Appendix 17A

TLUP and MATTE Assessment

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LAND USE PLANNING ASSESSMENT FOR PROPOSED DERRYGREENAGH POWER PROJECT, Co. OFFALY

Technical Report Prepared For

AECOM

Technical Report Prepared By

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EXECUTIVE SUMMARY

AWN Consulting Ltd. were instructed by AECOM to complete a Land Use Planning assessment of major accident hazards associated with the proposed Derrygreenagh Power Project, Co. Offaly.

Following the completion of the development, due to the storage of Petroleum Products in excess of the Lower Tier threshold, the Power Plant Area will be classified as a Lower Tier Seveso site and is subject to the provisions of the Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, 2015 (COMAH Regulations 2015).

The Land Use Planning assessment was completed in accordance with guidance published by the HSA (HSA, 2023). The following major accident scenarios were assessed:

- Vapour Cloud Explosion within a turbine enclosure
- Jet fire / Fireball following a leak or rupture of the natural gas pipeline at the Power Plant Area.
- Vapour Cloud Explosion following a leak or rupture of the natural gas, or natural gas and pipeline at the Power Plant Area.
- Flash fire following a leak or rupture of the natural gas pipeline at the Power Plant Area.
- Vapour Cloud Explosion following leak or rupture in an LPG tank
- Jet fire / fireball following leak or rupture in an LPG tank
- Flash fire following leak or rupture in an LPG tank
- Loss of containment of diesel and release to the environment (Major accident to the Environment (MATTE) assessment)

Environmental Risk Assessment (MATTE)

An assessment of Major Accidents to the Environment (MATTEs) at the Power Plant Area was completed in accordance with the environmental risk assessment methodology recommended by the Chemical and Downstream Oil Industries Forum (CDOIF, 2017).

The following table summarises the MATTE Scenario identified.

Scenario	Description	Environmental Receptors	MATTE Category	Tolerability Boundary	Scenario Frequency
MATTE – 1	Catastrophic rupture of bulk storage tank and overtop, migration of overtopped fraction to surface water drainage system and into the Monagh River and the Yellow River.	Fresh water habitats	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year	1.0E-06 per year
MATTE – 2	Catastrophic rupture and overtop to uncontained area on hardstanding may drain to the surface water drainage system and eventually to the surface water environment via the interceptor to the groundwater resource underlying the site.	Groundwater (non-drinking water source)	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year	1.0E-06 per year

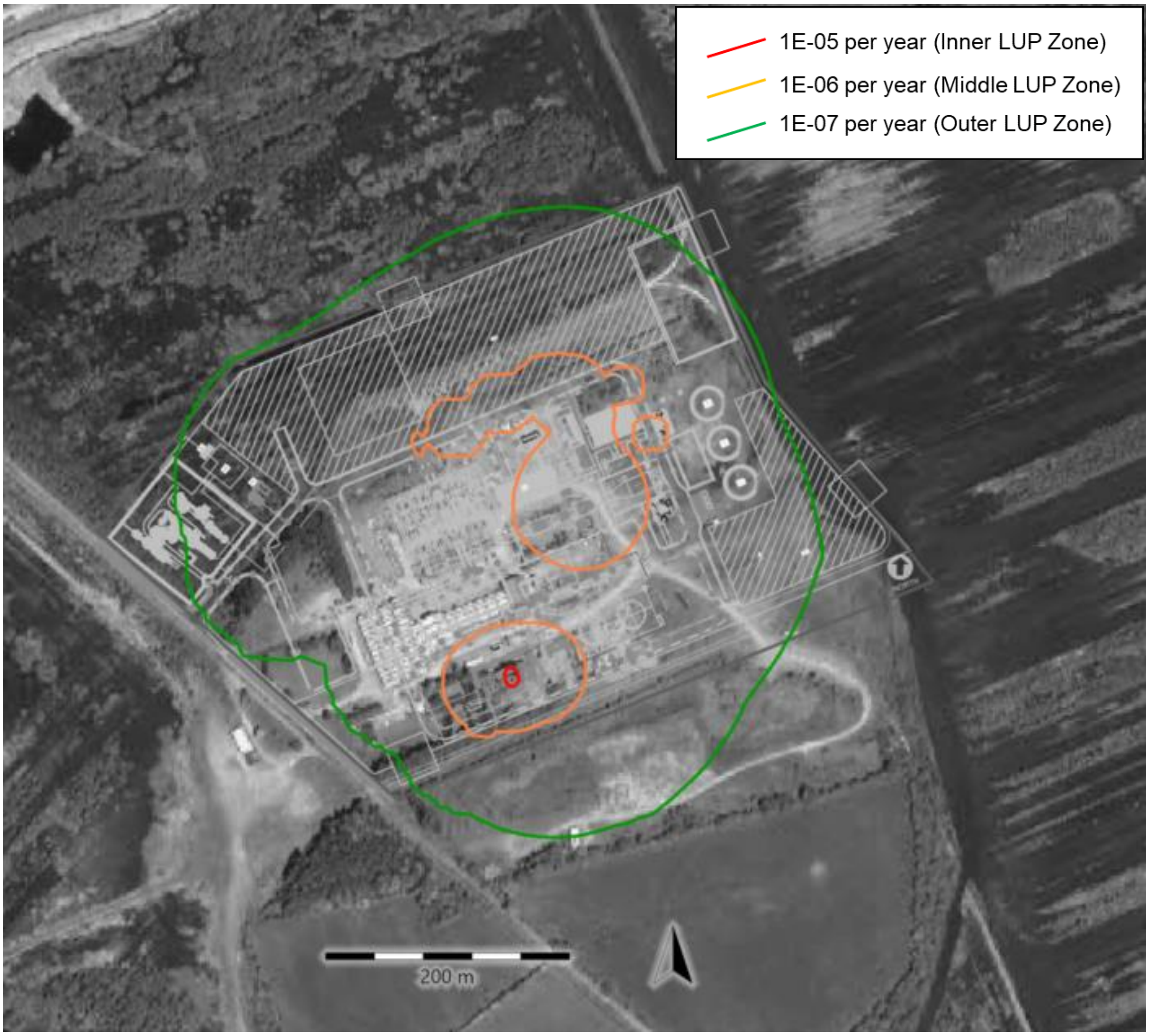
The tanks will comply with EN14015 and the pipework to EN13480 (or equivalent) and the maintenance regime will follow good engineering practice.

The event frequency of MATTE Scenario 1 and 2 was calculated as 1.0E-06 per year. This is in the **Broadly Acceptable** region for these MATTE categories. It is concluded no further risk reduction measures are necessary

Land Use Planning Contours

Gexcon RiskCurves Version 12.1.1 modelling software was used to model the cumulative risk contours for the establishment. The consequence results, frequencies of major accident hazards and Mullingar wind speed and frequency data were input to the software. Risk contours for the Power Plant Area corresponding to the boundaries of the inner, middle, and outer risk-based land use planning zones are illustrated on the Figure below.

The indiviudal risk contours illustrate the indiviudal risk to persons outdoors in the vicinty of the site. There were no off-site consequences to persons indoors; therefore, there is no risk to persons indoors off-site.



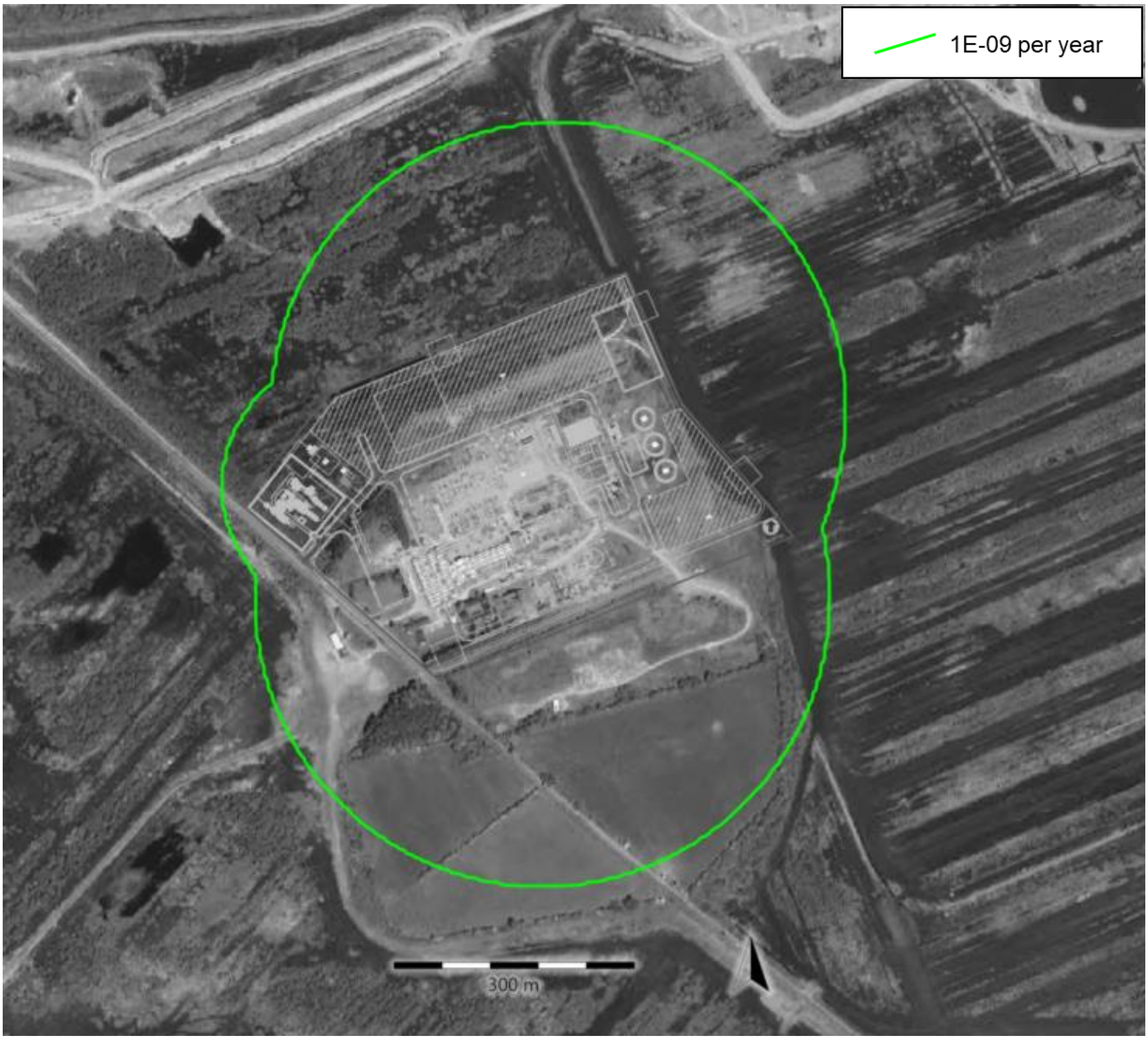
Land Use Planning Risk-based Contours

The following is concluded for the individual risk arising from the proposed development:

- The individual risk contours corresponding to the boundary of the inner risk zone (1E-05 per year) and middle risk zone (1E-06 per year) do not extend over the site boundary.
- The individual risk contour corresponding to the Outer LUP zone extends over the Power Plant Area to the north and south. These areas are typically unoccupied, and this level of individual risk is below the 1E-06 per year maximum tolerable risk to a member of the public threshold.

It is concluded that the level of individual risk off-site is acceptable.

The Figure below illustrates the individual risk contour corresponding to 1E-09 per year (1 in-a-billion). This is the level of individual risk the HSA have requested for new establishments as a proposed consultation distance.



Individual Risk Contour Corresponding to 1E-09 per year (Consultation Distance

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1.0 INTRODUCTION

AWN Consulting Ltd. were instructed by AECOM, on behalf of Bord na Móna to complete a Land Use Planning assessment of major accident hazards associated with the proposed Derrygreenagh Power Project, Co. Offaly. The Proposed Development is part consists of the Power Plant Area and the Electricity Grid Connection, while the Overall Project includes the Gas Connection Corridor.

Following the completion of the development, the Power Plant Area will be classified as a Lower Tier Seveso site and is subject to the provisions of the Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, 2015 (COMAH Regulations 2015).

This report contains the following:

- Description of development.
- Background to risk assessment and land use planning context.
- Land Use Planning assessment methodology and criteria.
- Identification of Major Accident Hazards.
- Land Use Planning Assessment of Major Accident Scenarios.
- Land Use Planning Contours.
- Conclusions.

2.0 DESCRIPTION OF PROPOSED GENERATING PLANT

2.1 Proposed Development Description

The Proposed Development consists of a Power Plant Area with Combined Cycle Gas Turbine (CCGT) and Open Cycle Gas Turbine (OCGT) operating primarily off natural gas with dual fuel capability to operate off secondary fuel. The power generated will be exported to the national grid electricity network via an Electricity Grid Connection comprising a 220kV substation, with hybrid transmission of Overhead Line (OHL) and Underground Cable (UGC) to a new loop-in 400kV substation at the Oldstreet-Woodland Line (c. 8km south of the Power Plant Area). The Overall Project includes a Gas Connection Corridor connecting the Power Plant Area to the Dublin-Galway high pressure gas network (BGE/77, c. 9.7km to the northwest of the Power Plant Area) (see Figure 1).

It is proposed to develop a Power Plant Area (PPA), that will be a responsive power generator to ensure the security of the national electricity networks. The Overall Project will allow for the replacement of existing conventional generation power stations with lower carbon technology. The plant will operate primarily off natural gas from the national grid pipeline supply and will be backed-up by 'Secondary Fuel'.

The Proposed Development will be situated within the Bord na Mona landbank with the exception of agricultural land for a section of the Electricity Grid Connection that includes the loop-in substation. The Proposed Development is situated within a subset of Bogs within the Derrygreenagh bog group and is entirely within the county of Offaly. The Gas Connection Corridor will be on third party lands in the counties of Offaly and Westmeath.

The Power Plant Area will consist of the following installations:

- Combined Cycle Gas Turbine (CCGT) unit
- Heat recovery steam generator
- Open Cycle Gas Turbine (OCGT) units.
- Gas Turbine Air Intake Filters
- Exhaust Stack for each Turbine
- Secondary Fuel Storage and Unloading Facility
- Subsidiary Plant Equipment
    - Blow Down Tanks
    - Propane Ignition System
    - Firefighting systems
    - Process water treatment
    - Main and Auxiliary Transformers
    - Associated Ancillary Equipment
- Administration Building
- Workshop
- Electrical Building
- Control Room

Figure 2 illustrates the COMAH boundary and the COMAH site layout.

2.1.1 Gas pipeline routing area

Natural gas is piped to the onsite Derrygreenagh Above Ground Installation (AGI) connection from the Gas Networks Ireland (GNI) Dublin-Galway grid network (BGE/77). There will be 3 No. buried gas pipelines on site that will feed the CCGT, OCGT and a small auxiliary boiler. Table 1 details the specification of each natural gas pipeline on site.

Pipeline	Diameter (mm)	Length (m)	Operating Pressure (barg)
CCGT	500	470	60
OCGT	300	340	38
Auxiliary Boiler	50	150	38

Table 1 Natural Gas Pipeline Specification

2.1.2 Secondary Fuel Storage

The proposed Power Plant will be required under the Grid Code to maintain a secondary fuel supply of distillate fuel to be stored in 2 No. tanks, each with a working volume of 7,500 m^3; within a bunded area on site. The purpose of this secondary fuel is to ensure that power can still be supplied to the Electricity Grid Connection in the event of an interruption to supply from the gas network.

The bund will be reinforced concrete and will have at least 110% the greatest individual tank capacity or 25% overall storage, whichever is greater. The bund will have a leak detection system.

The tanks will comply with EN14015 and the pipework to EN13480 (or equivalent). The fuel will be stored at ambient conditions. The tanks will have high and high-high level alarms. There will be a low power heating system to ensure the fuel is a minimum of 15^oC.

The procedure for unloading the distillate will follow these principles:

- The road tanker(s) will park in a dedicated unloading layby.
- Unloading will take place in accordance with the site rules and will be supervised by the station staff.
- The unloading point for each tank will be clearly labelled and there will be indication of the tank level, audio/visual high-level alarms at each unloading point.
- A drip tray will be provided at each filling point and the complete layby forms a retention area and will direct any spills to the appropriate part of the site drainage system

It is estimated that there will be 10 deliveries per year, under normal operation (no natural gas outages) and each delivery will be up to $38m^3$.

2.1.3 Fire Protection

The gas turbine enclosure will be protected from fire using an automatic carbon dioxide (CO_2) gaseous extinguishing system as well as optical flame detection, hydrocarbon sensing and thermal detectors.

The turbine enclosures will have emergency shutdown valves certified to EN14382. The valves are fail closed and will activate when gas is detected at a concentration of 20% Lower Explosion Limit (LEL).

A Fire Emergency Response Plan will also be developed and implemented in consultation with the Fire Service of Offaly County Council.

2.1.4 Surrounding Area

The Power Plant Area is located in the townland of Derrygreenagh, close to the border between Co. Offaly and Co. Westmeath. The Power Plant Area is located to the east of the R400 road (with the exception of process water discharge corridor).

2.1.5 Surface Water

Surface water runoff will be generated from all surfaces within the facility that are exposed to rainwater or to which water is applied to clean. This includes all hardstanding surfaces, roofs, and other impermeable surfaces.

As part of the surface water drainage design strategy, the following items have been included in order to effectively manage surface water at the site:

- Drains from all areas subject to potential oil contamination are routed through a Class 1 Oil Interceptor, which will be fitted with alarms in the event of oil within the system (located upstream of the attenuation tank).

- Attenuation Tank – it is proposed to attenuate all storm water accumulated on site within an attenuation tank, this will have a 6550 m^3 capacity. The outlet of the attenuation tank will have the means to stop the flow to mitigate the risk of a release leaving the site.

In the event of an emergency, a fuel spill, bund overtop or fire, the flow out of the attenuation tank will be stopped, remotely, by on-site personnel. This will contain any contaminated material in the attenuation tank where it will be disposed of safely.

The attenuation flow control can be operated from several locations around the site, namely, the Control Room which is manned 24/7.

The surface water drainage at the proposed development ensures that any spill of oil or contaminated firewater will be contained on-site by:

- Raising an alarm to the control room in the event oil is detected by the interceptors
- The control room is manned 24/7
- Upon activation of the alarm, the flow out of the attenuation tank will be stopped and the oil will be contained within the tank
- The oil and contaminated material within the attenuation tank will be disposed of appropriately

Tertiary containment is ensured by the tank (primary), bund (secondary) and attenuation tank (tertiary).

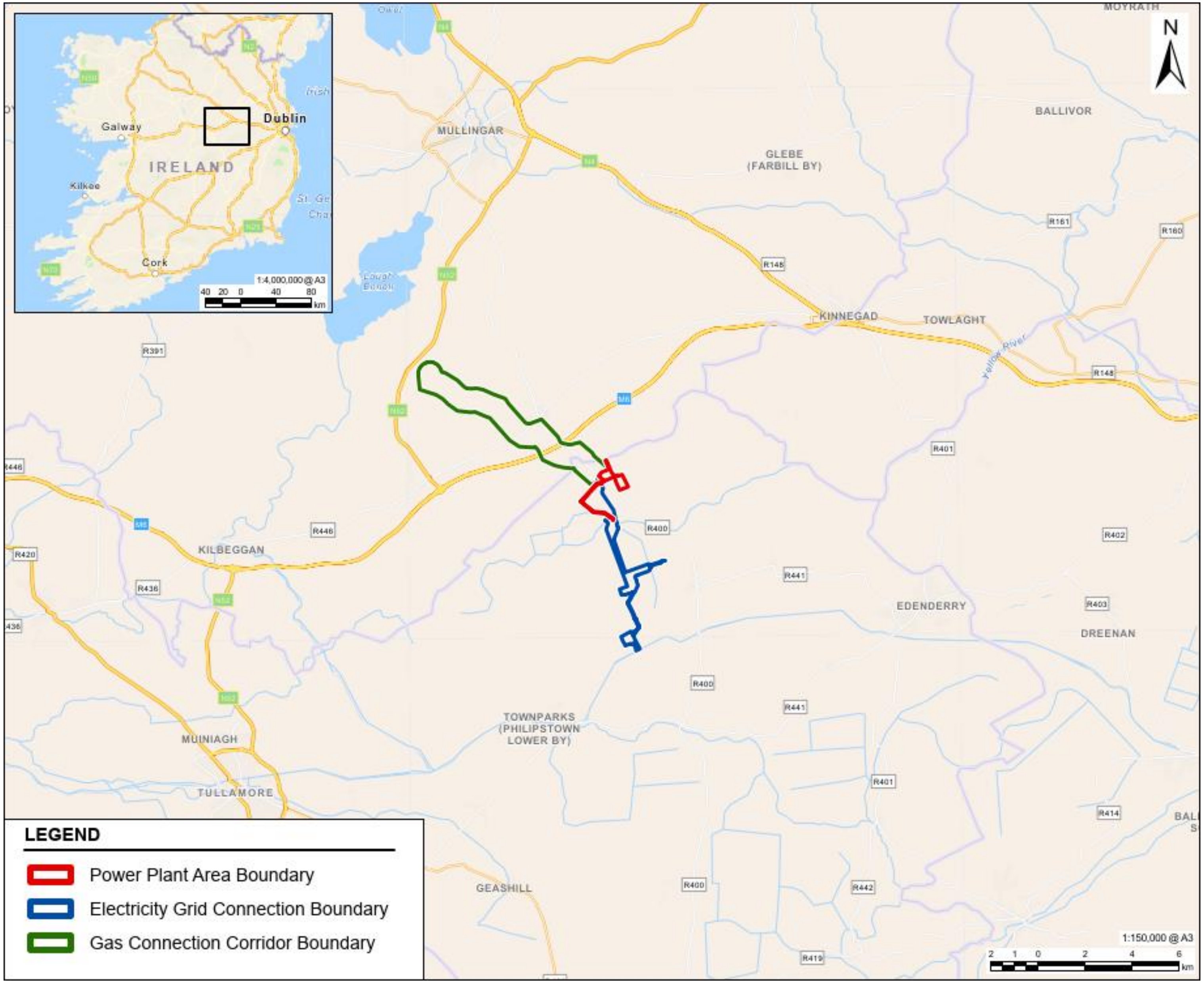


Figure 1 Proposed Development and Overall Project Location

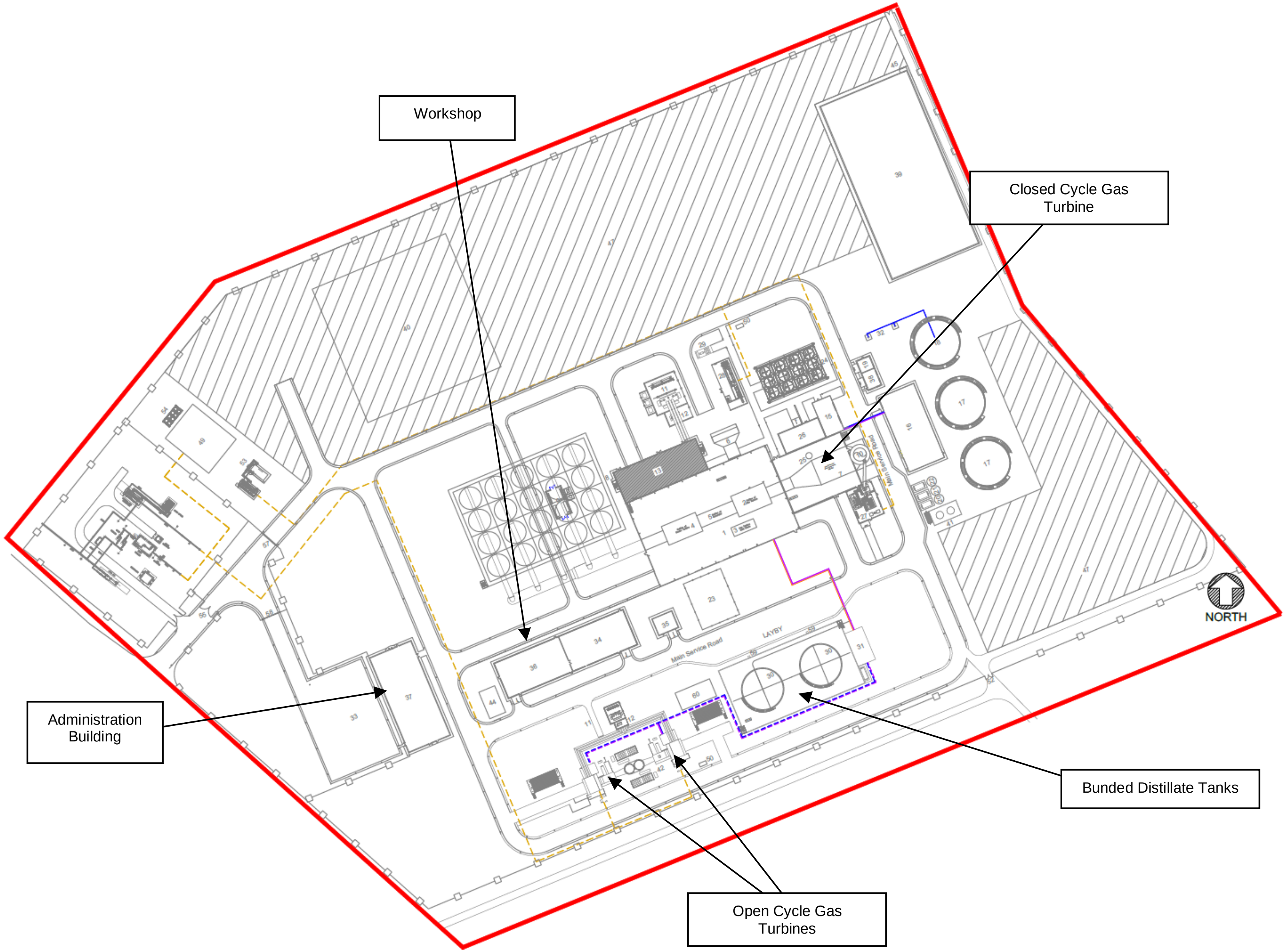


Figure 2 Proposed COMAH Site Layout

2.2 Properties of Dangerous Substances

Table 2 details the quantity of hazardous material stored at the proposed Power Plant.

Dangerous substance	**COMAH Classification**	**Quantity**	**Lower tier threshold**	**Upper tier threshold**	**Fraction of Lower tier threshold**	**Fraction of Upper tier threshold**
		tonnes				
Named Substances						
Petroleum products – (Distillate)	E2 - Aquatic Chronic 2	12,750	2500	25000	5.1	0.51
Liquified flammable gases: Natural Gas	P2 – Physical	4.3	50	200	0.086	0.022
Liquified flammable gases: LPG	P2 – Physical	2	50	200	0.04	0.01

Table 2 Quantities of Hazardous Substances at the proposed Power Plant

The maximum quantity of environmentally hazardous material results in a total Lower Tier fraction, for the Environmental Category, of 5.1. Therefore, the Power Plant Area will be classified as a Lower Tier Seveso site.

3.0 INTRODUCTION TO RISK ASSESSMENT

3.1 Risk Assessment – An Introduction

The Centre for Chemical Process Safety (CCPS) has defined risk as (CCPS 2000): "Risk is a measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood and the magnitude of the loss or injury."

Risk is a function of the consequences of an undesired event and how likely it is to occur. It is often expressed as the product of the likelihood and the consequences:

Risk = consequence x likelihood

In this form, risk has the units of losses per year.

Risk assessment in the chemical process sector seeks answers to the following questions:

- What are the hazards?
- What can go wrong (scenario)?
- How severe could it be (consequence)?
- How likely is it to happen (frequency)?
- How do consequence and frequency combine (risk)?
- Is the current level of risk tolerable, considering existing safeguards?
- If not, what needs to be done to reduce and manage the risk?

Risk assessment may be qualitative, semi-quantitative or quantitative, with the level of detail and analysis increasing from qualitative through to quantitative approaches. For COMAH establishments, the HSA Safety Report Assessment Guidelines (HSA, 2017) indicate that the depth of analysis should be proportionate to:

- the scale and nature of the major accident hazards presented by the establishment
- the risk posed to neighbouring populations and the environment

3.2 Land Use Planning and Risk Assessment

This land use planning assessment has been carried out in accordance with the HSA's *Guidance on technical land-use planning advice (HSA, 2023)*. This approach involves defining three zones for land use planning guidance purposes, based on the potential risk of fatality from major accident scenarios. The HSA has defined the boundaries of the Inner, Middle and Outer Land Use Planning (LUP) zones as:

1E-05/year	Risk of fatality for Inner Zone (Zone 1) boundary
1E-06/year	Risk of fatality for Middle Zone (Zone 2) boundary
1E-07/year	Risk of fatality for Outer Zone (Zone 3) boundary

The process for determining the distances to the boundaries of the inner, middle and outer zones is outlined as follows:

- Determine the consequences of major accident scenarios using the modelling methodologies described in the HSA's Guidance on technical land-use planning advice (HSA, 2023).
- Determine the severity (probability of fatality) using the Probit functions specified by the HSA.
- Determine the frequency of the accident (probability of event) using data specified

by the HSA.

- Determine the individual risk of fatality as follows:

Risk = Frequency x Severity ***(Equation 1)***

The HSA's Guidance on technical land-use planning advice (HSA, 2023) document provides guidance on the type of development appropriate to the inner, middle and outer LUP zones. The methodology sets four levels of sensitivity, with sensitivity increasing from 1 to 4, to describe the development types in the vicinity of a COMAH establishment.

The Sensitivity Levels used in the Land Use Planning Methodology are based on a rationale which allows progressively more severe restrictions to be imposed as the sensitivity of the proposed Power Plant Area increases. The sensitivity levels are:

Level 1 Based on normal working population;
Level 2 Based on the general public – at home and involved in normal activities;
Level 3 Based on vulnerable members of the public (children, those with mobility difficulties or those unable to recognise physical danger); and
Level 4 Large examples of Level 3 and large outdoor examples of Level 2 and Institutional Accommodation.

Table 3 details the matrix that is used by the HSA to advise on suitable development for technical LUP purposes:

Level of Sensitivity	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Table 3 LUP Matrix

3.3 Individual Risk Criteria

The TLUP guidelines (HSA, 2023) state the maximum tolerable risk to a member of the public is 1E-06 per year and the maximum tolerable risk to a person at an off-site work location is 5E-06 per year.

It is noted that these criteria apply to the total risk from all major accident hazards at an establishment.

3.4 Environment and Land Use Planning

The HSA's Generic TLUP Guidelines (HSA, 2023) outlined that the prevention of MATTEs is the primary objective, and it is expected that accident pathways will be prevented. Where this is not practicable, the assessment of major accidents to the environment focuses on the specific risks to sensitive receptors within the local environment, the extent of consequences to such receptors and the ability of such receptors to recover.

Assessment is based on a Source-Pathway-Receptor model. For new establishments, the Competent Authority will focus on the removal of accident pathways to receptors (through the use of additional technical measures: appropriate containment, within the confines of current good practice and ALARP, for example).

4.0 LAND USE PLANNING ASSESSMENT METHODOLOGY AND CRITERIA

This COMAH land use planning assessment has been completed in accordance with risk-based approach set out in the HSA's *Guidance on technical land-use planning advice* (HSA, 2023). LUP assessments are completed in the following steps:

- Identify major accident scenarios with reference to the HSA guidance document (HSA, 2023).
- Consequence modelling of major accident scenarios with physical consequences.
- Assign frequencies to major accident scenarios with reference to frequency values outlined in the HSA's Guidance document (HSA, 2023).
- Assessment of individual risk and generation of individual risk contours.
- Where necessary, assessment of societal risk using societal risk indices.
- Source-pathway-receptor model for major accident scenarios with environmental consequences, environmental receptor categorisation, assessment of MATTE harm and duration, compare MATTE frequency with tolerability criteria.

4.1 Assessment Methodology

4.1.1 Physical Effects Modelling

The impacts of physical and health effects on workers and the general public outside of the Power Plant Area were determined by modelling accident scenarios using Gexcon Effects version 12.1.1 and DNV Phast Version 8.7 modelling software.

4.1.2 Risk Assessment Methodology

Gexcon RiskCurves version 12.1.1 modelling software is used in this assessment to calculate individual risk of fatality contours and risk-based land use planning zones associated with major accident scenarios.

4.2 Thermal Radiation Criteria

Fire scenarios have the potential to create hazardous heat fluxes. Therefore, thermal radiation on exposed skin poses a risk of fatality.

Potential consequences of damaging radiant heat flux and direct flame impingement are categorised in Table 4 (HSA, 2023).

Thermal Flux (kW/m^2)	Consequences
1 – 1.5	Sunburn
5 – 6	Personnel injured (burns) if they are wearing normal clothing and do not escape quickly
8 – 12	Fire escalation if long exposure and no protection
32 – 37.5	Fire escalation if no protection (consider flame impingement)
31.5	US DHUD, limit value to which buildings can be exposed
37.5	Process equipment can be impacted, AIChE/CCPS
Up to 350	In flame. Steel structures can fail within several minutes if unprotected or not cooled.

Table 4 Heat Flux Consequences

In relation to persons indoors, the HSA have specified the thermal radiation consequence criteria (from an outdoor fire) detailed in Table 5 (HSA, 2023).

Thermal Flux (kW/m^2)	Consequences
> 25.6	Building conservatively assumed to catch fire quickly and so 100% fatality probability
< 25.6	People are assumed to escape outdoors, and so have a risk of fatality corresponding to that of people outdoors
< 12.7	People are assumed to be protected, and therefore there is a 0% fatality probability

Table 5 Heat Flux Consequences Indoors

Thermal Dose Unit (TDU) is used to measure exposure to thermal radiation. It is a function of intensity (power per unit area) and exposure time:

$$\text{Thermal Dose} = I^{1.33}\, t \qquad \text{(Equation 2)}$$

where the Thermal Dose Units (TDUs) are $(kW/m^2)^{4/3}.s$, I is thermal radiation intensity (kW/m^2), and t is exposure duration (s).

The HSA recommends that the Eisenberg Probit function (HSA, 2023) is used to determine probability of fatality to persons outdoors from thermal radiation as follows:

$$\text{Probit} = -14.9 + 2.56 \ln (I^{1.33}\, t) \qquad \text{(Equation 3)}$$

I Thermal radiation intensity (kW/m^2)
t exposure duration (s)

Probit (Probability Unit) functions are used to convert the probability of an event occurring to percentage certainty that an event will occur. The Probit variable is related to probability as follows (CCPS, 2000):

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y-5} \exp\left(-\frac{u^2}{2}\right) du \qquad \text{(Equation 4)}$$

where P is the probability of percentage, Y is the Probit variable, and u is an integration variable. The Probit variable is normally distributed and has a mean value of 5 and a standard deviation of 1.

The Probit to percentage conversion equation is (CCPS, 2000):

$$P = 50\left[1 + \frac{Y-5}{|Y-5|} erf\left(\frac{|Y-5|}{\sqrt{2}}\right)\right] \qquad \text{(Equation 5)}$$

The relationship between Probit and percentage certainty is presented in Table 6 (CCPS, 2000).

%	0	1	2	3	4	5	6	7	8	9
0	—	2.67	2.95	3.12	3.25	3.36	3.45	3.52	3.59	3.66
10	3.72	3.77	3.82	3.87	3.92	3.96	4.01	4.05	4.08	4.12
20	4.16	4.19	4.23	4.26	4.29	4.33	4.36	4.39	4.42	4.45
30	4.48	4.50	4.53	4.56	4.59	4.61	4.64	4.67	4.69	4.72
40	4.75	4.77	4.80	4.82	4.85	4.87	4.90	4.92	4.95	4.97
50	5.00	5.03	5.05	5.08	5.10	5.13	5.15	5.18	5.20	5.23
60	5.25	5.28	5.31	5.33	5.36	5.39	5.41	5.44	5.47	5.50
70	5.52	5.55	5.58	5.61	5.64	5.67	5.71	5.74	5.77	5.81
80	5.84	5.88	5.92	5.95	5.99	6.04	6.08	6.13	6.18	6.23
90	6.28	6.34	6.41	6.48	6.55	6.64	6.75	6.88	7.05	7.33
%	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
99	7.33	7.37	7.41	7.46	7.51	7.58	7.65	7.75	7.88	8.09

Table 6 Conversion from Probit to Percentage

For long duration fires, such as pool fires, it is generally reasonable to assume an effective exposure duration of 60 seconds to take account of the time required to escape (HSA, 2023). It is noted that this is a conservative estimation of the time taken to escape and is used in consequence assessment as the maximum exposure duration for heat radiation.

With respect to exposure to thermal radiation outdoors, the Eisenberg Probit relationship implies:

- 1% fatality – 963 TDUs (8.02 kW/m^2 for 60 s exposure duration)
- 10% fatality – 1450 TDUs (10.9 kW/m^2 for 60 s exposure duration)
- 50% fatality – 2399 TDUs (15.9 kW/m^2 for 60 s exposure duration)

4.3 Overpressure Criteria

Explosions scenarios can result in damaging overpressures, especially when flammable vapour/air mixtures are ignited in a congested area.

Combustion of a flammable gas-air mixture will occur if the composition of the mixture lies in the flammable range and if an ignition source is available. When ignition occurs in a flammable region of the cloud, the flame will start to propagate away from the ignition source. The combustion products expand causing flow ahead of the flame. Initially this flow will be laminar. Under laminar or near laminar conditions the flame speeds for normal hydrocarbons are in the order of 5 to 30 m/s which is too low to produce any significant blast over-pressure. Under these conditions, the vapour cloud will simply burn, causing a flash fire. In order for a vapour cloud explosion to occur, the vapour cloud must be in a turbulent condition.

Turbulence may arise in a vapour cloud in various ways:

- By the release of the flammable material itself, for instance a jet release from a high-pressure vessel.
- By the interaction of the expansion flow ahead of the flame with obstacles present in a congested area.

Table 7 describes blast damage for various overpressure levels (HSA, 2023).

Side-on Overpressure (mbar)	Description of Damage
1.5	Annoying noise
2	Occasional breaking of large windowpanes already under strain
3	Loud noise; sonic boom glass failure
7	Breakage of small windows under strain
10	Threshold for glass breakage
20	“Safe distance”, probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken
30	Limited minor structural damage
35 – 70	Large and small windows usually shattered; occasional damage to window frames
>35	Damage level for “Light Damage”
50	Minor damage to house structures
80	Partial demolition of houses, made uninhabitable
70 - 150	Corrugated asbestos shattered. Corrugated steel or aluminium panels fastenings fail, followed by buckling; wood panel (standard housing) fastenings fail; panels blown in
100	Steel frame of clad building slightly distorted
150	Partial collapse of walls and roofs of houses
150-200	Concrete or cinderblock walls, not reinforced, shattered
>170	Damage level for “Moderate Damage”
180	Lower limit of serious structural damage 50% destruction of brickwork of houses
200	Heavy machines in industrial buildings suffered little damage; steel frame building distorted and pulled away from foundations
200 – 280	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
300	Cladding of light industrial buildings ruptured
350	Wooden utility poles snapped; tall hydraulic press in building slightly damaged
350 – 500	Nearly complete destruction of houses
>350	Damage level for “Severe Damage”
500	Loaded tank car overturned
500 – 550	Unreinforced brick panels, 25 - 35 cm thick, fail by shearing or flexure
600	Loaded train boxcars completely demolished
700	Probable total destruction of buildings; heavy machine tools moved and badly damaged
830	Damage level for ‘total destruction’

Table 7 *Blast Damage*

The HSA recommends that the Hurst, Nussey and Pape Probit function (HSA, 2023) is used to determine probability of fatality to persons outdoors from overpressure as follows:

$$Probit = 1.47 + 1.35 \ln P$$

P Blast overpressure (psi)

The Hurst, Nussey and Pape Probit relationship implies:

- 1% fatality – 168 mbar
- 10% fatality – 365 mbar
- 50% fatality – 942 mbar

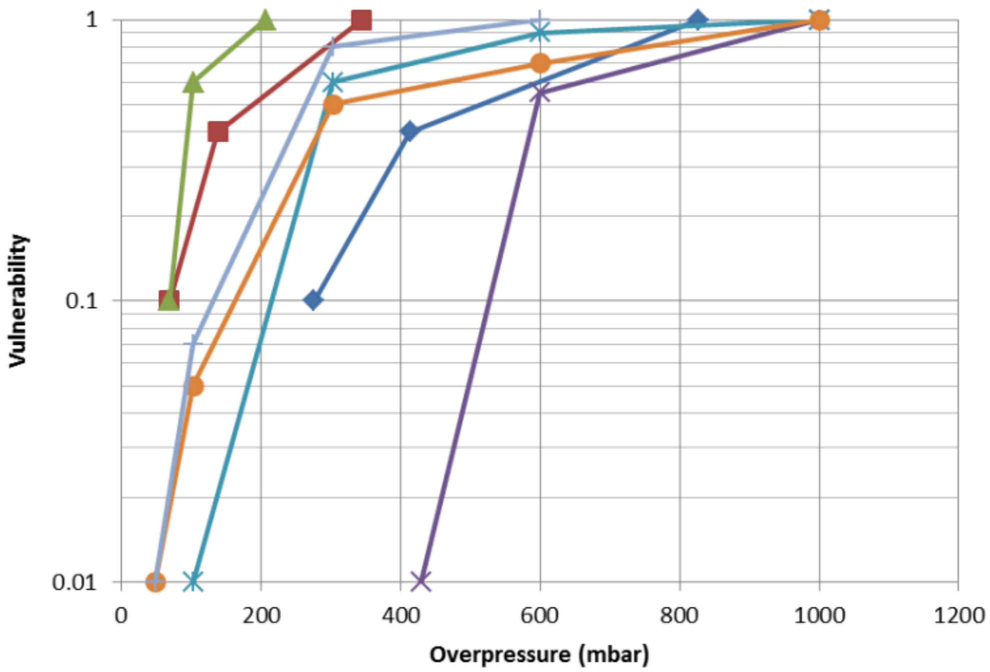
The HSA uses relationships published by the Chemical Industries Association (CIA) and the American Petroleum Institute (API) to determine the probability of fatality for building occupants exposed to blast overpressure. The CIA has developed relationships for 4 categories of buildings (CIA, 2020):

- CIA 1: hardened structure building (special construction, no windows).
- CIA 2: typical office block (four storey, concrete frame and roof, brick block wall panels).
- CIA 3: typical domestic dwelling (two storey, brick walls, timber floors); and
- CIA 4: ‘portacabin’ type timber construction, single storey.

The API has developed relationships for 5 categories of buildings (EIGA, 2014):

- API B1: Wood frame trailer or shack
- API B2: Steel frame/metal siding or pre-engineered building
- API B3: Unreinforced masonry bearing wall building
- API B4: Steel or concrete reinforced masonry infill or cladding
- API B5: Reinforced concrete or reinforced masonry shear wall building

Figure 3 illustrates the probability of occupant vulnerability to overpressure in CIA building categories CIA 1 – 4 and in API building types B1 – B5.



Graph Key:	
(purple line, cross marker)	CIA 1: Hardened structure building: special construction, no windows
(teal line, star marker)	CIA 2: Typical office block: four story, concrete frame and roof, brick block wall panels
(orange line, circle marker)	CIA 3: Typical domestic buildings: two story, brick walls, timber floors
(light blue line, plus marker)	CIA 4: Portacabin: timber construction, single story
(blue line, diamond marker)	API B5: Reinforced concrete or reinforced masonry shear wall building
(green line, triangle marker)	API B3: Unreinforced masonry bearing wall building
(red line, square marker)	API B1, B2, B4: Wood frame trailer or shack, steel-frame/metal siding or pre-engineered building, steel or concrete reinforced masonry infill or cladding
NOTE—Building key items 1 - 4 are defined by CIA; items B1 - B5 are defined by API RP 752 (2003) [5, 3].	

Figure 3 API Probability of Occupant Vulnerability

The CIA and API relationships imply the overpressure levels corresponding to probabilities of fatality of 1%, 10% and 50% detailed in Table 8 below.

Probability of fatality	Overpressure Level, mbar						
	CIA 1	CIA 2	CIA 3	CIA 4	API B1 B2 and B4	API B3	API B5
1% fatality	435	100	50	50	-	-	-
10% fatality	519	183	139	115	69	69	276
50% fatality	590	284	300	242	172	97	483

Table 8 Blast Overpressure Consequences Indoors

4.4 Modelling Parameters

4.4.1 Weather Conditions

Weather conditions at the time of a major accident have a significant impact on the consequences of the event. Typically, high wind speeds increase the impact of fires, particularly pool fires, while the associated turbulence dilutes vapour clouds, reducing the impact of toxic and flammable gas releases.

Atmospheric Stability Class and Wind Speed

Atmospheric stability describes the amount of turbulence in the atmosphere. The stability depends on the wind speed, time of day, and other conditions. Atmospheric stability classes are described in Table 9 (DNV, PHAST Supporting Documentation).

Wind speed (m/s)	Day: Solar Radiation			Night: Cloud Cover		
	Strong	Moderate	Slight	Thin, <40%	Moderate	Overcast, >80%
2	A	A-B	B	-	-	D
2 – 3	A-B	B	C	E	F	D
3 – 5	B	B-C	C	D	E	D
5 – 6	C	C-D	D	D	D	D
6	C	D	D	D	D	D

Table 9 Atmospheric Stability Class

Stability classes are described as follows:

- A very unstable (sunny with light winds)
- B unstable (moderately sunny, stronger winds than class A)
- C slightly unstable – very windy/sunny or overcast/light wind
- D neutral – little sun and high wind or overcast night
- E stable – moderately stable – less overcast and windy than class D
- F very stable – night with moderate clouds and light/moderate winds

The following Pasquil stability/wind speed pairs are specified by the HSA in Ireland for dispersion modelling:

- Average weather conditions are represented by stability category D and a wind speed of 5 m/s, i.e., Category D5.
- Worst case conditions for toxic dispersion are represented by stability category F and a wind speed of 2 m/s, i.e., Category F2.

D5 conditions are assumed to occur 80% of the time, with F2 occurring for the remaining 20%.

Wind Direction and Ambient Temperature

The nearest synoptic metrological station to the Power Plant Area for which long term meteorological data is available is at Mullingar Synoptic Station.

Figure 4 illustrates a wind rose for Mullingar (1991 – 2021). It can be seen that the prevailing wind direction is from the southwest (220°).

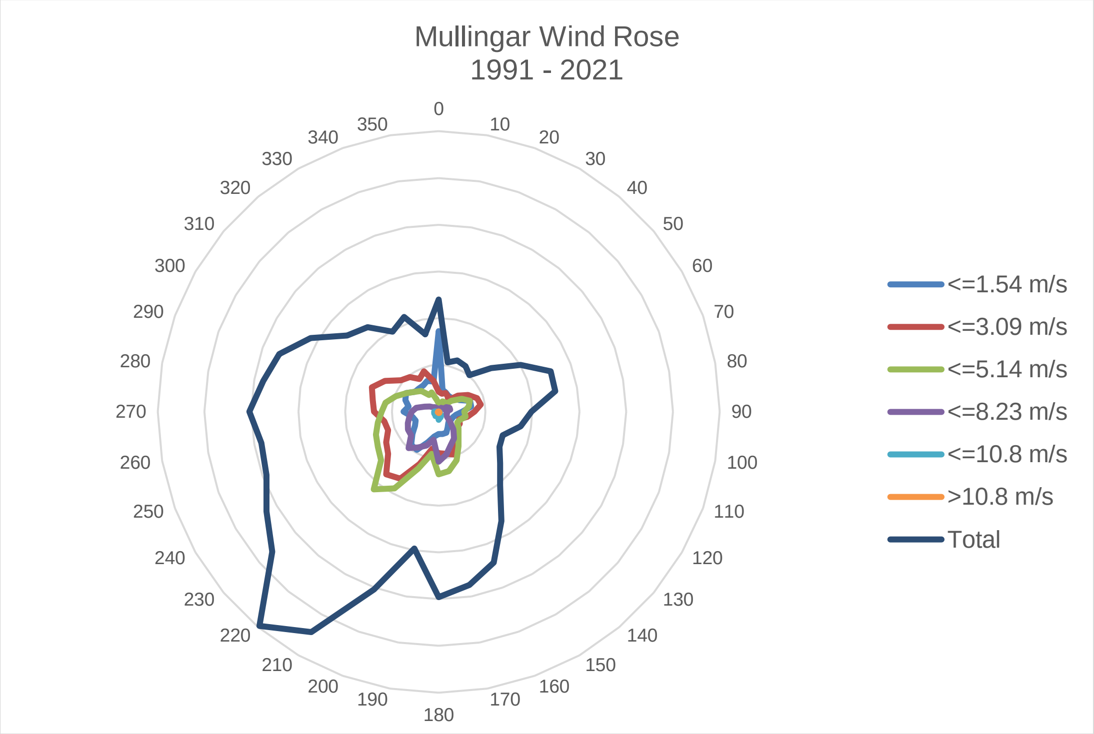


Figure 4 Wind Rose Mullingar 1991 - 2021 (www.met.ie)

Ambient Temperature

The TLUP guidance states that a temperature of 15 °C is used in D5 conditions and 10 °C for F2 conditions.

Ambient Humidity

For this assessment, the ambient humidity of 60% has used.

4.4.2 Surface Roughness

A surface roughness length of 0.1 m will be used for the study.

5.0 IDENTIFICATION OF MAJOR ACCIDENT HAZARDS

A major accident is defined in the 2015 COMAH Regulations as:

> *"an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by these Regulations, and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances"*

5.1 Major Accident Hazards at Proposed Gas Turbines within the Power Plant Area

5.1.1 Turbine Vapour Cloud Explosion Scenario

The turbine enclosures will have a leak detection system that will trip the incoming gas supply when the concentration within the enclosure reaches 20% LEL. Therefore, this system has to fail in order for there to be a build-up of natural gas to explosive concentrations.

In the event the leak detection system fails, there is the potential for a confined Vapour Cloud Explosion (VCE) as a result of a leak of natural gas within the turbine enclosures. The HSA TLUP guidance specifies the size of the flammable cloud to be taken as the volume of the region where the release may occur (i.e. turbine enclosure volume).

Individual risks of fatality can be calculated using a Probit of $Y = 1.47+1.35\ln(P)$, with P in psi (Hurst, Nussey and Pape, 1989) for the risk to people outdoors, and the Chemical Industries Association (CIA, 2020) vulnerability curves for the risk to people indoors.

5.1.2 Pipeline Release Scenario

The proposed CCGT and OCGTs will be supplied with natural gas pipelines originating at the AGI. The natural gas pipework will include the provision of a series of Emergency Shutdown Devices (ESDs), in compliance with EN 14382, which will act to block incoming gas flow in the event of a pressure drop. The specification of the ESDs will be finalised at detailed design; however, typical blocking response times are <1 second. For the purposes of this assessment, a 1 second response time on the Slam Shut valve shall be used as a conservative approach.

5.1.3 Major Accidents to the Environment (MATTE)

The distillate fuel is classified as a Flammable Category 3 material (HSA, 2023). Therefore, there are no flammable hazards associated with distillate as it has an ignition probability of 0, as it is not stored in a bund with other flammable material. The major accident hazards associated with distillate are a potential release to the environment.

5.1.4 Major Accident Scenarios

The following major accident scenarios arising from the proposed power generation plant are assessed herein:

- Vapour Cloud Explosion within a turbine enclosure
- Jet fire / Fireball following a leak or rupture of the natural gas pipeline at the Power Plant Area.

- Vapour Cloud Explosion following a leak or rupture of the natural gas, or natural gas and pipeline at the Power Plant Area.
- Flash fire following a leak or rupture of the natural gas pipeline at the Power Plant Area.
- Vapour Cloud Explosion following leak or rupture in an LPG tank
- Jet fire / fireball following leak or rupture in an LPG tank
- Flash fire following leak or rupture in an LPG tank
- Loss of containment of diesel and release to the environment (Major accident to the Environment (MATTE) assessment)

As regards loss of containment of diesel, the tertiary containment provided by the tank, bund and surface water drainage system (detailed in Section 2.1.5), ensures that a spill of diesel will not migrate off-site. Therefore, an off-site pool fire scenario is not credible.

The HSA's technical land-use planning advice document (HSA, 2023) provides the following major accident scenarios for natural gas pipelines:

- Pipeline rupture
- Pipeline leak through pipe hole (hole size 0.1 x Diameter)

6.0 LAND USE PLANNING ASSESSMENT OF MAJOR ACCIDENT HAZARDS

6.1 Natural Gas Pipeline Release

It is possible that a rupture or leak could occur at any point along the natural gas pipelines. For the purposes of this assessment, the consequences for the CCGT pipeline will be shown as a worst-case representative, for all pipelines, as it is the pipeline with the largest diameter, longest length, and highest pressure. The consequences for the OCGT pipeline and auxiliary boiler pipeline will be included in the risk calculation for the Power Plant Area.

The pipeline is below ground and buried; therefore, only a vertical release is a credible major accident scenario.

Phast Version 8.7 long pipeline model was used to model a release of natural gas following rupture of a pipeline or a leak from a pipeline (10% of diameter).

6.1.1 CCGT Natural Gas Pipeline Release Model Inputs

The pipeline model inputs are detailed in Table 10.

Phast Version 8.7 long pipeline model was used to model a release of natural gas following rupture of a pipeline or a leak from a pipeline (10% of diameter).

Parameter	Pipeline rupture	Pipeline leak, 10% of diameter	Source/Assumption
Scenario	Pipeline rupture	Pipeline leak, 10% of diameter	-
Material	Methane	Methane	-
Pipeline diameter	500 mm	500 mm	Project Engineer
Hole Size	500 mm	50 mm	Pipeline rupture assumes Guillotine fracture so entire pipeline diameter
Pipe inflow	18.4 kg/s	18.4 kg/s	Maximum Flow to CCGT Project Engineer
Length of pipeline	470 m	470 m	Project Engineer
Pressure	60 barg	60 barg	Pipeline pressure
Averaging time	Flammable – 18.75 s	Flammable – 18.75 s	DNV PHAST
Exposure duration	60 s	60 s	HSA recommended (HSA, 2023)
Release height	0 m	0 m	Underground pipeline in outdoor areas
Release direction	Vertical	Vertical	HSA TLUP, below ground pipeline
Effect height	1.5 m	1.5 m	Average height of person
Wind speed	5 m/s (daytime), 2 m/s (nighttime)	5 m/s (daytime), 2 m/s (nighttime)	Recommended by HSA as representative modelling conditions
Pasquill Stability Factor	D (daytime conditions) F (stable nighttime conditions)	D (daytime conditions) F (stable nighttime conditions)	
Temperature	10 degC (F2) 15 degC (D5)	10 degC (F2) 15 degC (D5)	HSA TLUP (HSA 2023)

Table 10 Natural Gas Pipeline Full Rupture: Discharge Model Inputs

6.1.2 CCGT Pipeline Release Discharge Model Outputs

For a natural gas pipeline release, the long pipeline discharge model is used with a time varying release. A time varying release follows valve closure immediately after the loss of containment occurs.

Figure 5 illustrates the Release Rate vs Time of natural gas following pipeline rupture.

Figure 5 Natural Gas Pipeline Full Rupture: Release Rate vs Time

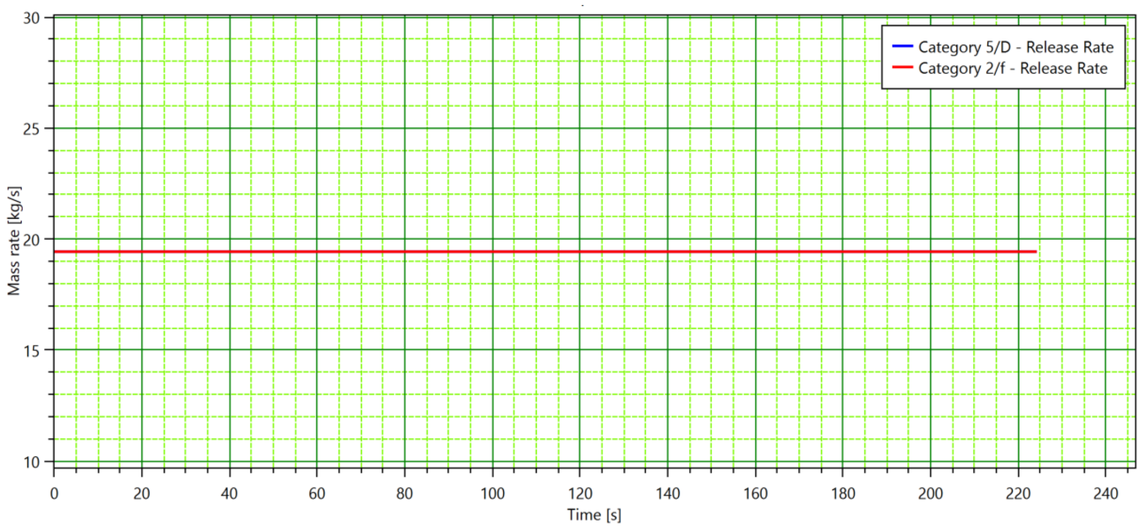


Figure 6 Natural Gas Pipeline Leak (10% of diameter): Release Rate vs Time

6.1.3 CCGT Natural Gas Pipeline Release: Predicted Phenomena

The unified dispersion model in DNV PHAST Version 8.7 predicts the following phenomena for each release scenario:

- Pipeline Rupture: Jet fire or fireball (immediate ignition), VCE or flash fire (delayed ignition)
- Pipeline leak, 10% of diameter: Jet fire or fireball (immediate ignition) or flash fire (delayed ignition)

6.1.4 CCGT Natural Gas Pipeline Release and Jet Fire

The (DNV Recommended) jet fire cone model was used to calculate the thermal radiation consequences from natural gas jet fires at the Power Plant Area.

As per HSA TLUP guidelines (HSA, 2023), jet fire results are presented for vertical releases.

Parameter	Pipeline Rupture and Jet Fire		Pipeline leak, 10% of diameter and Jet Fire	
	D5	F2	D5	F2
Calculated Mass flow rate	578 kg/s	589 kg/s	19.4 kg/s	19.7 kg/s
Release/jet fire duration	6.5 s	6.5 s	224 s	224 s
Flame Length (vertical flame)	126 m	162 m	29.1 m	29.4 m
Flame Lift-Off Distance	22.4 m	31.0 m	5.1 m	5.2 m
Flame Diameter	0.99 m	0.99 m	0.17 m	0.17 m

Table 11 Natural Gas Pipeline Release Scenarios: Jet Flame Parameters

Figure 7 and Figure 8 illustrate the thermal radiation *vs* distance profile for a jet fire following pipeline rupture and pipeline leak. Figure 10 and Figure 12 illustrate the thermal dose vs distance profile for a jet fire following pipeline rupture and pipeline leak.

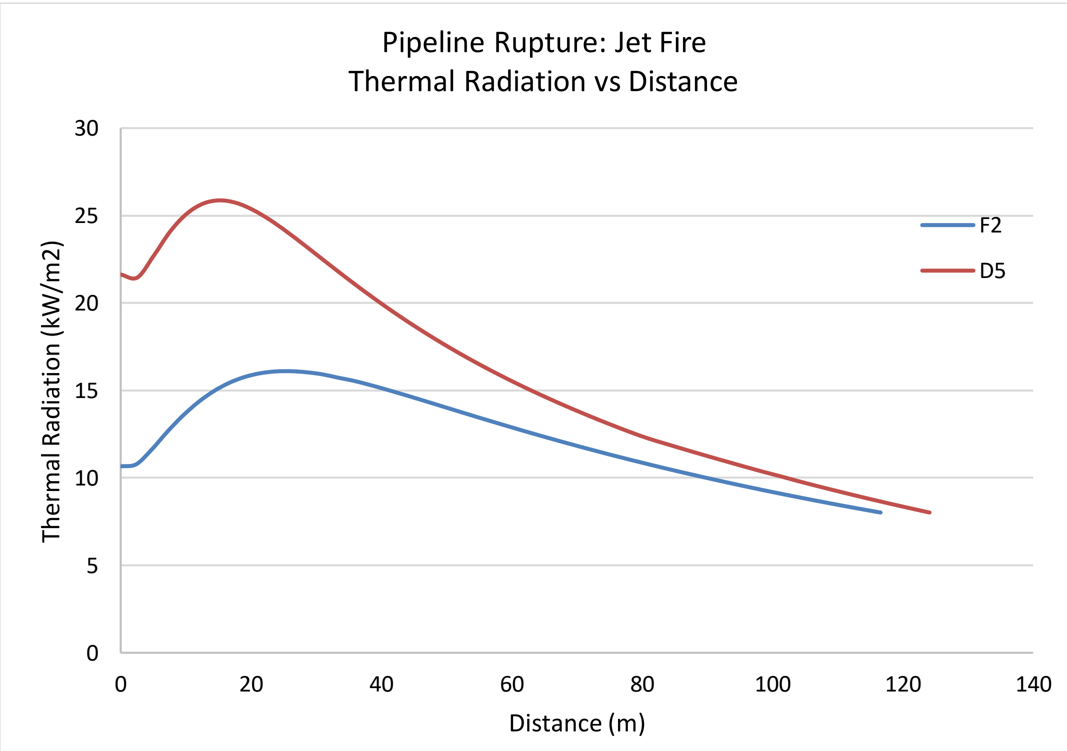


Figure 7 Pipeline Rupture and Jet Fire: Thermal Radiation vs Distance

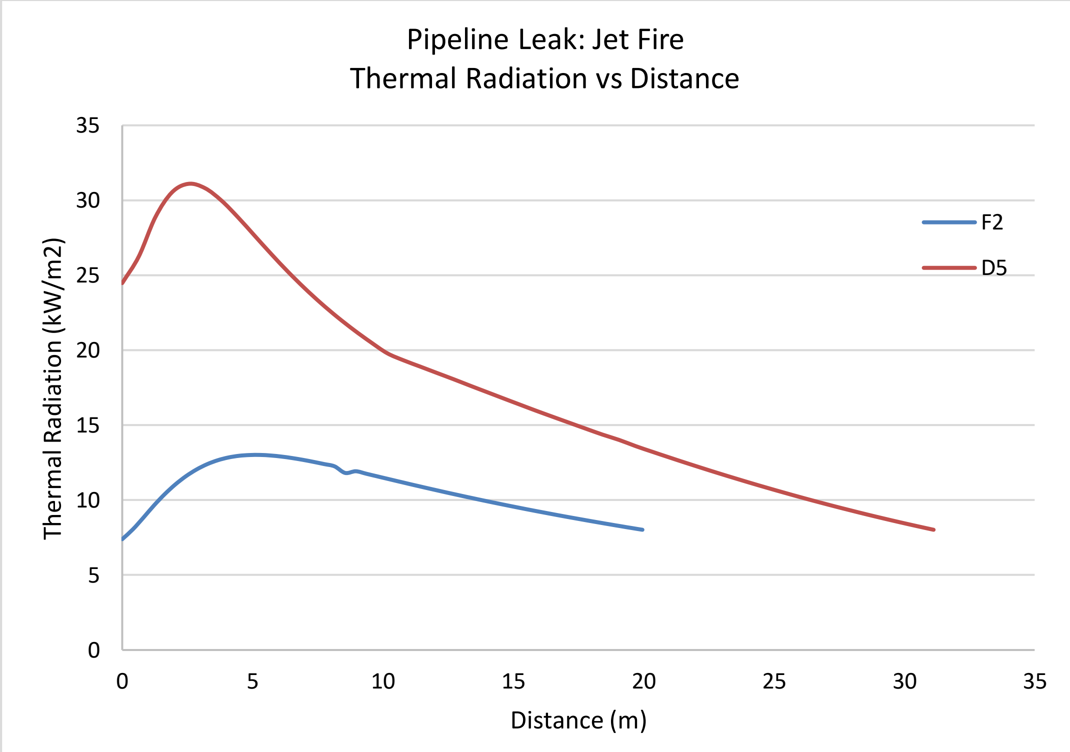


Figure 8 Pipeline Leak and Jet Fire: Thermal Radiation vs Distance

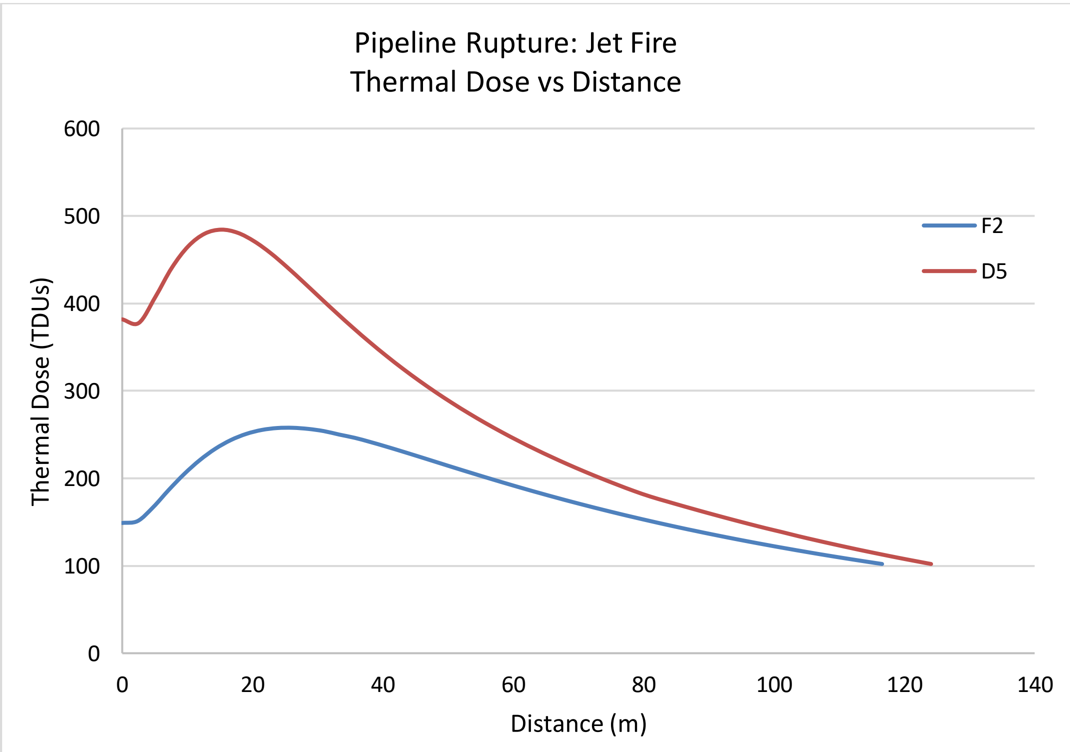


Figure 9 Pipeline Rupture and Jet Fire: Thermal Dose vs Distance

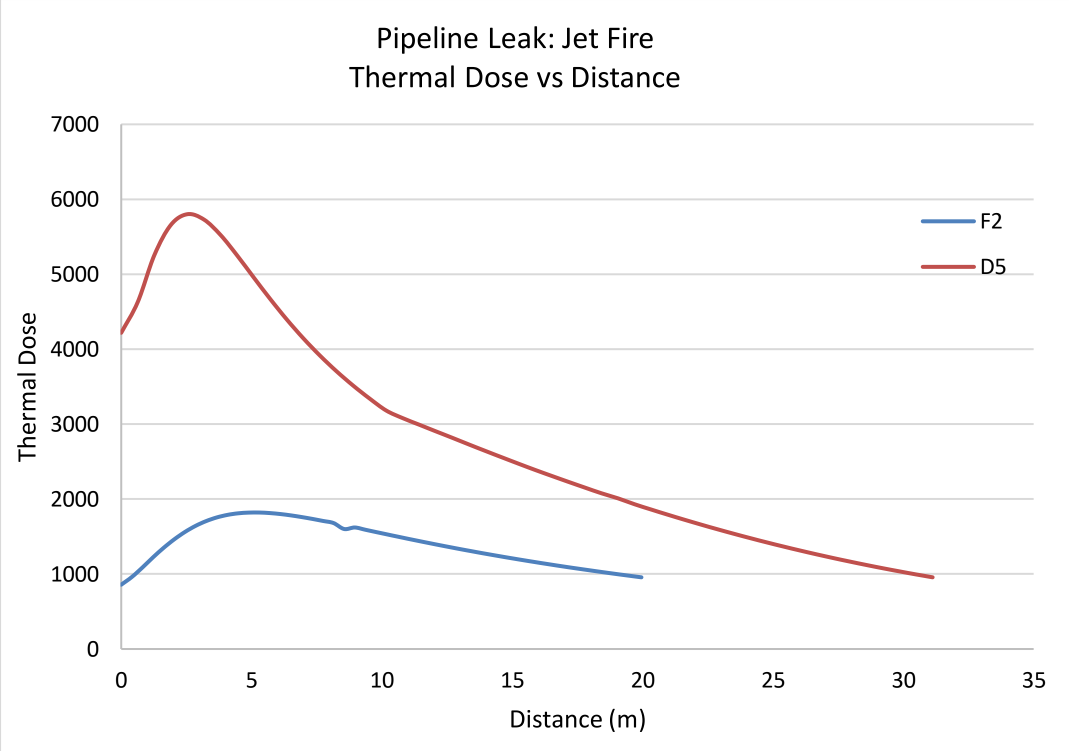


Figure 10 Pipeline Leak and Jet Fire: Thermal Dose vs Distance

Table 12 details distances to specified thermal radiation levels, at a receiver height of 1.5m, associated with

- 1%, mortality outdoors
- 0% mortality and 100% mortality indoors

Consequence	Thermal Dose	Thermal Radiation	Pipeline Rupture Distance (m)		Pipeline leak Distance (m)	
		kW/m^2	Cat. D5	Cat. F2	Cat. D5	Cat. F2
1% mortality outdoors	963	42.96*/8.02	-	-	31	20
0% mortality indoors	1777	12.7	78	62	22	8
100% mortality indoors	4527	25.6	18	-	7	-

Table 12 Natural Gas Pipeline Full Rupture and Jet Fire: Calculated Distances at Specified Thermal Radiation Levels (receiver height 1.5m) (*adjusted for exposure duration)

Due to the short duration of the jet fire following pipeline rupture, the thermal dose corresponding to physical consequences are not reached.

Figure 12 illustrates the thermal radiation contours and effect areas corresponding to 1% fatality outdoors for a pipeline leak and jet fire, for a receiver height 1.5m, for the worst-case weather scenario (D5).

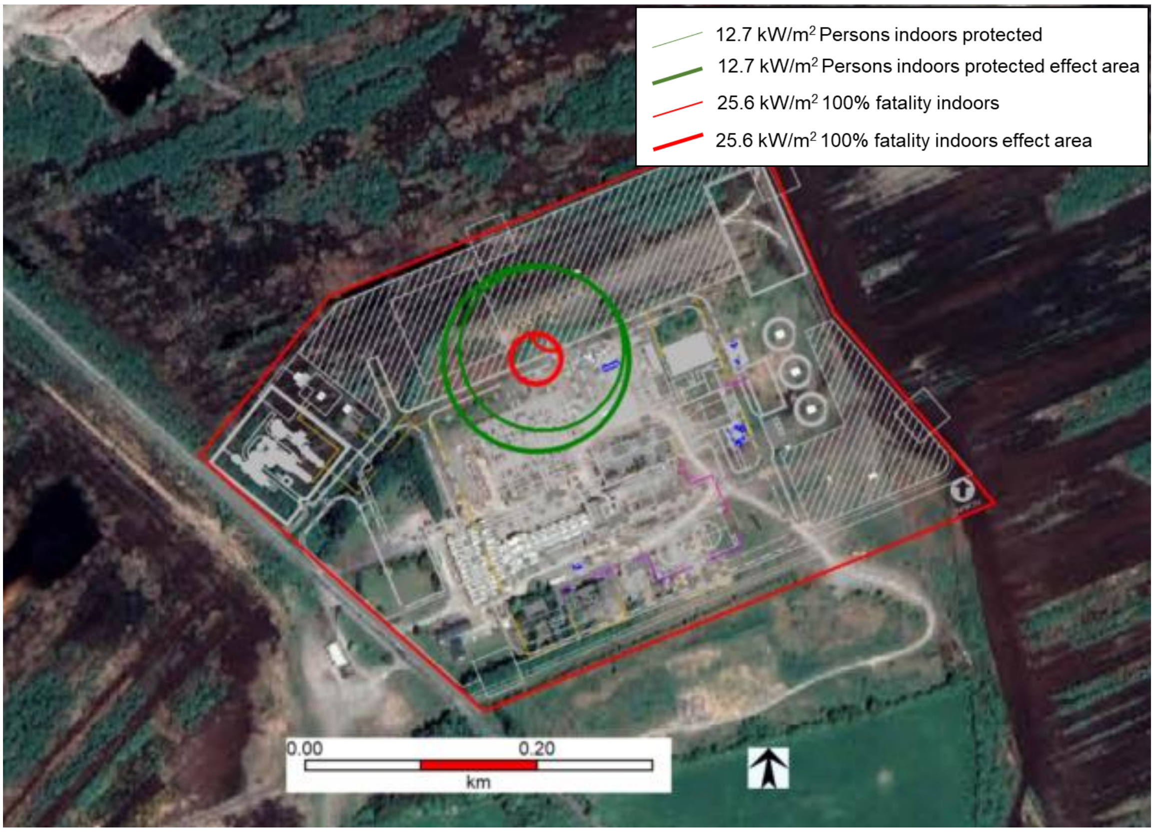


Figure 11 Natural Gas Pipeline Release and Jet Fire: Indoor Fatality Thermal Radiation Contours

Figure 12 Natural Gas Pipeline Leak and Jet Fire: Thermal Radiation Contours Corresponding to 1% Fatality Outdoors

It is concluded that in the event of a jet fire following a release from a natural gas pipeline, the thermal radiation level corresponding to 1% mortality outdoors and thermal radiation corresponding to indoor fatality does not extend over the Power Plant Area boundary.

It is concluded that no off-site fatalities are predicted for a jet fire following a rupture or leak in the CCGT natural gas pipeline.

6.1.5 CCGT Natural Gas Pipeline Release: Fireball Results

The HSE fireball model is used in this study. This is a static fireball model and assumes that the fireball is located on the ground with no lift-off.

In the event of a natural gas pipeline rupture scenario (and direct ignition), the HSE fireball model calculates a fireball radius of 46.6 m, and a fireball duration is 7.2 s.

In the event of a natural gas pipeline leak scenario (10% of diameter) (and direct ignition), the HSE fireball model calculates a fireball radius of 8.6 m, and a fireball duration is 1.3 s.

Figure 13 and Figure 14 illustrates the thermal radiation with distance for a fireball following pipeline rupture or leak (0.1D) respectively.

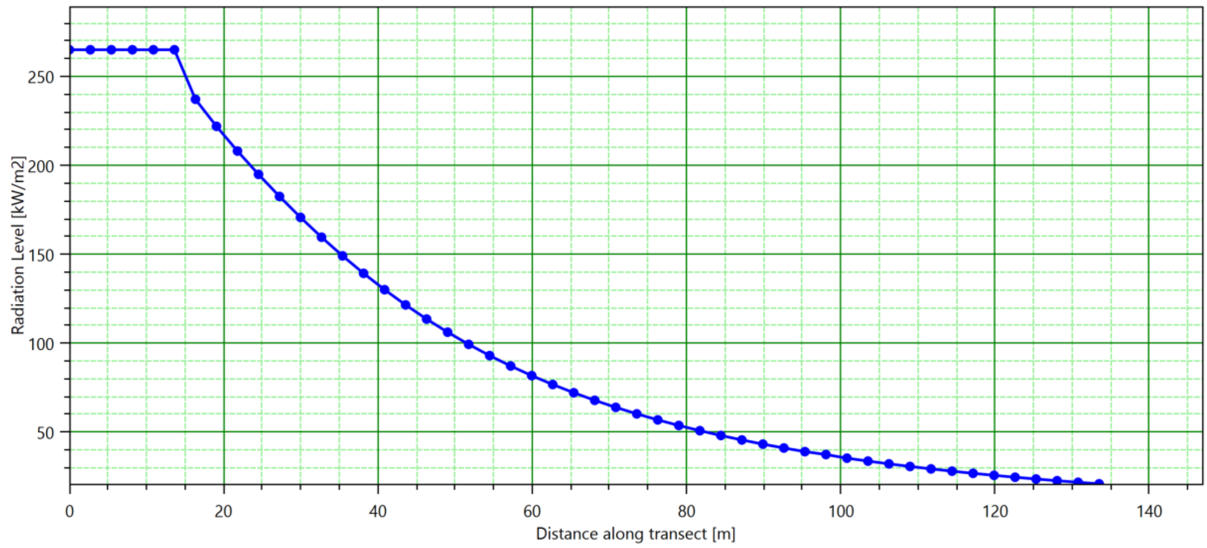


Figure 13 CCGT Natural Gas Pipeline Rupture and Fireball: Thermal Radiation vs. Distance

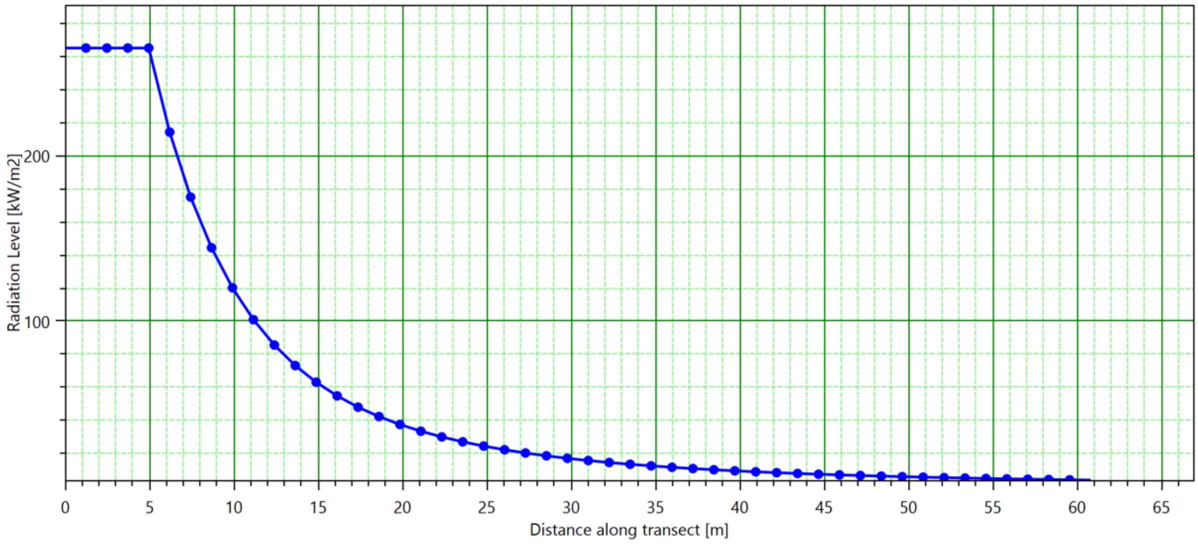


Figure 14 CCGT Natural Gas Pipeline Leak (10% Diameter) and Fireball: Thermal Radiation vs. Distance

Figure 15 illustrates thermal dose ($I^{1.33}$.t) based on the exposure duration (t) of the fireball.

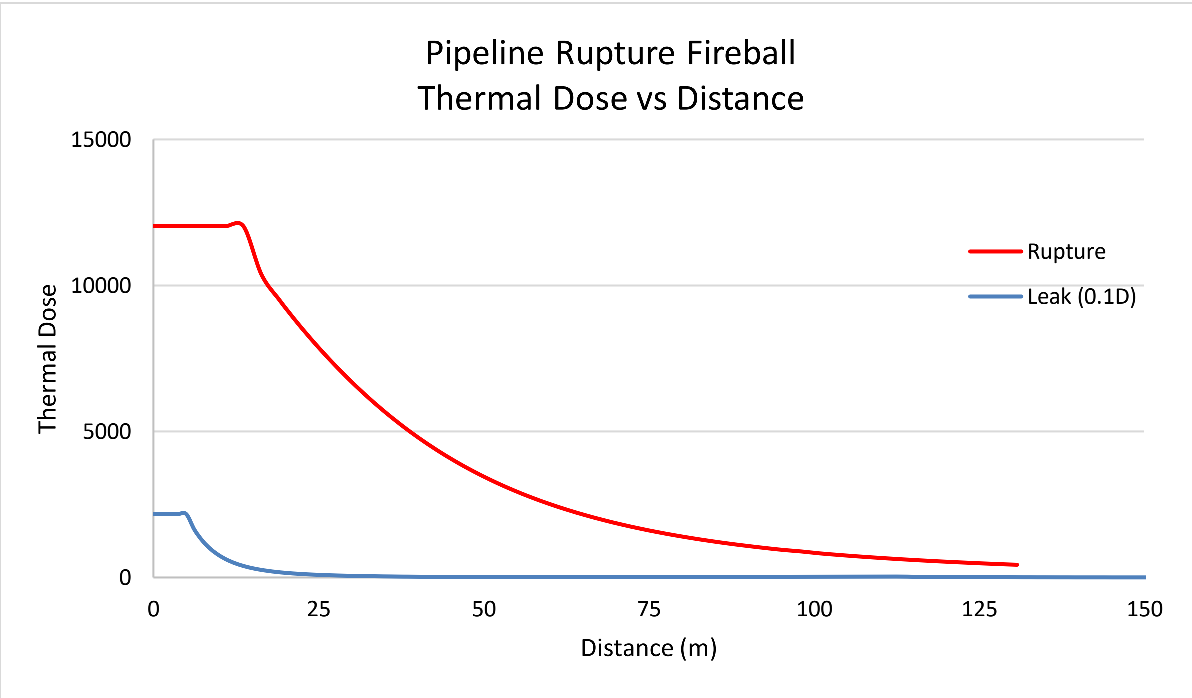


Figure 15 CCGT Natural Gas Pipeline Rupture and Fireball: Thermal Dose vs. Distance

Table 13 details the distances to thermal dose levels associated with specified levels of probability of fatality based on the Eisenberg Probit equation described in Section 4.2.

Criterion	Thermal Dose Level	Thermal Radiation	Rupture Distance	Leak (10% Diameter) Distance
	TDUs	kW/m^2	m	m
1% fatality	963	41.37 / 84.43	93	9
100% fatality	Fireball radius	-	47	9
Building protected below this level, 0% fatality probability	1777	12.7	172	35
Building will catch fire quickly, 100% fatality probability	4527	25.6	120	24

Table 13 CCGT Natural Gas Pipeline Rupture and Fireball: Distances to Specified Thermal Dose Levels

Figure 16 illustrates the thermal radiation contours corresponding to outdoor lethality levels.

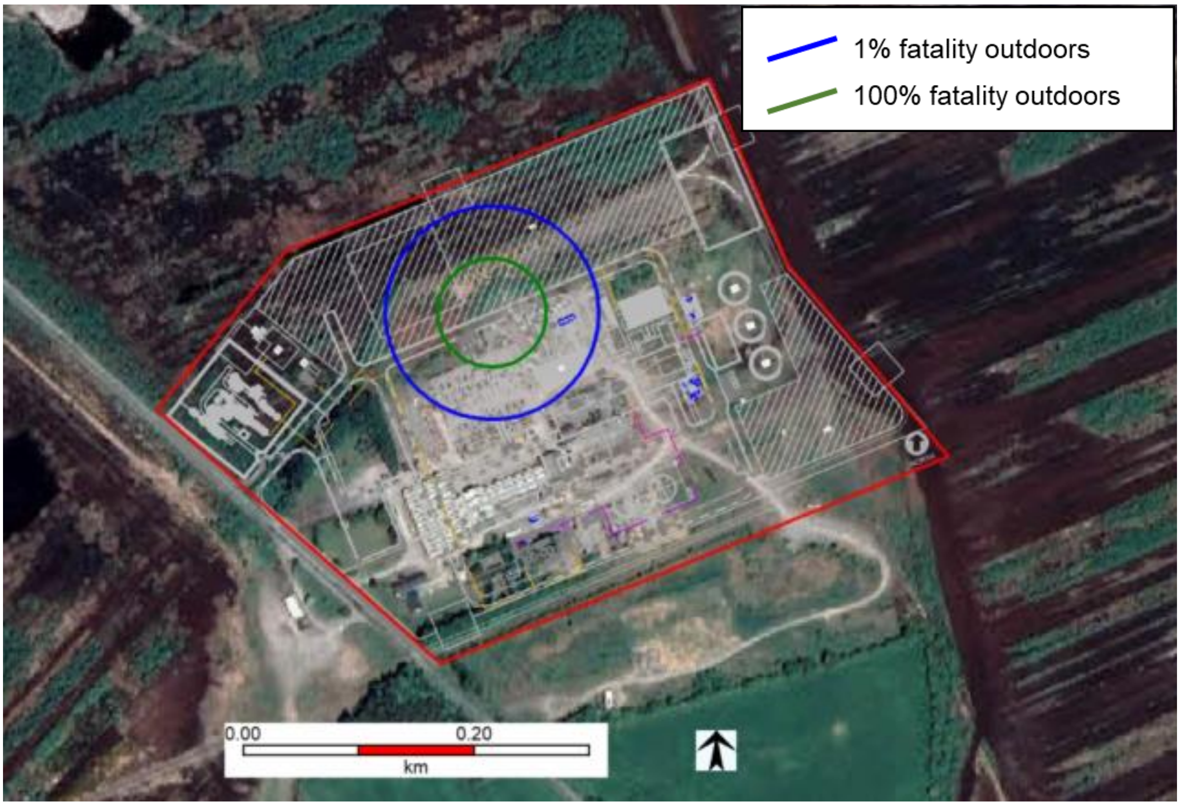


Figure 16 Natural Gas Pipeline Rupture and Fireball: Outdoor Fatality Contours

Figure 17 Natural Gas Pipeline Rupture and Fireball: Indoor Fatality Contours

It is concluded that the thermal radiation consequences corresponding to 1% fatality outdoors, following a fireball at the CCGT pipeline, does not extend over the Power Plant Area boundary. The thermal radiation contour corresponding to persons protected indoors extends over the site boundary but does not extend to any off site receptors.

It is concluded that no off-site fatalities are predicted for a fireball following a rupture or leak in the CCGT natural gas pipeline.

6.1.6 CCGT Natural Gas Pipeline Release: VCE Results

The TNO Multi Energy model was used to model the overpressure consequences in the event a VCE following rupture of a natural gas pipeline. As the natural gas pipeline is buried the VCE is modelled for a vertical release. The long pipeline model calculates that a VCE, in the event of a leak in the pipeline, does not occur as there is insufficient build-up of natural gas.

Figure 18 illustrates the overpressure vs distance profile for a rupture in the CCGT natural gas pipeline and VCE. There was

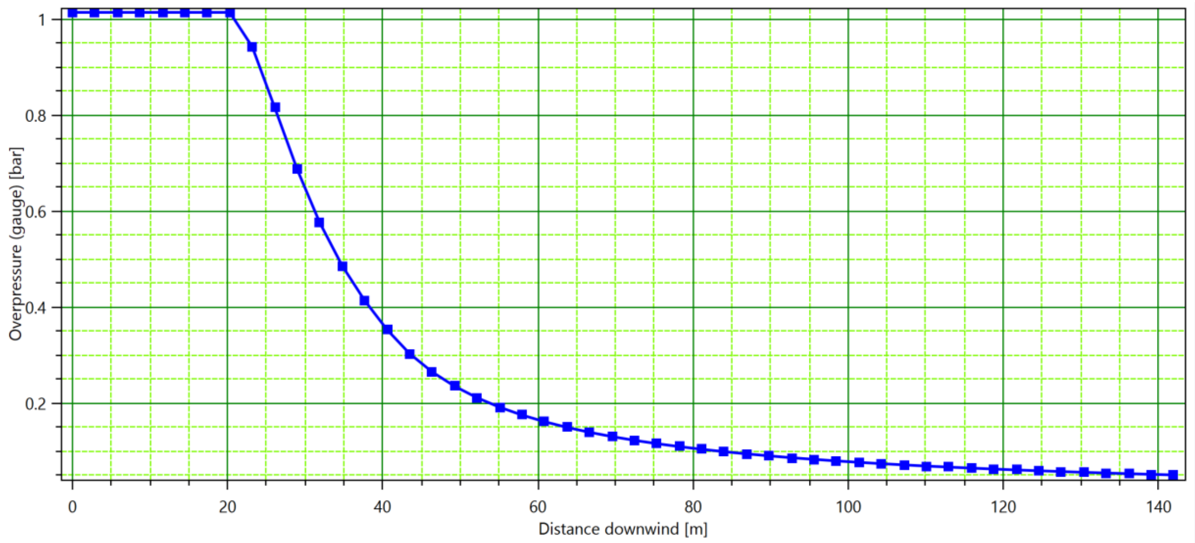


Figure 18 CCGT Natural Gas Pipeline Rupture and VCE: Overpressure vs Distance

Table 14 details the distances to specified overpressure endpoints.

Peak overpressure (mbar)	Consequences	Distance (m)	
		F2	D5
35	Light damage	252	193
170	Moderate damage	76	60
350	Severe damage	51	40
830	Total destruction	31	25
168	1% mortality outdoors	76	60
50	1% mortality indoors CIA Category 3	186	143

Table 14 Natural Gas VCE following CCGT Pipeline Release: Distances to Specified Overpressure Endpoints

Figure 19 illustrates the overpressure contour corresponding to 1% fatality outdoors.

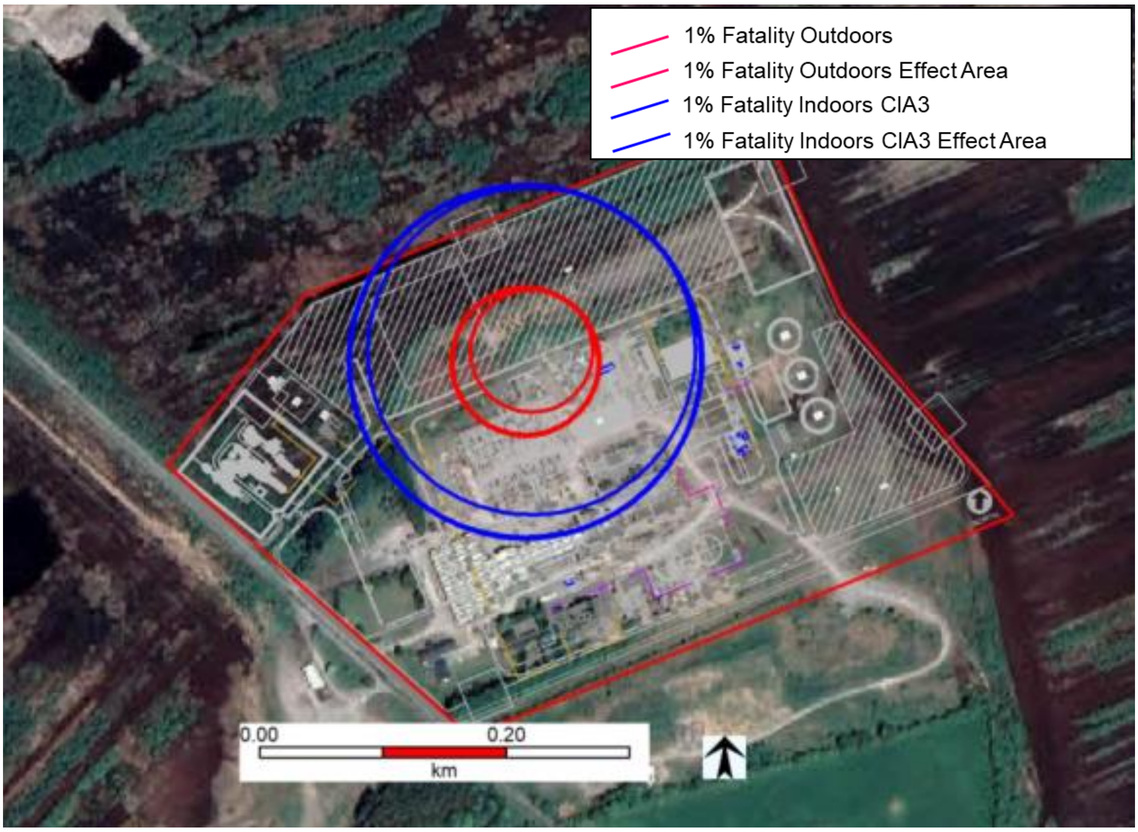


Figure 19 CCGT Natural Gas Pipeline Rupture and VCE: 1% Fatality Outdoors and Indoors Contours

It is concluded that the overpressure consequences corresponding to 1% fatality outdoors, following a VCE at the CCGT pipeline, does not extend over the Power Plant Area boundary. The overpressure contour corresponding to 1% fatality indoors CIA3 (representative of residential buildings) extends over the site boundary but does not extend to any off site receptors.

It is concluded that no off-site fatalities are predicted for a VCE following a rupture or leak in the CCGT natural gas pipeline.

6.1.7 CCGT Natural Gas Pipeline Release: Flash Fire Results

The DNV PHAST Version 8.7 unified dispersion model predicts the flash fire footprints illustrated on the following figures for natural gas pipeline release scenarios. The flash fire envelope and side view at the LFL concentration are shown in the following figures. As the natural gas pipeline is buried the flash fire is modelled for a vertical release.

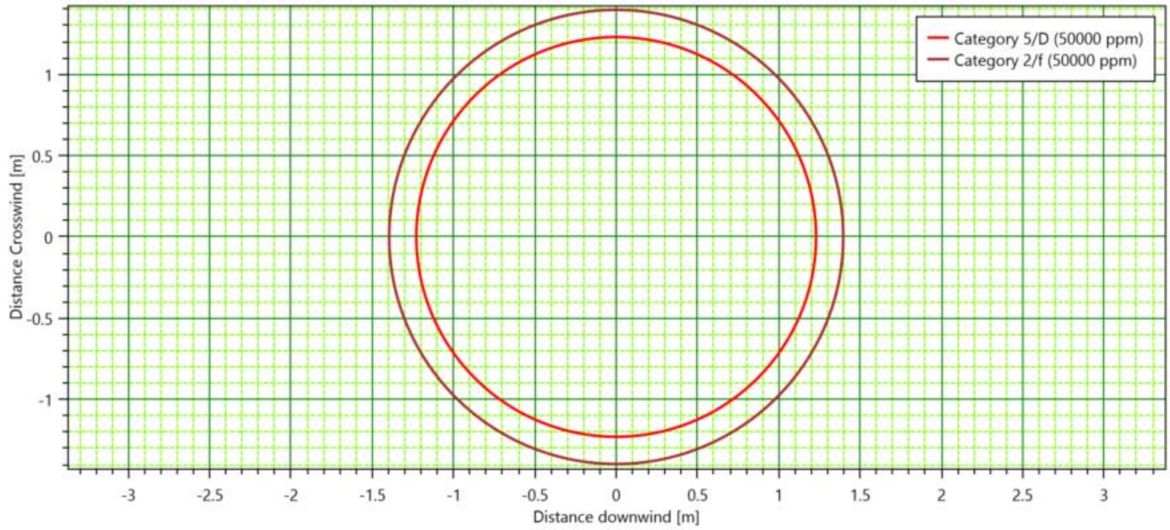


Figure 20 Natural Gas Pipeline Rupture: Flash Fire Footprint

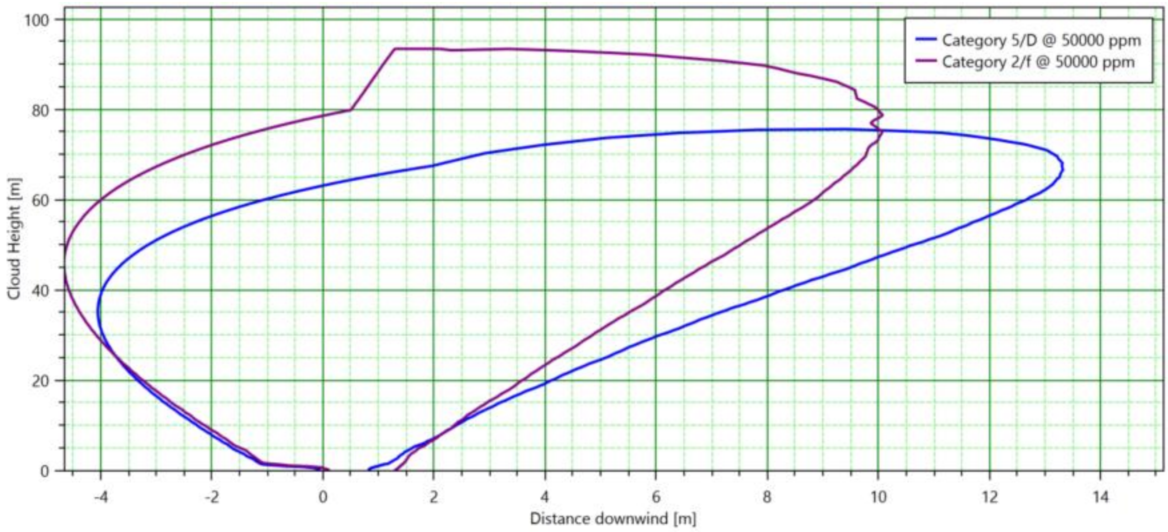


Figure 21 Natural Gas Pipeline Rupture: Side View of Cloud at LFL Concentration

In the event of a flash fire following rupture of the natural gas pipeline, the following is concluded:

- The Lower Flammability Limit extends up to 1.4 m from the pipeline at a receiver height of 1.5m.
- The maximum flash fire extent occurs 13 m downwind at a height of 65 m above ground level

It is concluded that a flash fire is unlikely to have any off-site thermal radiation consequences.

6.1.8 Event Frequencies

Table 15 details the natural gas pipeline specifications for the 3 No. buried pipelines on site.

Pipeline	Diameter (mm)	Length (m)	Operating Pressure (barg)
CCGT	500	470	60
OCGT	300	340	38
Auxiliary Boiler	50	150	38

Table 15 Natural Gas Pipeline Specification

Table 41 of the HSA's TLUP guidelines (HSA, 2023) gives the following pipeline loss of containment frequencies for underground natural gas pipelines within an establishment of diameter > 150 mm:

- Pipeline rupture frequency: 1E-08 per m per year
- Pipeline leak (10% of diameter) frequency: 5E-08 per m per year

Table 41 of the HSA's TLUP guidelines (HSA, 2023) gives the following pipeline loss of containment frequencies for underground natural gas pipelines within an establishment of diameter <75 mm:

- Pipeline rupture frequency: 1E-07 per m per year
- Pipeline leak (10% of diameter) frequency: 5E-07 per m per year

Methane is categorised as of low reactivity and the following ignition probabilities are specified in Table 42 of the HSA's TLUP guidelines (HSA, 2023):

- Fireball/Jet fire: 0.1
- Flash fire: 0.9 x 0.6 = 0.36
- VCE: 0.9 x 0.4 = 0.54

Table 16 summarises the event frequencies for a major accident at the natural gas pipeline.

Installation	LOC scenario	LOC frequency		Modifier	LOC frequency /year	Consequence	Conditional probability	Event frequency (per year)
CCGT Natural Gas Pipeline 60 barg, 470m	Pipeline rupture	1.00E-08	/m/yr	470	4.70E-06	Jet fire/Fireball	0.1	4.70E-07
						VCE	0.54	2.54E-06
						Flash fire	0.36	1.69E-06
	Pipeline leak (10% of diameter)	5.00E-08	/m/yr	470	2.35E-05	Jet fire/Fireball	0.1	2.35E-06
						VCE	0.54	1.27E-05
						Flash fire	0.36	8.46E-06
OCGT Natural Gas Pipeline 38 barg, 340m	Pipeline rupture	1.00E-08	/m/yr	340	3.40E-06	Jet fire/Fireball	0.1	3.40E-07
						VCE	0.54	1.84E-06
						Flash fire	0.36	1.22E-06
	Pipeline leak (10% of diameter)	5.00E-08	/m/yr	340	1.70E-05	Jet fire/Fireball	0.1	1.70E-06
						VCE	0.54	9.18E-06
						Flash fire	0.36	6.12E-06
Auxiliary Boiler Natural Gas Pipeline 38 bar, 340m 38 barg, 150m	Pipeline rupture	1.00E-07	/m/yr	150	1.50E-05	Jet fire/Fireball	0.1	1.50E-06
						VCE	0.54	8.10E-06
						Flash fire	0.36	5.40E-06
	Pipeline leak (10% of diameter)	5.00E-07	/m/yr	150	7.50E-05	Jet fire/Fireball	0.1	7.50E-06
						VCE	0.54	4.05E-05
						Flash fire	0.36	2.70E-05

Table 16 Natural Gas Pipeline Event Frequencies

6.2 Natural Gas VCE at CCGT and OCGT Turbine Enclosures

6.2.1 VCE Model Inputs

Gexcon Effects version 12.1.1 was used to calculate the Multi Energy model overpressures resulting from a VCE in one of the turbine enclosures.

It is assumed that an accidental release of natural gas occurs in a turbine enclosure. In order for a vapour cloud explosion to occur, the concentration of natural gas must lie between the lower and upper flammable limits. It is assumed that concentration within the turbine enclosure is a stoichiometric mixture of air and flammable gas. The complete combustion equation for methane is:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

The volume of the CCGT enclosure will be 1200 m^3 and the volume of the OCGT enclosure will be 562.5. For the purposes of modelling, it is assumed that the entire volume of 1 No. turbine enclosure is available for natural gas accumulation. Therefore, the (mass) fraction of methane within this volume was calculated as 0.056 and the total flammable mass was calculated as 76.61kg at the CCGT and 37.32 kg at the OCGT (see Appendix A for calculation).

The VCE model inputs are detailed in Table 17:

Parameter	Units	Value	Source
Chemical name		methane	-
Temperature	°C	10	30-year average at nearest synoptic meteorological station (Mullingar)
Volume of CCGT enclosure Volume of OCGT enclosure	m^3	1200 562.5	CCGT Enclosure Dimensions (15m *x* 10m *x* 8m) OCGT Enclosure Dimensions (15m *x* 7.5m *x* 5m)
Flammable mass CCGT Flammable mass OCGT	kg	76.61 37.32	See Appendix A for calculation
Fraction of flammable cloud confined	-	1	Confined VCE within turbine enclosure
Curve number	-	7	Very Strong Deflagration: Confined conditions and low ignition energy

Table 17 VCE Model Inputs

6.2.2 VCE Model Outputs

Figure 22 illustrates the overpressure vs distance profile for a VCE in the CCGT turbine and Figure 23 illustrates the overpressure vs distance profile for a VCE in the OCGT turbine.

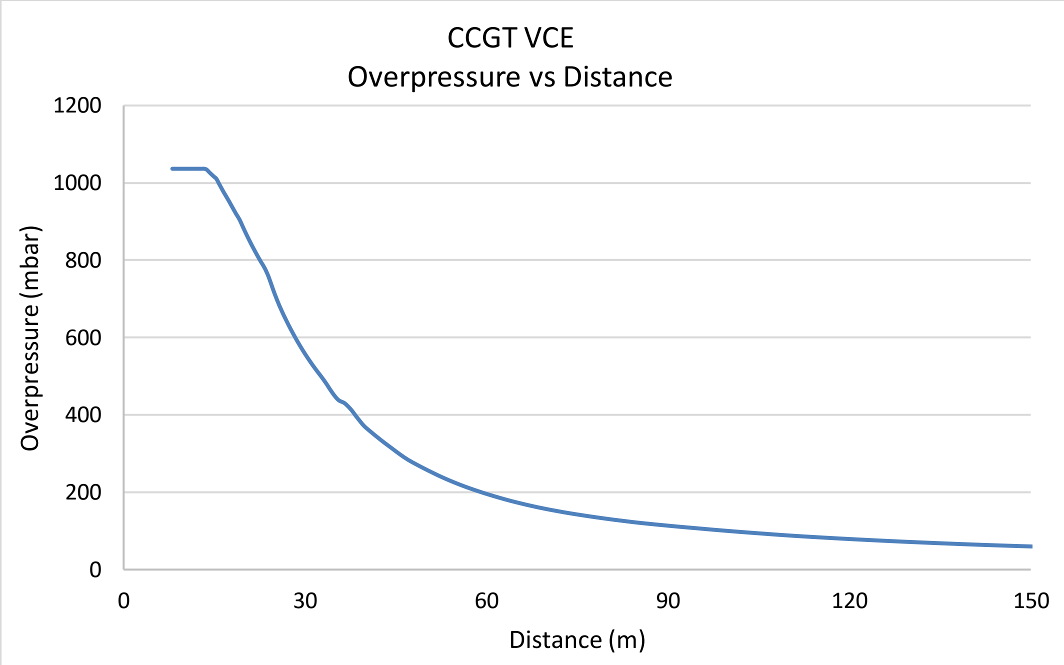


Figure 22 CCGT Natural Gas VCE: Overpressure vs Distance

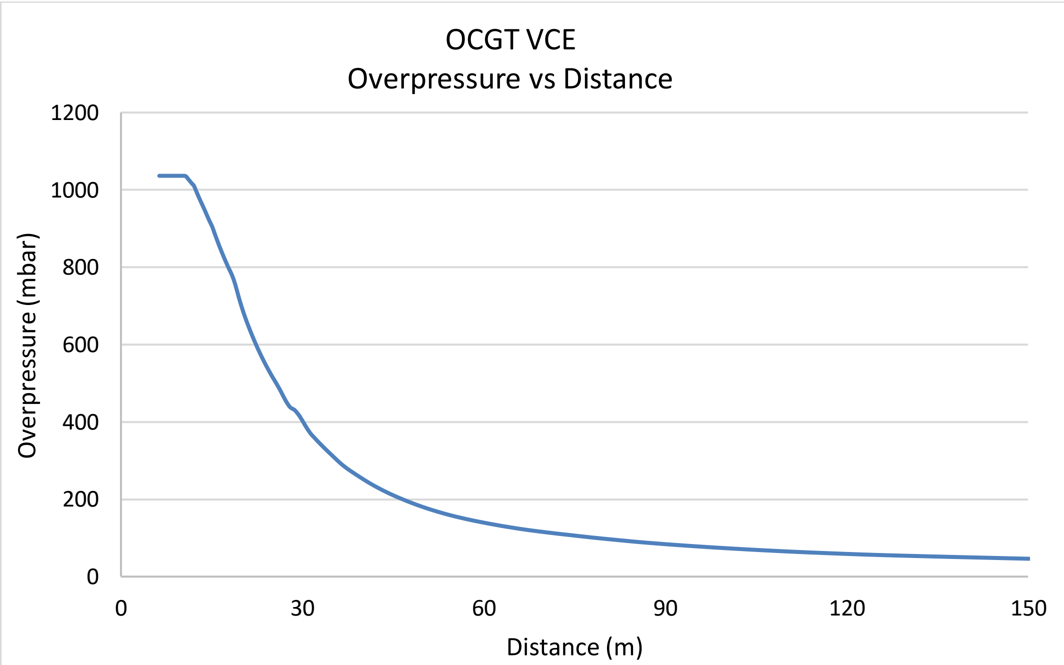


Figure 23 OCGT Natural Gas VCE: Overpressure vs Distance

Table 18 details the distances to specified overpressure endpoints.

Peak overpressure (mbar)	Consequences	CCGT Turbine Distance (m)	OCGT Turbine Distance (m)
35	Light damage	245	192
170	Moderate damage	66	52
350	Severe damage	41	33
830	Total destruction	21	17

Peak overpressure (mbar)	Consequences	CCGT Turbine Distance (m)	OCGT Turbine Distance (m)
168	1% mortality outdoors	67	52
50	1% mortality indoors CIA Category 3	178	140

Table 18 Natural Gas VCE in Turbine Enclosures: Distances to Specified Overpressure Endpoints

The following figures illustrate the overpressure effects following a Natural Gas VCE at a turbine:

- Figure 24 CCGT VCE: Overpressure Contours Corresponding to Fatality Outdoors and Indoors
- Figure 25 OCGT VCE: Overpressure Contours Corresponding to Fatality Outdoors and Indoors

Figure 24 CCGT VCE: Overpressure Contours Corresponding to Fatality Outdoors and Indoors

Figure 25 OCGT VCE: Overpressure Contours Corresponding to Fatality Outdoors and Indoors

The following is concluded for a VCE in the CCGT turbine enclosure:

- The overpressure contour corresponding to 1% mortality outdoors (168 mbar) does not extend over the Power Plant Area
- The overpressure contour corresponding to 1% fatality indoors CIA Cat. 3 (representative of residential dwellings) extends over the Power Plant Area but does not extend to any off-site receptor.

The following is concluded for a VCE in the OCGT turbine enclosure:

- The overpressure contour corresponding to 1% mortality outdoors (168 mbar) does not extend over the Power Plant Area
- The overpressure contour corresponding to 1% fatality indoors CIA Cat. 3 (representative of residential dwellings) extends over the Power Plant Area but does not extend to any off-site receptor.

It is concluded that no off-site fatalities are predicted for a VCE in the CCGT or the OCGT's.

6.2.3 VCE Frequency

The HSA specifies a likelihood of 5E-06 per year when assessing an instantaneous release from a process vessel; for modelling purposes, each turbine is 1 No. of process equipment. A 100% ignition probability indoors is to be assumed.

It is conservatively assumed that a natural gas pipe rupture or leak in a turbine enclosure could also lead to a vapour cloud explosion scenario of the magnitude assessed above. There could be up to 10m of pipeline within each turbine enclosure. Section 6.1.8 details the loss of containment frequencies for a natural gas pipeline.

In order for there to be a build-up of natural gas in the enclosure, the leak detection and blocking system has to fail. The purple book (2005) states that the failure on demand of a blocking system, such as the one proposed, is 0.01 per demand. This will be applied to the 'release through a 10mm pipe' scenario as a mitigation measure.

Table 19 details the events and corresponding frequencies that could lead to a VCE within the CCGT enclosure.

Installation	LOC scenario	LOC frequency		Consequence	Conditional Prob.	Event freq. (per turbine)
Indoor equipment (release in Turbine enclosure)	Equipment rupture/leak	5E-06	/yr	VCE	-	5E-06
Indoor equipment (release in Turbine enclosure)	Release over 10 minutes	1E-05	/yr	VCE	-	1E-05
Indoor equipment (release in Turbine enclosure)	Release through 10mm pipe	5E-04	/yr	VCE	0.01	5E-06

Table 19 CCGT Enclosure VCE Event Frequency

Therefore, the total frequency for a VCE within a CCGT enclosure **2.0E-05 per year.**

Table 20 details the events and corresponding frequencies that could lead to a VCE within 1 No. OCGT enclosure. There will be 2 No. OCGT's on-site. The frequency for of a VCE will be applied to each turbine for the risk profile of the site.

Installation	LOC scenario	LOC frequency		Consequence	Conditional Prob.	Event freq. (per turbine)
Indoor equipment (release in Turbine enclosure)	Equipment rupture/leak	5E-06	/yr	VCE	-	5E-06
Indoor equipment (release in Turbine enclosure)	Release over 10 minutes	1E-05	/yr	VCE	-	1E-05
Indoor equipment (release in Turbine enclosure)	Release through 10mm pipe	5E-04	/yr	VCE	0.01	5E-06

Table 20 OCGT Enclosure VCE Event Frequency

Therefore, the total frequency for a VCE within an OCGT enclosure is **2.0E-05 per turbine, per year.**

The turbine enclosures will be compliant with EN 21789 (Gas Turbine Applications – Safety) and will have emergency shutdown valves certified to EN14382. The valves are fail closed and will activate, immediately, when gas is detected at a concentration of 20% Lower Explosion Limit (LEL). In order for there to be a build-up of natural gas in the enclosure, the leak detection and emergency shutdown valves have to fail. Therefore, the frequencies associated with a VCE are extremely conservative.

6.3 LPG Release

There will be 2 No. 1000kg propane tanks on site, serving the CCGT and the OCGTs. The propane tank serving the OCGTs is closer to the Power Plant Area

Instantaneous rupture of an LPG tank has the potential to result in a BLEVE/ (boiling liquid expanding vapour explosion) /fireball, vapour cloud explosion or flash fire event.

The consequences from a catastrophic rupture will be shown in this assessment as a representative worst-case scenario. The consequences from a Continuous Leak over 10 minutes and 10mm pipe leak over 30 minutes will be included in the risk calculation for the Power Plant Area.

6.3.1 LPG Tank Catastrophic Rupture Model Inputs

Catastrophic rupture model inputs are detailed in Table 21. The flammable mass involved in the fireball is 3 x the adiabatic flash vapour mass fraction as calculated by the discharge/dispersion model. The methodology is detailed in the BLEV (Fireball) Theory Review and Validation supporting DNV PHAST software (DNV, 2023).

Parameter	Units	Weather Category	
		F2	D5
Contents	kg	1000	1000
Substance	-	Propane	Propane
Temperature	^{0}C	10	15
Mass modification factor	-	3	3
Burst Pressure (3 *x* design pressure)	barg	42	42
Maximum SEP	kW/m^2	275	275

Table 21 Propane Cylinder Release: Model Inputs

6.3.2 Tank BLEVE/Fireball Model Outputs

Table 22 details the diameter, radius and fireball duration results obtained using the HSE static fireball model.

Parameter	Units	Weather Category	
		F2	D5
No. of vessels	No.	2	2
Fireball diameter, D	m	52.6	54.2
Fireball radius, R	m	26.3	27.1
Fireball duration, T	s	4.2	4.2

Table 22 LPG Tank Rupture: Fireball Model Outputs

Figure 26 illustrates the thermal radiation vs distance profile for an LPG tank fireball and Figure 27 illustrates the thermal dose vs distance profile for an LPG tank fireball.

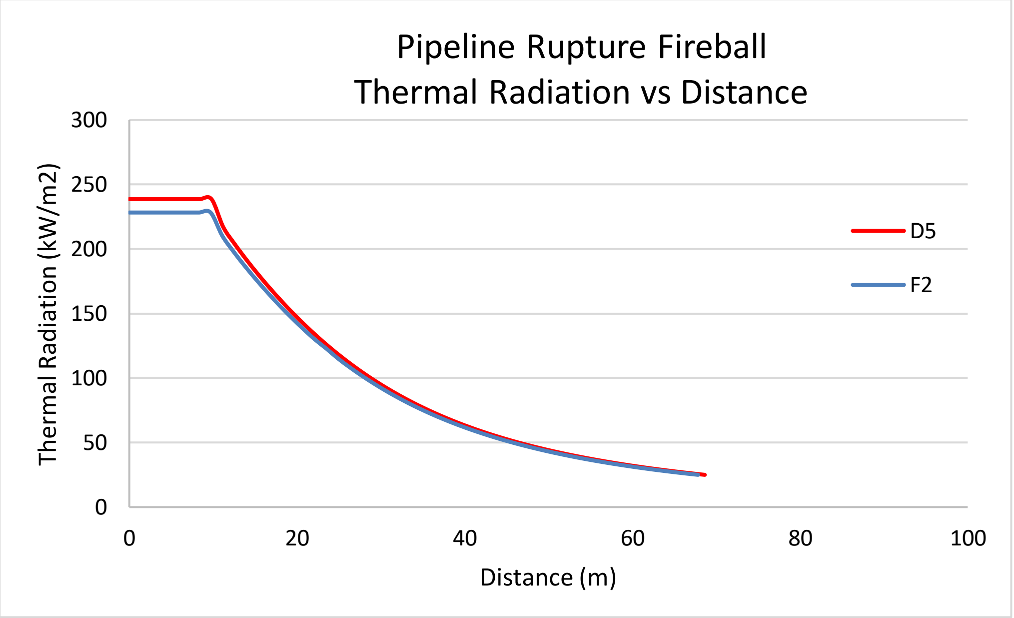


Figure 26 LPG Tank Rupture: Thermal Radiation vs Distance

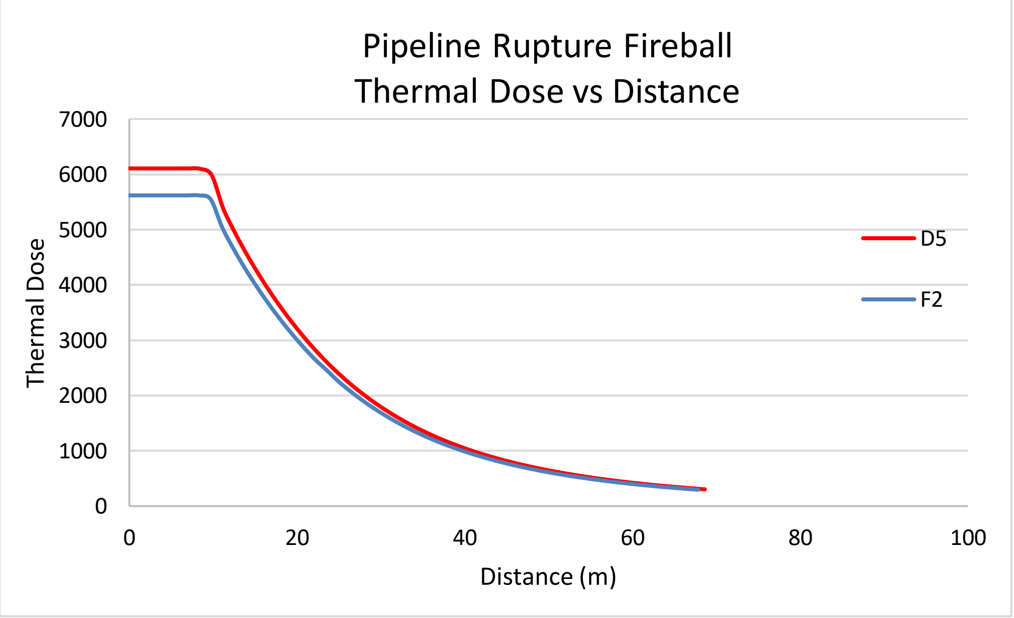


Figure 27 LPG Tank Rupture: Thermal Dose vs Distance

Table 23 details the distances to thermal dose levels associated with specified levels of probability of fatality based on the Eisenberg Probit equation described in Section 4.2.

Criterion	Thermal Dose Level	Thermal Radiation	F2	D5
	TDUs	kW/m^2	Distance (m)	Distance (m)
1% fatality	963	58.9	40	41
100% fatality	Fireball radius	-	26	27
Building protected below this level, 0% fatality probability	1777	12.7	28	30
Building will catch fire quickly, 100% fatality probability	4527	25.6	12	13

Table 23 LPG Tank Rupture: Distances to Thermal Radiation Endpoints

Figure 28 illustrates the thermal radiation contours corresponding to outdoor lethality levels.

Figure 28 LPG Tank Rupture and Fireball: Outdoor Lethality Contours

Figure 29 LPG Tank Rupture and Fireball: Indoor Lethality Contours

It is concluded for a fireball following catastrophic LPG Tank Rupture that the thermal radiation contour corresponding to 1% fatality outdoors does not extend over the Power Plant Area.

The thermal radiation contour corresponding to persons protected indoors extends over the site boundary but does not extend to any off site receptors.

It is concluded that no off-site fatalities are predicted for a fireball following a failure of the LPG tank.

6.3.3 Tank VCE Model Outputs

The flammable mass for each loss of containment scenario is calculated by the unified dispersion mode in PHAST Version 8.7 modelling software.

The explosion strength was specified in the Multi-energy VCE model as 20% of the cloud volume at strength 7 and 80% at strength 2.

The overpressure vs distance profile for a VCE following LPG Tank rupture is illustrated on

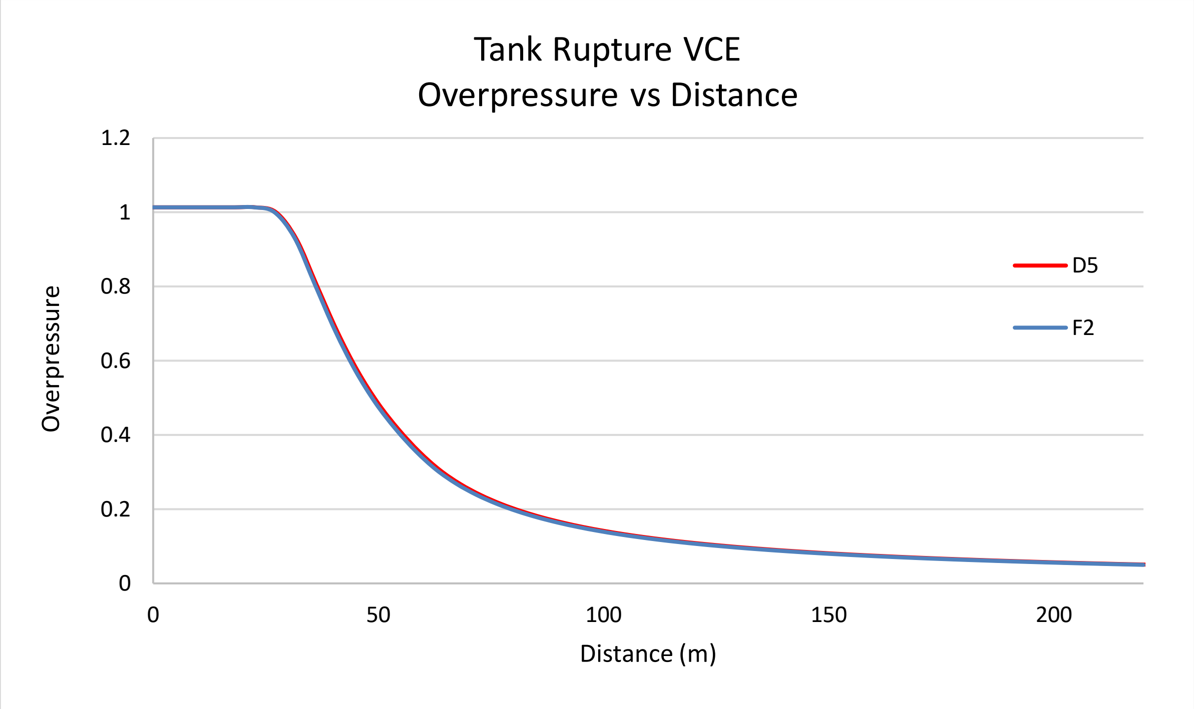


Figure 30 LPG Tank Rupture and VCE: Overpressure vs Distance

Table 24 details the distances to specified overpressure endpoints.

Peak overpressure (mbar)	Consequences	Distance (m)	
		F2	D5
35	Light damage	299	303
170	Moderate damage	88	86
350	Severe damage	59	59
830	Total destruction	35	35
168	1% mortality outdoors	88	89
50	1% mortality indoors CIA Category 3	220	222

Table 24 LPG Tank Rupture and VCE: Distances to Specified Overpressure Endpoints

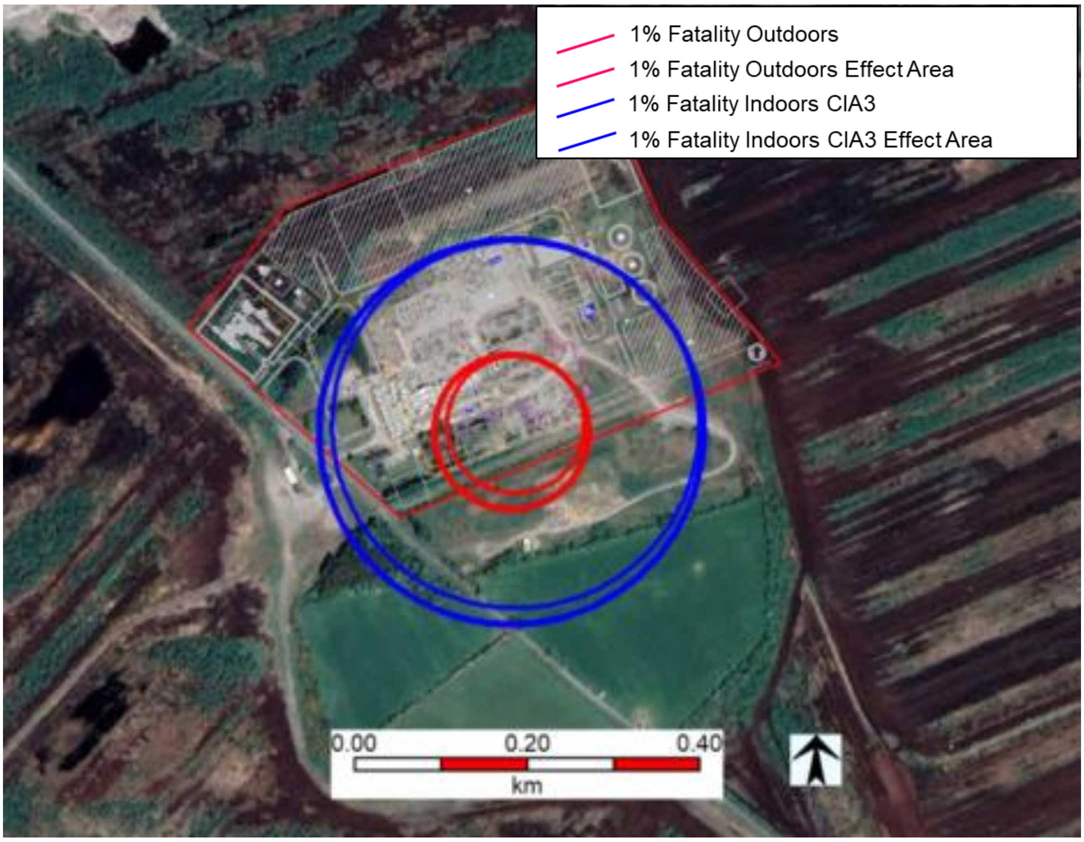


Figure 31 LPG Tank Rupture and VCE: 1% Fatality Outdoors Overpressure Contour

It is concluded that the overpressure contour corresponding to 1% fatality outdoors and 1% fatality indoors CIA3 (representative of residential buildings) extends over the Power Plant Area boundary, but does not extend to any off-site receptor. No off-site fatalities are expected.

6.3.4 Flash Fire Model Outputs

The flash fire envelope was modelled using the unified dispersion model in DNV PHAST Version 8.7 software.

Table 25 details the distance to the LFL concentration (flash fire envelope).

LPG Tank	Flash Fire envelope, distance (m)	
	D5	F2
1000 kg	45	31

Table 25 LPG Tank Rupture and Flash Fire: Flash Fire Envelope

Figure 32 illustrates the flash fire envelope for D5 and F2 weather conditions.

Figure 32 LPG Tank Rupture and Flash Fire: Worst-case Flash Fire Envelope

It is concluded that the flash fire envelope extends slightly over the Power Plant Area boundary to the south. This area is not typically occupied, and no fatalities are expected.

6.3.5 LPG Tanker Instantaneous Failure Model Inputs

Catastrophic rupture model inputs are detailed in Table 26. Table 21 Propane Cylinder Release: Model InputsThe flammable mass involved in the fireball is 3 x the adiabatic flash vapour mass fraction as calculated by the discharge/dispersion model. The methodology is detailed in the BLEV (Fireball) Theory Review and Validation supporting DNV PHAST software (DNV, 2023). LPG Road Tanker deliveries will only take place during the daytime; therefore, only the D5 weather category will be modelled.

Parameter	Units	Weather Category D5
Contents	kg	12000
Substance	-	Propane
Temperature	^{0}C	15
Mass modification factor	-	3
Burst Pressure (3 *x* design pressure, assume tanker pressure equivalent to tank pressure)	barg	42
Maximum SEP	kW/m^2	275

Table 26 LPG Tanker Rupture: Model Inputs

6.3.6 Road Transport BLEVE/Fireball Model Outputs

Table 27 details the diameter, radius and fireball duration results obtained using the HSE static fireball model.

Parameter	Units	Weather Category
		D5
Fireball diameter, D	m	124
Fireball radius, R	m	62
Fireball duration, T	s	9.6

Table 27 LPG Tanker Rupture: Fireball Model Outputs

Figure 33 illustrates the thermal radiation vs distance profile for an LPG tanker fireball and Figure 34 illustrates the thermal dose vs distance profile for an LPG tanker fireball.

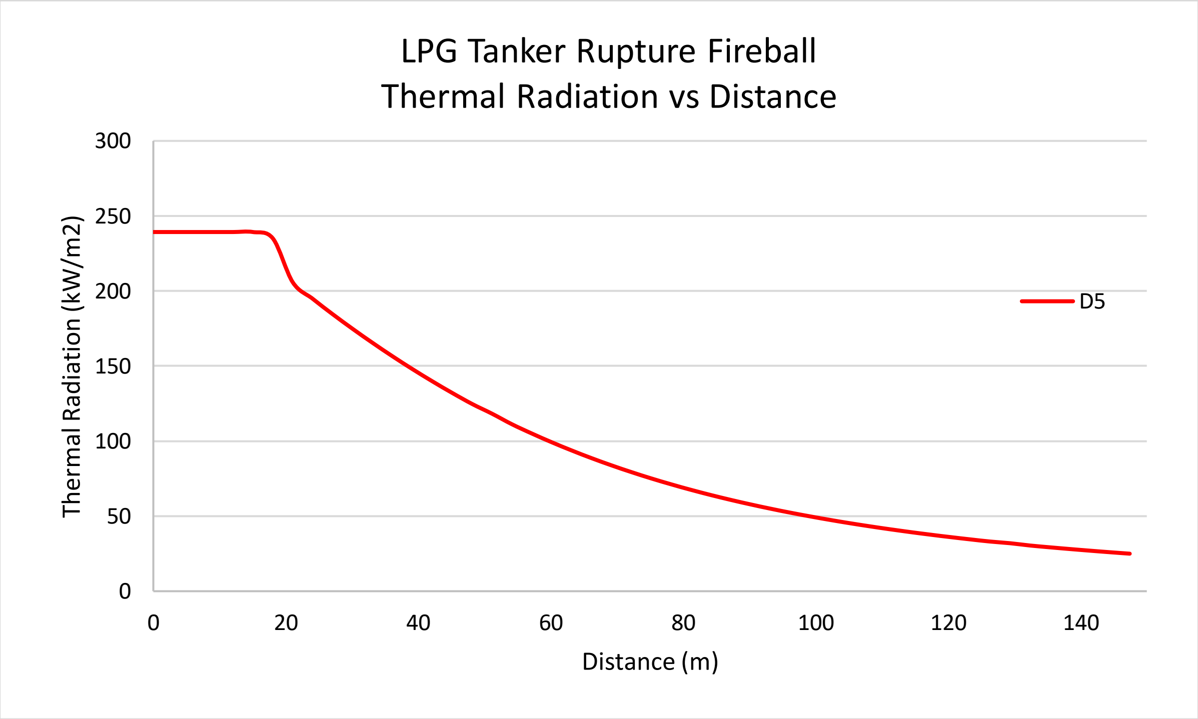


Figure 33 LPG Tanker Rupture: Thermal Radiation vs Distance

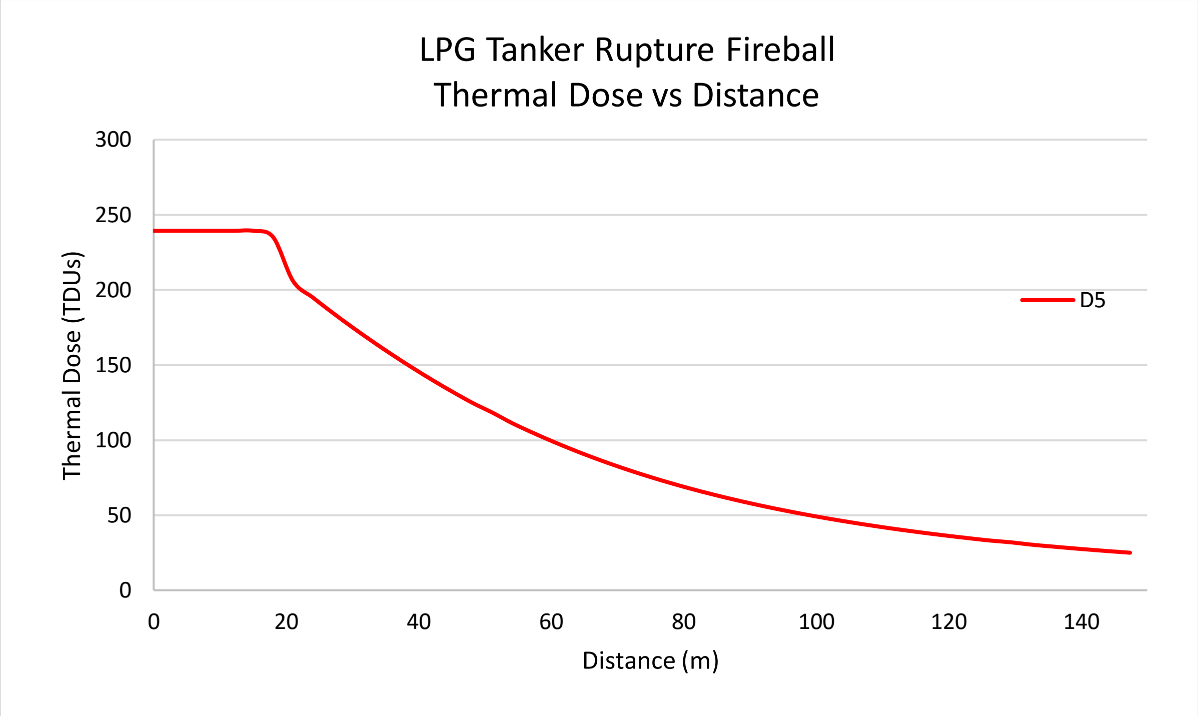


Figure 34 LPG Tanker Rupture: Thermal Dose vs Distance

Table 23 details the distances to thermal dose levels associated with specified levels of probability of fatality based on the Eisenberg Probit equation described in Section 4.2.

Criterion	Thermal Dose Level	Thermal Radiation	D5
	TDUs	kW/m^2	Distance (m)
1% fatality	963	31.7	132
100% fatality	Fireball radius	-	62
Building protected below this level, 0% fatality probability	1777	12.7	212
Building will catch fire quickly, 100% fatality probability	4527	25.6	146

Table 28 LPG Tank Rupture: Distances to Thermal Radiation Endpoints

Figure 35 illustrates the thermal radiation contours corresponding to outdoor lethality levels.

Figure 35 LPG Tanker Rupture and Fireball: Outdoor Lethality Contours

It is concluded for a fireball following catastrophic LPG Tanker Rupture that the thermal radiation contour corresponding to 1% fatality outdoors and persons protected indoors extends over the Power Plant Area boundary to the south, but does not extend to any off-site receptor. No off-site fatalities are expected.

6.3.7 Tanker VCE Model Outputs

The flammable mass for each loss of containment scenario is calculated by the unified dispersion mode in PHAST Version 8.7 modelling software.

The explosion strength was specified in the Multi-energy VCE model as 20% of the cloud volume at strength 7 and 80% at strength 2.

The overpressure vs distance profile for a VCE following LPG Tanker rupture is illustrated on Figure 36.

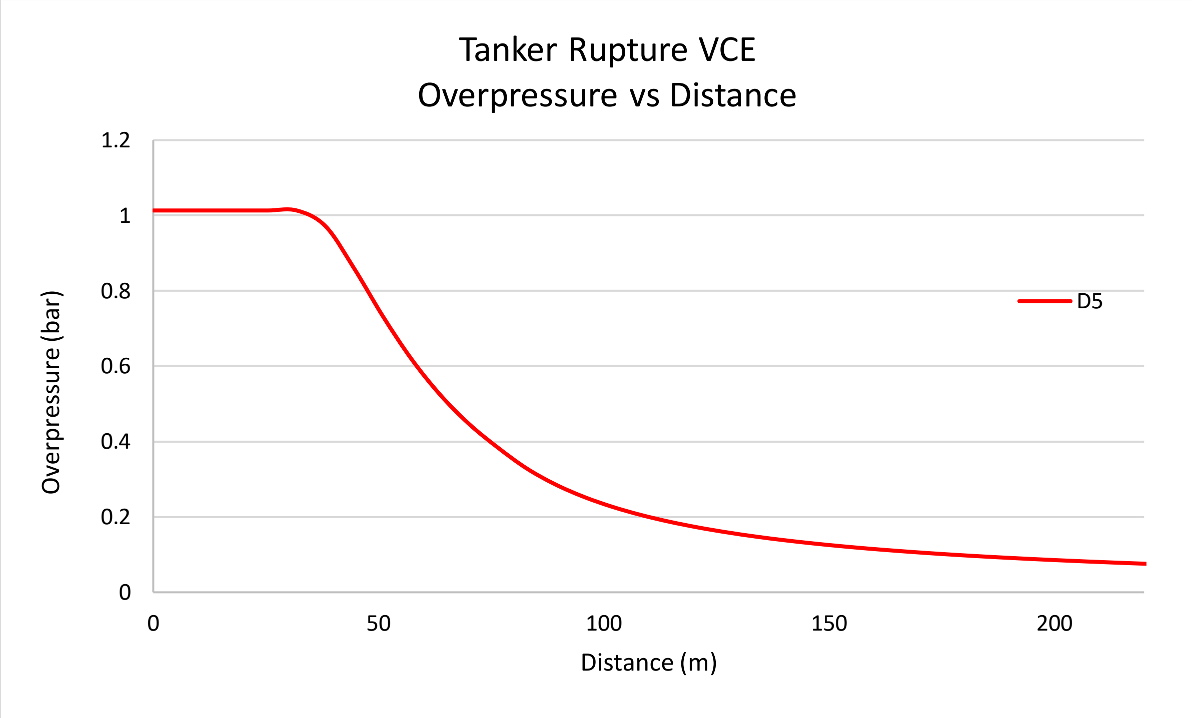


Figure 36 LPG Tanker Rupture and VCE: Overpressure vs Distance

Table 29 details the distances to specified overpressure endpoints.

Peak overpressure (mbar)	Consequences	Distance D5
35	Light damage	426
170	Moderate damage	123
350	Severe damage	79
830	Total destruction	46
168	1% mortality outdoors	123
50	1% mortality indoors CIA Category 3	312

Table 29 LPG Tanker Rupture and VCE: Distances to Specified Overpressure Endpoints

Figure 37 illustrates the overpressure contour corresponding to 1% fatality outdoors.

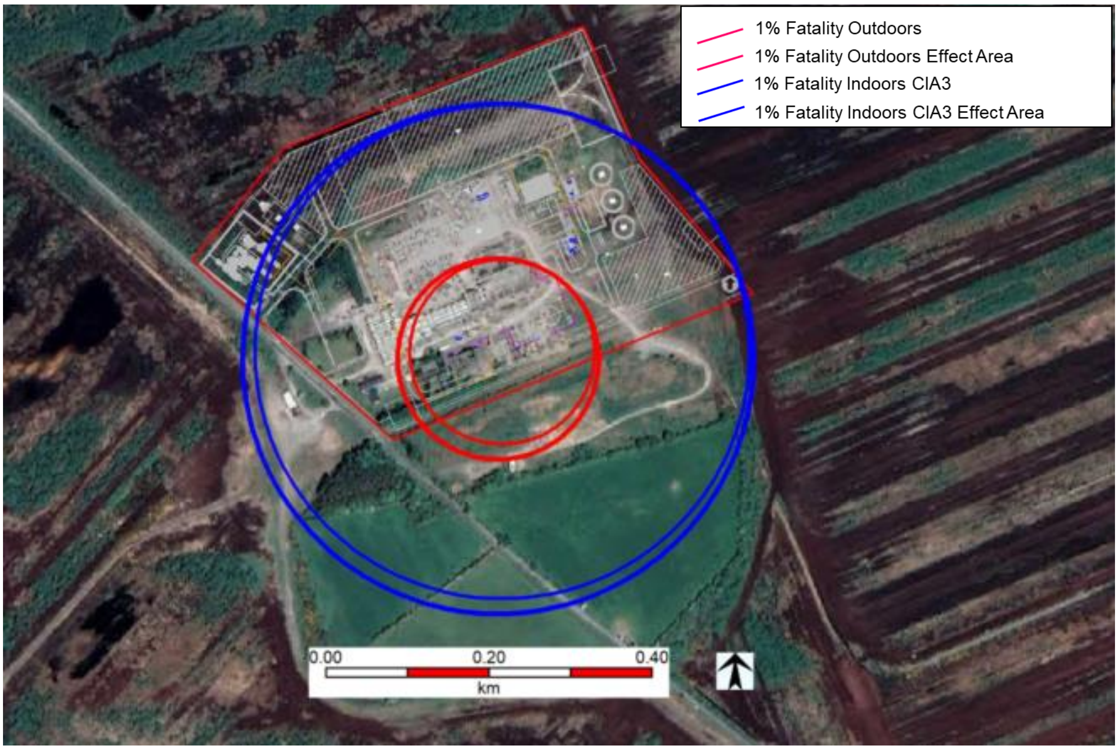


Figure 37 LPG Tanker Rupture and VCE: 1% Fatality Outdoors and Indoors Overpressure Contour

It is concluded that the overpressure contour corresponding to 1% fatality outdoors and 1% fatality indoors CIA3 (representative of residential buildings) extends over the Power Plant Area boundary, but does not extend to any off-site receptor. No off-site fatalities are expected.

6.3.8 Flash Fire Model Outputs

The flash fire envelope was modelled using the unified dispersion model in DNV PHAST Version 8.7 software.

Table 30 details the distance to the LFL concentration (flash fire envelope).

LPG Tanker	Flash Fire envelope, distance (m)
	D5
12000 kg	144

Table 30 LPG Tanker Rupture and Flash Fire: Flash Fire Envelope

Figure 38 illustrates the flash fire envelope for D5 weather conditions.

Figure 38 LPG Tanker Rupture and Flash Fire: Flash Fire Envelope

It is concluded that the flash fire envelope extends over the Power Plant Area boundary to the south. This area is not typically occupied, and no fatalities are expected.

6.3.9 Propane Tank Release Frequencies

Event frequencies are as specified in HSA guidance (HSA, 2023) and are detailed in Table 31.

The road tankers delivering propane to site will have the capacity to store 12 tonnes Road tankers are treated as road transport units and unloading operations will be short due to the low capacity of the LPG tank. Therefore, leaks associated with unloading will be neglected due to the short duration and blocking measures that will be present. It is estimated that there will be 2 deliveries per year for the OCGTs and 12 deliveries per year for the CCGT. The delivery vehicle will be on site for approximately 1.5 hours. Therefore, the fraction that the road tanker is on-site for per year is 0.0021 (18 / 8760). Table 24 of the TLUP states an instantaneous failure frequency and loss of entire contents through largest connection of 5E-07 per year, this is adjusted to 1.20E-09 per year.

Installation	LOC scenario	Consequence	Frequency (per year)
Propane Tank	Instantaneous failure (per tank)	BLEVE/Fireball	3.50E-07
		VCE	6.00E-08
		Flash fire	9.00E-08
	Continuous leak over 10 minutes (per tank)	Jet fire	3.50E-07
		VCE	6.00E-08
		Flash fire	9.00E-08
	10 mm pipe leak over 30 minutes (per tank)	Jet fire	7.00E-06
		VCE	1.20E-06
		Flash fire	1.62E-07
LPG Road Tanker	Instantaneous failure	Fireball	4.79E-10
		VCE	2.88E-10
		Flash fire	4.32E-10
	Loss of contents through largest connection	Jet fire	4.79E-10
		VCE	2.88E-10
		Flash fire	4.32E-10

Table 31 LPG Event Frequencies

7.0 ENVIRONMENTAL RISK ASSESSMENT (MATTE)

7.1 Description of Environmental Receptors

The following sections give a description of the environmental receptors surrounding the site.

7.1.1 Geology

According to the GSI's online map viewer, the entire Site is underlain by Carboniferous limestone and shale of the Lucan Formation (commonly known as 'Calp'). This stratum comprises dark grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey. There are rare dark coarser grained calcarenitic limestones, sometimes graded, and interbedded dark-grey calcareous mudstone. There are no GSI-mapped karst bedrock features recorded within 2km of the Power Plant Area; however, previous site investigations interpreted the Limestone gravel with clay bands as deeply weathered karst limestone.

7.1.2 Soils

According to the Teagasc soils map (available on the GSI map viewer), the Power Plant Area is largely underlain by Made Ground (i.e. the existing Derrygreenagh Works site which comprises a workshop, stores and office complex that supports Bord na Móna's peat harvesting activities, including workshops for mobile plant overhaul and for wagon and locomotive maintenance), with adjoining areas underlain by blanket peat (largely cutaway), made ground and deep well drained mineral (mainly basic) soils (to the south and west).

The GSI/Teagasc mapping database of the subsoils in the area of the subject site indicates the Power Plant Area is underlain by Made Ground (Fill) underlain by till derived from limestone and sand and gravels.

7.1.3 Regional Hydrogeology

The GSI has devised a system for classifying the bedrock aquifers in Ireland. The aquifer classification for bedrock depends on a number of parameters including, the area extent of the aquifer (km^2), well yield (m^3/d), specific capacity ($m^3/d/m$) and groundwater transmissivity (mm^3/d). There are three main classifications: regionally important, locally important and poor aquifers. Where an aquifer has been classified as regionally important, it is further subdivided according to the main groundwater flow regime within it. This sub-division includes regionally important fissured aquifers (Rf) and regionally important karstified aquifers (Rk). Locally important aquifers are sub-divided into those that are generally moderately productive (Lm) and those that are generally moderately productive only in local zones (Ll). Similarly, poor aquifers are classed as either generally unproductive except for local zones (Pl) or generally unproductive (Pu).

The bedrock aquifers underlying the Power Plant Area according to the GSI National Draft Bedrock Aquifer Map are classified as "Locally Important Aquifer - Bedrock which is moderately productive only in local zones" and "Locally Important Aquifer - Bedrock which is generally moderately productive".

Based on the most recent data (www.epa.ie) the Athboy GWB (IE_EA_G_001) for which the site is located entirely within, has a WFD status of "*Good*" (2016-2021) and is "*Not at Risk*".

In addition, no groundwater source protection zones, which are zones defined by the GSI within which development is limited in order to protect groundwater from potential pollution, are identified beneath the site or in the immediate vicinity. There are no karst features in the area.

7.1.4 Aquifer Vulnerability

Aquifer vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated generally by human activities. Due to the nature of the flow of groundwater through bedrock in Ireland, which is almost completely through fissures, the main feature that protects groundwater from contamination, and therefore the most important feature in protection of groundwater, is the subsoil (which can consist solely or of mixtures of peat, sand, gravel, glacial till, clays or silts).

The Power Plant Area is mapped as being underlain by till (boulder clay) derived from limestones (TLs). These deposits are not mapped as being an aquifer but are considered likely to act as a pathway to the underlying bedrock aquifer, where permeable.

7.1.5 Groundwater Wells and Flow Direction

There is no licensing system for wells in Ireland at present and as such no complete data set. The GSI Well Card Index is a record of wells drilled in Ireland, kept by the Geological Survey of Ireland. It is noted that this record is not comprehensive as licensing of wells is not currently a requirement in Ireland and therefore it requires individual drillers to submit details of wells in each area.

There is one well located in the Power Plant Area - 'PW1' – and one well located 80m outside of the Proposed Development - the 'Hostel Well'. These wells are not recorded in the GSI's National Well Database (GSI, 2023). The PW1 well was drilled to 65mbGL into and screened opposite the Lucan Formation. This well was pump tested and was considered capable of supplying 1008 m^3/ day on an ongoing basis. It is understood that this well is not currently in use.

7.1.6 Groundwater Quality

The Water Framework Directive (WFD) Directive 2000/60/EC was adopted in 2000 as a single piece of legislation covering rivers, lakes, groundwater and transitional (estuarine) and coastal waters. In addition to protecting said waters, its objectives include the attainment of 'Good Status' in water bodies that are of lesser status at present and retaining 'Good Status' or better where such status exists at present.

The WFD requires 'Good Water Status' for all European waters to be achieved through a system of river basin management planning and extensive monitoring. 'Good status' means both 'good ecological status' and 'good chemical status'.

Based on the most recent data (www.epa.ie) the Athboy GWB (IE_EA_G_001) for which the site is located entirely within, has a WFD status of "*Good*" (2016-2021) and is "*Not at Risk*" meaning the GWB has achieved its objectives and has either no significant trends or improving trends.

7.1.7 Surface Water Environment

The Power Plant Area site lies within the Boyne Catchment.

The nearest river to the Power Plant Area is the Castlejordan_020 (EPA Code 07C04) river waterbody (also referred to as the Mongagh River), located immediately adjacent to the northernmost boundary of the Power Plant Area. The Castlejordan_020 is a WFD designated river waterbody (IE_EA_07C040100).

The Yellow River flows into the Boyne_030 (EPA Code 07B04) (also referred to as the River Boyne) a further 2 km downstream. Both the Mongagh and Yellow Rivers are tributaries of the River Boyne WFD river body (IE_EA_07B040400).

The Mongagh River is a tributary of the Yellow [Castlejordan] (EPA Code 07Y02) river waterbody (also referred to as the Yellow River) and flows into this waterbody approximately 15 km downstream of the Power Plant Area. The Yellow [Castlejordan] is a WFD designated river waterbody (IE_EA_07Y020300).

Table 32 details the WFD status of the water surface waterbodies in the vicinity of the power plant.

WATERCOURSE NAME	WFD WATERBODY NAME	WFD ID	WFD STATUS (2016-2021)	WFD AT RISK STATUS (3RD CYCLE)
Mongagh River	Castlejordan_020	IE_EA_07C040100	Good	Review
Yellow River	Yellow (Castlejordan)_010	IE_EA_07Y020070	Poor	At Risk (Extractive industry significant pressures)
	Yellow (Castlejordan)_020	IE_EA_07Y020100	Good	Not At Risk
	Yellow (Castlejordan)_030	IE_EA_07Y020300	Good	Not At Risk

Table 32 WFD Surface Water Bodies in the Vicinity of the Power Plant

Surface water quality is monitored periodically by the EPA at various regional locations along with principal and other smaller watercourses. The EPA assess the water quality of rivers and streams across Ireland using a biological assessment method, which is regarded as a representative indicator of the status of such waters and reflects the overall trend in conditions of the watercourse. The biological indicators range from Q5 - Q1. Level Q5 denotes a watercourse with good water quality and high community diversity, whereas Level Q1 denotes very low community diversity and bad water quality.

Table 33 details the latest Q values for rivers in the vicinity of the Power Plant.

WATERCOURSE NAME	WFD WATERBODY NAME	RIVER STATION NAME	LATEST RIVER Q VALUE (STATUS)	YEAR	DISTANCE FROM SITE (KM)
Mongagh River	Yellow (Castlejordan)_020	Baltinoran Bridge	4 (Good)	2020	6.0
Yellow River		Nr Derryarkin	3 (Poor)	2003	2.0

WATERCOURSE NAME	WFD WATERBODY NAME	RIVER STATION NAME	LATEST RIVER Q VALUE (STATUS)	YEAR	DISTANCE FROM SITE (KM)
	Yellow (Castlejordan)_010	Bridge downstream of Big River confluence	3 (Poor)	2020	1.5
	Yellow (Castlejordan)_020	Garr Bridge	4 (Good)	2020	3.5

Table 33 EPA Q Values for Rivers in the Vicinity of the Power Plant

7.1.8 Flooding

The EU Floods Directive (2007/60/EC) required Member States to undertake a national preliminary flood risk assessment by 2011 to identify areas where significant flood risk exists or might be considered likely to occur. Members States were also required to prepare catchment-based Flood Risk Management Plans by 2018 that will set out flood risk management objectives, actions and measures. The OPW in co-operation with various Local Authorities produced a number of PFRAs which aimed to map out current and possible future flood risk areas and develop risk assessment plans. These have been used to form the Draft Flood Risk Management Plans aimed at identifying possible structural and non-structural measures to improve the flood risk. As part of the CFRAM programme provisional flood maps had been produced by the OPW which have been used in this assessment.

In the FRM Guidelines, the likelihood of a flood occurring is established through the identification of Flood Zones which indicate a high, moderate, or low risk of flooding from fluvial or tidal sources, as defined as follows:

- *Flood Zone A* - Where the probability of flooding is highest (greater than 1% AEP or 1 in 100 for river flooding and 0.5% AEP or 1 in 200 for coastal flooding) and where a wide range of receptors would be vulnerable.
- *Flood Zone B* - Where the probability of flooding is moderate (between 0.1% AEP or 1 in 1000 and 1% AEP or 1 in 100 for river flooding and between 0.1% AEP or 1 in 1000 year and 0.5% AEP or 1 in 200 for coastal flooding); and
- *Flood Zone C* - Where the probability of flooding is low (less than 0.1% AEP or 1 in 1000 for both river and coastal flooding).

According to the OPW flooding maps (available on site www.floodinfo.ie) the Power Plant Area is located within Flood Zone C (i.e., where the probability of flooding from rivers or rainfall is less than 0.1% or 1 in 1000 years – i.e. probability of fluvial flooding is low risk). No historic flooding was identified at the site or surrounding area. No residual risk is foreseen as the development is located outside any flooding zones associated with future scenarios (MRFS and HEFS).

7.1.9 Conservation Areas

The nearest designated land to the Power Plant Area is the Grand Canal pNHA (Site Code: 002104) located c. 7km to the south of the site. The Raheenmore Bog SAC and Raheenmore Bog Proposed Natural Heritage Area are located c. 5.3km to the West of the site. The site does not share a hydrological connection with any of the protected sites mentioned above, nor is there any protected site located downstream of site <50km downstream. Furthermore, the canal is a contained feature (fully lined) and there is no potential for a source pathway linkage.

7.2 MATTE Assessment Methodology

The HSA Safety Report Guidelines (HSA, 2017) recommend that the Chemical and Downstream Oil Industries Forum (CDOIF) Guideline on Environmental Risk Tolerability for COMAH Establishments (CDOIF, 2017) should be followed for completing environmental risk assessments of major accidents to the environment.

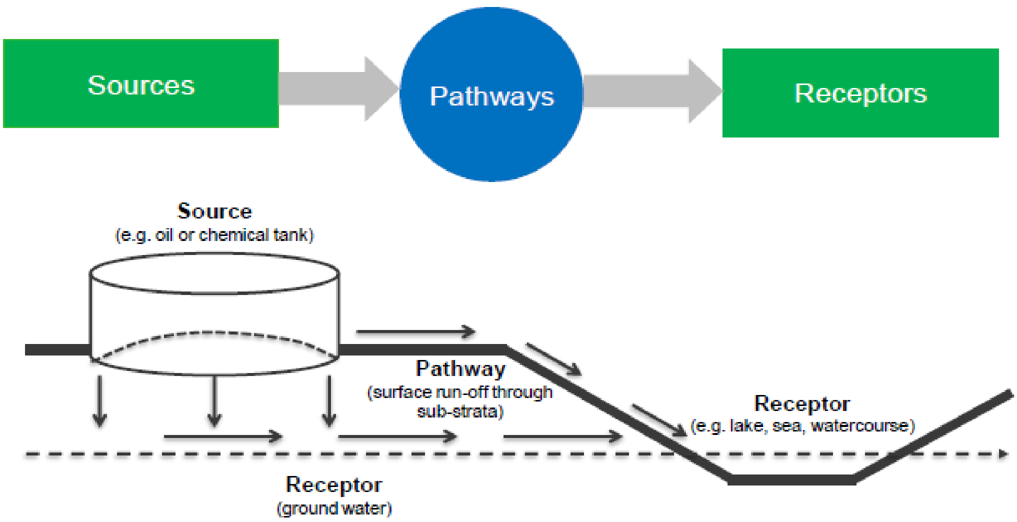
The CDOIF guidance describes a methodology by which environmental risk assessments can be carried out and addresses the following:

Major accidents to the environments (MATTEs) are those that cause:

- Permanent or long-term damage to terrestrial habitats
- Significant or long-term damage to freshwater and marine habitats
- Significant damage to an aquifer or underground water

Harm to species (fauna and flora) and the ecosystem is also a factor.

A source-pathway-receptor approach is taken which is illustrated as follows:



The following steps are involved in the CDOIF methodology:

- Phase 1a: MATTE screening to identify if the hazardous scenario meets the threshold for a MATTE, as set out in the CDOIF guidance document which defines criteria for the extent of harm (the area/distance), the severity of harm (the degree of harm within the impact area), and the duration (the recovery period) that define a MATTE.

- Phase 1b: High level risk screening to identify the (unmitigated) consequence, frequency and risk of credible MATTEs and comparison with target tolerable frequencies.

- If a hazard/scenario is screened out due to no MATTE potential (Phase 1a) or the risks are demonstrated to be broadly acceptable through a conservative, high-level assessment (Phase 1b), then Phase 2 detailed assessment is not required

- Phase 2 detailed risk assessment is completed where there is the potential for a MATTE as follows:
    - Determine unmitigated consequences from credible accident scenarios and use this to establish the tolerability thresholds per receptor per establishment per year (this is from the Appendix 4 risk matrix).
    - Determine the unmitigated aggregated risk to the receptor from all credible scenarios (i.e. risk with no mitigation measures in place).
    - Determine the mitigated risk (with existing measures in place) from all credible scenarios; and
    - Determine if further measures are required to reduce the risk to Broadly Acceptable or Tolerable if As Low As Reasonably Practicable (TifALARP) and ALARP justification where risks are in this region.

7.3 Dangerous Substances

The site layout is illustrated in Figure 2 including bund and tank locations.

Table 34 outlines the hazardous classification of the distillate on sit and Table 35 outlines the environmental properties of diesel.

Table 34 Dangerous Substances at Derrygreenagh						
Substance	**CAS #**	**Hazard Statement**	**Classification**	**COMAH Category/Named Substance**	**Total volume (m3)**	**Specific Gravity**
Distillate (diesel)	68476-33-5	H226 H411	Flammable Liquid Cat. 3 Aquatic Chronic Cat. 2	Petroleum products	16,800 (2 no. tanks 8,400 m3 each)	0.8-0.91 @ 15 ºC

Table 35 Environmental Properties of diesel			
Substance	**Persistence and Degradability**	**Eco toxicity**	**Mobility in Soil**
Distillate (diesel)	Using a mixed culture of estuarine bacteria, Fuel Oil No. 2 was found to be biodegradable (55% in 28 days) with the aromatic components more degraded than the saturated hydrocarbons (5) (TOXNET Website accessed April 2018).	LL50 (4 days) 1.13 - 65 mg/L rainbow trout LL50 (72 h) 21 - 150 mg/L rainbow trout LL50 (48 h) 28 - 180 mg/L rainbow trout LL50 (24 h) 100 - 1 000 mg/L rainbow trout	The log Koc of Fuel Oil No. 2 is reported to range from 3.0 to 5.7 (Koc range of 1,000 to 501,000) (1,2). According to a suggested classification scheme (3), this Koc range suggests that Fuel Oil No. 2 is expected to have low to no mobility in soil (SRC). Addition of Fuel Oil No. 2 to a laboratory marine ecosystem showed that the insoluble, saturated hydrocarbons in the oil were slowly transported to the sediment on suspended particulate (TOXNET Website accessed April 2018).

7.4 Environmental Receptors

The CDOIF Environmental Risk Assessment Guidelines identify potential environmental receptors including terrestrial habitats, freshwater habitats, marine habitats and groundwater bodies. These guidelines have defined MATTE thresholds based on the extent and severity and duration of harm to different types of receptors. Thresholds have been set for:

1. Designated areas – land/water receptors including National Nature Reserves, Sites of Special Scientific Interest, Marine Nature Reserves (as defined in UK legislation)
2. Designated areas – land/water receptors including Natura 2000 sites (SPAs, SACs) and Ramsar sites
3. Other designated land (as defined in UK legislation) including Environmentally Sensitive Areas, Areas of Outstanding Natural Beauty, Greenbelt land, national Parks, Local Nature Reserves, Wildlife Trust Sites, National Trust land, Common land/country parks
4. Scarce habitats (land/water) including Biodiversity Action Plan habitats and geological features
5. Widespread habitat (land/water) including agricultural land and forestry
6. Aquifers or groundwater
7. Soil or sediment
8. Built heritage
9. Various water receptors including groundwater, drinking water, fish and shellfish water and bathing waters – Appendix 2 of the CDOIF ERA Guidelines state that standards relating to continuous emissions and contained within the relevant European legislation should not be adopted to define a major accident. However, the specific level of exceedance of these standards should be considered in the post-accident remediation and restoration works.
10. Particular species in land/water/air habitats
11. Marine including non-estuarine marine waters, littoral, sub-littoral zone, benthic community adjacent to coast, fish spawning grounds
12. Freshwater and estuarine habitats

Table 36 summarises the environmental receptors in the vicinity of the proposed development and the level of harm corresponding to a MATTE for each.

Table 36 Summary of Environmental Receptors, Potential Impact Pathway and MATTE Thresholds

ID	MATTE description	Medium	Site receptor description	Distance from Source (km)	Potential Impact Pathway	MATTE Threshold
6	Aquifers or groundwater	Water	Poor aquifer	Under site With varying overburden thickness	Fuel oil overtopping bund and release of fuel oil to low permeability subsoil. Aquifer beneath the area according to GSI aquifer map. Site is protected by hardstanding areas.	• Any incident likely to require large-scale and long-term remedial measures or • Any incident of contamination/pollution (by persistent compounds) occurring within groundwater protection zone 1
7	Soil or sediment	Land/water	Onsite poor drained mineral soul	On-site	Fuel oil overtopping bund and release to local ground.	Contamination or pollution of the receptor such that: • Soil would be regarded as contaminated land by relevant authorities (i.e. contamination such that planned present or future uses could be compromised) or • Sediment would become loaded with sufficient material to compromise the chemical or biological quality of underlying waters for any period in excess of a few days
12	Freshwater & estuarine habitats	Water	Yellow River	Adjacent to site 0.2	On-site drainage system, firewater run-off, tank rupture and spill of overtopped fraction to Monagh River and Yellow River	Effects on a significant part (10 km stretch of a river or 10% of length of watercourse, 2 ha or 10% of area of an estuary) of any estuary receptor.

7.5 Phase 1a MATTE Screen

The following scenarios involve the potential for fuel to be released to off-site environmental receptors:

- A major accident scenario involving catastrophic rupture of a bulk storage tank (2 No. tanks in bund) with bund overtopping and migration of the overtopped fraction to the ground or surface water environment surrounding the site has the potential to damage groundwater and surface water receptors in the vicinity of the site.

- A spill in an uncontained area on unmade ground may also drain to the surface water drainage system or to the groundwater resource underlying the site, and eventually to the surface water environment.

Table 37 details the Phase 1a MATTE Screen and identifies the worst-case environmental release scenarios and those that exceed the MATTE Threshold.

Bund overtopping was assumed (by default) to be 50% of the tank volume (HSA, 2023).

Table 37 Phase 1a MATTE Screen

Scenario	Substance	Quantity	Comments/MATTE Screening	MATTE Potential
Catastrophic rupture of bulk storage tank and overtop, migration of overtopped fraction to surface water drainage system and into the Monagh River and Yellow River	Distillate (2 No. tanks 7,500 m^3 each).	Overtop volume for one tank: 3,750 m^3	Assuming a minimum slick thickness of 0.0002 m on the surface of the Yellow River (based on the Bonn Agreement Oil Appearance Code BAOAC value for > 200 m^3 spills) and an average river width of 2 m, the worst-case spill would cover 9.4 km of the Yellow River. This scenario has the potential to result in a MATTE as >2 km.	**Y-MATTE 1**
Catastrophic rupture and overtop to uncontained area on hardstanding may drain to the surface water drainage system and eventually to the surface water environment via the interceptor to the groundwater resource underlying the site.	Distillate (2 No. tanks 7,500 m^3 each).	Overtop volume for one tank: 3,750 m^3	Assuming a minimum thickness of 0.02 m, (Yellow book Table 3.1 average roughness for rough sandy soils / farmland / grassland), the worst-case spill would cover 18.8 ha of area surrounding site. Groundwater vulnerability is moderate to high in this area; therefore, this scenario has the potential to cause a MATTE.	**Y- MATTE 1**

7.6 Phase 1b Risk Screen

The Phase 1b, high level risk screening step identifies the (unmitigated) consequence, frequency and risk of credible MATTEs and compares the frequency and risk with target tolerable frequencies.

Table 38 outlines the Phase 1a MATTE Screening assessment. The severity and duration/recovery period are identified with reference to Table 4.1 and Table 4.2 of Appendix 4 of the CDOIF ERA Guidelines.

The MATTE category and tolerability boundaries are identified with reference to Table 4.3 of Appendix 4 of the CDOIF ERA Guidelines.

Table 38 Phase 1b Risk Screen

Scenario ID	Scenario Description	Receptor	Severity	Duration/Recovery Category	MATTE Category	Tolerability Boundary
MATTE 1	Catastrophic rupture of bulk storage tank and overtop, migration of overtopped fraction to surface water drainage system and into the Monagh River and Yellow River	Fresh water habitats	Severe (2) WFD Chemical or ecological status lowered by 1 class for 2-10 km of watercourse	Estimated as Long Term (3) WFD hazardous subs > 6yrs (unmitigated)	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year
MATTE 2	Catastrophic rupture and overtop to uncontained area on hardstanding may drain to the surface water drainage system and eventually to the surface water environment via the interceptor to the groundwater resource underlying the site.	Groundwater – non-drinking source	Severe (2) 1-100ha of aquifer where water quality standards are breached	Estimated as Long Term (3) WFD hazardous subs > 6yrs (unmitigated)	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year

7.7 Phase 2 Detailed Risk Assessment

The Phase 1a and Phase 1b risk screen detailed in Sections 7.5 and 7.6 identify two potential MATTE scenarios:

- MATTE 1 - Catastrophic rupture of oil tank and overtop, migration of overtopped fraction to surface water drainage system and into the Yellow River.
- MATTE 2 - Catastrophic rupture of oil tank, overtop to uncontained area on hardstanding may drain to the surface water drainage system and eventually to the surface water environment via the interceptor to the groundwater resource underlying the site.

7.7.1 Frequency of MATTE Scenarios

7.7.1.1 Unmitigated Frequency

There are 2 No. bulk storage tanks on site that contain diesel that is classified as hazardous to the aquatic environment and that could cause a MATTE if a significant release occurred.

The design includes for 2 No. bulk storage tanks that contain fuel oil that is classified as hazardous to the aquatic environment and that could cause a MATTE if a significant release occurred. The tanks will comply with EN14015 and the pipework to EN13480 (or equivalent). Fuel storage conditions are at atmospheric temperature and pressure.

The HSA's Guidance on Technical Land Use Planning Advice (HSA, 2023) states a frequency of 5E-06 per year (per tank) for instantaneous failure of a tank (containing flammable liquids) and bund overtopping (Table 41).

Therefore, the initiating event frequency for a MATTE scenario is 1.0E-05 per year.

7.7.1.2 Mitigated Frequency

Human error is the likely initiating event that would lead to a failure to respond to a major fuel oil spill. The UK HSE Planning Case Assessment Guide Chapter 6K (Failure Rate and Event Data for Use Within Risk Assessments) (UK HSE, 2017) provides guidance on human factors and states:

> *In most cases, a human error potential of 0.1 can be considered a conservative or cautious estimate of the risk of human failure.*

Applying a human error potential of 0.1 for failure to respond to a major fuel oil spill in gives a mitigated frequency of 1.0E-06 per year for MATTE 1 or MATTE 2.

7.7.2 Frequency of Category B MATTE Scenarios

MATTE Scenario 1 and 2 have been identified as a MATTE category B. The tolerability boundaries for Category B MATTE Scenarios are as follows:

- Intolerable > 1E-03 per year
- 1E-05 per year ≤Tolerable if ALARP ≤ 1E-03 per year
- Broadly Acceptable < 1E-05 per year

The event frequency of MATTE Scenario 1 and 2 was calculated as 1.0E-06 per year. This is in the **Broadly Acceptable** region for this scenario. No further risk reduction measures are deemed necessary.

8.0 RISK CONTOURS

Gexcon RiskCurves Version 12.1.1 modelling software was used to model the cumulative risk contours for the establishment.

The HSA specify that D5 conditions are assumed to occur 80% of the time, with F2 occurring for the remaining 20%.

The consequence results, frequencies of major accident hazards and Mullingar wind speed and frequency data (see Figure 4) were input to the software.

Table 39 details the matrix that is used by the HSA to advise on suitable development for technical LUP purposes:

Level of Sensitivity	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Table 39 LUP Matrix

The HSA has defined the boundaries of the Inner, Middle and Outer Land Use Planning (LUP) zones as:

1E-05/year	Risk of fatality for Inner Zone (Zone 1) boundary
1E-06/year	Risk of fatality for Middle Zone (Zone 2) boundary
1E-07/year	Risk of fatality for Outer Zone (Zone 3) boundary

Individual risk contours for the proposed development corresponding to the boundaries of the inner, middle, and outer risk-based land use planning zones are illustrated in Figure 39.

The indiviudal risk contours illustrate the indiviudal risk to persons outdoors in the vicinty of the site. There were no off-site consequences to persons indoors; therefore, there is no risk to persons indoors off-site.

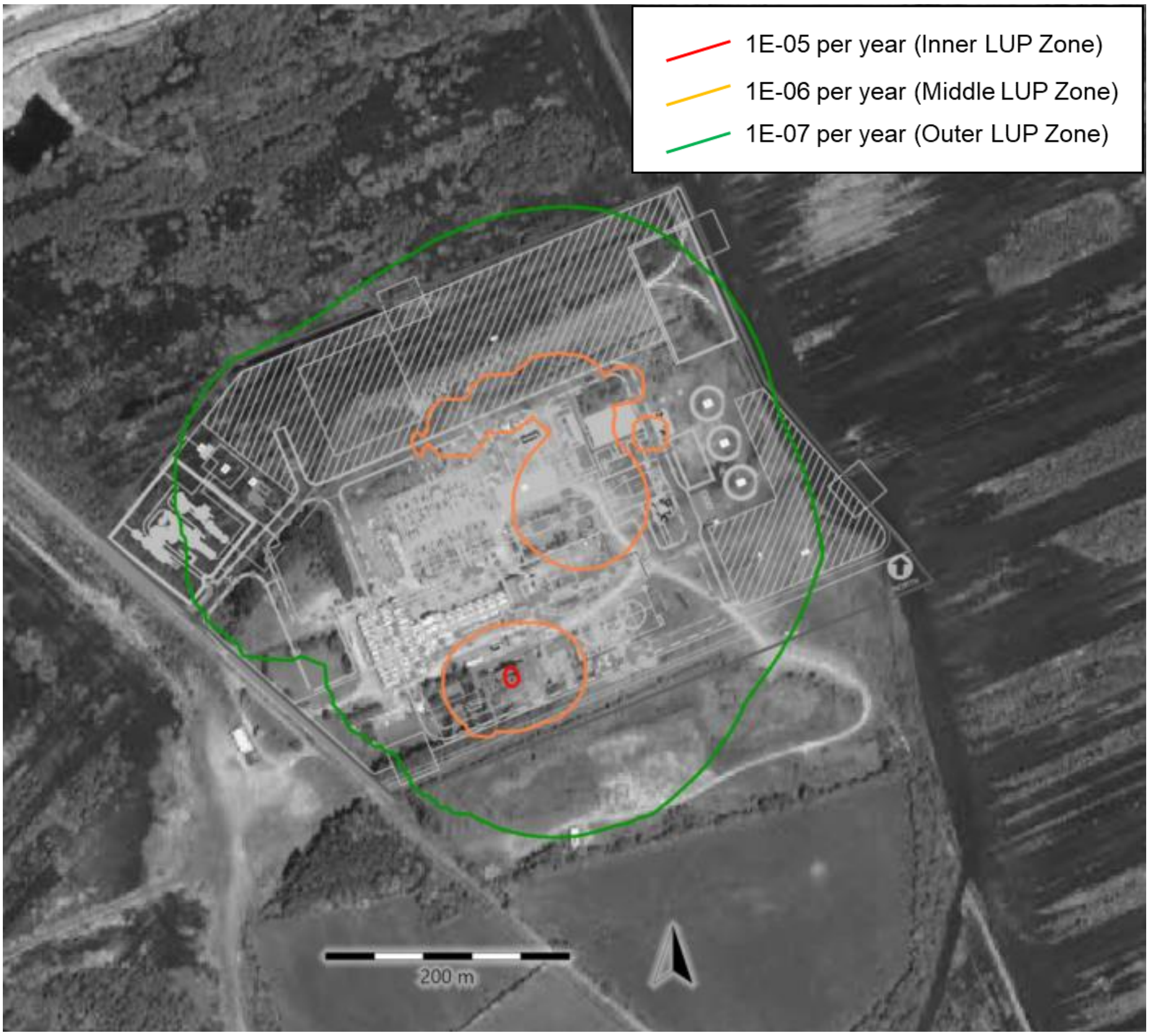


Figure 39 Land Use Planning Risk-based Contours

The following is concluded for the individual risk arising from the Power Plant Area:

- The individual risk contours corresponding to the boundary of the inner risk zone (1E-05 per year) and middle risk zone (1E-06 per year) do not extend over the site boundary.
- The individual risk contour corresponding to the Outer LUP zone extends over the proposed development boundary to the north and south. These areas are typically unoccupied, and this level of individual risk is below the 1E-06 per year maximum tolerable risk to a member of the public threshold.

It is concluded that the level of individual risk off-site is acceptable.

9.0 CONCLUSION

AWN Consulting Ltd. were instructed by AECOM on behalf of Bord na Móna Powergen Ltd to complete a Land Use Planning assessment of major accident hazards associated with the proposed Derrygreenagh Power Project, Co. Offaly.

Following the completion of the development, the site will be classified as a Lower Tier Seveso site and is subject to the provisions of the Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, 2015 (COMAH Regulations 2015).

The Land Use Planning assessment was completed in accordance with guidance published by the HSA (HSA, 2023). The following major accident scenarios were assessed:

- Vapour Cloud Explosion within a turbine enclosure
- Jet fire / Fireball following a leak or rupture of the natural gas pipeline at the proposed development.
- Vapour Cloud Explosion following a leak or rupture of the natural gas, or natural gas and pipeline at the proposed development.
- Flash fire following a leak or rupture of the natural gas pipeline at the proposed development.
- Vapour Cloud Explosion following leak or rupture in an LPG tank
- Jet fire / fireball following leak or rupture in an LPG tank
- Flash fire following leak or rupture in an LPG tank
- Loss of containment of diesel and release to the environment (Major accident to the Environment (MATTE) assessment)

<u>Environmental Risk Assessment (MATTE)</u>

An assessment of Major Accidents to the Environment (MATTEs) at the Power Plant Area was completed in accordance with the environmental risk assessment methodology recommended by the Chemical and Downstream Oil Industries Forum (CDOIF, 2017).

The following table summarises the MATTE Scenario identified.

Scenario	Description	Environmental Receptors	MATTE Category	Tolerability Boundary	Scenario Frequency
MATTE – 1	Catastrophic rupture of bulk storage tank and overtop, migration of overtopped fraction to surface water drainage system and into the Monagh River and Yellow River	Fresh water habitats	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year	1.0E-06 per year
MATTE – 2	Catastrophic rupture and overtop to uncontained area on hardstanding may drain to the surface water drainage system and eventually to the surface water environment via the interceptor to the groundwater resource underlying the site.	Groundwater (non-drinking water source)	B	Intolerable > 1E-03 per year Broadly acceptable < 1E-05 per year	1.0E-06 per year

The tanks will comply with EN14015 and the pipework to EN13480 (or equivalent) and the maintenance regime will follow good engineering practice.

The event frequency of MATTE Scenario 1 and 2 was calculated as 1.0E-06 per year. This is in the **Broadly Acceptable** region for these MATTE categories. It is concluded no further risk reduction measures are necessary

Land Use Planning Contours

Gexcon RiskCurves Version 12.1.1 modelling software was used to model the cumulative risk contours for the establishment. The consequence results, frequencies of major accident hazards and Mullingar wind speed and frequency data were input to the software. Risk contours for the Power Plant Area corresponding to the boundaries of the inner, middle, and outer risk-based land use planning zones are illustrated on the Figure below.

The indiviudal risk contours illustrate the indiviudal risk to persons outdoors in the vicinty of the site. There were no off-site consequences to persons indoors; therefore, there is no risk to persons indoors off-site.

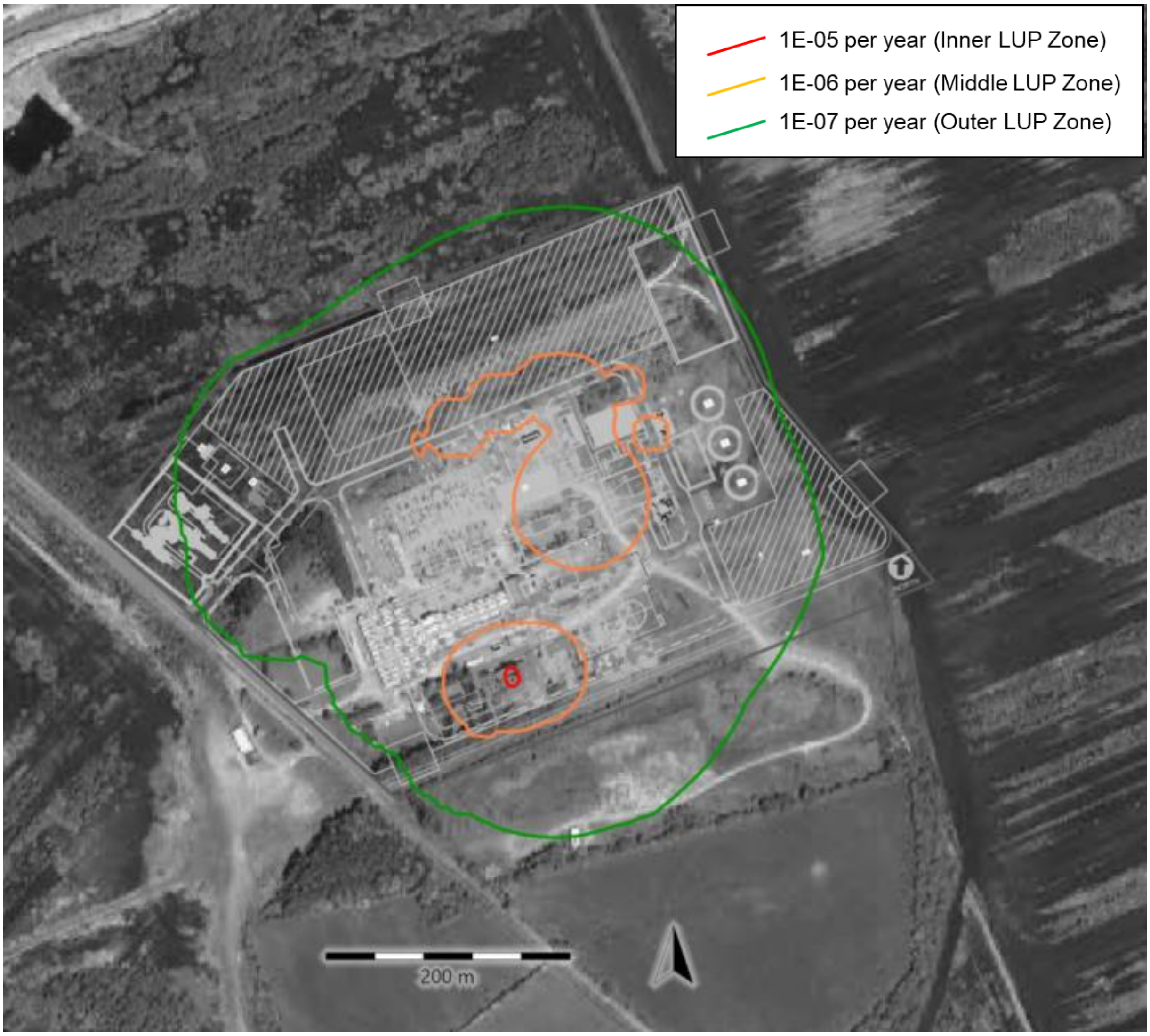


Figure 40 Land Use Planning Risk-based Contours for the proposed Power Plant Area

The following is concluded for the individual risk arising from the proposed development:

- The individual risk contours corresponding to the boundary of the inner risk zone (1E-05 per year) and middle risk zone (1E-06 per year) do not extend over the site boundary.
- The individual risk contour corresponding to the Outer LUP zone extends over the Power Plant Area to the north and south. These areas are typically unoccupied, and this level of individual risk is below the 1E-06 per year maximum tolerable risk to a member of the public threshold.

It is concluded that the level of individual risk off-site is acceptable.

The Figure below illustrates the individual risk contour corresponding to 1E-09 per year (1 in-a-billion). This is the level of individual risk the HSA have requested for new establishments as a proposed consultation distance.

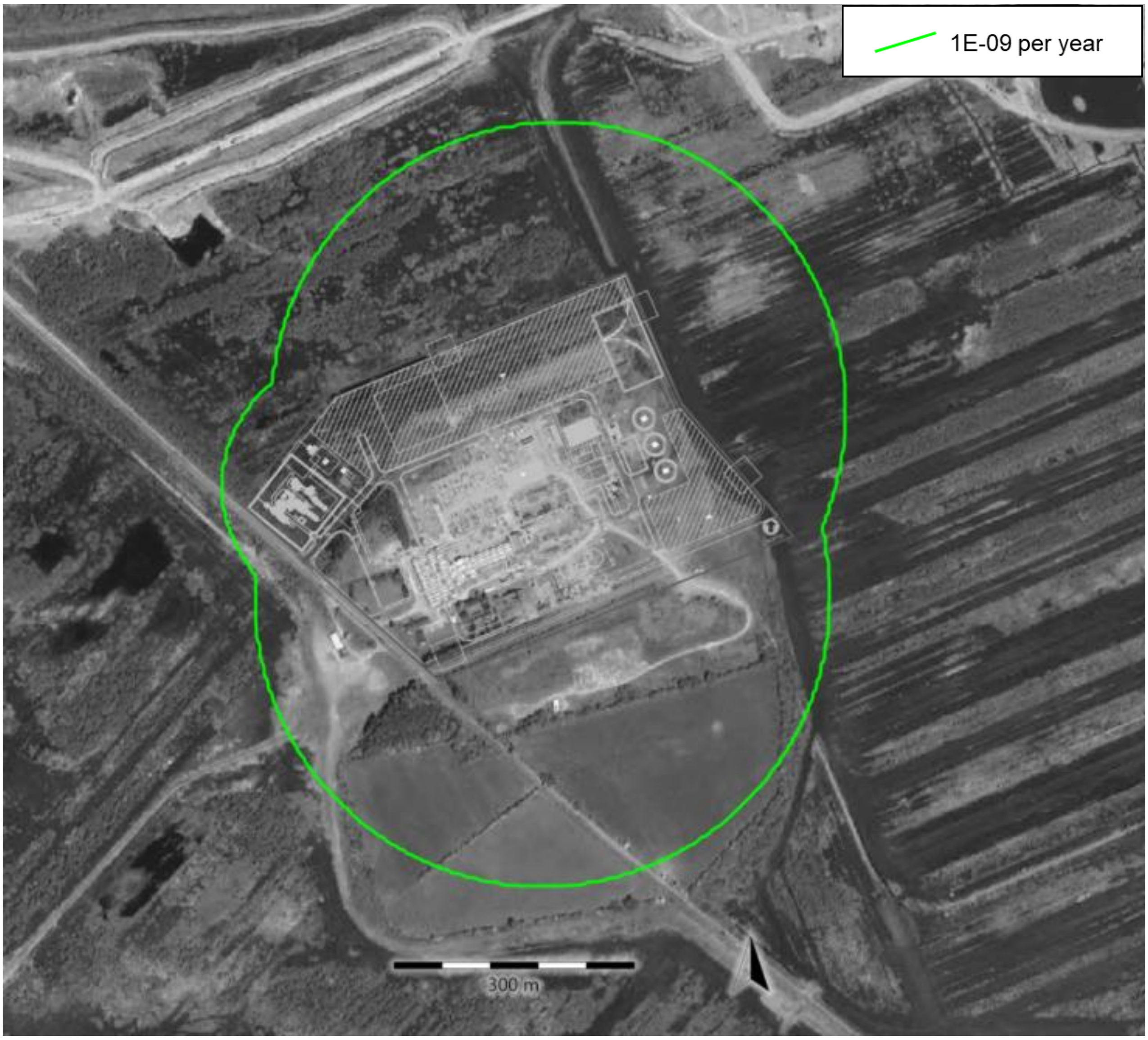


Figure 41 Individual Risk Contour Corresponding to 1E-09 per year (Consultation Distance)

10.0 REFERENCES

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APPENDIX A

Natural Gas VCE Calculation

Complete combustion equation for Methane:

$CH_4 + 2O_2 = CO_2 + H_2O$

Stoichiometric Mass Fraction Calculation:

Compound	Mol	Mol fraction	Molecular weight (kg/kmol)	Mass (kg)	Mass fraction
CH_4	**1**	**0.096**	**16.040**	**1.54**	**0.056**
O_2	2	0.192	31.999	6.13	0.222
N_2	7.44	0.713	28.014	19.96	0.723
Total	10.44	1		27.63	1.000

Volume of CCGT Turbine Enclosure: 1200 m^3

Volume of OCGT Turbine Enclosure: 562.5 m^3

Density of Natural Gas Mixture at 10°C (calculated from DNV PHAST 8.7): 1.193 kg/m^3

Mass of Flammable Mixture in OCGT: 671.06 kg (562.5 m^3 x 1.193 kg/m^3)

Mass of Flammable Mixture in CCGT: 1431.6 kg (1200 m^3 x 1.193 kg/m^3)

Compound	CCGT Mass (kg)	OCGT Mass (kg)
CH_4	79.61	37.32
O_2	317.62	148.88
N_2	1034.38	484.86

Flammable Mass of Methane in CCGT Turbine Enclosure: **79.61 kg**

Flammable Mass of Methane in OCGT Turbine Enclosure: **37.32 kg**