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COMAH LAND USE PLANNING ASSESSMENT OF FUTURE MIXED-USE DEVELOPMENT OF "INNER HARBOUR" AREA AT GALWAY HARBOUR

Technical Report Prepared For

The Land Development Agency

Technical Report Prepared By

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Our Reference

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Revision Level	Revision Date	Description	Sections Affected
a	30th January 2025	Updated description of development	Section 1, 2 and 11
b	26th August 2025	Updated development description and modelling to include for a Buncefield VCE scenario.	All

Record of Approval

Details	Written by	Approved by
Signature		
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Title	Senior Risk Consultant	Principal Risk Consultant
Date	26th August 2025	26th August 2025

EXECUTIVE SUMMARY

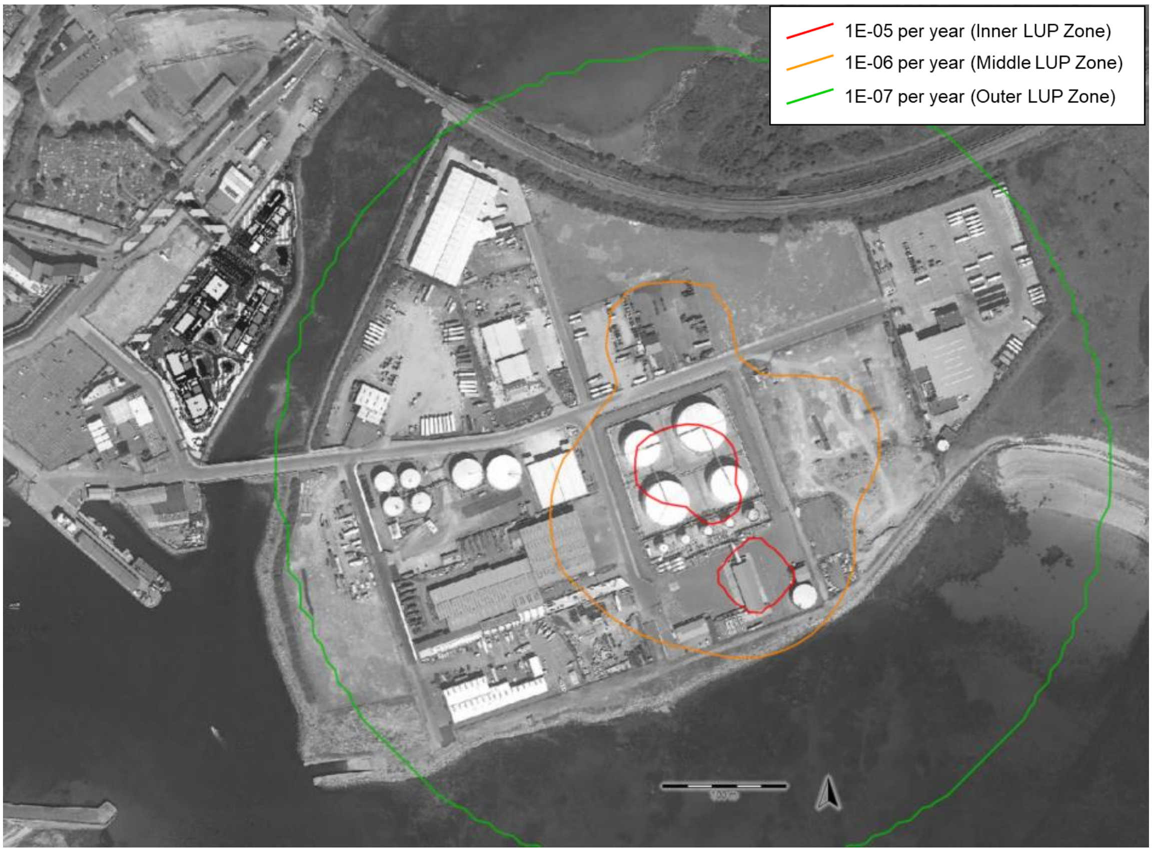
AWN Consulting Ltd. was requested by the Land Development Agency (LDA) to complete a land use planning assessment addressing potential constraints posed by the Circle K Galway Terminal Upper Tier COMAH establishment to the development of the “Inner Harbour” landbank at Galway Harbour. The landbank has potential to yield a substantial residential-led mixed-use development, of 356 No. Units, creche, retail unit and cafe/restaurant units, over four blocks, extending from 6 – 13 storeys in height. The proposed landbank is not within the Consultation Distance of any other COMAH establishments.

The assessment is completed following the Health and Safety Authority’s Guidance on technical land-use planning advice (TLUP) For planning authorities and COMAH establishment operators (HSA, 2023) and the *Land Use Planning Policy and Approach Document (HSA, 2010)*.

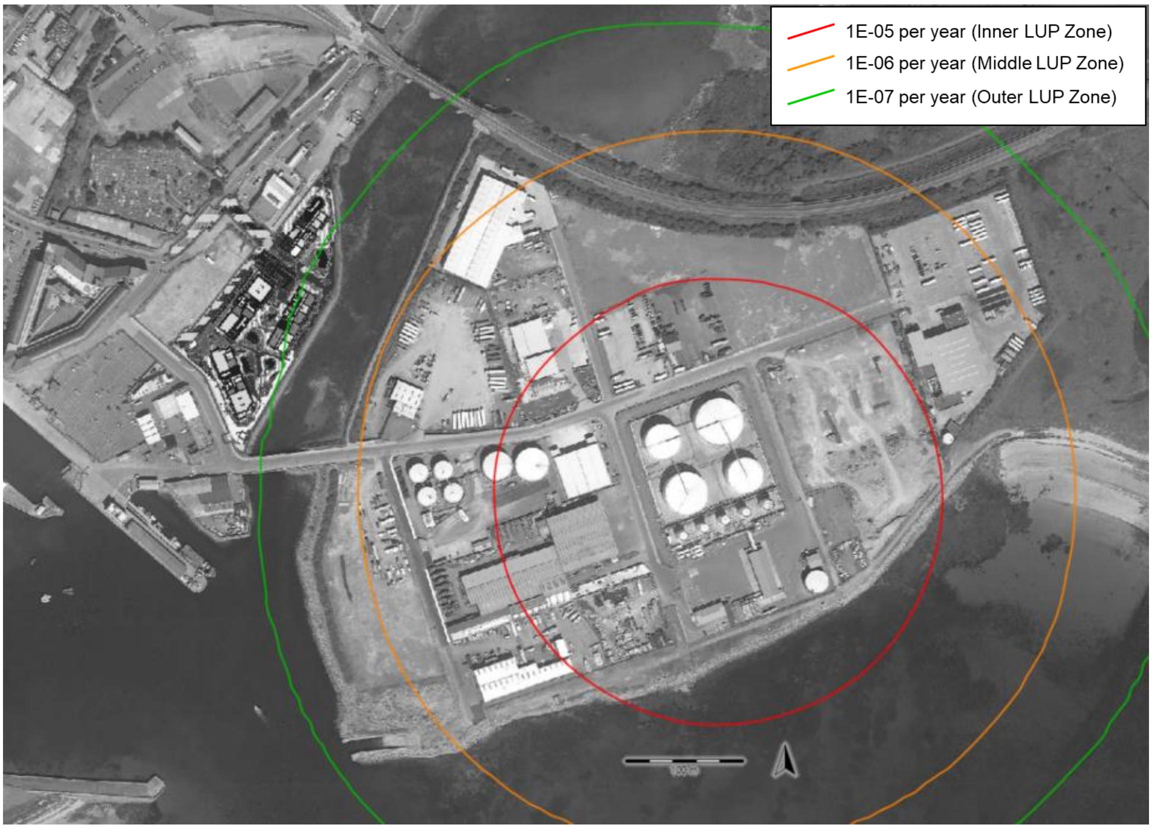
The Circle K Galway Upper Tier COMAH facility handles the import and storage of ultra-low sulphur diesel (ULSD), kerosene (kero), and gasoline delivered by ship, as well as ethanol received via road tankers. This document assesses major accident scenarios identified in the TLUP (HSA, 2023), including pool fires, vapour cloud explosions, and flash fires.

During consultation with the HSA, prior to the lodgement of this planning application, explicit reference was made by the HSA to include the assessment of a Buncefield-type explosion scenario. At the HSA’s request. This assessment is included in this report. Modelling methodology for a Buncefield-type explosion does not feature in the most recently published guidance issued by the HSA; therefore, we have utilised the previous iteration of the Land Use Planning guidance (HSA, 2010) to undertake this assessment, as the most recently available, relevant guidance for same.

The individual risk contours, to persons outdoors and persons indoors (CIA 2), for the Circle K upper tier COMAH establishment corresponding to the boundaries of the Inner, Middle and Outer risk-based land use planning zones are illustrated as follows:



Individual Risk of Fatality Contours, to Persons Outdoors, for Circle K Galway Terminal



Individual Risk of Fatality Contours, to Persons Indoors (CIA 2), for Circle K Galway Terminal

The proposed scheme is a Sensitivity Level 3 type development as it is a *'Larger housing developments for more than 30 dwelling units'* (HSA, 2023). Therefore, the proposed scheme is permitted within the Outer Zone.

It is concluded that the level of individual risk at the proposed scheme is acceptable.

The proposed scheme is within the consequence zone of major accidents at the Circle K facility. Therefore, a Societal Risk assessment is required to take account of group risk to the receptors at the proposed scheme.

Societal risk calculations aggregate the risks presented to all populations at the proposed development arising from all major accidents at the Circle K facility. A Societal Risk assessment for the proposed scheme was completed and the Expectation Value (EV) at the proposed scheme is calculated to be **667.**

Section 1.7 of the TLUP (HSA, 2023) states:

> *'for new developments near an establishment, where the calculated off-site EV at the development greater than 2,000, further assessment of societal risk will be required.'*

The total Expectation Value (EV) at the proposed scheme is **667.** This is <2,000; therefore, no further risk calculation is required.

It is concluded that the level of individual risk and societal risk, at the proposed residential led mixed-use scheme, is in accordance with the HSA's criteria and is acceptable.

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1.0 INTRODUCTION

AWN Consulting Ltd. was requested by the Land Development Agency (LDA) to complete a land use planning assessment addressing potential constraints posed by the Circle K Galway Terminal Upper Tier COMAH establishment to the development of the "Inner Harbour" landbank at Galway Harbour. The landbank has potential to yield a substantial residential-led mixed-use development, of 356 No. units, over four blocks, extending from 6 – 13 storeys in height. The proposed landbank is not within the Consultation Distance of any other COMAH establishments.

This assessment is completed following the Health and Safety Authority's (HSA) Guidance on technical land-use planning advice For planning authorities and COMAH establishment operators (TLUP) (HSA, 2023) and the *Land Use Planning Policy and Approach Document (HSA, 2010)*.

This report is an updated version following feedback from the HSA advising that the original report did not include a Vapour Cloud Explosion (VCE) arising from a major tank overfilling event (i.e. a 'Buncefield' type event).

The HSA considered that the inclusion of a Buncefield-type event is necessary and requested that the consequences were to be included in this Land Use Planning report.

This report outlines the following:

- Overview of proposed works and Circle K Galway Terminal;
- Assessment methodology and criteria;
- Identification of major accident scenarios;
- Assessment of major accident hazards;
- Land Use Planning risk contours;
- Societal risk constraints;
- Conclusions.

2.0 OVERVIEW OF PROPOSED SCHEME AND CIRCLE K GALWAY TERMINAL

2.1 Proposed scheme

The proposed scheme principally consists of the demolition of the existing office / bus depot building (370.2 sq m) and ancillary building (26 sq m); the partial demolition of the existing ESB sub-station (67.4 sq m); the demolition of existing boundary walls at the south-west and north-west; and the construction of a mixed-use development.

The proposed mixed-use development primarily comprises: 356 No. residential apartments (172 No. 1-bed, 169 No. 2-bed and 15 No. 3-bed); crèche (255.9 sq m); 2 No. café/restaurant units (totalling 428.4 sq m) and 1 No. retail unit (156.0 sq m). The development has a total floor area of 32,096.0 sq m and is primarily proposed in 4 No. blocks (identified as A–D) that generally range in height from 6 No. to 13 No. storeys.

The layout of the proposed scheme is illustrated on Figure 1 and the location of the proposed scheme relative to the Circle K Fuel Terminal is illustrated on Figure 2.

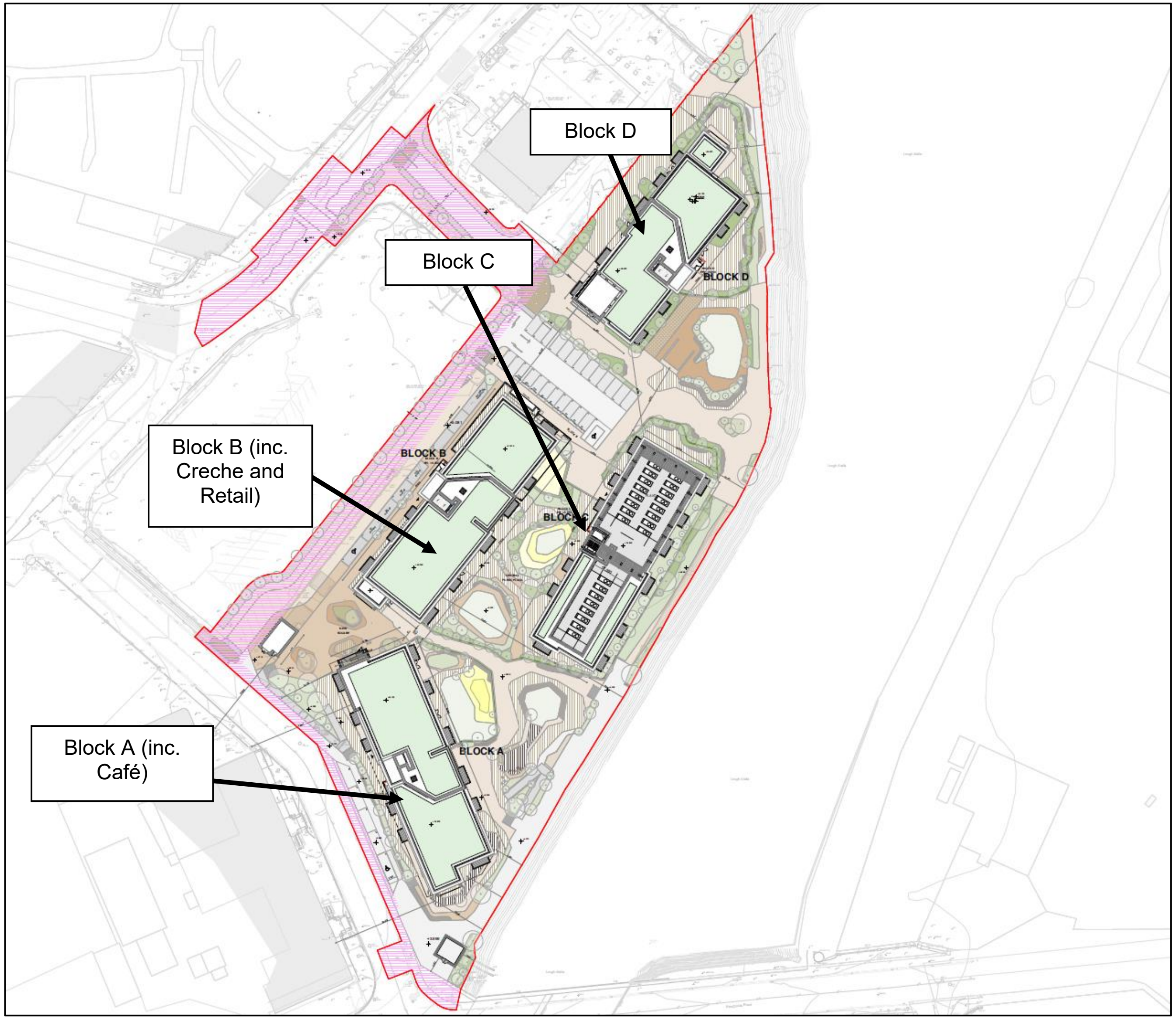


Figure 1 Proposed Mixed-use Scheme Layout

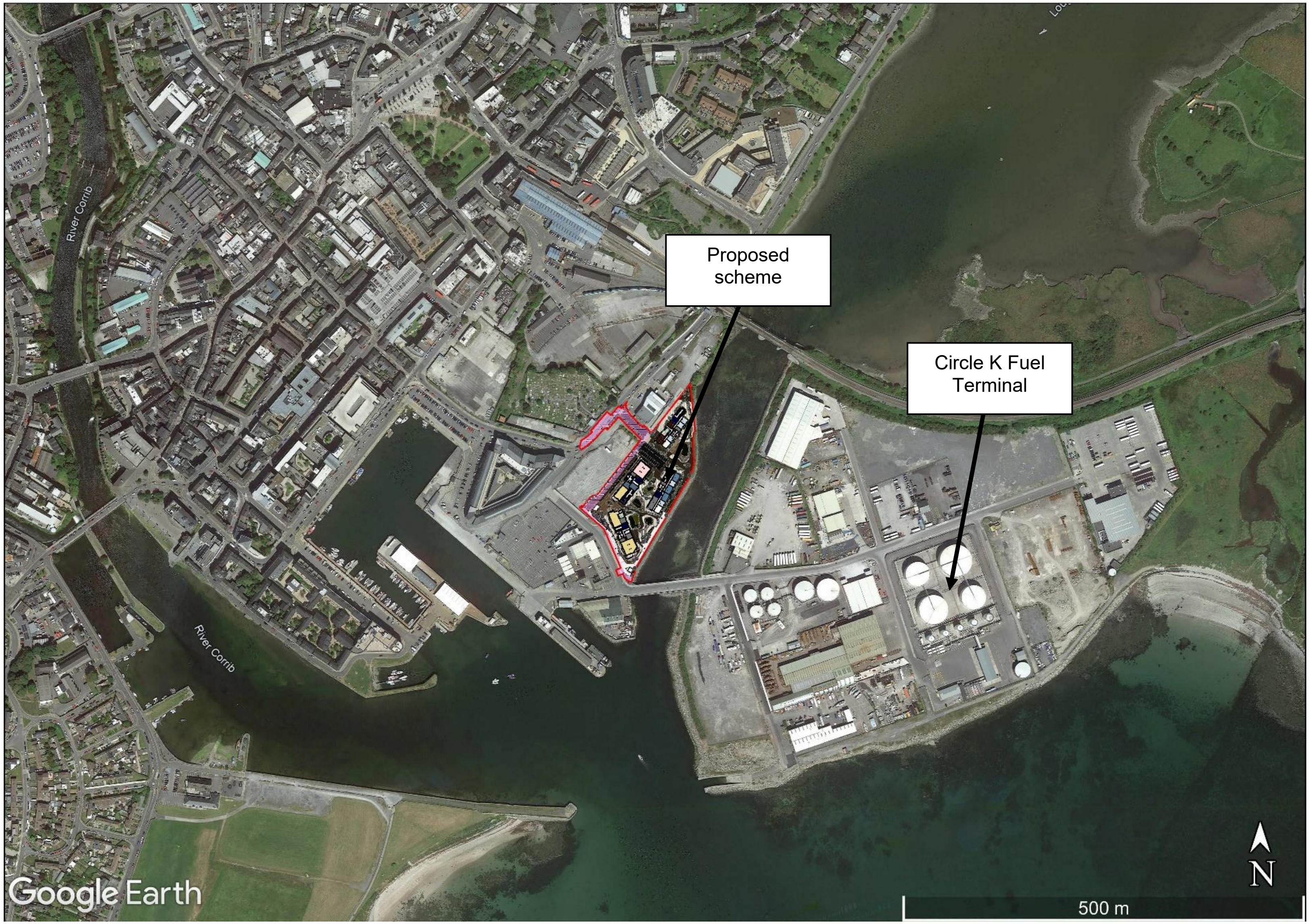


Figure 2 *Location of Proposed Scheme and Circle K Fuel Terminal*

2.2 Circle K Galway Terminal Upper Tier COMAH Site

Information on the Circle K Galway Fuel Terminal was provided by The Port of Galway.

The Circle K Galway Fuel Terminal is located in Galway Enterprise Business Park. The Terminal provides for the transfer of fuel from ship, storage in bulk fuel storage tanks and offload to road tankers. The Circle K Fuel Terminal was constructed post-Buncefield, a major explosion and fire event that occurred at a fuel terminal in England. The review of the Buncefield event provided recommendations for fuel terminals and it is expected that Circle K implemented these recommendations in the design of the Galway facility.

The following products are stored on site:

- KERO (kerosene)
- Gasoline
- ULSD (diesel)
- MGO (Medium gas oil)
- Ethanol

The facility is designed to import Ultra-low sulphur diesel (ULSD), kero (kerosene), MGO and gasoline from ships. It is also designed to receive ethanol from road tankers. The distance from the ship to the tank farm is 540 m.

The site layout is illustrated on Figure 3.

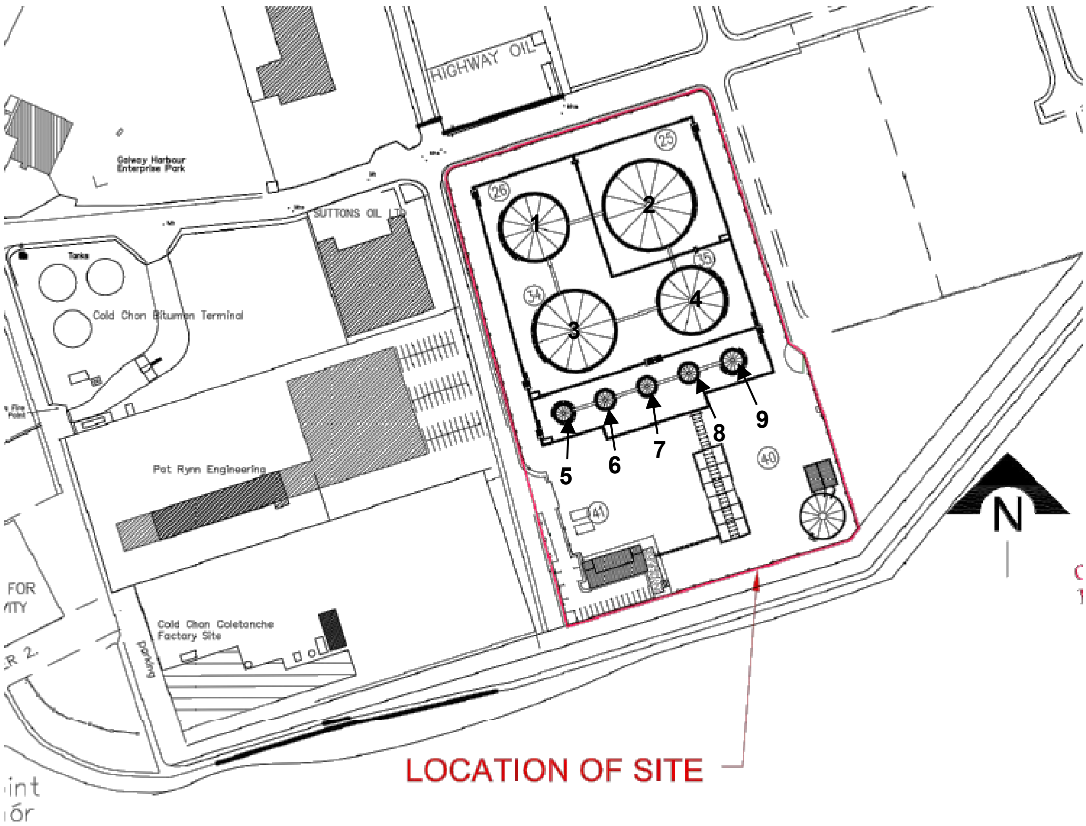


Figure 3 Circle K Galway Terminal Layout

Pat Rynn Engineering is located to the west of the fuel terminal and Cold Chon Bitumen Terminal to the north west. It is noted that these facilities are not COMAH establishments and there are no major accident hazards associated with activities that take place at these businesses.

Details of the products currently notified to the HSA in Tanks 1 – 9 are provided in Table 1.

Tank	Product	Diameter (m)	Height (m)	Maximum Inventory (m^3)
1	Kerosene or Gasoline	30	13.2	8630
2	Kerosene or Gasoline	40	13.2	15495
3	ULSD	36	13.2	13245
4	ULSD	30	13.2	9155
5	Kerosene	9	13.2	765
6	ULSD	9	13.2	800
7	ULSD	9	13.2	800
8	Gasoline	9	13.2	760
9	Gasoline or Ethanol	11.5	13.2	1055

Table 1 Products in Tanks 1 – 9 at Circle K Galway Terminal

It is noted that Tank 1 and Tank 2 currently store kerosene. Tank 1 or Tank 2 may revert to gasoline storage in future and this gasoline scenario is considered in the assessment. Circle K are permitted by the HSA to store gasoline in Tank 1 or Tank 2 at any time. Tank 9 may contain gasoline or ethanol.

In addition, FAME (biodiesel) additive is stored in 2 No. tanks of 50 m^3 capacity each.

ULSD, Kero and gasoline are transferred to the main tanks T1 to T4 from ships in the local harbour. Day tanks are provided so that tanker filling can be maintained whilst a ship is being unloaded. Road tankers can be loaded either from bulk tank or day tank at one of six purpose-built loading gantries. There is also provision to receive ethanol from road tankers into a day tank, T9. Ethanol is blended with gasoline at 5.75% – 10%. It is added directly to the road tanker at the gantry. There is provision for storage of FAME additive in 2 No. bulk storage tanks.

Table 2 provides information on the classification, hazard statements and flammable properties of products stored at Circle K Galway Terminal.

Substance	CAS #	Classification	Hazard Statements	Flash Point	Lower Flammability Limit	Upper Flammability Limit	Vapour pressure	Fire hazard
Kerosene (desulphurised)	64742-81-0	Flam. Liq. 3, Asp. Tox. 1, Skin Irr. 2, STOT SE 3, Aquatic Chronic 2	H226, H304, H315, H336, H411	> 38 °C	0.5% Vol	7% Vol	0.1-30 hPa @ 20°C	Flammable material
Kerosene (petroleum)	8008-20-6							
Ultra Low Sulphur Diesel	64742-46-7	Asp. Tox. 1, Skin Irr. 2, STOT SE 3, Aquatic Chronic 2	H304, H315, H332, H411	> 61 °C	0.5% Vol	7% Vol	< 1 hPa @ 20°C	Combustible material
Gasoline	86290-81-5	Flam. Liq. 1, Asp. Tox. 1, Skin Irr. 2, STOT SE 3, Muta 1, 1A or 1B, Carc. 1, 1A or 1B, Aquatic Chronic 2, Repr. 2	H224, H304, H315, H336, H340, H350, H411, H361fd	< -40 °C	1.3 % Vol	7.7% Vol	450 - 1000 hPa @ 20°C	Extremely flammable material
Ethanol (L-(+)-Selenomethionine 99+ > 95%, Methanol < 2%)	3211-76-5	Acute Tox. 3, STOT RE 2	H301, H331, H373	-10.6 °C	3.3% Vol	19% Vol	No data available	Highly flammable material
	67-56-1	Flam Liq. 2, Acute Tox. 3, STOT SE 1	H225, H311, H331, H301, H370					
FAME	67762-38-3	Not a hazardous substance or mixture	-	173 °C	No data available	No data available	4.2 hPa @ 25 °C	Combustible material

Table 2 Classification and Hazards of Products Stored at Circle K Galway Terminal

Note 1: EUHO66 - Repeated exposure may cause skin dryness or cracking

Details of substance classifications and hazard statements included in Table 2 are provided in Table 3.

Classification		Hazard Statements	
Flam. Liq. 1	Flammable liquid category 1 (flash point < 23 °C and initial boiling point ≤ 35 °C)	H224	Extremely flammable liquid and vapour
Flam Liq. 2	Flammable liquid category 2 (flash point < 23 °C and initial boiling point > 35 °C)	H225	Highly flammable liquid and vapour
Flam. Liq. 3	Flammable liquid category 3 (flash point ≥ 23 °C and ≤ 60 °C)	H226	Flammable liquid and vapour
Asp. Tox. 1	Aspiration toxicity category 1	H304	May be fatal if swallowed and enters airways
Acute Tox. 3	Acute toxicity category 3	H301 H311 H331	Toxic if swallowed Toxic in contact with skin Toxic if inhaled
Acute Tox. 4	Acute toxicity category 4	H302 H312 H332	Harmful if swallowed Harmful in contact with skin Harmful if inhaled
Skin Irr. 2	Skin irritation category 2	H315	Causes skin irritation
STOT SE 1	Specific target organ toxicity (single exposure) category 1	H370	Causes damage to organs
STOT SE 3	Specific target organ toxicity (single exposure) category 3	H335	May cause respiratory irritation
		H336	May cause drowsiness or dizziness
STOT RE 2	Specific target organ toxicity (repeated exposure) category 2	H373	May cause damage to organs through prolonged or repeated exposure
Muta 1, 1A or 1B	Germ cell mutagenicity category 1 and sub-category 1A and 1B	H340	May cause genetic defects
Carc 1, 1A or 1B	Carcinogenicity category 1 and sub-category 1A and 1B	H350	May cause cancer
Repr. 2	Reproductive toxicity category 2	H361fd	Suspected of damaging fertility. Suspected of damaging the unborn child.
Aquatic Chronic 2	Hazardous to the aquatic environment, chronic category 2	H411	Toxic to aquatic life with long lasting effects

Table 3 Details of Substance Classification and Hazard Statements

3.0 ASSESSMENT METHODOLOGY AND CRITERIA

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 delineating three zones for land use planning guidance purposes, based on the potential risk of fatality from major accident scenarios resulting in damaging levels of thermal radiation (e.g., from pool fires), overpressure (e.g., from vapour cloud explosions) and toxic gas concentrations (e.g., from an uncontrolled toxic gas release).

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) 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 scheme 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 4 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 4 LUP Matrix

3.3 Environment and Land Use Planning

The HSA's Generic TLUP Guidelines (HSA, 2023) outlined that the prevention of Major Accidents To The Environment (MATTE) 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 CCA 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 a 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 establishment boundary were determined by modelling accident scenarios using Gexcon Effects version 12.5.1 and DNV PHAST modelling software.

4.1.2 Risk Assessment Methodology

Gexcon RiskCurves version 12.5.1 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.

4.1.3 Thermal Radiation Criteria

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

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

In relation to property and equipment damage, the HSA have specified the thermal radiation consequence criteria (from an outdoor fire) detailed in Table 6 (HSA, 2023).

Thermal Flux (kW/m²)	Consequences
37.5	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
14.7	People are assumed to be protected, and therefore there is a 0% fatality probability

Table 6 Heat Flux Consequences to Property and Equipment

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 7 (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 7 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)

4.1.4 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 8 below 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 8 *Blast Damage Overpressures*

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:

$$\textbf{Probit} = 1.47 + 1.35 \ln P$$

P Blast overpressure (psi)

The Hurst, Nussey and Pape Probit relationship implies:

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

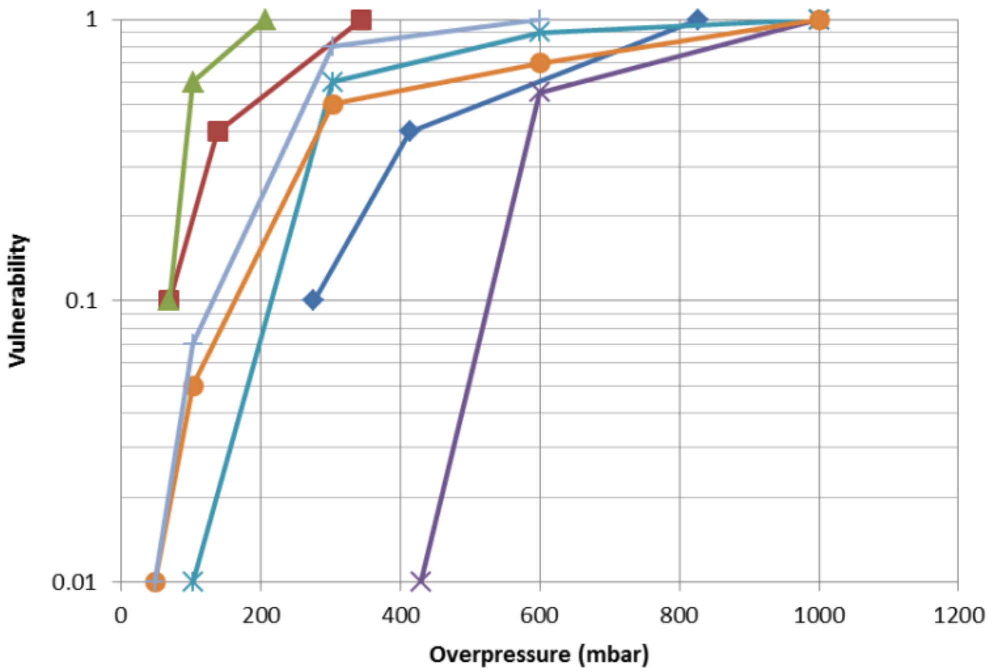
The HSA uses relationships published by the Chemical Industries Association (CIA) and the American Petroleum Institute (API) to determine the probability of fatality for building occupants exposed to blast overpressure. The CIA has developed relationships for 4 categories of buildings (CIA, 2020):

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



Graph Key:	
	CIA 1: Hardened structure building: special construction, no windows
	CIA 2: Typical office block: four story, concrete frame and roof, brick block wall panels
	CIA 3: Typical domestic buildings: two story, brick walls, timber floors
	CIA 4: Portacabin: timber construction, single story
	API B5: Reinforced concrete or reinforced masonry shear wall building
	API B3: Unreinforced masonry bearing wall building
	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 4 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 9 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 9 Blast Overpressure Consequences Indoors

The proposed scheme will comprise 4 no. blocks ranging from 6 – 13 storeys in height. The overpressure vulnerability of CIA Category 2 buildings, classified as four storey, concrete frame and roof, brick block wall panels is assumed to be most representative of buildings at the proposed scheme. The CIA Category 3 building designation is not representative of the buildings at the proposed scheme, as they are not two story and not made of brick walls and timber floors.

This Land Use Planning study will assess the individual risk from the Circle K establishment to the proposed scheme. It is not an assessment of the generic Land Use Planning contours for the Circle K establishment, as this would require the use of CIA Category 3 buildings, in line with the TLUP (HSA, 2023).

4.1.5 Flash Fire Criteria

A flash fire comprises the combustion of a flammable vapour and air mixture in which the flame passes through that mixture at less than sonic velocity, such that negligible damaging overpressure is generated.

The flash fire envelope is the lower flammable limit (LFL) concentration, determined using the unified dispersion model in PHAST Version 9.1 consequence modelling software.

For flash fires, fatality levels of 100% are assumed inside the lower flammable limit (LFL) envelope, with 0% fatalities outside that envelope. For flash fire, within the flash fire envelope, indoor fatality levels are conservatively assumed to be 10%. (HSA, 2023)

4.2 Modelling Parameters

4.2.1 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 slightly increase the impact of fires, particularly pool fires.

Atmospheric Stability Class and Wind Speed

In order to adequately assess the consequences of a major-accident, weather conditions must be selected that represent the weather experienced at the site. The standard atmospheric stability classes are listed in Table 10**.**

A-G Stability	Conditions	Typically observed during
A	Very unstable – Sunny with light winds	Day-time
B	Unstable – Less sunny or more windy than A	Day-time
C	Moderately unstable – Very windy/sunny or overcast/light wind	Day-time
D	Neutral – little sun and high wind or overcast/windy night	Day or Night-time
E	Moderately stable – Less overcast and less windy than D	Night-time
F	Stable – Night with moderate clouds and light/moderate winds	Night-time
G	Very Stable – Possibly Fog	Night-time

Table 10 Atmospheric Stability Classes

For TLUP purposes, the HSA specifies that D_5 conditions are assumed to occur 80% of the time, with F2 occurring for the remaining 20% (HSA, 2023).

4.2.2 Wind Direction

The nearest weather station to Galway Harbour at which hourly wind speed and direction measurements are taken is at Athenry Station. Figure 5 illustrates a wind rose based on hourly wind speed and direction data for Athenry Weather Station (2011 – 2018). Data was obtained from the Met Eireann website. It can be seen that the prevailing wind direction is approximately from the south west (250 º).

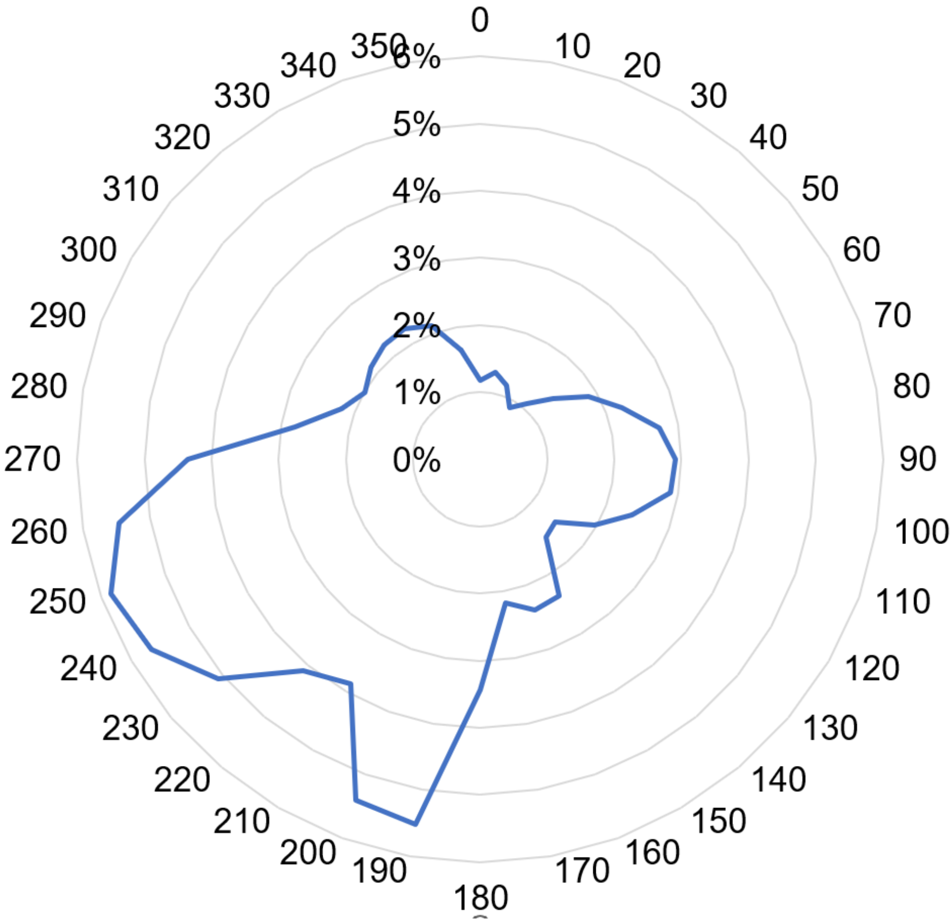


Figure 5 Wind Rose Athenry Weather Station 2010 - 2023

Ambient Temperature

For TLUP purposes the HSA specifies that Outdoor storage vessel contents are assumed to be at ambient atmospheric temperatures. Ambient temperatures vary throughout the day and the seasons. For TLUP purposes, a temperature of 15 °C is used in D5 conditions and 10 °C for F2 conditions. (HSA, 2023).

Ambient Humidity

For TLUP purposes, a humidity of 60% is used.

4.2.3 Surface Roughness

For TLUP purposes a surface roughness value of 0.1 m will be used as default (HSA, 2023).

4.3 Societal Risk Assessment Methodology

Where a large population is potentially exposed to the consequences of major accidents, and there is the potential for multiple fatalities, societal risk is taken into account.

To take account of societal risk, the HSA will initially obtain an estimate of the expectation value.

Expectation Value and FN Curve

The Expectation Value (EV) is the average number of persons receiving a specified level of harm. Hirst and Carter (Hirst et al., 2000) shows that:

$$\boldsymbol{EV = F \times N}$$

Where F is the cumulative frequency of all events leading to N fatalities

HSE (2001) provides an upper limit value for an intolerable societal risk criterion: for a predicted accident occurring no more frequently than once in 5,000 years, there should be no more than 50 fatalities. This has gained international acceptance as an anchor point for a line (of slope -1) to create an intolerable societal risk criterion for single accidents. HSA Guidance on Technical Land Use Planning recommended using points at 200 cpm / 50 fatalities and 1000 cpm/10 fatalities to create that line. An acceptable societal risk single risk criterion line can then be drawn at frequencies that are two orders of magnitude below the intolerable line (so a frequency of 1×10^{-4} on the intolerable line becomes 1×10^{-6} on the acceptable line).

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"*

As detailed in Section 2.2, the following products are stored in bulk storage tanks at the Circle K terminal:

- KERO (kerosene) – Category 3 flammable liquid (Tank 1/2 and 5)
- Gasoline – Category 0 flammable liquid (Tank 1/2, Tank 8 and 9)
- ULSD (diesel) – Category 3 flammable liquid (Tank 3, 4, 6, 7)
- Ethanol – Category 2 flammable liquid (Tank 9)

Tank 1 and Tank 2 currently store kerosene. Tank 1 or Tank 2 may revert to gasoline storage in future and this gasoline scenario is considered. Circle K are permitted by the HSA to store gasoline in Tank 1 or Tank 2 at any time. Tank 9 may contain gasoline or ethanol.

A conservative approach is adopted and the following tank contents are included in the study.

- Tank 1: Kerosene
- Tank 2: Gasoline (largest of tanks 1 and 2)
- Tank 3: ULSD
- Tank 4: ULSD
- Tank 5: Kerosene
- Tank 6: ULSD
- Tank 7: ULSD
- Tank 8: Gasoline
- Tank 9: Gasoline (more conservative than ethanol due to higher vapour pressure and lower flash point of gasoline)

Table 11 lists the loss of containment (LOC) scenarios to be modelled for single containment atmospheric storage tanks storing Ignition Category 0 substances. This applies to Tank 2, 8 and 9 (gasoline) (HSA, 2023).

Ignition probabilities for Category 3 substances (kero and ULSD) are zero. Fire and explosion events are not considered for Category 3 substances, unless they are co-located in the same bund as Category 1 or Category 2 substances, in which case they could be modelled as Category 1 or Category 2 substances.

At Circle K, Kero and ULSD are co located in the same bund as ethanol (Category 2 substance). Table 12 lists the loss of containment (LOC) scenarios to be modelled for single containment atmospheric storage tanks storing Ignition Category 3 substances (kerosene/ULSD) that are co-located in the same bund as bulk storage tanks containing Ignition Category 2 substances. A pool fire hazard is assumed to apply to kero/ULSD and VCE/flash fire hazards are screened out.

In relation to road tankers, full tankers are not parked up on site, therefore loss of containment scenarios associated with road tanker loading/unloading activities are considered for gasoline road tankers.

Installation	LOC scenario	Consequence	Event #
Tank 2 – bulk gasoline storage tank, 15,495 m3	Instantaneous failure	Pool fire – within bund	001
		Poo fire – uncontained adjacent to bund	002
		VCE	003
		Flash fire	004
	Continuous leak over 10 minutes	Pool fire	005
		VCE	006
		Flash fire	007
	10 mm pipe leak over 30 minutes	Pool fire	008
		VCE	009
		Flash fire	010
Tank 8 /9 – bulk gasoline storage tank, 760 m3/1150 m3	Instantaneous failure	Pool fire – within bund	001
		Poo fire – uncontained adjacent to bund	002
		VCE	011
		Flash fire	012
	Continuous leak over 10 minutes	Pool fire	013
		VCE	014
		Flash fire	015
	10 mm pipe leak over 30 minutes	Pool fire	016
		VCE	017
		Flash fire	018
Gasoline road tanker (loading area)	Rupture of loading/unloading arm	Pool fire	019
		VCE	020
		Flash fire	021
	Leak of unloading arm 10% of diameter	Pool fire	022
		VCE	023
		Flash fire	024

Table 11 Loss of Containment Scenarios and Consequences for Gasoline

Installation	LOC scenario	Consequence	Event #
Tank 1-7 – bulk kero/ULSD	Instantaneous failure	Pool fire – within bund	025
		Pool fire – uncontained adjacent to bund	026
	Continuous leak over 10 minutes	Pool fire	027
	10 mm pipe leak over 30 minutes	Pool fire	028

Table 12 Loss of Containment Scenarios and Consequences for Kero/ULSD

5.1 Buncefield Explosion Scenario

Following the original submission of the LUP assessment to the HSA (prior to the lodgment of the planning application), the HSA responded stating that the report did not include the VCE scenario following an overfill of Tank 2.

Section 3.6.1 of the TLUP states:

'The consequences of tank overfilling are expected to be within the envelope of consequences described in Table 44, but could be added to by the CCA, if considered necessary.'

The HSA considered that the inclusion of a Buncefield-type event is necessary and requested that the consequences were to be included in this Land Use Planning report.

The most recent guidance Land Use Planning guidance from the HSA, *Guidance on Technical Land Use Planning Advice* (HSA, 2023) does not include a methodology for a Buncefield-type event. The previous Land Use Planning guidance, COMAH Land Use Planning Policy and Approach Document (HSA, 2010), detailed a methodology for assessing a Buncefield-type VCE. This methodology follows the UK Health and Safety Executive's Research Report 512 (RR512) document (HSE, 2007), which is a publicly available methodology that is specifically intended to assess Buncefield-type sites.

The methodology outlined in the Land Use Planning guidance (HSA, 2010) will be used in this study as it is a methodology specifically for Buncefield-type sites and has been previously used, in published guidance in Ireland, by the HSA.

6.0 ASSESSMENT OF MAJOR ACCIDENT HAZARDS FOR IGNITION CATEGORY 0 SUBSTANCES – GASOLINE

6.1 Gasoline Loss of Containment Scenarios

Currently, there are 2 No. bulk storage tank at Circle K containing gasoline which is classified as ignition category 0 (Tank 8 and Tank 9). Tank 2 may revert to gasoline storage in the future. Table 11 lists the loss of containment scenarios including catastrophic tank rupture, failure over 10 minutes, 10 mm diameter leak over 30 minutes and road tanker loss of containment. Consequence modelling of pool fire, vapour cloud explosion and flash fire scenarios is described in the following sections.

The total bund area is given in the Safety Report for the fuel terminal as 11695 m^2.

In the event of catastrophic failure of Tank 8/9 or Tank 2, the pool area is taken as the area within the bund, excluding remaining tanks.

In the event of bund overtopping, due to the lack of information on the surrounding topography, the maximum pool size of 100m diameter will be used, as given in the TLUP guidance document (Section 2.7, HSA, 2023).

For a tank leak scenario, the leaking tank remains intact; therefore, occupies space within the bund. Therefore, the pool area is taken as the area within the bund, excluding the tanks, and is calculated as 7665 m^2.

In relation to gasoline road tankers, Table 11 lists the loss of containment scenarios including rupture of the loading/unloading arm or leak of the loading/unloading arm (10% of diameter). Consequence modelling of pool fire, vapour cloud explosion and flash fire scenarios is described in the following sections.

6.2 Tank 2 or 8/9 LOC and Gasoline Pool Fire Scenarios

In the event of rupture of a bulk fuel storage tank (and bund overtopping) there is the potential for the released material to form a pool which on ignition could result in an uncontained pool fire. Alternatively, a pool may form within the bund which would result in a bund fire on direct ignition. As outlined above in Section 6.1, the maximum pool radius for both scenarios is 50 m. As per Table 11, a continuous leak over 10 minutes or a 10 mm pipe leak over 30 minutes have the potential to result in a pool fire within the bund.

6.2.1 Pool Fire Model Inputs

Pool fire model inputs are summarised in Table 13. Tank 9 contains a larger volume of gasoline than tank 8 and is therefore selected as the representative source for gasoline loss of containment scenarios in the day tank bund.

Parameter	Units	Tank 2 (Main bund)			Tank 9 (Day tank bund)		
Scenario	-	Catastrophic rupture	Failure over 10 minutes (fixed duration release)	10 mm leak over 30 minutes	Catastrophic rupture	Failure over 10 minutes (fixed duration release)	10 mm leak over 30 minutes
Substance	-	Gasoline (modelled as n-pentane)					
Tank diameter	m	40	40	40	9	9	9
Liquid volume	m^3	15495	15495	15495	1055	1055	1055
Liquid height	m	12.3	12.3	12.3	10.2	10.2	10.2
Weather conditions	-	D5: 5 m/s windspeed & 15 ^{0}C F2: 2 m/s windspeed & 10 ^{0}C					
Max. pool dia.	m	100	100	100	100	100	100

Table 13 Gasoline LOC from Bulk Storage: Pool Fire Model Inputs

Pentane is used as a surrogate for gasoline with the maximum SEP set at 130 kW/m^2. The two-zone pool fire model in DNV PHAST Version 9.0 modelling software was used to model the consequences of pool fire involving gasoline (modelled as pentane).

6.2.2 Pool Fire Model Outputs

Pool fire model outputs are summarised in Table 14.

Parameter	Units	Catastrophic rupture/ Failure over 10 minutes		10 mm leak over 30 minutes	
		D5	F2	D5	F2
Pool fire diameter (late pool fire)	m	100	100	10	13
Pool fire flame length	m	118	115	24	28
Total burn rate	kg/s	862	838	9	15
Radiative fraction	-	0.023	0.023	0.20	0.21

Table 14 Gasoline LOC Scenarios: Pool Fire Model Outputs

6.2.3 Pool Fire Thermal Radiation Consequences

Modelling parameters are as described in Section 4.2. The receiver height was specified as 1.5 m.

Thermal radiation vs. distance downwind is illustrated on Figure 6. The catastrophic tank failure scenario results in a 100 m diameter pool fire outside of the bund or inside the bund (also 100 m diameter based on bund dimensions). The tank failure over 10 minutes scenario results in a 100 m diameter pool fire within the bund. The 10 mm leak over 30 minutes scenario results in a 10.3 m / 13.2 m (D5 / F2) diameter pool fire scenario inside the bund.

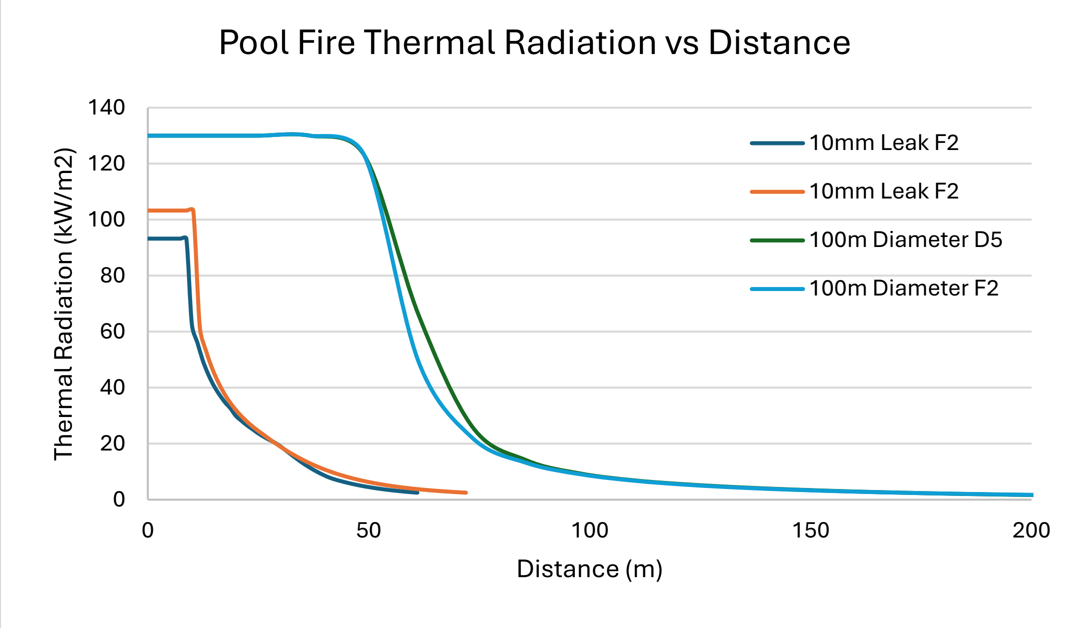


Figure 6 Tank 2 or 8 Gasoline LOC and Pool Fire: Thermal Radiation vs. Distance

Thermal radiation results are summarised in Table 15.

The outdoor mortality consequence is based on the Eisenberg probit equation (see Section 4.1.3) and an exposure duration of 60 s.

Thermal radiation level, kW/m^2	Consequences	Distance (m)			
		Catastrophic rupture/ Failure over 10 minutes		10 mm leak over 30 minutes	
		D5	F2	D5	F2
8.02	1% mortality outdoors	105	103	40	46
12.7	Persons indoors protected	90	87	35	38
25.6	100% fatality indoors	72	74	25	26

Table 15 Tank 8 Gasoline LOC and Pool Fire: Thermal Radiation Results

The worst-case 1% mortality outdoors contour is illustrated on Figure 7 for the worst-case bund fire.

In the event of rupture of Tank 2, there is the potential for the released liquid to overtop the bund to the north or to the east. A pool fire centred 50 m to the north of the bund has greater potential for impacts at the Proposed scheme, than a pool fire centred 50 m to the east of the bund. Figure 8 illustrates the1% outdoor mortality contour, centred 50 m to the north of the bund.

In the event of rupture of Tank 8 or 9 there is the potential for the released liquid to overtop the bund to the south. The 1% mortality outdoors contour centred 50 m to the south of the bund is illustrated on Figure 9.

The shape of the contour is shown for the prevailing wind direction as well as the effect zone which takes account of all possible wind directions.

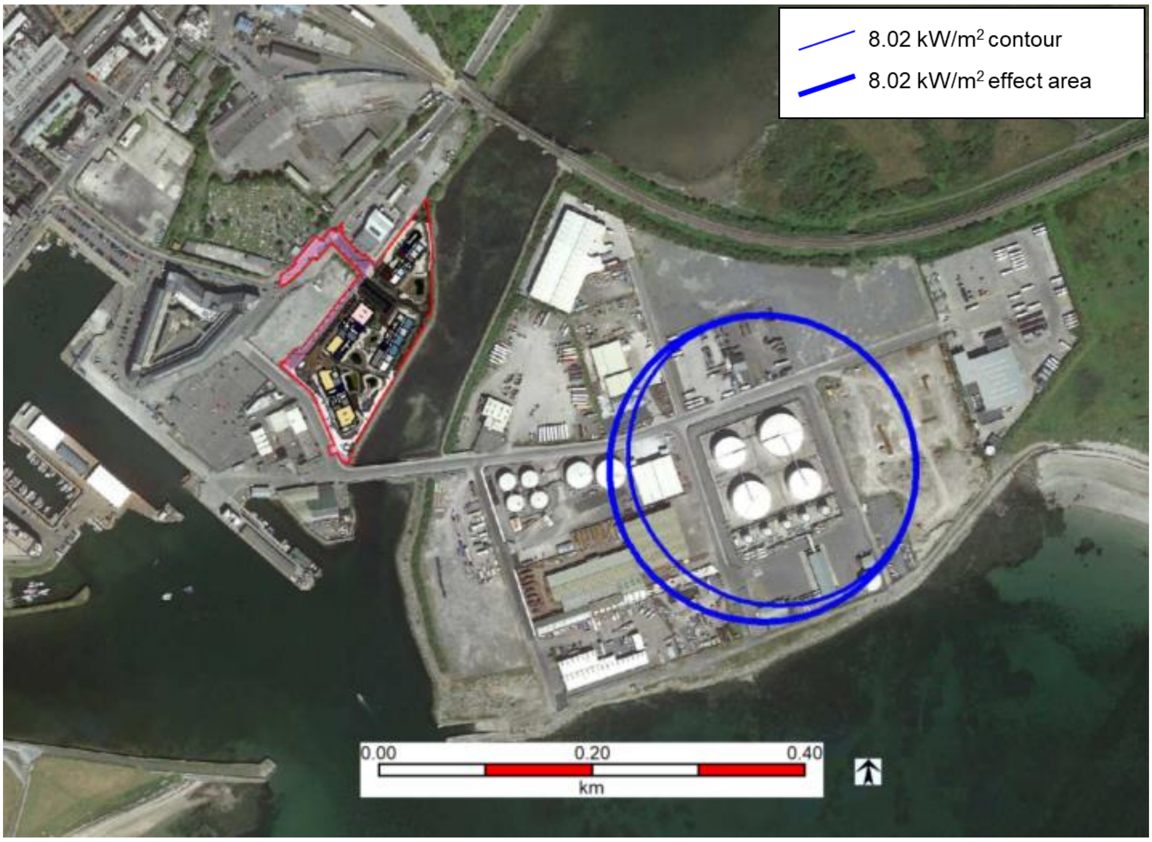


Figure 7 Gasoline Bund Fire: Case 1% Mortality Outdoors Contour Category D5

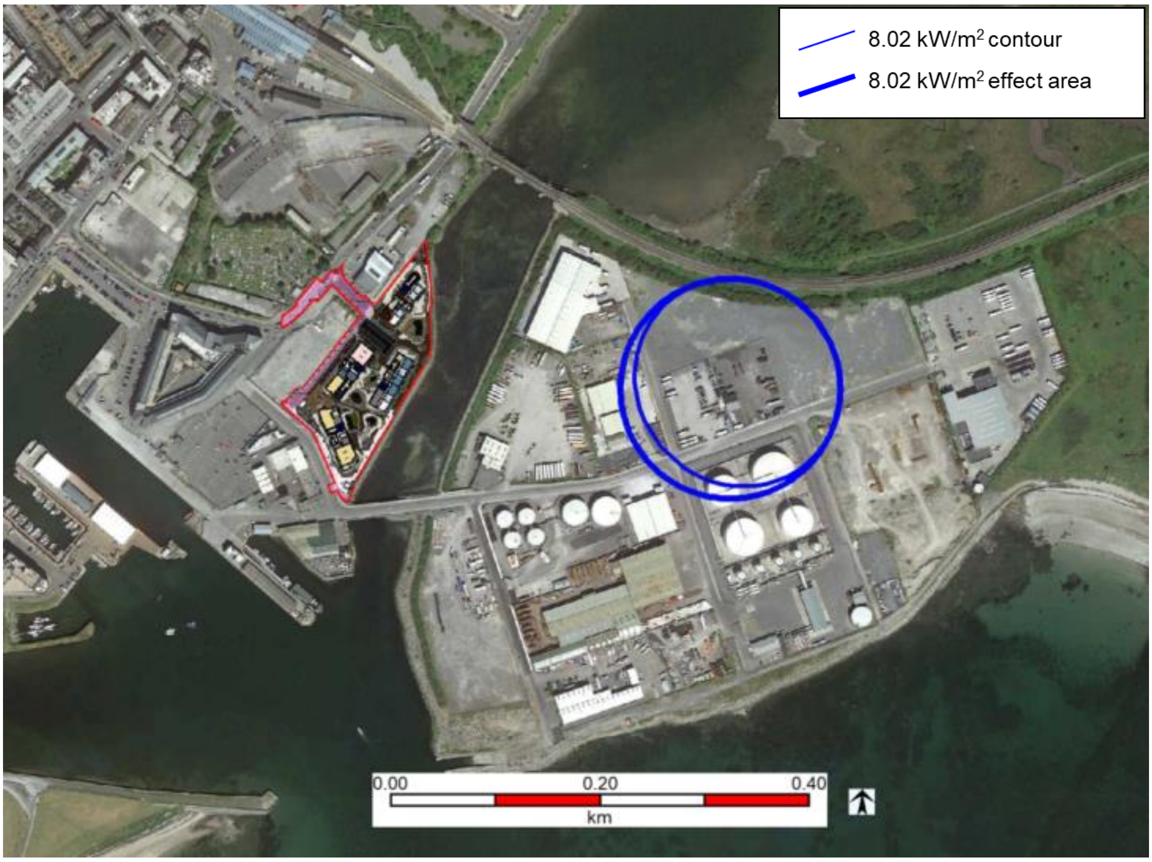


Figure 8 Gasoline Uncontained Fire to North of Bund: 1% Mortality Outdoors Contour D5

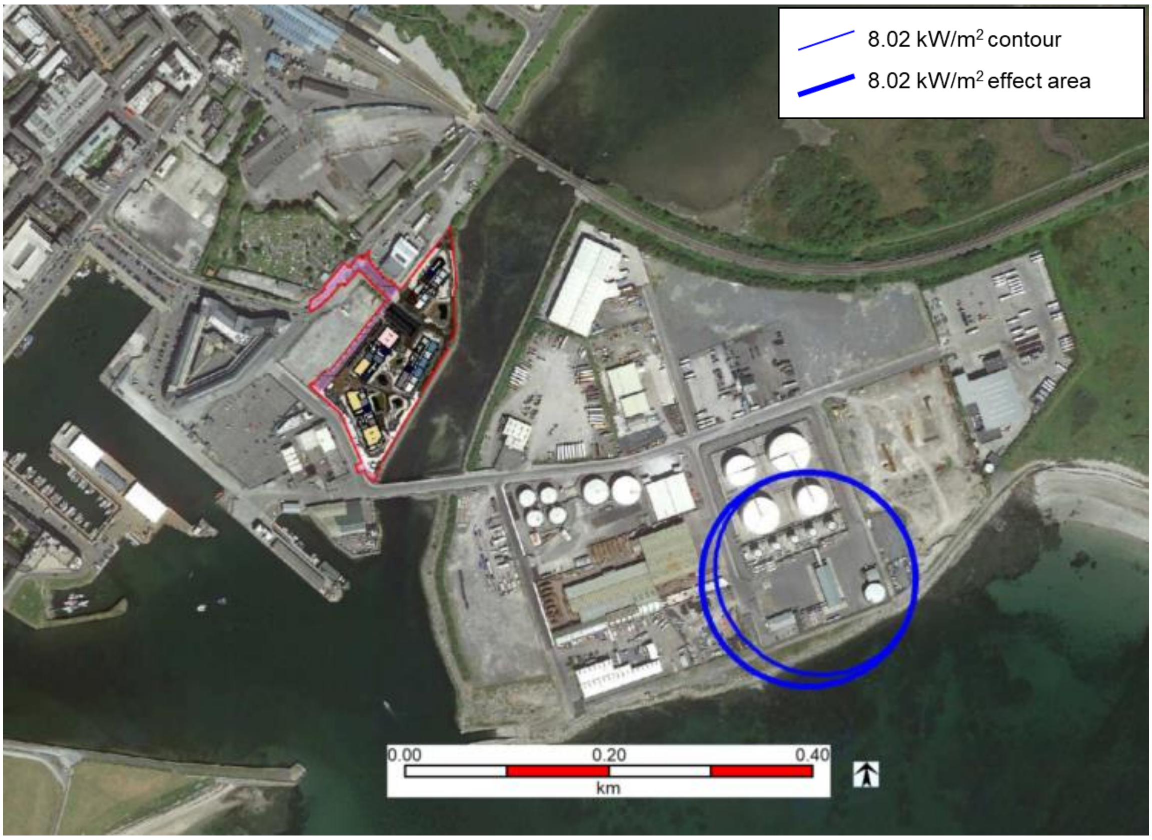


Figure 9 Gasoline Uncontained Pool Fire to South of Bund: 1% Mortality Outdoors Contour D5

The following is concluded:

- The thermal radiation level corresponding to the 1% mortality outdoors does not reach the proposed scheme, persons outdoors at this location would not be exposed to harmful levels of thermal radiation;
- The thermal radiation level below which persons in indoor locations are protected does not extend to the proposed scheme, persons indoors at this location are protected from the thermal radiation consequences of a pool fire at the Circle K terminal.

6.3 Tank 2, 8 or 9 LOC and Gasoline Vapour Cloud Explosion Scenarios

In the event of ignition of a flammable cloud of vapour following a major release of gasoline, there is the potential for a vapour cloud explosion to occur with damaging levels of peak overpressure. Tank 9 contains a larger volume of gasoline than Tank 8 and is therefore selected as the representative source for gasoline loss of containment scenarios in the day tank bund

6.3.1 VCE Model Inputs

Table 16 details the model inputs for a VCE following loss of containment from Tank 2, 8 or 9.

Parameter	Units	Value	Source
Chemical name	-	Gasoline, modelled as n-pentane	-
Temperature	°C	10 (F2) 15 (D5)	HSA guidance (HSA, 2023)
Inventory	m^3	15,495 (Tank 2) 1055 (Tank 9)	GHC
Maximum pool size (Tank 2 LOC scenarios)	m^2	8922 m^2 in bund 7854 m^2 adjacent to bund 7665 m^2 in bund	rupture scenario rupture scenario (overtop) leak scenario
Maximum pool size (Tank 9 LOC scenarios)	m^2	7752 m^2 in bund 7854 m^2 adjacent to bund 7665 m^2 in bund	rupture scenario rupture scenario (overtop) leak scenario
Surface roughness	m	0.1	HSA guidance (HSA, 2023)
Explosion strength	-	7 for 20% of cloud volume	HSA guidance (HSA, 2023)
Combustion energy	MJ/m^3	3.5	HSA guidance (HSA, 2023)
Ignition location	-	60 m downwind	Distance from centre of bund to site roadway where ignition may be initiated by a vehicle

Table 16 Gasoline Bulk Storage Tank LOC and VCE: Model Inputs

The pool source for the tank rupture and bund overtopping scenario is the sum of the pool source within the bund (rupture scenario) + the pool source adjacent to the bund (overtop).

The TNO Multi Energy Model was used to predict the overpressure consequences of vapour cloud explosion scenarios.

6.3.2 Flammable Mass

The unified dispersion model in DNV PHAST Version 9.0 determined the following flammable mass for each loss of containment scenario:

Tank	LOC Scenario	Flammable mass Category D5 (kg)	Flammable Mass Category F2 (kg)
Tank 2	Catastrophic Rupture	1526	1501
	Failure over 10 minutes	192	170
	10 mm diameter leak	No VCE hazard	No VCE hazard
Tank 9	Catastrophic Rupture	377	350
	Failure over 10 minutes	130	208
	10 mm diameter leak	No VCE hazard	No VCE hazard

Table 17 Gasoline LOC and VCE: Model Inputs

6.3.3 VCE Overpressure Consequence Results

Figure 10 illustrates overpressure vs. distance for Tank 2 loss of containment scenarios. In the event of a 10 mm diameter leak, the lower flammable limit is not reached at the identified ignition location (60 m downwind from the release) and no VCE hazard arises.

Figure 11 illustrates overpressure vs. distance for Tank 9 loss of containment scenarios. In the event of a 10 mm diameter leak, the lower flammable limit is not reached at the identified ignition location (60 m downwind from the release) and no VCE hazard arises.

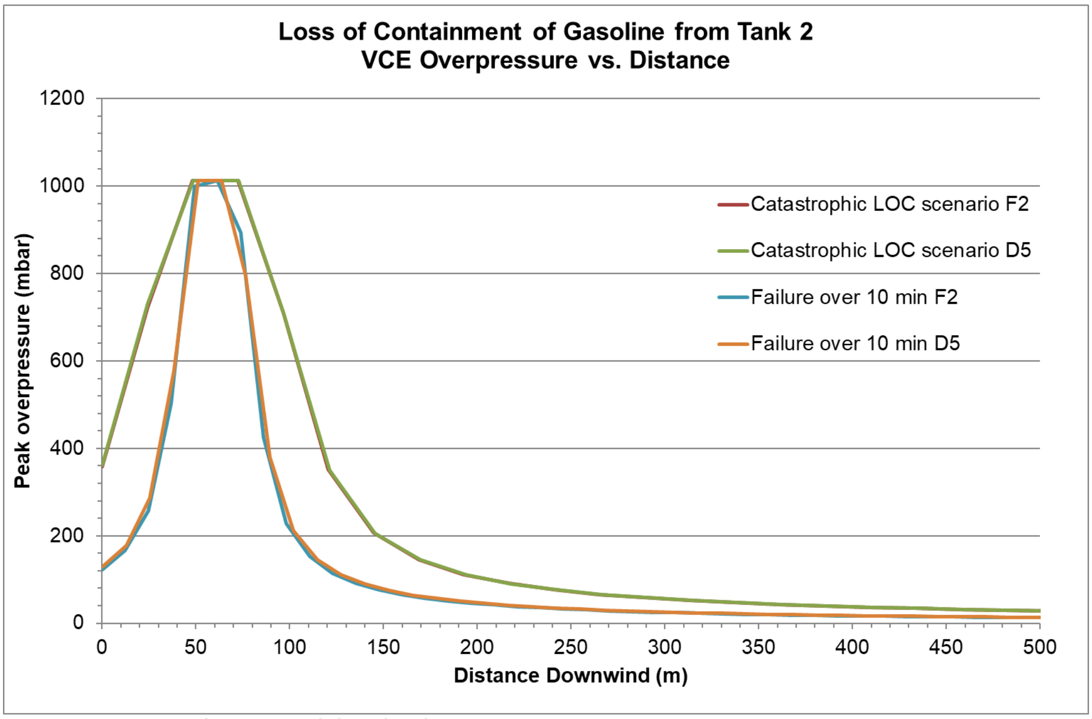


Figure 10 Tank 2 Gasoline LOC: VCE Overpressure vs. Distance

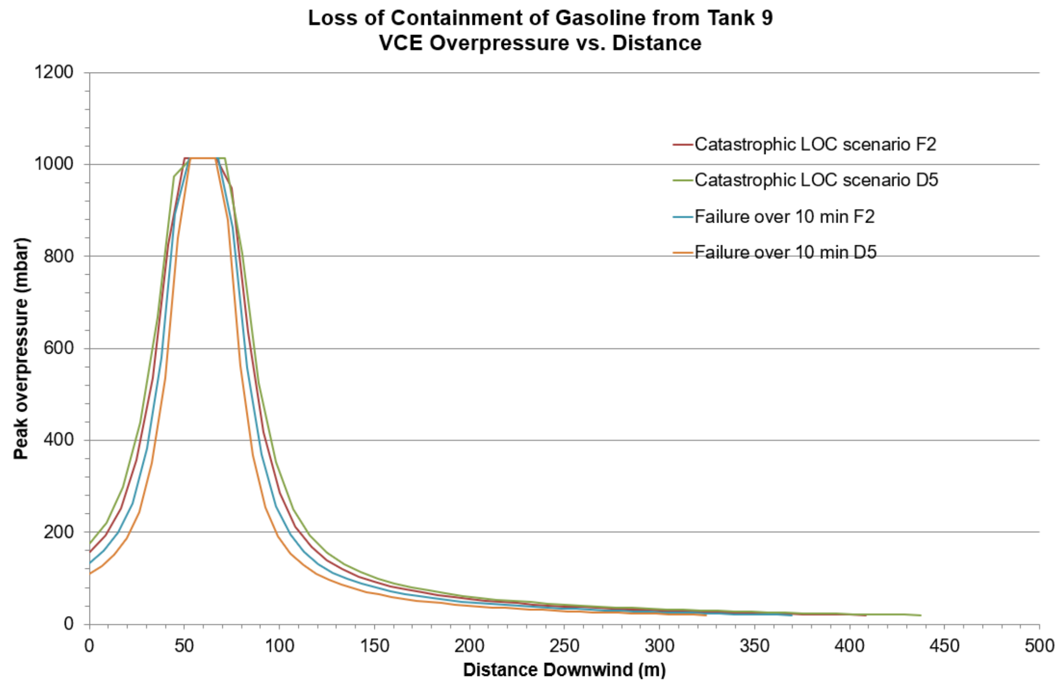


Figure 11 Tank 9 Gasoline LOC: VCE Overpressure vs. Distance

Table 18 details the distances to overpressure levels associated with specified levels of damage and mortality to persons outdoors and indoors arising from Tank 2 loss of containment scenarios.

Table 19 details the distances to overpressure levels associated with specified levels of damage and mortality to persons outdoors and indoors arising Tank 9 loss of containment scenarios.

Definition of damage (Lees LPPI) / mortality (HNP Probit)	Overpressure level (mbar)	Catastrophic LOC scenario		Failure over 10 minutes	
		F2	D5	F2	D5
		Distance (m)	Distance (m)	Distance (m)	Distance (m)
Safe distance, probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken	20	659	662	350	362
Light damage (minor building damage)	35	421	423	234	242
Moderate damage (structural damage starts)	170	159	160	108	110
Severe damage	350	121	121	91	91
Total destruction	830	87	87	75	75
Mortality Outdoors (Hurst Nussey Pape Probit)					
50% outdoors	942	78	78	69	68
10% outdoors	365	120	120	90	90
1% outdoors	168	160	160	108	110
Mortality indoors					
50% mortality, CIA 2 (4 storey, typical office buildings)	284	132	132	95	96
10% mortality, CIA 2	183	154	154	106	108
1% mortality, CIA 2	100	206	207	131	134
50% mortality, CIA 3 (typical domestic building)	300				
10% mortality, CIA 3	139				
1% mortality, CIA 3	50				

Table 18 Tank 2 Gasoline LOC and VCE: Overpressure Results

Definition of damage (Lees LPPI) / mortality (HNP Probit)	Overpressure level (mbar)	Catastrophic LOC scenario		Failure over 10 minutes	
		F2	D5	F2	D5
		Distance (m)	Distance (m)	Distance (m)	Distance (m)
Safe distance, probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken	20	408	438	369	325
Light damage (minor building damage)	35	270	287	246	219
Moderate damage (structural damage starts)	170	117	122	110	104
Severe damage	350	96	98	92	87
Total destruction	830	80	78	76	74
Mortality Outdoors (Hurst Nussey Pape Probit)					
50% outdoors	942	75	75	72	70
10% outdoors	365	95	98	91	86
1% outdoors	168	117	122	110	104
Mortality indoors					
50% mortality, CIA 2 (4 storey, typical office buildings)	284	100	104	96	91
10% mortality, CIA 2	183	114	118	108	101
1% mortality, CIA 2	100	145	152	135	124

Table 19 Tank 9 Gasoline LOC and VCE: Overpressure Results

The worst case VCE scenario is predicted to arise following catastrophic rupture of Tank 2 during D5 (daytime) conditions. Figure 12 illustrates overpressure contours corresponding to outdoor and indoor mortality (168 mbar and 100 mbar respectively).

The VCE scenario assumes vapour cloud drift and ignition of the flammable mass by a vehicle on the ring road and is centred at the western ring road area in order to conservatively predict impacts at the Proposed scheme site.

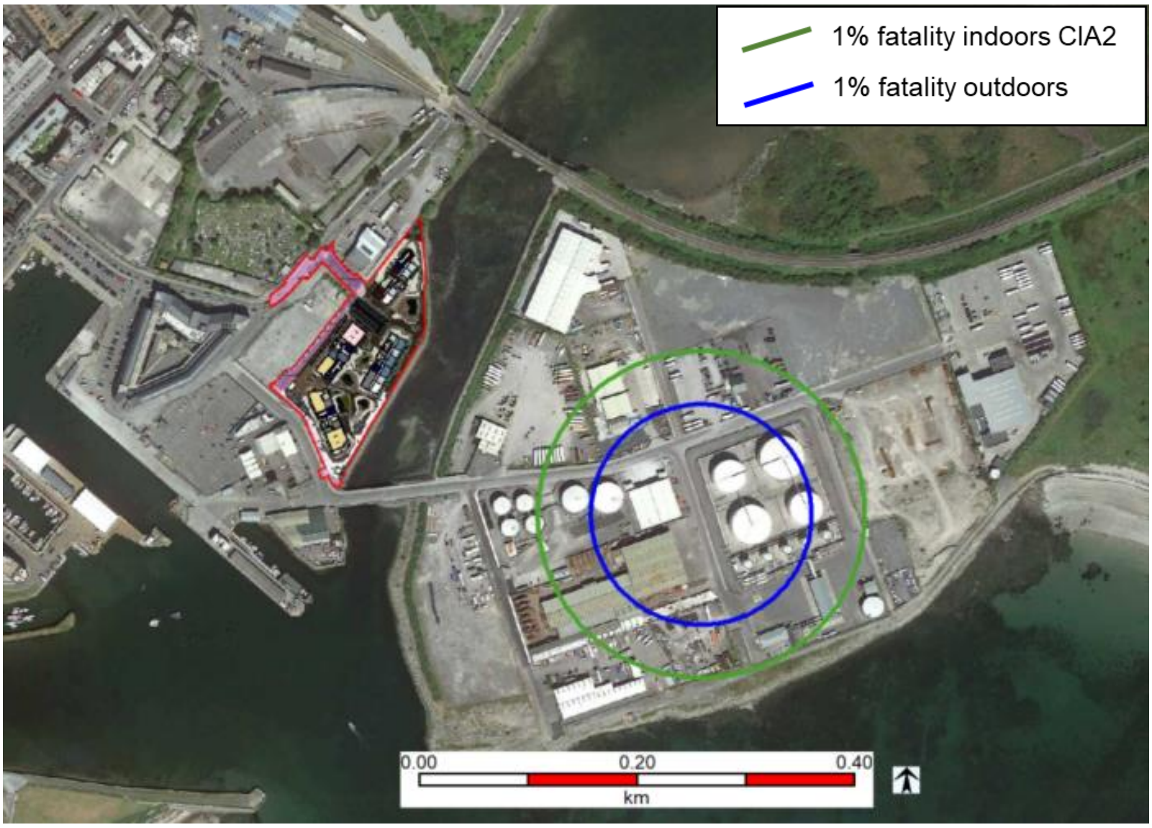


Figure 12 Tank 2 Gasoline LOC and VCE: Outdoor and Indoor Mortality Contours

The following is concluded:

- The overpressure level corresponding to 1% mortality outdoors does not extend to the proposed scheme;
- The overpressure level corresponding to 1% mortality indoors in CIA 2 buildings does not extend to the proposed scheme;
- No fatalities are predicted to arise at the proposed scheme.

6.4 Tank 2 or 9 LOC and Gasoline Flash Fire Scenarios

6.4.1 Flash Fire Model Inputs

Parameter	Units	Value	Source
Chemical name	-	Gasoline, modelled as n-pentane	-
Temperature	°C	10 (F2) 15 (D5)	HSA guidance (HSA, 2023)
Inventory	m^3	15,495 (Tank 2) 760 (Tank 8)	GHC
Maximum pool size (Tank 2 LOC scenarios)	m^2	8922 m^2 in bund 7854 m^2 adjacent to bund 7665 m^2 in bund	rupture scenario rupture scenario (overtop) leak scenario
Maximum pool size (Tank 9 LOC scenarios)	m^2	7752 m^2 in bund 7854 m^2 adjacent to bund 7665 m^2 in bund	rupture scenario rupture scenario (overtop) leak scenario
Surface roughness	m	0.1	HSA guidance (HSA, 2023)

Table 20 Tank 8 Gasoline LOC and Flash Fire: Model Inputs

The pool source for the tank rupture and bund overtopping scenario is the sum of the pool source within the bund (rupture scenario) + the pool source adjacent to the bund (overtop).

The unified dispersion model in DNV PHAST Version 9.1 was used to model the flash fire envelope.

6.4.2 Flash Fire Envelope

The flash fire envelope is the maximum distance to the lower flammability limit. Distances are given at ground level which represents the worst-case scenario for a ground source evaporating pool. Table 21 summarises the flash fire model outputs for Tank 2 and Tank 9 gasoline LOC scenarios.

LOC Scenario	Flash Fire Envelope	
	Category D5	Category F2
Tank 2 Catastrophic failure	269 m	349 m
Tank 2 Failure over 10 minutes	325 m	519 m
Tank 2 10 mm diameter leak	Not Reached	20 m
Tank 9 Catastrophic failure	145 m	240 m
Tank 9 Failure over 10 minutes	205 m	311 m
Tank 9 10 mm diameter leak	Not Reached	19 m

Table 21Gasoline LOC and Flash Fire: Model Outputs

Figure 13 illustrates the worst-case flash fire contours for Tank 2 Failure over 10 minutes.

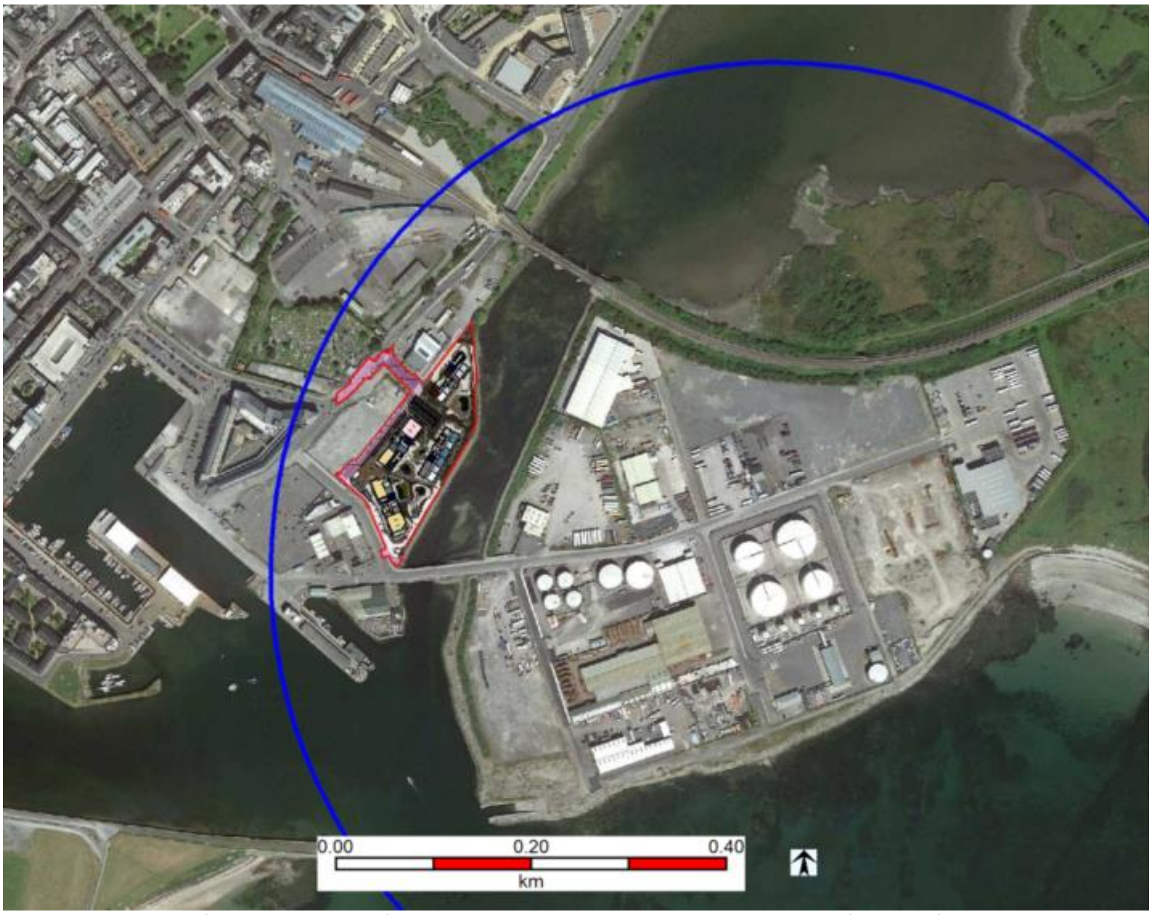


Figure 13 Tank 2 Gasoline Failure Over 10 Minutes and Flash Fire: Flash Fire Contour for F2 Weather Conditions

In the event of a LOC of gasoline from Tank 2, it is concluded that the worst-case flash fire contour extends to the proposed scheme. The probability of fatality outdoors is 100% within this footprint and the probability of fatality indoors is 10%. Persons are assumed to be indoors 90% of the time (HSA, 2023).

In the event of a LOC of gasoline from Tank 9, it is concluded that the worst-case flash fire contour does not extend to the proposed scheme and persons both outdoors and indoors are protected.

6.5 Gasoline Road Tanker LOC and Pool Fire Scenarios

Consequence modelling results are presented for the worst-case gasoline road tanker loss of containment scenario (loading arm rupture).

6.5.1 Pool Fire Model Inputs

Pool fire model inputs are summarised in Table 22.

Parameter	Units	Value
Substance	-	Gasoline (modelled as n-pentane)
Liquid volume	m^3	45
Loading arm diameter	mm	101.6
Length of pipeline	m	70
Weather conditions		D5: 5 m/s windspeed & 15 ^0C F2: 2 m/s windspeed & 10 ^0C
Maximum pool diameter	m	100 (conservative estimation)

Table 22 Gasoline Road Tanker LOC Scenarios: Pool Fire Model Inputs

Pentane is used as a surrogate for gasoline with the maximum SEP set at 130 kW/m^2. The two-zone pool fire model in DNV PHAST Version 9.0 modelling software was used to model the consequences of pool fire involving gasoline (modelled as pentane).

6.5.2 Pool Fire Model Outputs

Pool fire model outputs are summarised in Table 23.

Parameter	Units	Loading arm rupture	
		D5	F2
Pool fire diameter	m	10	10
Pool fire flame length	m	24	24
Total burn rate	kg/s	8.7	8.8
Radiative fraction	-	0.113	0.111

Table 23 Gasoline Road Tanker LOC: Pool Fire Model Outputs

6.5.3 Pool Fire Thermal Radiation Consequences

Modelling parameters are as described in Section 4.2. The receiver height was specified as 1.5 m. Thermal radiation vs. distance downwind is illustrated on Figure 14.

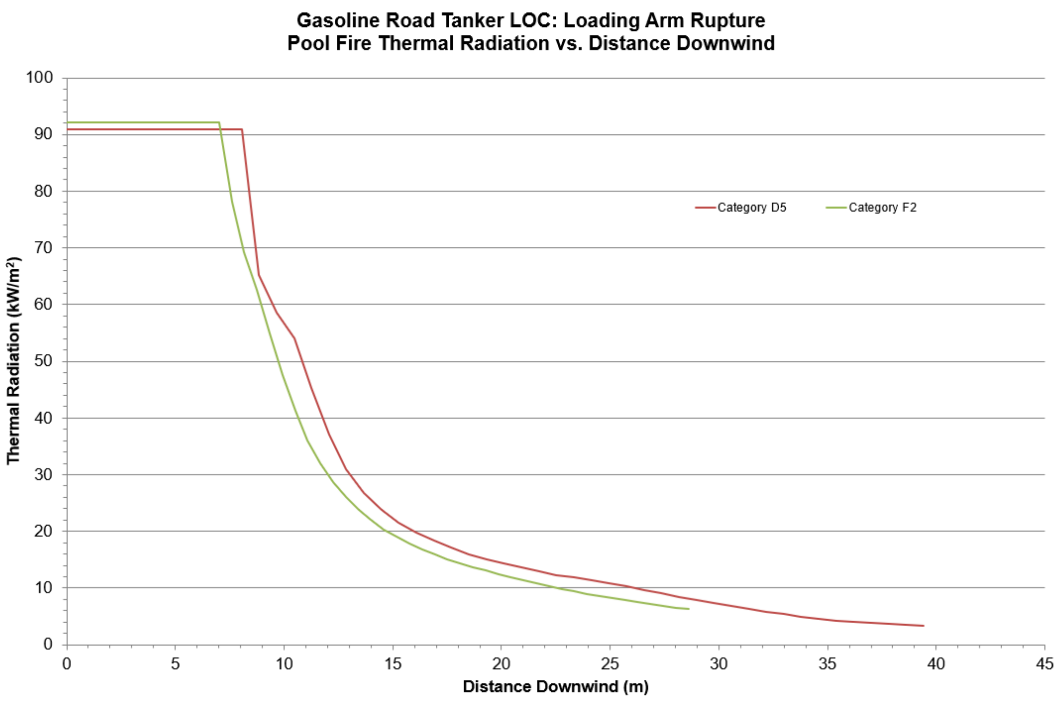


Figure 14 Gasoline Road Tanker LOC and Pool Fire: Thermal Radiation vs. Distance

Thermal radiation results are summarised in Table 24. The outdoor mortality consequence is based on the Eisenberg probit equation and an exposure duration of 60 s.

Thermal radiation level, kW/m^2	Consequences	Distance (m)	
		Loading arm rupture	
		D5	F2
8.02	1% mortality outdoors	29	26
12.7	Persons indoors protected	22	20
25.6	100% fatality indoors	14	13

Table 24 Gasoline Road Tanker LOC and Pool Fire: Thermal Radiation Results

It is concluded that the thermal radiation level corresponding to the 1% mortality outdoors/indoors is confined to the road tanker loading bay area and does not reach the Circle K site boundary or the Proposed scheme, persons outdoors/indoors at this location would not be exposed to harmful levels of thermal radiation.

6.6 Gasoline Road Tanker LOC and VCE Scenarios

In the event of ignition of a flammable cloud of vapour following a loss of containment of gasoline from a road tanker, there is the potential for a vapour cloud explosion to occur with damaging levels of peak overpressure.

6.6.1 VCE Model Inputs

Parameter	Units	Value	Source
Chemical name	-	Gasoline, modelled as n-pentane	-
Temperature	°C	10 (F2) 15 (D5)	HSA guidance (HSA, 2023)
Inventory	m^3	45	GHC
Maximum pool diameter	m	100	conservative estimation
Surface roughness	m	0.1	HSA guidance (HSA, 2023)
Explosion strength	-	7 for 20% of cloud volume	HSA guidance (HSA, 2023)
Combustion energy	MJ/m^3	3.5	HSA guidance (HSA, 2023)

Table 25 Tank 8 Gasoline LOC and VCE: Model Inputs

The maximum pool diameter is specified as 100 m. As detailed in Section 6.5.2, the pool size is calculated as 10 m by the discharge model in PHAST Version 9.0.

6.6.2 Flammable Mass

The unified dispersion model in DNV PHAST Version 9.0 estimates a flammable mass of 1 kg for category D5 and 0.84 kg for category F2.

6.6.3 VCE Overpressure Consequence Results

Figure 15 illustrates overpressure vs. distance and Figure 16 illustrates impulse vs. distance for Tank 2 loss of containment scenarios. In the event of a 10 mm diameter leak for weather category D5, the lower flammable limit is not reached and no VCE hazard arises.

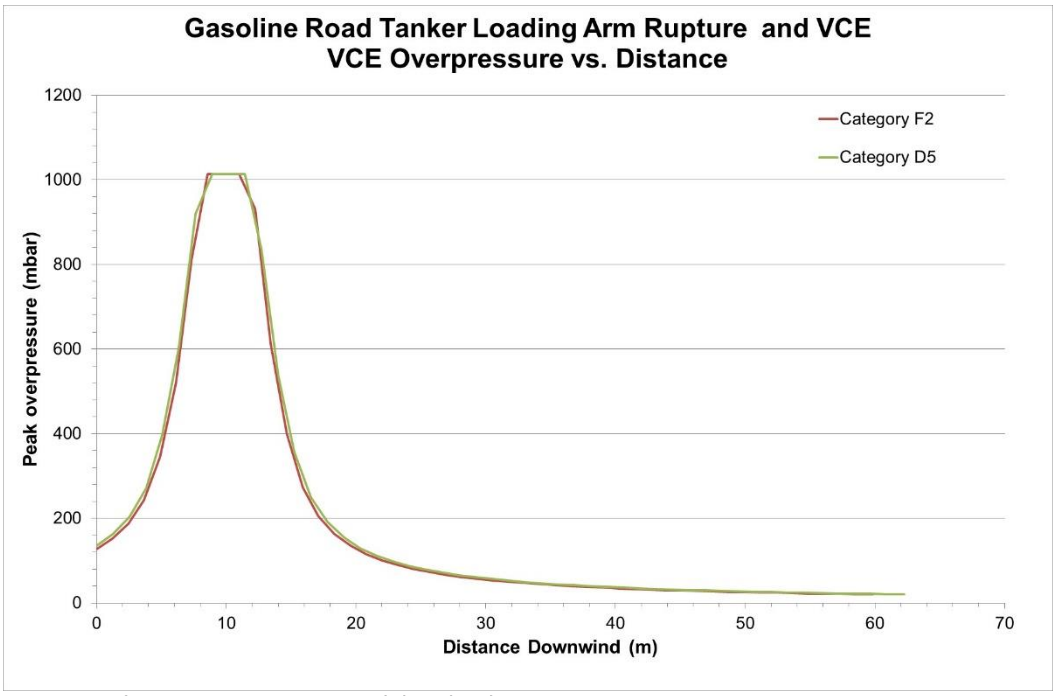


Figure 15 Gasoline Road Tanker LOC: VCE Overpressure vs. Distance

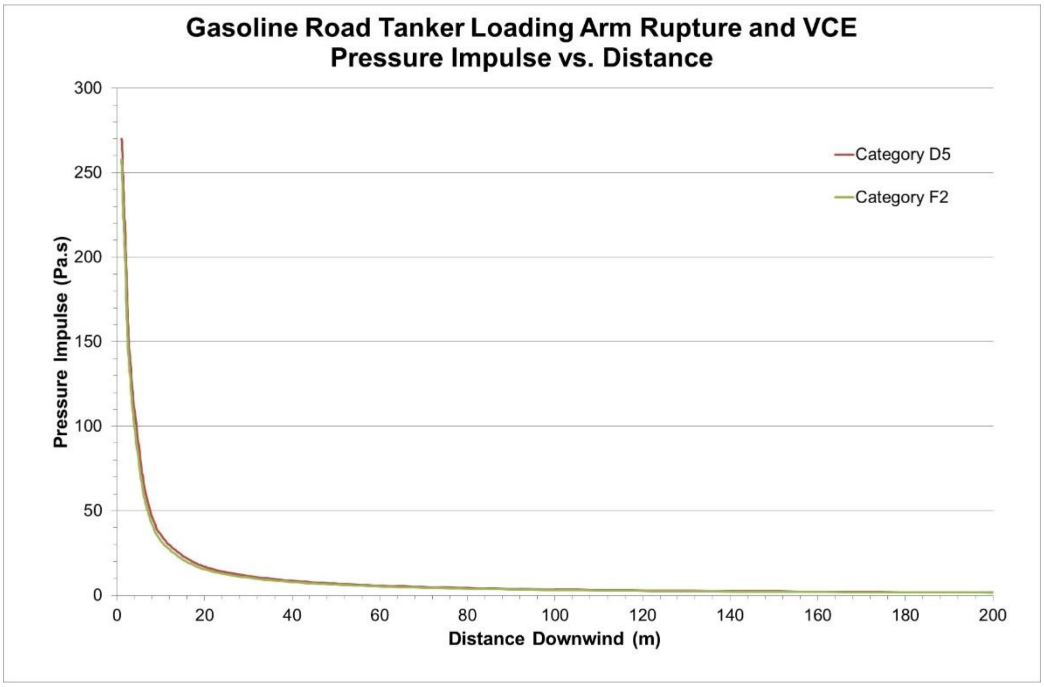


Figure 16 Tank 2 Gasoline LOC: VCE Pressure Impulse vs. Distance

Table 26 details the distances to overpressure levels associated with specified levels of damage and mortality to persons outdoors and indoors arising from Tank 2 loss of containment scenarios.

Definition of damage (Lees LPPI) / mortality (HNP Probit)	Overpressure level (mbar)	Loading Arm Rupture	
		D5	F2
		Distance (m)	Distance (m)
Safe distance, probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken	20	62	60
Light damage (minor building damage)	35	41	40
Moderate damage (structural damage starts)	170	18	18
Severe damage	350	15	15
Total destruction	830	13	13
Mortality Outdoors (Hurst Nussey Pape Probit)			
50% outdoors	942	12	12
10% outdoors	365	15	15
1% outdoors	168	19	18
Mortality indoors			
50% mortality, CIA 2 (4 storey, typical office buildings)	284	16	16
10% mortality, CIA 2	183	18	18
1% mortality, CIA 2	100	23	22

Table 26 Gasoline Road Tanker Loading Arm Rupture and VCE: Overpressure Results

The proposed scheme is located *ca.* 430m west of the road tanker loading area. In the event of VCE following rupture of a gasoline road tanker loading arm, the distance the overpressure level corresponding to 1% mortality outdoors is 19 m / 18 m (Category D5 / F2) and the distance to the overpressure level corresponding to 1% mortality indoors in CIA Category 2 buildings is 23 m / 22 m (Category D5 / F2). The distance to the overpressure level corresponding to light damage is 41 m / 40 m (D5 / F2). It is not anticipated that this scenario would result in any injuries or fatalities at the proposed scheme.

6.7 Gasoline Road Tanker LOC and Flash Fire Scenarios

6.7.1 Flash Fire Model Inputs

Parameter	Units	Value	Source
Chemical name	-	Gasoline, modelled as n-pentane	-
Temperature	°C	10 (F2) 15 (D5)	HSA guidance (HSA, 2023)
Inventory	m^3	45	GHC
Maximum pool diameter	m	100	conservative assumption
Surface roughness	m	0.1	HSA guidance (HSA, 2023)

Table 27 Gasoline Road Tanker Loading Arm Rupture and Flash Fire: Model Inputs

The maximum pool diameter is specified as 100 m. As detailed in Section 6.5.2, the pool size is calculated as 10 m by the discharge model in PHAST Version 9.0.

6.7.2 Flash Fire Envelope

The flash fire envelope is the distance to the lower flammability limit. The unified dispersion model in PHAST Version 9.0 predicts a flash fire envelope of 5 m. Therefore, no impacts are anticipated at the proposed scheme which lies *ca.* 430 m west of the road tanker loading area.

6.8 Buncefield VCE

The Health and Safety Authority have requested a Buncefield-type VCE scenario is included in this Land Use Planning assessment.

The most recent guidance Land Use Planning guidance from the HSA, *Guidance on Technical Land Use Planning Advice* (HSA, 2023) does not include a methodology for a Buncefield-type event. The previous Land Use Planning guidance, COMAH Land Use Planning Policy and Approach Document (HSA, 2010), detailed a methodology for assessing a Buncefield-type VCE. This methodology follows the UK Health and Safety Executive's Research Report 512 (RR512) document, which is a methodology that is specifically intended to assess Buncefield-type sites.

The methodology outlined in the Land Use Planning guidance (HSA, 2010) will be used in this study as it is a methodology specifically for Buncefield-type sites and has been previously used in published guidance by the HSA.

6.8.1 Buncefield VCE Model Inputs

The VCE model inputs and modelling methodology is as detailed in the HSA COMAH Land Use Planning Policy and Approach Document (HSA, 2010) and Appendix A of this report.

The magnitude of the overpressure generated by the VCE is defined as that arising from a 50,000 m^3 VCE with an ignition strength of 7 (strong deflagration) and a combustion energy of 3.5 MJ/m^3 using the TNO multi-energy method.

The VCE event could be centred anywhere on site (for practical purposes, the frequency can be uniformly distributed between the locations close to all the main fuel storage tanks).

6.8.2 Buncefield VCE Model Outputs

Figure 17 illustrates overpressure vs. distance.

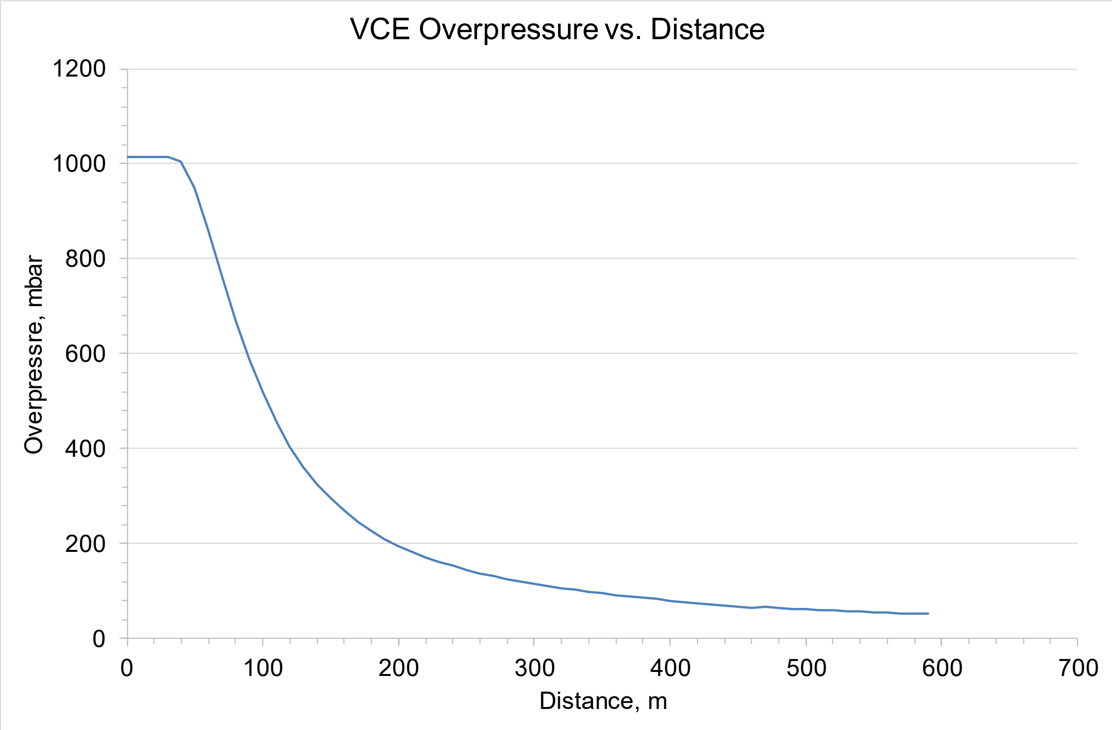


Figure 17 *Buncefield VCE: Overpressure vs Distance*

Table 18 details the distances to overpressure levels associated with specified levels of damage and mortality to persons outdoors and indoors arising from a Buncefield VCE.

Definition of damage (Lees LPPI) / mortality (HNP Probit)	Overpressure level (mbar)	Distance (m)
Safe distance, probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken	20	1400
Light damage (minor building damage)	35	846
Moderate damage (structural damage starts)	170	232
Severe damage	350	143
Total destruction	830	73
Mortality Outdoors (Hurst Nussey Pape Probit)		
50% outdoors	942	61
10% outdoors	365	139
1% outdoors	168	234
Mortality indoors		
50% mortality, CIA 2 (4 storey, typical office buildings)	284	164
10% mortality, CIA 2	183	220
1% mortality, CIA 2	100	346
50% mortality, CIA 3 (typical domestic building)	300	158
10% mortality, CIA 3	139	268
1% mortality, CIA 3	50	615

Table 28 Buncefield VCE: Overpressure Results

Figure 18 illustrates the overpressure contours corresponding to indoor and outdoor fatality. To illustrate the representative worst-case scenario, the explosion is centred at the closest point to the proposed scheme, at the northwestern corner of the Circle K bund.

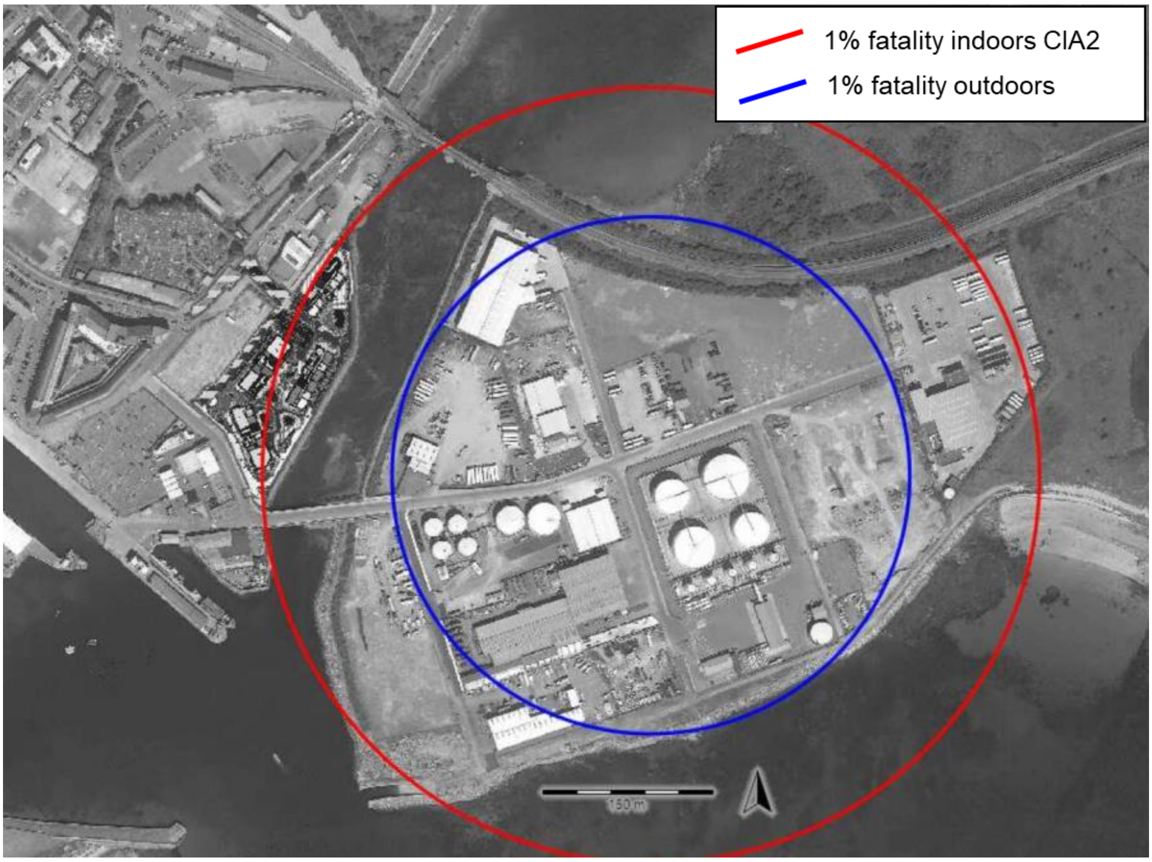


Figure 18 Buncefield VCE: Indoor and Outdoor Overpressure Contours

Following a Buncefield-type VCE at the Circle K fuel terminal, the following is concluded:

- The overpressure corresponding to 1% fatality outdoors, does not extend to the proposed scheme.
- The overpressure corresponding to 1% fatality indoors, CIA. 2, could extend to the proposed scheme. This overpressure contour could extend to Block C and Block D and a small section of Block A and Block B.

7.0 ASSESSMENT OF MAJOR ACCIDENT HAZARDS FOR IGNITION CATEGORY 3 SUBSTANCES – KERO AND ULSD

7.1 Kero or ULSD Loss of Containment Scenarios

There are 7 No. bulk storage tank at Circle K currently containing kero or ULSD which is classified as ignition category 3 (Tanks 1 – 7). The assessment is based on gasoline in Tank 2, and kerosene in Tank 1 and Tanks 3 – 7.

Ignition probabilities for Category 3 substances (kero and ULSD) are zero. Fire and explosion events are not considered for Category 3 substances, unless they are co-located in the same bund as Category 1 or Category 2 substances, in which case they could be modelled as Category 1 or Category 2 substances.

At Circle K, kero and ULSD are co located in the same bund as ethanol (Category 2 substance). Table 12 lists the loss of containment (LOC) scenarios to be modelled for single containment atmospheric storage tanks storing Ignition Category 3 substances (kerosene/ULSD) that are co-located in the same bund as bulk storage tanks containing Ignition Category 2 substances. A pool fire hazard is assumed to apply to kero/ULSD and VCE/flash fire hazards are screened out.

The total bund area is given in the Safety Report for the fuel terminal as 11695 m^2.

In the event of catastrophic failure of Tanks 1 and 3 - 7, the pool size within the bund (excluding remaining tanks) is calculated as 7729 m^2, the equivalent radius is 50 m.

In the event of bund overtopping, the maximum pool size outside of the bund is given in the TLUP guidance document as 50 m radius (HSA, 2023).

For a tank leak scenario, the maximum pool size is 7665 m^2. For a 10 mm tank leak scenario the pool size is determined within the consequence modelling software by the discharge model.

7.2 Kero or ULSD Pool Fire Scenarios

In the event of rupture of a bulk storage tank (and bund overtopping) there is the potential for the released material to form a pool which on ignition could result in an uncontained pool fire. Alternatively, a pool may form within the bund which would result in a bund fire on direct ignition. As outlined above, the maximum pool radius for both scenarios is 50 m. A continuous leak over 10 minutes or a 10 mm pipe leak over 30 minutes have the potential to result in a pool fire within the bund.

7.2.1 Pool Fire Model Inputs

Pool fire model inputs are summarised in Table 29.

Parameter	Units	Catastrophic rupture	Failure over 10 minutes	10 mm leak over 30 minutes
Substance	-	Kerosene / ULSD (modelled as xylene)	Kerosene / ULSD (modelled as xylene)	Kerosene / ULSD (modelled as xylene)
Tank diameter (largest tank, Tank 2)	m	40	40	40
Liquid volume	m^3	15495	15495	15495
Scenario		Catastrophic rupture	Fixed duration release 600 s	Leak, 10 mm
Weather conditions	-	D5: 5 m/s windspeed & 15 ^{0}C F2: 2 m/s windspeed & 10 ^{0}C		
Maximum pool diameter	m	100	100	100

Table 29 Bulk Storage LOC Scenarios: Pool Fire Model Inputs

Xylene is used as a surrogate for kerosene/ULSD with the maximum SEP set at 130 kW/m^2. The two-zone pool fire model in DNV PHAST Version 9.1 modelling software was used to model the consequences of pool fire involving kero/ULSD (modelled as m-xylene).

7.2.2 Pool Fire Model Outputs

Pool fire model outputs are summarised in Table 30.

Parameter	Units	Catastrophic rupture/ Failure over 10 minutes		10 mm leak over 30 minutes	
		D5	F2	D5	F2
Pool fire diameter	m	100	100	5.5 m after 30 minutes	4.5 m after 30 minutes
Pool fire flame length	m	48.7	48.7	6.5	6.4
Total burn rate	kg/s	201	201	0.61	0.61
Radiative fraction	-	0.56	0.56	0.94	0.93

Table 30 Bulk Storage LOC Scenarios: Pool Fire Model Outputs

7.2.3 Pool Fire Thermal Radiation Consequences

Modelling parameters are as described in Section 4.2. The receiver height was specified as 1.5 m.

Thermal radiation vs. distance downwind is illustrated on Figure 19. The catastrophic tank failure scenario results in a 100 m diameter pool fire outside of the bund or inside the bund (also 100 m diameter based on bund dimensions). The tank failure over 10 minutes scenario results in a 100 m diameter pool fire within the bund. The 10 mm leak over 30 minutes scenario results in an 18.8 m diameter pool fire scenario inside the bund.

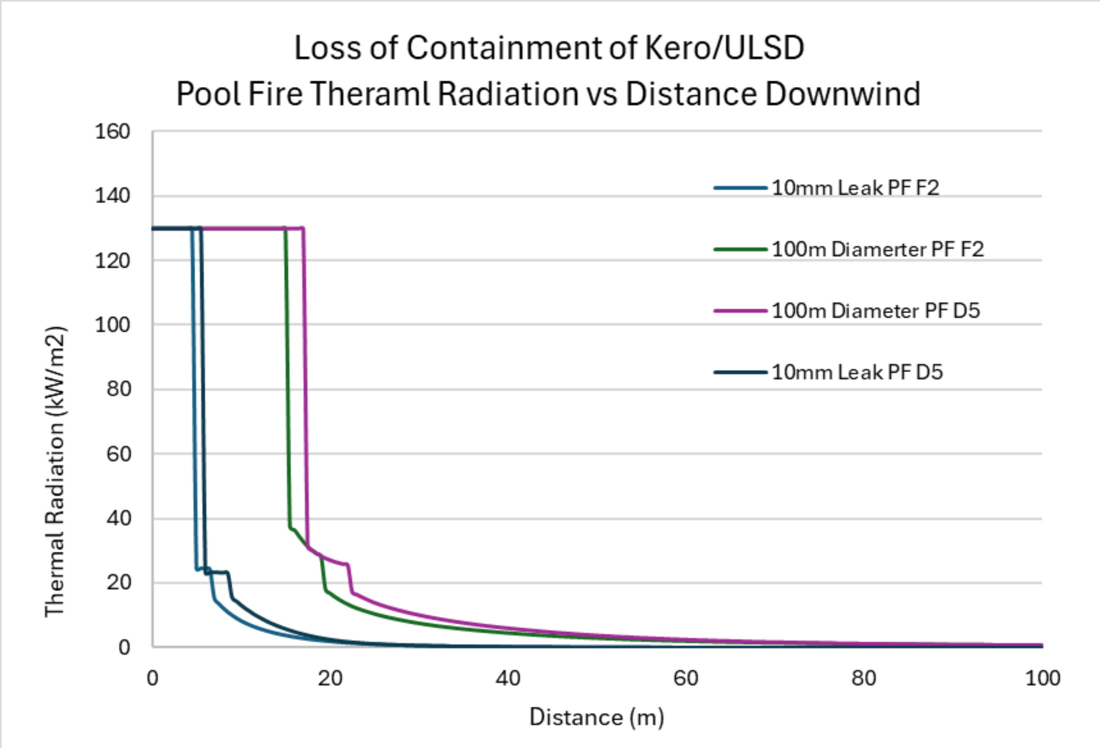


Figure 19 Bulk Storage LOC and Pool Fire: Thermal Radiation vs. Distance

Thermal radiation results are summarised in Table 31. The outdoor mortality consequence is based on the Eisenberg probit equation and an exposure duration of 60 s.

Thermal radiation level, kW/m^2	Consequences	Distance (m)			
		Catastrophic rupture/ Failure over 10 minutes		10 mm leak over 30 minutes	
		D5	F2	D5	F2
8.02	1% mortality outdoors	75	63	13	10
12.7	Persons indoors protected	58	50	10	8
25.6	100% fatality indoors	47	42	6	5

Table 31 Bulk Storage LOC and Pool Fire: Thermal Radiation Results

The worst-case 1% mortality outdoors contour is illustrated on Figure 20 for the worst case bund fire. The shape of the contour is shown for the prevailing wind direction (see wind rose on Figure 5 as well as the effect area which takes account of all possible wind directions.

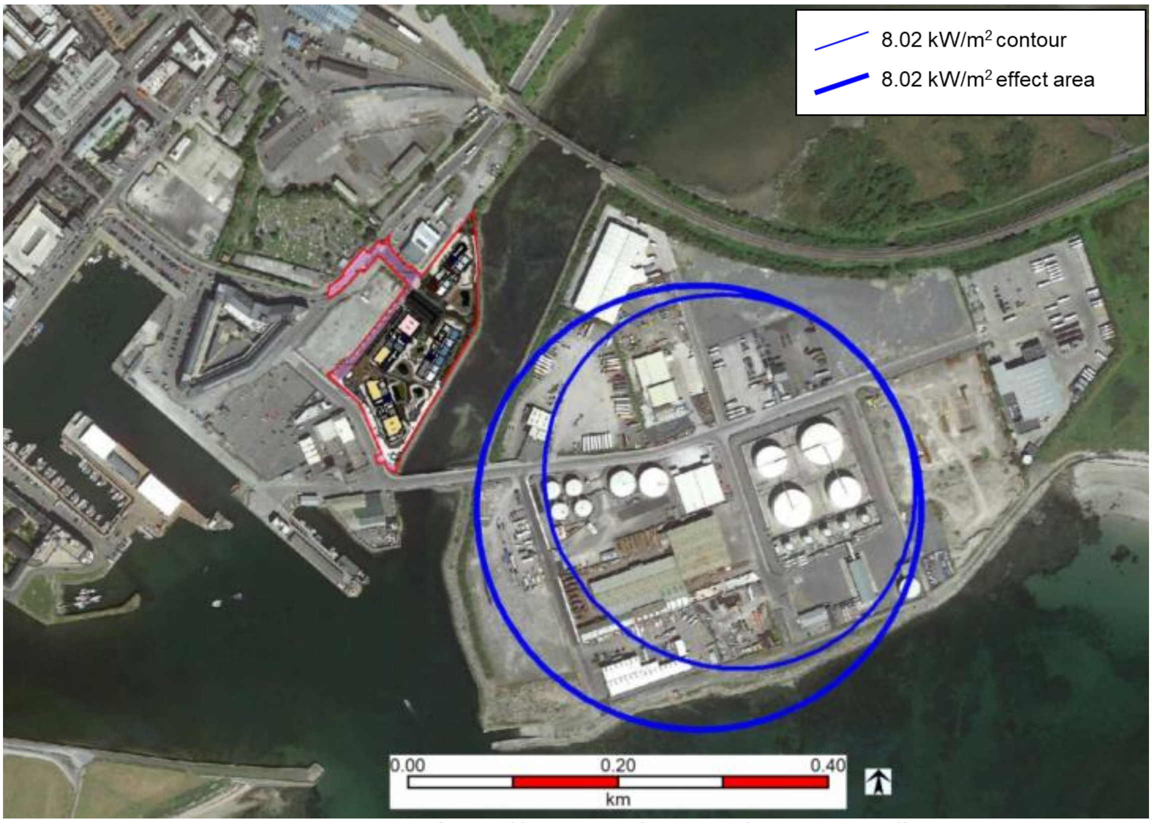


Figure 20 Kerosene Bund Fire: Worst Case 1% Mortality Outdoors Contour and Effect Area

The following is concluded:

- The thermal radiation level corresponding to the 1% mortality outdoors does not reach the proposed scheme, persons outdoors at this location would not be exposed to harmful levels of thermal radiation;
- The thermal radiation level below which persons in indoor locations are protected does not extend to the proposed scheme, persons indoors at this location are protected from the thermal radiation consequences of a pool fire at the Circle K terminal.

8.0 EVENT FREQUENCIES

Event frequencies are as specified in HSA guidance (HSA, 2023) and are detailed in Table 32. The event frequencies for Category 0 flammable liquid loss of containment scenarios are applied to gasoline. The event frequencies for Category 2 flammable liquid pool fire scenarios are applied to kero/ULSD pool fire scenarios as the kero/ULSD tanks are co-located in the same bund as Tank 9 which may contain ethanol and which is classified as a Category 2 flammable liquid.

Road tankers are treated as road transport units (Table 24 of HSA guidance). Bulk tank filling by road tanker and road tanker loading are treated as loading/unloading operations as per Table 25 of HSA guidance (HSA, 2023). The loading hose rupture frequency is taken as 4E-06 per hour, and the loading hose leak (10% of diameter) frequency is taken as 4E-05 per hour. No information is available on the number of road tanker movements; therefore, road tanker loading is assumed to occur continuously (i.e. 8766 hours per year). The pool fire / VCE / flash fire frequencies are calculated in the event trees in Figure 21 (gasoline road tanker).

Installation	LOC scenario	Consequence	Event #	Frequency	Units
Tank 2 – bulk gasoline storage tank, 15,495 m^3	Instantaneous failure	Pool fire – within bund	001	9.96E-07	/year /tank
		Pool fire – uncontained adjacent to bund	002	9.96E-07	/year /tank
		VCE	003	1.82E-06	/year /tank
		Flash fire Indoors*	004a	4.91E-08	/year /tank
		Flash fire Outdoors*	004b	5.46E-08	/year /tank
	Continuous leak over 10 minutes	Pool fire	005	9.96E-07	/year /tank
		VCE	006	1.82E-06	/year /tank
		Flash fire Indoors*	007a	4.91E-08	/year /tank
		Flash fire Outdoors*	007b	5.46E-08	/year /tank
	10 mm pipe leak over 30 minutes	Pool fire	008	1.99E-05	/year /tank
		VCE	009	3.64E-05	/year /tank
		Flash fire Indoors	010a	9.81E-07	/year /tank
		Flash fire Outdoors	010b	1.09E-06	/year /tank
Tank 8/9 – bulk gasoline storage tank, 760 m^3 /1055 m3	Instantaneous failure	Pool fire – within bund	001	9.96E-07	/year /tank
		Pool fire – uncontained adjacent to bund	002	9.96E-07	/year /tank
		VCE	011	1.82E-06	/year /tank

Installation	LOC scenario	Consequence	Event #	Frequency	Units
		Flash fire Indoors*	012a	4.91E-08	/year /tank
		Flash fire Outdoors*	012b	5.46E-08	/year /tank
	Continuous leak over 10 minutes	Pool fire	013	9.96E-07	/year /tank
		VCE	014	1.82E-06	/year /tank
		Flash fire Indoors*	015a	4.91E-08	/year /tank
		Flash fire Outdoors	015b	5.46E-08	/year /tank
	10 mm pipe leak over 30 minutes	Pool fire	016	1.99E-05	/year /tank
		VCE	017	3.64E-05	/year /tank
		Flash fire Indoors	018a	9.81E-07	/year /tank
		Flash fire Outdoors	018b	1.09E-06	/year /tank
Gasoline road tanker (loading area)	Rupture of loading/unloading arm	Pool fire	019	1.84E-04	/year
		VCE	020	3.16E-05	/year
		Flash fire Indoors*	021a	4.26E-06	/year
		Flash fire Outdoors*	021b	4.73E-06	/year
	Leak of unloading arm 10% of diameter	Pool fire	022	1.84E-03	/year
		VCE	023	3.16E-04	/year
		Flash fire Indoors*	024a	4.73E-05	/year
		Flash fire Outdoors*	024b	4.26E-05	/year
Tank 1& 3-7 – bulk kero/ULSD	Instantaneous failure	Pool fire – within bund	025	5.00E-08	/year /tank
		Pool fire – uncontained adjacent to bund	026	5.00E-08	/year /tank
	Continuous leak over 10 minutes	Pool fire	027	5.00E-08	/year /tank
	10 mm pipe leak over 30 minutes	Pool fire	028	1.00E-06	/year /tank

Table 32 Event Frequencies

<u>Note 1: Flash Fire Frequency</u>

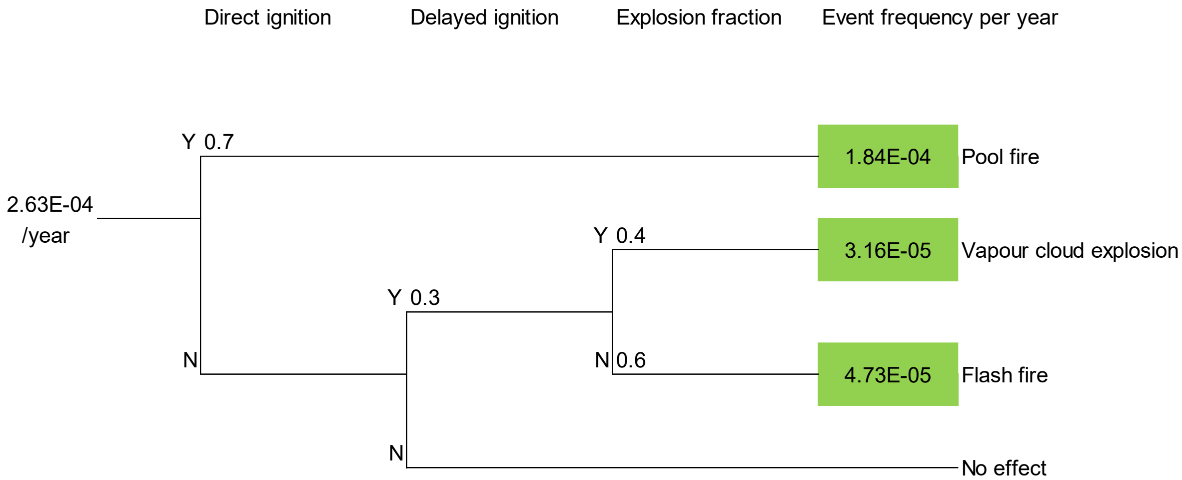
The TLUP Guidelines (HSA, 2023) states that persons are assumed to be indoors 90% of the time. The TLUP Guidelines also state that the probability of fatality within the flash fire envelope to persons indoors is 10%. Therefore, for the purposes of this assessment, the frequency for a flash fire will be adjusted, from the frequency in the TLUP Guidelines, to account for persons outdoors and persons indoors, as follows:

- Outdoor Flash Fire: 100% fatality will be assumed for 10% of the time an adjustment of 0.1 (1 *x* 0.1)
- Indoor Flash Fire: 10% fatality will be assumed for 90% of the time: an adjustment of 0.09 (0.1 *x* 0.9)

Gasoline Hose rupture

Rupture of loading/unloading arm

fills per year		no information availble
hours per fill		no information availble
hours per year	8766	hours - continuous
base freq	3.00E-08	per hour
	2.63E-04	per year



Gasoline Hose leak

Leak of loading/unloading arm 10% diamter

fills per year		no information availble
hours per fill		no information availble
hours per year	8766	hours - continuous
base freq	3.00E-07	per hour
	2.63E-03	per year

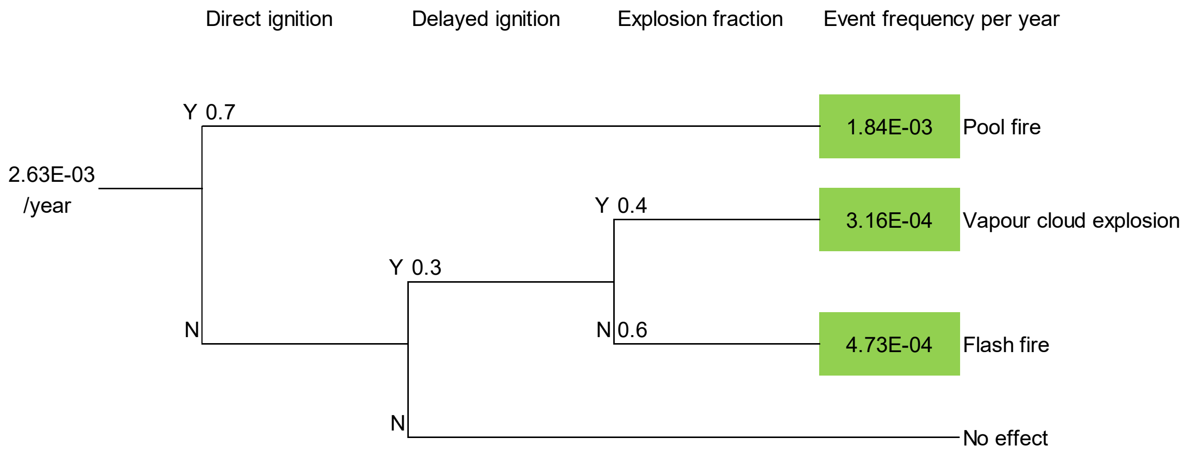


Figure 21 Event Trees for Gasoline Road Tanker Loading/Unloading Operations

In Figure 21, the probability of direct/delayed ignition and the explosion fraction (VCE/flash fire) is as per HSA guidance (HSA, 2023).

8.1 Buncefield VCE

The most recent guidance Land Use Planning guidance from the HSA, Guidance on Technical Land Use Planning Advice (HSA, 2023) does not include a frequency for a Buncefield-type event.

The previous Land Use Planning guidance, Land Use Planning Policy and Approach Document (HSA, 2010) states that the likelihood of a VCE event at a large scale petroleum storage depot is conservatively taken as 1E-04 per year per installation. However, the Circle K facility is not a ‘large scale’ petroleum storage depot; therefore, a frequency of 1E-05 per Buncefield-type tank per year will be used. There are 3 No. Buncefield-type tanks at the Circle K facility; therefore, the total frequency of a Buncefield type VCE at Circle K is 3E-05 per year. The UK HSE’s RR512 document, states that the explosion centre could be anywhere within the bund, where 9 points can be considered, with the event frequency evenly distributed between these points. Tank 2 is in a separate bund to Tanks 8 and 9; therefore, these bunds will be treated independently.

9.0 LAND USE PLANNING RISK CONTOURS

Gexcon Riskcurves Version 12.5.1 modelling software was used to model the cumulative risk contours for the Circle K establishment.

The consequence results from all of the major accident hazards identified in this report, scenario frequencies and Athenry synoptic station wind speed and frequency data (see Figure 5) were input to the software. The fraction for D5 (daytime conditions) was 0.8 and the fraction for F2 night time conditions was 0.2. The HSA's technical LUP guidance document states that people are assumed to be indoors 90% of the time and outdoors 10% of the time.

The individual risk contours, to persons outdoors and persons indoors (CIA 2), for the Circle K upper tier COMAH establishment corresponding to the boundaries of the Inner, Middle and Outer risk-based land use planning zones are illustrated on Figure 22 and Figure 23.

Figure 22 Individual Risk of Fatality Contours, to Persons Outdoors, for Circle K Galway Terminal

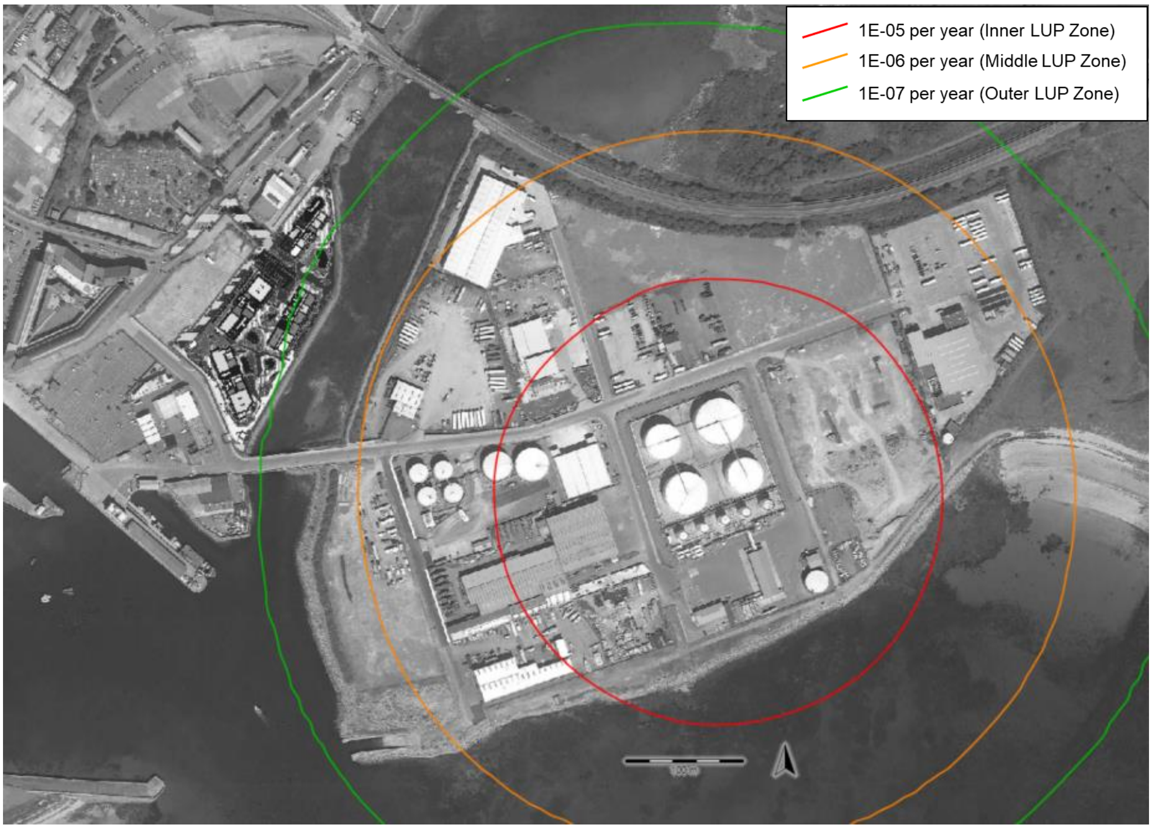


Figure 23 Individual Risk of Fatality Contours, to Persons Indoors (CIA 2), for Circle K Galway Terminal

It is concluded that the individual risk contours, to persons outdoors and indoors (CIA 2), corresponding to the Outer Land Use Planning zone, extends to Block C of the proposed scheme.

Table 33 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 33 LUP Matrix

The proposed scheme is a Sensitivity Level 3 type development as it is a '*Larger housing developments for more than 30 dwelling units'* (HSA, 2023). Therefore, the proposed scheme is permitted within the Outer Zone.

It is concluded that the level of individual risk at the proposed scheme is acceptable.

The proposed scheme is within the consequence zone of major accidents at the Circle K facility. Therefore, a Societal Risk assessment is required to take account of group risk to the receptors at the proposed scheme.

10.0 SOCIETAL RISK CONSTRAINTS

The purpose of this societal risk study is to generate advice on the types/nature and scale of development that is likely to be acceptable to the HSA at the proposed scheme at the "Inner Harbour" landbank at Galway Harbour. Societal risk calculations aggregate the risks presented to all populations at the proposed development arising from all major accidents at the Circle K facility.

The largest potential scheme at the landbank would have 356 No. Units.

Block	Max. Occupancy
A	243
B	323
C	194
D	301
Cafe (Block A)	120
Retail (Block B)	350
Creche (Block B)	120
Café (Block A)	120

Table 34 Occupancy of Largest Proposed Scheme

Consequence modelling indicates that pool fire scenarios do not have the potential to result in fatalities at the proposed scheme.

In the event of a loss of containment of gasoline from Tank 2 (failure over 10 minutes), the flash fire envelope extends to the proposed scheme. The probability of fatality outdoors is 100% within this footprint and the probability of fatality indoors is 10%. The HSA's technical LUP guidance document states that people are assumed to be indoors 90% of the time. The flash fire frequency following tank failure over 10 minutes is given by the HSA as 5.46E-07 per year. The flash fire envelope extends to the Proposed scheme for F2 conditions only. The fraction for occurrence is given as 0.2 in the HSA's TLUP guidance document (HSA, 2023). Therefore, the flash fire frequency leading to fatalities at the Proposed scheme is 1.09E-07 per year (0.109 chances per million per year).

The consequences corresponding to fatalities indoors (CIA2), following a Buncefield VCE-type scenario, could extend to the proposed scheme. The frequency of this event leading to fatalities at the proposed scheme is 3.0E-05 per year (30 chances per million). To represent the worst-case scenario, the explosion is centred at the closest point to the proposed scheme, at the north-western corner of the Circle K bund.

Table 35 details the Societal Risk calculation for the proposed scheme. The Expectation Value (EV) at the proposed scheme is calculated to be **667.**

Section 1.7 of the TLUP (HSA, 2023) states:

'for new developments near an establishment, where the calculated off-site EV at the development greater than 2,000, further assessment of societal risk will be required.'

The total Expectation Value (EV) at the proposed scheme is 667**.** This is <2,000; therefore, no further risk calculation is required.

Receptor	Vul to Rupture Flash Fire (Indoors)	Vul to Leak Flash fire (Outdoors)	Vul to VCE (Indoors)	Occupants	Occupancy (indoors)	Occupancy (outdoors)	Occupancy Factor	Fatalities	Expectation Value
Block A	0.1	1	0.013	243	218.7	24.3	1	49	90
Block B	0.1	1	0.012	323	290.7	32.3	1	65	111
Block C	0.1	1	0.023	194	174.6	19.4	1	41	124
Block D	0.1	1	0.023	301	270.9	30.1	1	63	193
Cafe Block A	0.1	1	0.01	120	108	12	0.5	24	51
Retail Block B	0.1	1	0.01	350	315	35	0.5	70	51
Creche Block B	0.1	1	0.013	120	108	12	0.5	24	22

Receptor	Vul to Rupture Flash Fire (Indoors)	Vul to Leak Flash fire (Outdoors)	Vul to VCE (Indoors)	Occupants	Occupancy (indoors)	Occupancy (outdoors)	Occupancy Factor	Fatalities	Expectation Value
Café Block A	0.1	1	0.014	120	108	12	0.5	24	24
Total									**667**

Table 35 *Societal Risk Calculation*

11.0 CONCLUSION

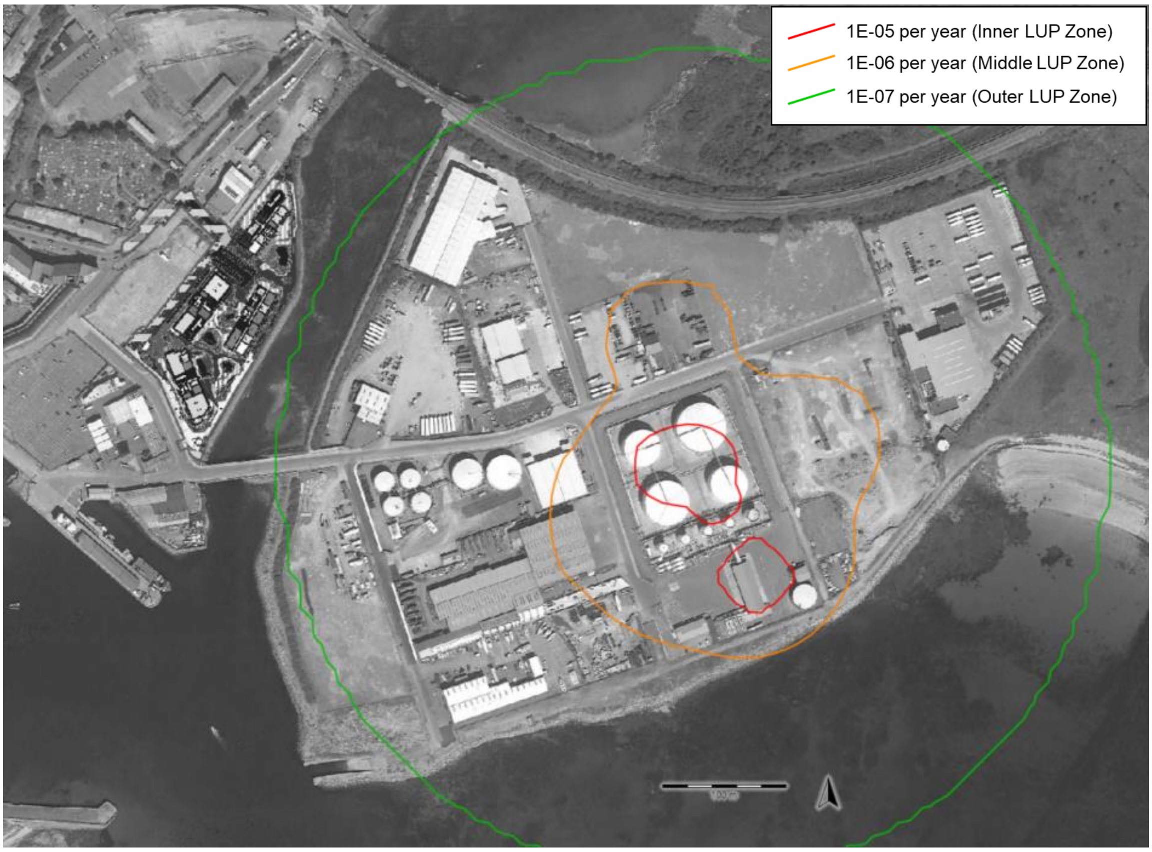
AWN Consulting Ltd. was requested by the Land Development Agency (LDA) to complete a land use planning assessment addressing potential constraints posed by the Circle K Galway Terminal Upper Tier COMAH establishment to the development of the "Inner Harbour" landbank at Galway Harbour. The landbank has potential to yield a substantial residential-led mixed-use development, of 356 No. Units, creche, retail unit and cafe/restaurant units, over four blocks, extending from 6 – 13 storeys in height. The proposed landbank is not within the Consultation Distance of any other COMAH establishments.

The assessment is completed following the Health and Safety Authority's Guidance on technical land-use planning advice For planning authorities and COMAH establishment operators (HSA, 2023) and the *Land Use Planning Policy and Approach Document (HSA, 2010)*.

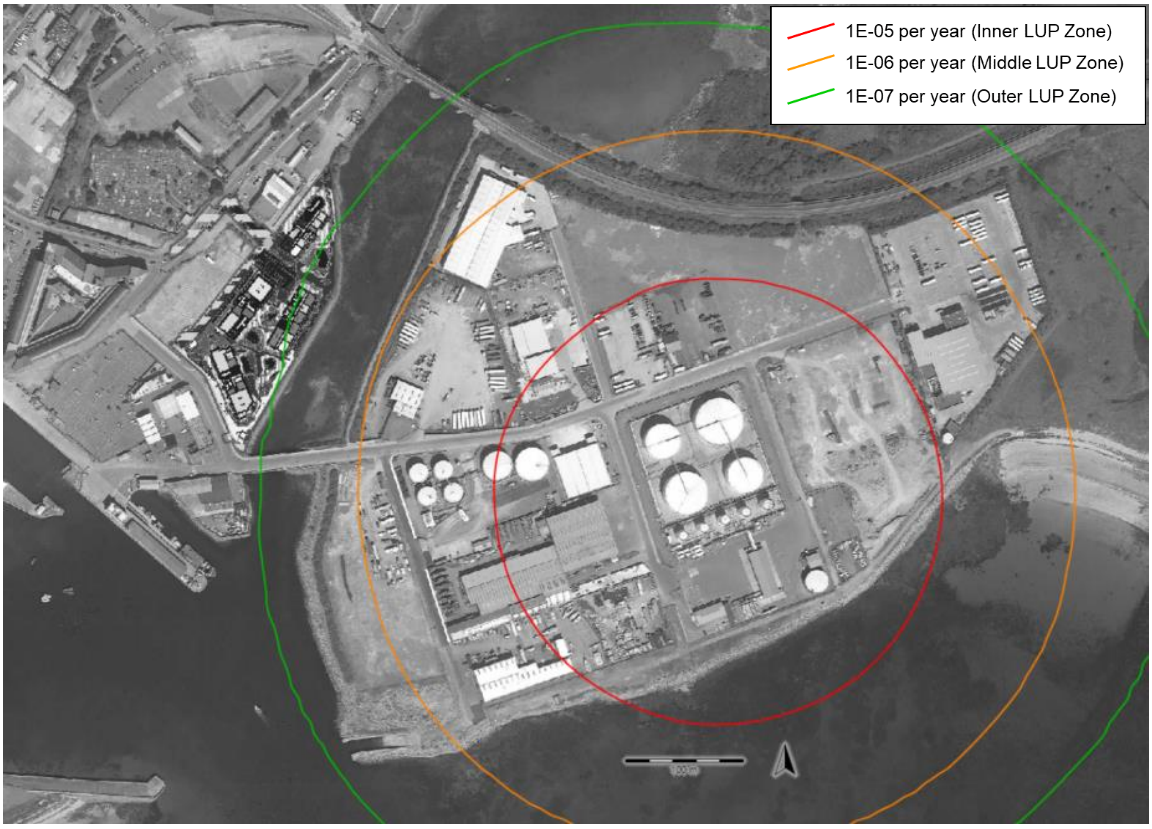
The Circle K Galway Upper Tier COMAH facility handles the import and storage of ultra-low sulphur diesel (ULSD), kerosene (kero), and gasoline delivered by ship, as well as ethanol received via road tankers. This document assesses major accident scenarios identified in the TLUP (HSA, 2023), including pool fires, vapour cloud explosions, and flash fires.

During consultation with the HSA, prior to the lodgement of this planning application, explicit reference was made by the HSA to include the assessment of a Buncefield-type explosion scenario. Modelling methodology for a Buncefield-type explosion does not feature in the most recently published guidance issued by the HSA; therefore, the previous iteration of the Land Use Planning guidance (HSA, 2010) has been utilised to undertake this assessment, as the most recently available, relevant guidance for same.

The individual risk contours, to persons outdoors and persons indoors (CIA 2), for the Circle K upper tier COMAH establishment corresponding to the boundaries of the Inner, Middle and Outer risk-based land use planning zones are illustrated as follows:



Individual Risk of Fatality Contours, to Persons Outdoors, for Circle K Galway Terminal



Individual Risk of Fatality Contours, to Persons Indoors (CIA 2), for Circle K Galway Terminal

It is concluded that the individual risk contours, to persons outdoors and indoors (CIA 2), corresponding to the Outer Land Use Planning zone, extends to Block C of the proposed scheme.

The proposed scheme is a Sensitivity Level 3 type development as it is a '*Larger housing developments for more than 30 dwelling units'* (HSA, 2023). Therefore, the proposed scheme is permitted within the Outer Zone.

It is concluded that the level of individual risk at the proposed scheme is acceptable.

The proposed scheme is within the consequence zone of major accidents at the Circle K facility. Therefore, a Societal Risk assessment is required to take account of group risk to the receptors at the proposed scheme.

Societal risk calculations aggregate the risks presented to all populations at the proposed development arising from all major accidents at the Circle K facility. A Societal Risk assessment for the proposed scheme was completed and the Expectation Value (EV) at the proposed scheme is calculated to be **667.**

Section 1.7 of the TLUP (HSA, 2023) states:

'for new developments near an establishment, where the calculated off-site EV at the development greater than 2,000, further assessment of societal risk will be required.'

The total Expectation Value (EV) at the proposed scheme is **667.** This is <2,000; therefore, no further risk calculation is required.

It is concluded that the level of individual risk and societal risk, at the proposed residential led mixed-use scheme, is in accordance with the HSA's criteria and is acceptable.

12.0 REFERENCES

Buncefield Standards Task Group (BSTG) (2007), Safety and environmental standards for fuel storage sites Buncefield Standards Task Group (BSTG) Final report

Chemical Industries Association (CIA) (2020), Guidance for the location and design of occupied buildings on chemical manufacturing sites, 4th Edition

Centre for Chemical Process Safety (CCPS) (2000), Guidelines for Chemical Process Quantitative Risk Analysis, 2nd Edition, AIChemE

Committee for Prevention of Disasters (1997), Methods for Determining and Processing Probabilities, TNO Red Book (CPR 12E), First Edition

Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC

Energy Institute (EI) (2007), Model Code of Safe Practice Part 19 Fire Precautions at

Health and Safety Authority (HSA) (2023), Guidance on Technical Land-use Planning Advice for planning authorities and operators of COMAH establishments

Hirst, I.L. and Carter, D.A., A “Worst Case” Methodology for Risk Assessments of Major Accident Installations, Process Safety Progress, Vol. 19, No. 2, 2000

Hirst, I.L., Carter, D.A., Porter, S.R and Turner, R.M., Numerical Risk Assessment and Land Use Planning

Kletz T. (1999), HAZOP and HAZAN, Identifying and assessing process industry hazards, Institute of Chemical Engineers, 4th Edition

Mannan S. (2012), Lees’ Loss Prevention in the Process Industries Hazard Identification, Assessment and Control, 4th Edition, Elsevier

McGrattan K.B., Baum H.R., Hamins A. (2000), National Institute for Standards and Technology (US Department of Commerce), NISTIR 6546, Thermal Radiation from Large Pool Fires

Trbojevic V.M. (2005), Risk criteria in EU, Proceedings of European Safety and Reliability Conference 2005, Poland

UK Health and Safety Executive (HSE) (2001), Reducing Risks Protecting People

UK Health and Safety Executive (HSE) (1997), Derivation of Fatality Probability Functions for Occupants of Building Subject to Blast Loads Phases 1, 2 & 3 Prepared by WS Atkins Science & Technology, Contract Research Report 147/1997

UK Health and Safety Executive (HSE) (1997), Derivation of Fatality Probability Functions for Occupants of Building Subject to Blast Loads Phase 4 Prepared by WS Atkins Science & Technology, Contract Research Report 151/1997

Vrijling, J.K. and van Gelder (2004), P.H.A.J.M., Societal Risk and the Concept of Risk Aversion

Health and Safety Authority (HSA) (2010), Policy and Approach of the Health & Safety Authority to COMAH Risk-Based Land-Use Planning Including Detailed Implementation by Sector

Health and Safety Executive (HSE) (2007) Review of significance of societal risk for proposed revision to land use planning arrangements for large scale petroleum storage sites (HSE RR512)

APPENDIX A

TNO Multi Energy VCE Methodology (HSA, 2010)

Using the TNO vapour cloud explosion model, the vapour cloud is assumed to be a stoichiometric mixture of volume V (m^3) with a heat of combustion (H) of 3,500,000 J/m^3 and an ignition strength of 7.

The scaled distance R at a distance r (m) is defined as:

$$R = r\left(\frac{101325}{VH}\right)^{\frac{1}{3}}$$

The level of overpressure (P in atm) as a function of scaled distance is given by TNO as a graphical correlation, which can be represented as follows:

Define $x = \log_{10}(R)$

For $R <= 0.4$ $P = 1$

For $0.4 < R < 4$ $P = 10^{(-0.2211x^6 - 2.1917x^5 - 0.1924x^4 + 2.2432x^3 - 0.7044x^2 - 1.4617x - 0.3465)}$

For $R >= 4$ $P = 10^{(-1.1113x - 0.5178)}$

P can be converted to mbar by multiplying by 1013.25. To convert mbar to psi divide by 68.947573.

The outdoor risk associated with any level of overpressure can be calculated using the HSE probit defined by Hurst, Nussey and Pape (1989):

Probit = 1.47 + 1.35 ln(P) with P in psi

Levels of risk to people indoors can be calculated using vulnerability relationships such as those presented by the CIA (2003).

END OF REPORT