reported in Resource Report 13[16].

The expansion project increases the maximum isolated inventory from the current maximum inventory of 850,000 barrels in the 5th tank to 1,000,000 barrels in each of the 2 new tanks proposed, an increase of 18%. These changes lead to only a minor increase in the consequences of individual incidents that may occur on the facility.

6.4 *COMPARISON WITH HISTORICAL RISK STUDIES FOR THE COVE POINT LNG FACILITY*

As part of the planning and development of this study, a range of background information and documents were reviewed including, but not limited to the Arthur D. Little (ADL) Hazard Analysis, 2001 and the Williams Cove Point FERC Application, 2001.

The ADL hazard study of the facility in 1992 for BGE concluded that the hazards to the CCNPP posed by the reopening of the Cove Point LNG Facility in 1992 were acceptable with a cumulative risk level of 4 per ten-million (4.0×10^{-7}) per year of an LNG spill reaching onto CCNPP. A conservative combined frequency of spill and ignition was found to be 4 per one-hundred-million (4.0×10^{-8}) per year. For purposes of comparison with the current study, it is important to note that the ADL study was a product of BGE to solely examine the LNG spill impact on CCNPP. As such, the ADL study did not conform to current practices in terms of risk management protocol and also would not have included the increases in storage capacity and shipping frequency that are integral to the proposed expansion.

Similarly, the 2001 hazards analysis performed by Williams also concluded that risk to the CCNPP as well as the general public were acceptable with a cumulative risk of greater than 4 per one-hundred-million (4.2×10^{-8}) per year. It is important to note that although the Williams study did measure risk to the general public, it would not have included the increases associated with the proposed expansion.

The risk study completed in this report concluded a smaller risk to CCNPP than both the ADL and Williams study. It is important to note that our study was a

[16] Resource Report 13, Additional Information Related to LNG Plants, Cove Point LNG Terminal Expansion Project, Submitted by Dominion Cove Point, L.P., April 2005.

more comprehensive and detailed risk study and the scenarios presented in both historical studies were reviewed and considered in the current study. The risk results from all studies agree that CCNPP appears to be well within the NRC NUREG-1407 criteria for risk from external events to nuclear facilities for the existing Cove Point facility. In addition, the current study concludes CCNPP appears within the criteria for the expansion as well.

6.5 *COMPARISON WITH OTHER LNG FACILITIES IN THE US*

There are many existing, approved and proposed LNG terminals around the US. One way of evaluating the significance and potential acceptability of the risk from the Cove Point terminal is to compare it with other LNG terminals that have been operating or approved elsewhere in the US.

In simple terms, the level of inherent risk of major hazard incidents posed by a facility to offsite populations is determined by its processing and storage capacities and the shortest distance to populated locations. The processing capacity roughly determines the amount and scale of processing equipment and frequency of operations, and therefore the inherent frequency of potential incidents. The storage capacity determines the number and size of the main material inventories, and therefore the largest consequence ranges. The nearest distance to population determines the potential scale of offsite impacts. Thus by comparing these key risk parameters between facilities of the same type, a broad comparison may be made between the relative inherent offsite risks posed by those facilities. The key inherent risk parameters are compared in ***Table 6.3*** for Cove Point and several other LNG terminals in the US. The information was obtained from FERC (www.ferc.gov/industries/lng), company websites (www.sempra.com and www.cheniere.com), and local area map websites, unless specifically stated.

Table 6.3 ***Key Risk Parameters for Several LNG Terminals in the US***

Operator	Site	Processing Capacity (BCFD)	Storage Capacity (BCF)	Approx. Distance to nearest population (miles)	Status
Dominion	Cove Point, MD	1 (current), 1.8 (expanded)	7.8 (current), 14.6 (expanded)	1	Existing (expansion proposed)
Tractebel - DOMAC	Everett, MA	1.035	3.5	1.4	Existing
El Paso - Southern LNG	Elba Island, GA	0.68	4.0	8.1	Existing
Southern Union - Trunkline LNG	Lake Charles, LA	1.0	6.3	2.8	Existing

Operator	Site	Processing Capacity (BCFD)	Storage Capacity (BCF)	Approx. Distance to nearest population (miles)	Status
Sempra Energy	Cameron (Hackberry), LA	1.5	10.1	3-4	Approved, under construction
Cheniere/ Freeport LNG	Freeport, TX	1.5[17]	6.7[16]	3.5	Approved, under construction
Weaver's Cove Energy/Hess	Fall River, MA	0.8	4.3	3.5	Proposed
Mitsubishi - ConocoPhillips	Long Beach, CA	0.7	20	0.9	Proposed
Sempra Energy	Port Arthur, TX	1.5 expandable to 3	6.7 expandable to 13.4	2-3	Proposed

Note: This is a representative list of existing and proposed terminals. It is not intended to be inclusive of all potential locations.

Table 6.3 indicates that following expansion, Cove Point will be one of the largest facilities in the US in terms of processing and storage capacities. It also has a relatively short distance to the nearest populated location, compared with other LNG terminals. There are facilities with similar or larger capacities and there are also facilities with similar or shorter distances to population. However taking these parameters in combination, Cove Point has a relatively high inherent risk level compared with other facilities.

It must be emphasized that this is a simple comparison technique. No method of assessing risk is without limitations, and the following caveats apply to this technique:

- There are other facilities which have not been included in the comparison;
- The distances to population are approximations estimated from public domain maps; there may be other populated areas not shown on maps which are closer (No account is taken of population density and type);
- Other factors also affect offsite risk - including layout, process design, engineering controls, fire protection systems, management systems etc., although all modern facilities should be comparable in these terms;
- If the nearest population is beyond the maximum effect range of the facility then any further separation distance provides no further risk benefit;
- Some of the above facilities are proposed rather than accepted; and
- Reduction of inventory or processing capacity will reduce the risk but if this results in one large facility being replaced by several smaller facilities the overall risk to society may not be reduced;

[17] LNG Journal, June 2005 page 6

6.6 *COMPARISON WITH OTHER TYPES OF RISK*

Society tolerates a wide range of risks, some of which can be reasonably accurately calculated and are well recognized. Comparing the Cove Point facility risks with risks from other activities which are familiar and generally accepted enables the Cove Point risks to be placed into context and its acceptability judged relative to these other activities. A range of common activities with associated risks is shown in *Table 6.4* below.

The acceptability of risk from different activities varies significantly according to the nature of the activity and its associated risk: for example, smoking and rock-climbing both carry high fatality risks which are accepted by the group exposed because they volunteer to do so due to the perceived benefits. Involuntary risks have lower tolerability than voluntary risks. Society generally accepts a higher rate of fatalities from road transport than from rail and air, because individuals are in control of their cars whereas they have no control over a train or airplane. Also the average number of people killed in a single road accident is much less than the average number killed in a rail or air crash; as discussed above, society tends to react more strongly to a single multiple fatality event than to a similar number of fatalities spread over many smaller events. The perceived risk also influences tolerability: risks that create concern, are unusual or have a high profile (e.g. radioactive or biological hazards) are tolerated less than other risks.

Table 6.4 ***Risk of Fatality from Various Causes, UK and US***

Source	Activity	Risk/Yr	Notes	Source
UK	All causes	1.03×10^{-2}	Total population average	UK 1999 Annual Abstract of Statistics (2001)
	Smoking	9.50×10^{-3}	Adult smokers only	ASH, UK (2005)
	Injury or poisoning	3.19×10^{-4}	Total population average	UK 1999 Annual Abstract of Statistics (2001)
	All forms of road accident	5.95×10^{-5}	Total population average	UK 1999 Annual Abstract of Statistics (2001)
	Rail travel accidents	1.12×10^{-5}	Commuter travel 480 journeys/yr	GB 1995/97 - 1999/00 Health and Safety Executive (2001)
	Industrial accidents to workers	8.00×10^{-6}	All employees, all sectors	UK Health & Safety Commission, H&S Stats 2001
	General gas incidents	6.62×10^{-7}	domestic and all other sources of gas	GB 1994/95-1998/99 Health and Safety Executive (2000)
	Air travel accidents	8.00×10^{-8}	10 aircraft journeys per year	UK 1991-2000 Civil Aviation Authority (2001)
	Lightning strike	5.35×10^{-8}	Total population average	UK Office of National Statistics (2001)
	Fairground rides	1.20×10^{-8}	10 rides per year	UK 1996/7-1999/00 Tilson and Butler (2001)
US	All Accidents	3.11×10^{-4}		Federal Energy Regulatory
	Motor Vehicles	1.55×10^{-4}		Commission. "Final
	Falls, drowning, poisoning, fires, suffocation	1.03×10^{-4}		Environmental Impact Statement, Sabine Pass LNG

Source	Activity	Risk/Yr	Notes	Source
	Tornado, flood, earthquake	4.46×10^{-7}		and Pipeline Project." CP04-47-00, 2004.
	Lightning strike	3.18×10^{-7}		
	all pipelines	9.12×10^{-8}		
	gas transmission lines	8.45×10^{-9}		

The risk of fatalities to the public posed by Cove Point would be classified as an involuntary risk, with the capability to cause multiple fatalities and a moderate amount of associated concern, over which the public have little control. The individual risk to the most exposed residential location (south of the Cove Point terminal) is just under 2 ½ per million (2.41×10^{-6}) each year. This is about 100 times lower than the risk of fatality from road accidents, and about seven times higher than the risk of being killed by lightning. It is four times higher than the risk from general gas incidents in the UK and five times lower than the risk from rail crashes. These results suggest that the risk from the expanded facility is within the range of other involuntary risks and would not be considered intolerable from this perspective.

6.7 *RISK SUMMARY*

Comparing the risk levels with risk criteria established in the UK and Australia, the individual and societal risks from the expanded facility may be considered tolerable subject to it being demonstrated that the risks have been reduced to the minimum practicable level. In other words, the risks are not so high that they would be considered intolerable, but it needs to be shown that all reasonable steps have been taken to reduce the risk level as far as practicable before they can be considered to be fully acceptable. The risk levels from the existing facility also falls into this zone but it is reasonable to assume that the existing risk has been accepted historically (i.e., FERC has licensed the existing facility and found the risks to be acceptable); therefore there is little need to further demonstrate the existing facility risk levels are acceptable.

Cove Point LNG terminal has been compared with several existing and proposed LNG terminals around the US. It is concluded that Cove Point is one of the largest LNG terminals and has residential areas relatively close by. Hence the inherent risk level associated with the expanded facility is comparatively high; however, this is currently the case for the existing licensed facility.

Comparing the risks from Cove Point LNG operations with the examples of risk levels from other unrelated but well recognized activities such as road transport and accidents such as drowning or falling, the risks from Cove Point terminal in either the existing or expanded case are a very low proportion of the total fatality risk from all accidents.

In summary:

- Risks to the CCNPP for the expansion project were quantified at 6.6 per billion (6.6×10^{-9}) per year, which is well within the NRC's threshold of acceptable risk from external events (1 in a million per year);
- The estimated risk for the nearest residential population is approximately 2 ½ fatalities in a population of one million (2.4×10^{-6}), which equates to 0.8% of the total risk of fatality that an individual faces from all accidents; and
- The absolute level of risk for the expanded facility is considered acceptable relative to relevant industry criteria and benchmarks; however, consideration should be given to further reduce those risks to as low as reasonably achievable.

APPENDIX A: Summary of Models & Data Input

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1 SUMMARY OF CONSEQUENCE MODELS

The BP Cirrus suite of consequence models was developed by BP International Limited, London (BP) and others. The purpose of the package is to provide a standard and validated set of consequence models which can be used to predict the effects of a release of hydrocarbon liquid or vapor.

The individual models which make up the package have a variety of origins, and were selected for use in the code on the basis of their pedigree. Models used in this analysis have been developed by government or industry groups and are internationally recognized.

The following sections describe the models used in the assessment of consequences related to Cove Point terminal operations.

1.1 SOURCE MODELS

1.1.1 Release from a Liquid Tank

This model calculates the rate of release of a material which is liquid at the containment temperature and atmospheric pressure, i.e. the containment temperature is such that the vapor pressure of the material is less than atmospheric pressure.

S1 provides three pressure related options:

1 tank open to the atmosphere;
2 tank sealed from the atmosphere; and,
3 tank with maintained pressure head.

Option 2 has been applied for scenarios modeled using this model. This option is intended for use for tanks or vessels which are isolated from the atmosphere. It implies that liquid will drain from the tank under the force of gravity but will draw a vacuum in the tank as the release continues.

1.1.2 Release from a Liquid Pipeline

This model calculates the release rate of liquids from pipelines.

1.1.3 Release from a Gas Pipeline

This model estimates the release rate as a function of time from a pipeline containing a gas or vapor which is not a saturated vapor.

This model provides three pipeline options:

1 constant volume reservoir feeding pipeline: this option is used where the pipeline system is attached to a vessel or other containment holding a large volume of gas;
2 continuous flow feeding pipeline: this option is used where gas is being pumped into and through the pipeline system; and,
3 no flow feeding the pipeline: this option is used where the pipeline is effectively isolated from an external vessel or pumps which could feed into the system.

Modeling was carried out using both options 1 and 2.

1.1.4 *Vapor Release from a Boiling or Evaporating Pool*

The model calculates the rate of evaporation and spreading of a pool of liquid on land or water. There are three release options which have the following implications:

1 instantaneous release: the inventory is released instantaneously, with the associated speed of the pool being very rapid;
2 continuous release: the inventory is released at a constant rate for a given time period; and,
3 transient release: the inventory is released at a variable rate for a given time period.

Option 3 has been applied for scenarios modeled using this model.

1.2 *DISPERSION MODELS*

1.2.1 *Dispersion from a Momentum Release*

This model is used to model the dispersion of gas from a pressurized vessel or pipeline where the gas is emitted at high velocity. A significant feature of this type of model is the ability to allow for the additional entrainment of air due to the velocity of the release.

1.2.2 *Dispersion of Heavier than Air Vapor from a Low Momentum Release*

This model is appropriate to predict the dispersion behavior of a vapor cloud which is heavier than air. As vapor is released from a boiling pool of liquid methane (LNG) at -161.5 °C it is heavier than air and will hug the ground. As it disperses it will mix with air and warm up. At some stage the mixed vapor will become lighter than air and will begin to lift off the ground.

1.3 FIRE AND EXPLOSION MODELS

1.3.1 *Pool Fire Model*

This model is used to assess fires from pools of hydrocarbons lying on the ground or in a bund, berm, or dike. These types of model estimate the flame height and surface emissive flux of the fire (the quantity of heat radiated from the surface of the fire) to characterize the fire, and then use a 'view factor' calculation and an 'atmospheric attenuation' algorithm in order to estimate the thermal radiation burden at a specific point some distance from the fire.

This model is capable of modeling confined and unconfined fires on either land or water.

1.3.2 *Jet Fire Model*

Jet fires are the generic name given to the long pencil shaped flame which results following ignition of an accidental release of a flammable gas or liquid from a pressurized vessel or pipeline.

Jet fires can ignite because the jet of hydrocarbon can entrain air and burn at its edge. They remain ignited because the burning velocity of the flame is greater than the velocity of the hydrocarbon jet; in other words the flame is able to burn back towards the source of the jet.

In this model the flame is assumed to be the frustum of a cone, and to radiate heat from the entire surface with uniform surface emissive power.

1.3.3 *Vapor Cloud Explosion (VCE) Model*

This model assumes that a vapor cloud explosion occurs due to the obstructions in the path of the flame front. The overpressure generated by the VCE is related to the obstructed volume and to the obstacle density and type of material. In Cirrus this is encapsulated within an 'energy coefficient' which ranges between 1 and 10. Use of a coefficient of 10 represents detonation; use of coefficients of less than 10 represents a deflagration of corresponding relative energy.

For the purposes of carrying out representative consequence assessments of major accident hazards identified at the Cove Point LNG terminal, the scenarios presented in ***Table 5.1*** are broken down into a number of consequence stages based on the release material (as shown in ***Table A 2-1*** below).

Table A 2-1 ***Hazard Scenario Breakdowns***

Material	Step 1	Step 2	Step 3	Step 4
LNG	Calculate liquid release rate from tank or pipeline	If unignited, calculate rate of evaporation from confined/ unconfined LNG pool	Calculate dispersion ranges to LFL and ½ LFL	Calculate blast overpressure for releases into confined regions
		If ignited, calculate distances to thermal flux levels for confined/ unconfined pool fire		
Methane	Calculate gas release rate from pipeline	If unignited, calculate dispersion ranges to LFL and ½ LFL		
		If ignited, calculate distances to thermal flux levels for jet fire		

The physical properties of LNG (at standard temperature and pressure) used in consequence models are shown in ***Table A 2-2*** with assumed atmospheric conditions shown in ***Table A 2-3***; the values in these tables were used in the modeling of all scenarios unless otherwise stated in the sections below.

Table A 2-2 ***LNG Physical Properties***

Property	Value
Material	Pure Methane
Liquid Density, kg m^{-3}	432
Boiling Point, °C	-161.5
Melting Point, °C	-182.5
Liquid phase viscosity, Ns m^{-2}	0.00011
Phase viscosity ratio	18
Molecular Weight, kg $kmol^{-1}$	16.043
Ratio of specific heats	1.31
Lower Flammable Limit, %v/v	5
Specific Heat, kJ kg^{-1} °C^{-1}	2.08
Flame Temperature, °C	1400
Black body emissive power, kW m^{-2}	220
Burning Rate (Land), m s^{-1}	3.2×10^{-4}
Burning Rate (Water), m s^{-1}	6.0×10^{-4}

Property	Value
Extinction Coefficient, m^{-1}	0.43
Heat of Combustion, J kg^{-1}	5.01×10^7

Table A 2-3 ***Atmospheric Conditions***

Property	Value	Comment
Pasquill Stability Classes	A, D, E, F	Selection of Pasquill stability classes and wind speeds based on analysis of detailed weather data (see *Section 3*)
Wind speeds, m/s	2 (D, E, F), 3 (A), 4 (D, E)	
Ambient Temperature, °C	31	
Relative Humidity, %	39	
Solar Radiation, W m^{-2}	200	

2.1 RELEASE RATES

All of the scenarios identified in ***Table* 5.1** are hazardous because of a loss of containment of LNG or methane. As shown in ***Table A* 2-1** above, the first stage of all consequence assessment is to establish the rate at which LNG or methane is released through a hole in a liquid tank, pipeline or gas pipeline; Models S1, S2 and S3 (as described in ***Section* 1.1**) are used for these purposes respectively.

2.1.1 *Liquid Releases from Storage Tanks and Tanker Compartment*

Tank input data are shown in ***Table A* 2-4**. Tank configurations are based on capacities of 60,000 m^3 (230,000 barrels), 135,000 m^3 (850,000 barrels), 160,000 m^3 (1,000,000 barrels), and 25,000 m^3 (157,000 barrels) for Tanks A to D, Tank E, Tank F or G, and a single compartment in an LNG tanker respectively. Storage tank diameters were measured from site plans, with heights then calculated from the tank capacity. The tanker compartment height was estimated on the assumption that the compartment was spherical, with the diameter (of a cylindrically vertical tank; the only tank type allowed in the liquid release rate model) estimated from the assumed capacity.

Table A 2-4 ***Liquid Releases from Storage Tanks and Tanker Compartment***

Applies to scenarios: *SH-AB-S, SH-AB-M, SH-AB-L, SH-AB-T* *SH-ER-S, SH-ER-M, SH-ER-L, SH-ER-T* *SH-ER-S_P, SH-ER-M_P, SH-ER-L_P, SH-ER-T_P* *ST-S, ST-M, ST-L, ST-T*		
Storage Temperature, °C	-166.5	5°C below boiling point
Storage Pressure	Atmospheric	
Orifice location, m from tank base	0	Maximum liquid head
Discharge Coefficient	0.6	Typical for sharp edged orifice

Orifice sizes considered, mm [ft]	300, 1000, 5000 [1, 3.5, 16.5]		
Tank configurations:			
Tank	*Diameter, m [ft]*	*Height, m [ft]*	*Liquid Level, m [ft]*
A, B, C, or D	54 [177]	27 [88]	26.5 [87]
E	78 [256]	30 [98]	28.6 [94]
F or G	81 [266]	32 [105]	31.5 [103]
Tanker Compartment	42 [138]	18 [59]	18 [59]

2.1.2 *Liquid Releases from Process Inventory*

Scenario PR-T considers a major loss of containment in the Cove Point processing areas. A representative case was modeled involving the guillotine failure of a length of 24" pipework (running from the storage tanks to each of the processing areas). The main assumptions made in the modeling of the release rate from the 24" pipework are shown in ***Table A 2-5***.

Table A 2-5 Liquid Releases from Process Inventory

Applies to scenario:		
PR-T		
Pipe diameter, mm [in]	610 [24]	Assumed typical diameter
Material flowrate, kg s^{-1}	83.4	Equivalent to 700m^3 hr^{-1}
Release orifice diameter	Full bore rupture	
Wall roughness, mm [in]	1 [0.04]	Model default
Average temperature, °C	-159	
Initial pressure, bara	6.7	
Time to isolation, min	5	

2.1.3 *Liquid Releases from Transfer Pipeline*

A similar scenario to that described above is rupture of the LNG transfer pipelines between the jetty head and the storage tank areas. The consequences of transfer pipeline rupture during offloading operations have been modeled (recirculation rates would result in much lesser consequences, which have been discounted for this study). Assumed data for calculation of the liquid release rate from a ruptured transfer line are shown in ***Table A 2-6***.

Table A 2-6 Liquid Releases from Transfer Pipeline

Applies to scenario:		
TR-R		
Pipe diameter, mm [in]	813 [32]	
Material flowrate, kg s^{-1}	1440	Equivalent to 12,000m^3 hr^{-1}
Release orifice diameter	Full bore rupture	
Wall roughness, mm [in]	1 [0.04]	Model default
Average temperature, °C	-159	

Initial pressure, bara	3
Time to isolation, min	5

2.1.4 *Gas Releases from Export Pipeline*

The final release rate calculation is that of methane from the gas export pipelines. Although buried throughout much of their length, the pipeline release rate calculations essentially assume that the pipeline is above ground (the release rates and velocities are so large that it is reasonable to assume that the momentum of a rupture release would rapidly reveal the pipeline to the surface). Input data for these release rate calculations are shown in ***Table A 2-7***.

Table A 2-7 *Gas Releases from Export Pipeline*

Applies to scenario: *PL-R*	
Pipe diameter, mm [in]	920 [36]
Length to block valve, km [miles]	8 [5]
Initial pressure, bara [psi]	87 [1250]
Initial temperature, °C	4
Release orifice diameter	Full bore rupture

No isolation was assumed for releases from the gas export pipeline. Because of the large "reservoir" of methane available for release, the release rate from the pipeline would not rapidly decrease were isolation to be effective. As such, the consequences of a gas export pipeline rupture have been pessimistically based on an immediate gas release rate.

2.2 SPREADING AND EVAPORATION RATES

2.2.1 *Spreading and Evaporation of LNG Released on Land or Water*

Once LNG has been released from its normal containment, it begins to boil and evaporate as it is exposed to the relatively hot substrate (land or water) and air. Model S8 (as described in ***Section 1.1.4***) was used to estimate the spreading and evaporation rate of the LNG release.

Large, sudden releases of LNG may overtop a bund intended to contain the release. In this study, overtopping of bunds has been modeled for catastrophic tank failure scenarios using a correlation developed by Liverpool John Moores University as part of a UK HSE research project[18]. This correlation relates the fraction of tank volume that overtops the bund (*Q*) to the ratio of bund height (*h*) and tank height (*H*).

[18] An experimental investigation of bund wall overtopping and dynamic pressures on the bund wall following catastrophic failure of a storage vessel, a report prepared by Liverpool John Moores University for the Health and Safety Executive 2005, Research Report 333.

$$Q = A \times \exp\left[-B \times \left(\frac{h}{H} \right) \right] \quad \text{where, A = 0.7588, B = 2.3529}$$

Table A 2-8 summarizes the main assumptions made in the calculation of pool spreading and evaporation rates.

Table A 2-8 ***Methane Spreading and Evaporation Rate Input Data***

Applies to scenarios: *SH-AB-S, SH-AB-M, SH-AB-L, SH-AB-T* *SH-ER-S, SH-ER-M, SH-ER-L, SH-ER-T* *SH-ER-S$_P$, SH-ER-M$_P$, SH-ER-L$_P$, SH-ER-T$_P$* *ST-S, ST-M, ST-L, ST-T*		
Substrate	Concrete or Water	
Roughness Parameter	0.01	Turbulence of wind blowing over pool
Wind Speed, m/s	5	Pessimistic assumption
Release Duration	Bund overtopping cases treated as instantaneous. All other scenarios use duration derived from release rate calculation	
Bunded/Unbunded	Releases over water and overtopping cases modeled as unbunded pools	

Bund configurations:

Bund	*Diameter, m [ft]**	*Bund Height (h), m [ft]*	*Tank Height (H), m [ft]*
A or B	70 [230]	5 [16] (estimate)	26.5 [87]
C or D	74 [240]	5 [16] (estimate)	26.5 [87]
E	104 [340]	5 [16] (estimate)	28.6 [94]
F or G	113 [370]	11 [36]**	31.5 [103]

* Equivalent diameter of bund excluding tank footprint

** From impoundment layout drawings

2.3 *DISPERSION DISTANCES*

Evaporated methane, or gas released from a pipeline, will disperse in the atmosphere. At concentrations between 15% (upper flammable limit, UFL) and 5% (lower flammable limit, LFL) methane is flammable. Models D1 and D2 are used to estimate the distance to which a release of methane will disperse to half the LFL for momentum driven (high pressure, high velocity releases) and dense gas scenarios respectively.

Feed rates for gas dispersion models are taken from gas release rate and methane evaporation rate calculation results; other input data are shown in ***Table A 2-9*** and ***Table A 2-10***.

Table A 2-9 ***Momentum Driven Gas Dispersion Input Data***

Applies to scenario: *PL-R*

Orifice Diameter, mm [ft]	920 [36]	
Release duration	Continuous	Gives worst-case range
Upstream temperature, °C	4	

Table A 2-10 Dense Gas Dispersion Input Data

Applies to scenarios: *SH-AB-S, SH-AB-M, SH-AB-L, SH-AB-T* *SH-ER-S, SH-ER-M, SH-ER-L, SH-ER-T* *SH-ER-S_P, SH-ER-M_P, SH-ER-L_P, SH-ER-T_P* *ST-S, ST-M, ST-L, ST-T*		
Roughness Parameter, m	0.0001	Sea (water)
	0.03	Long Grass (used in Resource Report 13)

* Other inputs provided in ***Table A 2-3*** (Atmospheric Conditions)

2.4 THERMAL RADIATION DISTANCES

Ignited releases from LNG storage, vaporization and delivery processes lead to either pool or jet fires. Both of these phenomena result in thermal radiation which can harm people, the environment, and assets. Feed rates for the various fires modeled were taken from the release rate calculation results. The input data used in the pool fire and jet fire thermal radiation calculations are given in ***Table A 2-11*** and ***Table A 2-12*** respectively.

Table A 2-11 Pool Fire Thermal Radiation Input Data

Applies to scenarios: *SH-AB-S, SH-AB-M, SH-AB-L, SH-AB-T* *SH-ER-S, SH-ER-M, SH-ER-L, SH-ER-T* *SH-ER-S_P, SH-ER-M_P, SH-ER-L_P, SH-ER-T_P* *ST-S, ST-M, ST-L, ST-T*		
Wind speeds, m/s	2, 3, 4	Maximum ranges of thermal flux levels calculated using same wind speeds derived in weather data analysis
Atmospheric attenuation	None	

Bund configurations: *Bund*	*Diameter, m [ft]**	*Bund Height (h), m [ft]*
A or B	89 [290]	5 [16] (estimate)
C or D	92 [300]	5 [16] (estimate)
E	131 [430]	5 [16] (estimate)
F or G	140 [460]	11 [36]**

* Equivalent diameter of entire bund

** From impoundment layout drawings

Table A 2-12 Jet Fire Thermal Radiation Input Data

Applies to scenario: *PL-R*		
Wind speeds, m/s	2, 3, 4	Maximum ranges of thermal flux levels calculated using same wind speeds derived in weather data analysis
Atmospheric attenuation	None	

2.5 *BLAST OVERPRESSURE DISTANCES*

Drifting methane clouds, if ignited in congested regions, can give rise to high blast overpressures. From an initial analysis, there are few areas of notable congestion within the terminal boundary. However, the terminal is surrounded on three sides (west, north and east) by the Calvert County State Park; a forested region where areas of congestion exist.

The blast overpressure model requires a volume of gas to be defined and an energy coefficient (10 gives worst-case overpressure, 1 gives no overpressure). The output from the dense gas dispersion calculations (effectively a cloud footprint area) were used to estimate a volume of dispersed gas (to ½ LFL) with an assumed mean plume height of 5 m (16 ft). This provided the main model input. Other input parameters are given in ***Table A 2-13***.

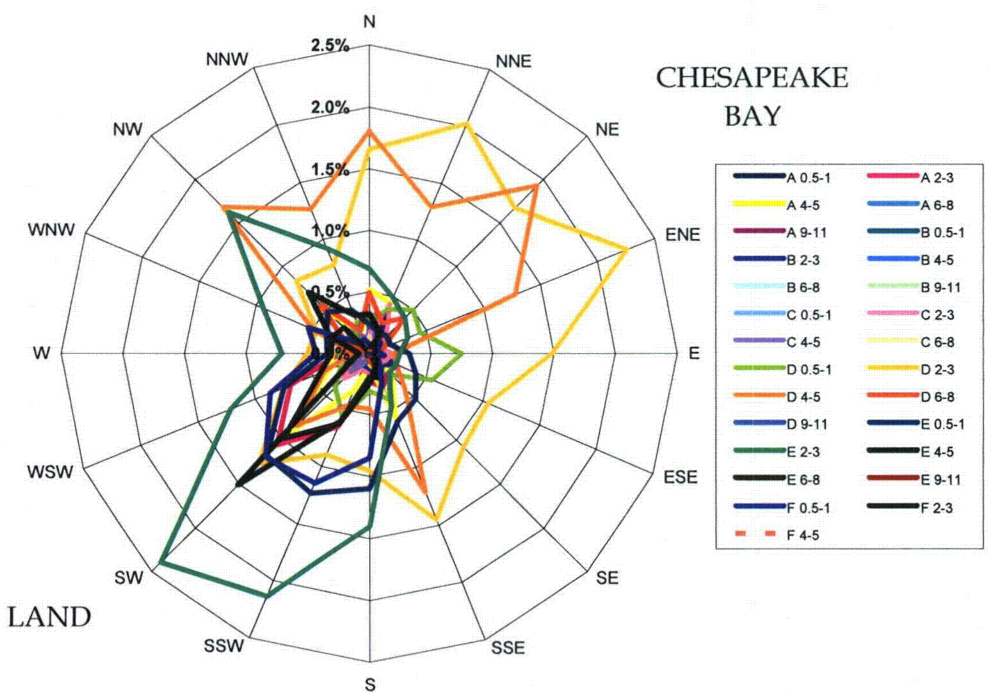
Table A 2-13 Blast Overpressure Input Data

Applies to scenarios: *ST-S, ST-M, ST-L, ST-T*		
% fuel in fuel/air mixture	9.09	Model default
Energy coefficient	10	Worst case blast overpressure ranges

Atmospheric Pasquill stability class and wind speed and direction prevalence data were analyzed to generate a rationalized set of weather data for use in the Cove Point risk assessment.

The wind rose shown in ***Figure A 3.1*** is based on the weather data before any analysis was carried out (A 2-3 represents 2 and 3 m/s wind speeds during stability class A). One can see that there are many stability class and wind speed combinations.

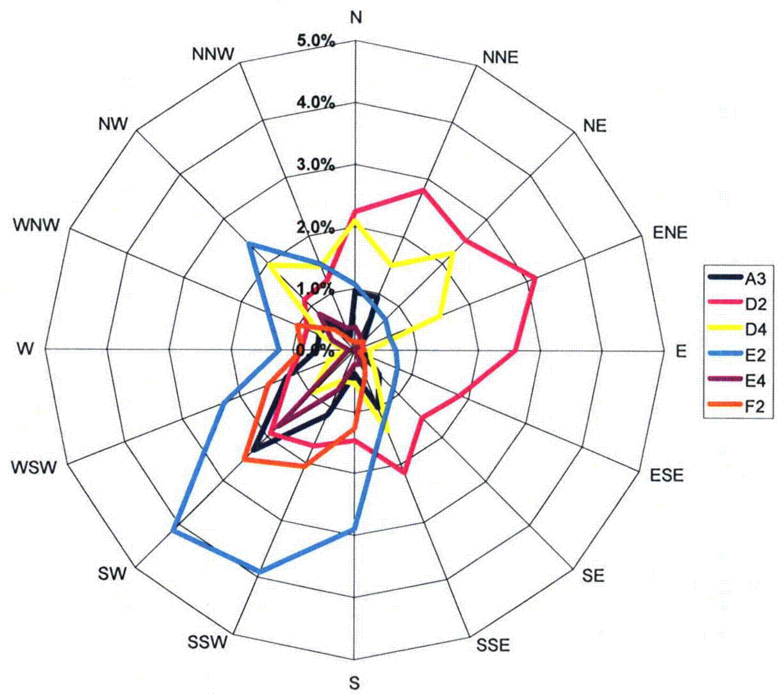
Figure A 3.1 Weather Data before Analysis



Note: Wind directions show where the wind is blowing from.

The most prevalent stability class and wind speed combinations were derived from the data, and are shown in ***Figure A 3.2***. These data were used in the Cove Point risk assessment.

Figure A 3.2   Weather Data used in Cove Point Risk Assessment



Note: Wind directions show where the wind is blowing from.

4 *FREQUENCY ASSESSMENT SUMMARY*

Table A 4-1 shows the scenarios (with their frequencies, data sources and principal assumptions) used in this study. Note that ship event frequencies are based on 90+ and 200 visits per year for existing and expanded operations respectively.

Table A 4-1 Scenario Frequencies and Bases

	Scenario	Frequency (per year)		Comments	
		Existing(1)	Expanded		
1	SH-ER-S	2.19×10^{-3}	4.88×10^{-3}	Data Source:	Internal study based on UK HSC (Health and Safety Commission) research and other shipping studies
2	SH-ER-M	2.19×10^{-4}	4.88×10^{-4}		
3	SH-ER-L	2.19×10^{-5}	4.88×10^{-5}	Assumptions:	5km approach distance 8 Encounters per visit 90% visits involve southerly approach
4	SH-ER-T	2.44×10^{-6}	5.42×10^{-6}		Frequency of total ship loss taken as 10% of a large container release
5	SH-ER-S_P	1.96×10^{-4}	4.36×10^{-4}	Data Source:	As 1-4
6	SH-ER-M_P	1.96×10^{-5}	4.36×10^{-5}	Assumptions:	10km approach distance 6 Encounters per visit
7	SH-ER-L_P	1.96×10^{-6}	4.36×10^{-6}		10% visits involve northerly approach
8	SH-ER-T_P	2.18×10^{-7}	4.84×10^{-7}		Frequency of total ship loss taken as 10% of a large container release
9	SH-AB-S	1.45×10^{-3}	3.28×10^{-3}	Data Source: Assumptions:	PCAG, 6K and as 1-4 4 Passings per visit
10	SH-AB-M	1.36×10^{-3}	3.03×10^{-3}		SH-AB-S includes failure of a single hard arm during unloading
11	SH-AB-L	9.66×10^{-7}	2.76×10^{-6}		SH-AB-M includes simultaneous failure of multiple hard arms during unloading
12	SH-AB-T	1.07×10^{-7}	3.07×10^{-7}		Frequency of total ship loss taken as 10% of a large container release

Scenario		Frequency (per year)		Comments
		Existing(1)	Expanded	
13	TL-R	4.17 x 10^{-4}	8.30 x 10^{-4}	Data Source: PCAG, 6K and Office of Pipeline Safety (OPS), Maryland Incident and Mileage Overview (http://primis.phmsa.dot.gov/comm/StatePages/htmGen/MD_detail1.html) Assumptions: Overall frequency based on 2 x 2.4km (2 x 1.5 miles) of pipeline between jetty head and east of terminal, and 6 jetty head booster pumps Base pipeline frequency of 0.2 failures per year (for 728.5 miles of pipeline) All pipeline failures assumed to be ruptures Existing operations release frequency taken as 50% of annual frequency Expanded operations release frequency taken as annual frequency
14	ST-S	4.00 x 10^{-4}	5.60 x 10^{-4}	Data Source: UK HSE's Planning Consequence Assessment Guidelines (PCAG), chapter 6K Assumptions: Single walled refrigerated ambient pressure vessels (although tanks at Cove Point have an inner and outer tank, the outer tank is not designed for full containment of contents following inner tank failure) Frequency of all tanks failing taken as 10% of a large tank failure
15	ST-M	5.00 x 10^{-4}	7.00 x 10^{-4}	
16	ST-L	3.00 x 10^{-4}	4.20 x 10^{-4}	
17	ST-T	2.00 x 10^{-4}	2.80 x 10^{-4}	
18	ST-F	4.00 x 10^{-6}	4.00 x 10^{-6}	
19	PR-T	1.42 x 10^{-4}	2.81 x 10^{-4}	Data Source: PCAG, 6K Assumptions: Existing frequency based on 360 m (1180 ft) of 24" process pipework (measured off site plans) between existing storage tanks and processing area (at 4.0 x 10^{-8} m^{-1} yr^{-1}), four booster pumps (at 3.0 x 10^{-5} yr^{-1}) and four vaporizers (at 2.0 x 10^{-6} yr^{-1}) Expanded frequency includes an additional 260 m (850 ft) of process pipework between the new storage tanks and processing area, four booster pumps and four vaporizers.
20	PL-R	3.60 x 10^{-3}	7.48 x 10^{-3}	Data Source: Office of Pipeline Safety (OPS), Maryland Incident and Mileage Overview (http://primis.phmsa.dot.gov/comm/StatePages/htmGen/MD_detail1.html) Assumptions: Base frequency of 0.2 failures per year (for 728.5 miles of pipeline) All failures assumed to be ruptures Frequency based on 21.2 km (13 miles) of existing gas export pipeline and 22.8 m (14 miles) of new export pipeline (visible lengths on map used)

APPENDIX B: References

REFERENCES

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