Burnaby Risk Assessment

M211446LP

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0	21.07.30	Issued for Use	Dr. N. Ramsden / J. Riordan	J. Riordan P.E.

ONEC
3821 – 78 Ave Edmonton, AB, Canada T6B 3N8
P: (780) 440-0400 F: (780) 440-0413
www.onecgroup.com

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1.0 INTRODUCTION

The purpose of this project was to identify various incident scenarios that have occurred in the oil industry across the globe and then adapt those scenarios into a technical representation at the planned expansion of the Burnaby Tank Farm and Westridge Marine Terminal (WMT). The intent was to determine the effects beyond the fence-line for community emergency planning purposes. Efforts were made to depict real-life scenarios in a balanced approach that recognizes the low probability along with the possibility that they could still occur. The process that was followed involved researching historical tank fire scenarios and develop that scenario inside the fence line at Burnaby Tank Farm and the WMT followed by a determination of the scale of escalation outside the fence line. Finally, 3D static and dynamic models were created for the selected scenarios at the Burnaby and WMT locations to visualize the effects for emergency planning purposes.

The Burnaby location has multiple exacerbating risks along with the potential for extremely large seismic events. The Cascadia megathrust fault lies offshore Canada's west coast and runs 1,000 km from northern Victoria Island to California. The fault has one of the highest seismic potential in the world, which is classified as M9. That puts it in the same category as the Tohoku earthquake that resulted in catastrophic damage to northern Japan in 2011 including the Fukushima nuclear facility. The lesser-known effects from the 2011 quake included extensive damage with fires at refineries and oil storage facilities across Japan and the extreme demand and shifting priorities placed on first responders e.g., preventing tank fire escalation versus community emergency response. Of particular concern with Burnaby is the high likelihood of a major seismic event that has been estimated by some at 37% within the next 40 years. For perspective the American Petroleum Institute's (API) seismic design for oil storage tanks is based on a probability of 2% within 50 years.

The Burnaby Tank Farm location is unique among tank farms around the world. One co-author of this report who has carried out storage facility fire hazard management reviews in more than 80 countries has remarked that it is probably the highest risk facility of this type that he has seen due to the unique combination of fuels stored and the operating environment. The location is in close proximity to residential neighborhoods, a major university, commercial district, critical infrastructure, and has mountain topography with limited access and egress. If any major incident did happen then there could be regional, provincial, and possibly national impacts. Notwithstanding the deficiencies with the proposed new tanks, nothing is planned for upgrading the existing tanks which are equally prone to the same incidents. It is recognized that incident probability with the newer tanks might be reduced but it cannot be discounted.

Finally, the scenario work sheet analysis did not focus on multi-tank fire scenarios or the most severe incidents; a tank boilover or a vapor cloud explosion, however, they cannot be ignored nor the impact overstated. A boilover is possible where light hydrocarbons are blended with heavier ones which is the case with diluted bitumen (Dilbit) that would be stored at the Burnaby Tank Farm. Although uncommon, the phenomenon can be catastrophic due to the extreme heat and volume expansion of the burning crude oil which has been described as a flaming Niagara Falls. The only certain means to avoid a boilover is to prevent a full surface fire, or, if a smaller fire escalated to a full surface fire, to extinguish the fire in a very short time. The stated required response time (not extinguishment) for Burnaby is within 4-hrs which is deemed excessive given that good industry practice recommends a full surface extinguishment time within two hours.

2.0 EXECUTIVE SUMMARY

This report describes the work, carried out by international industry specialists at the request of the City of Burnaby, to review potential incident scenarios and their consequences at the Burnaby and Westridge Terminals. The intention has been to develop a better understanding, based on previous incidents around the world, of events that can happen and even given their low probability, to assess the consequences and associated risks beyond the fence line for emergency planning purposes.

The major concerns identified in this study include:

- Miscalculation of the code requirements of fire foam needed and applied
- Firewater quantities and flow rates insufficient for major scenarios
- Inadequate number of trained fire responders to deal with a tank fire
- Reliance on external specialist responders for major accident scenarios to respond in a timely fashion to prevent a major escalation to a catastrophic event
- Storing diluted bitumen that has the potential for vapour cloud explosion or boilover
- Any major scenario could lead to public panic in the area jeopardizing access and evacuation routes and resulting in considerable additional pressure on emergency resources

Of note is the reliance on active fire protection systems. Tank fire protection systems have a relatively poor success rate due to their complexity, infrequent usage, and nature of the events e.g., seismic, or initial explosion that can render them inoperable. The combination of the above listed concerns and a seismically active region, creates the potential for a catastrophic event e.g., a boilover that would have lasting effects on the community, region, and the environment.

Best industry practices in line with international risk-based reviews of oil processing and storage facilities have been used to describe and quantify the consequences, both on and off site, and the resources and procedures required to minimize them. The selected scenarios are based on incidents that have occurred elsewhere although not necessarily in the same sequence. Each incident is different so it's not possible to predict exact outcomes but, given the alignment of factors, have resulted in catastrophic events.

Incident effects are described in the report, but more graphic representations have also been developed showing potential effects specific to Burnaby. A unique combination of topography, residential and commercial development, forestry, educational facilities, road and rail infrastructures and environmental sensitivity exists which means incident consequences can be catastrophic. The intent of the study is not just to show this but to recognize that if they happen then the need for effective and efficient response measures is paramount, both on and off site, to minimize the risk to life safety and the environment.

The experts for this project have the shared belief that the Burnaby Tank Farm and its unique operating environment poses an unusually high risk, particularly for seismically caused tank fires that could escalate beyond those identified in this study e.g., multi-tank fires. Therefore, the authors believe that every precaution must be taken to mitigate the on-site risk with particular emphasis on fire hazard management systems that aren't prone to seismic damage. These include fire systems that require less water, PFAS-free foam, and trained fire responders with sufficient resources to address the event quickly and competently. In addition, there is the need for the resources to manage the immediate and longer-term offsite consequences of fires and the associated public panic, including loss of infrastructure, residences, and business activity.

3.0 Project Description

3.1 Background

The Trans Mountain Pipeline (TMP) Expansion involves, in part, expanding the existing Burnaby Tank Farm and rebuilding the Westridge Marine Terminal. Both areas are in relatively close proximity to private property owners and public infrastructure beyond the TMP fence line. The City of Burnaby (CoB) is interested in understanding likely scenarios and consequential effects to the public and the environment beyond the TMP fence line for emergency response planning purposes.

3.2 Project Objectives

The project identified scenarios and their impacts to the community outside the fence line. The starting assumption is that the TMP will require 4-hours to assemble firefighting teams, so any fire response scenario has a 4-hour delayed response. The two areas of interest are the Westridge Marine Terminal and the Burnaby Tank Farm. During phase 1 both areas were analyzed for risks due to various scenarios and community impacts. The CoB made a selection for phase 2 which developed one of those scenarios involving a seismic event that triggered a bund fire that led to a full surface fire. Likewise, the phase 2 effort involved a seismic event resulting in a jet fuel tank spill at the Westridge Marine Terminal that escalated into a full surface fire that led to a fire in the process area leading to a Boiling Liquid Expanding Vapor Explosion (BLEVE) of a propane tank. The analysis involved identification of required resources to address the identified risk. It is recognized that the oil industry has developed best practices over many years to minimize incident probability, but the scenarios that were used were based on real events that have previously occurred in some form or another.

3.3 Summary of Project Scope

Two companies were involved with this study: ONEC Group and ENRgConsultants. ENRgConsultants performed the research and scenario development and provided expert assistance to ONEC for the 3D modeling. ENRgConsultants is led by Dr. Niall Ramsden who is the coordinator for the internationally recognized oil industry fire protection consortium known as Large Atmospheric Storage Tank Fire (LASTFIRE). Dr. Ramsden is also a long-standing member of the NFPA 11 committee. ONEC provided 3D modeling for all static and dynamic modeling and project management services.

The scope of the study included identification of critical scenarios that can have significant impacts to the community outside the fence line of the Westridge Marine Terminal and the Burnaby Tank Farm. The scope included a visual representation using high-definition simulation modeling of various scenarios.

The scope of work was structured in two major phases:

- Phase 1- Static 3D models and scenario development with risk and resource requirements.
- Phase 2- Simulation modeling (dynamic 3D models) with event timelines, community impacts and resource requirements.

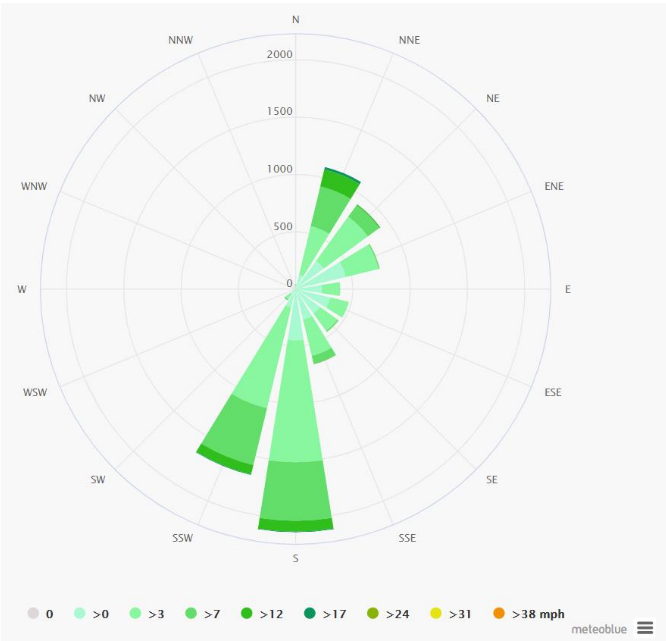
3.4 Project Management Process

The project relied completely on publicly sourced information regarding the Burnaby Tank Farm and the Westridge Marine Terminal. Project plans provided by Trans Mountain to the public and satellite imagery was used to create the static 3D models. It is recognized that since the project is in the construction phase some information might be outdated and subject to change by the time of completion however, an effort was made to capture and comment on the design at its current state of completion.

Each project stage was a layer in the process. Stage 1 provided the base 3D static model that became the basis for all subsequent work. Stage 2 was built upon the static models and using advanced computational fluid dynamic modeling to accurately depict an event. The smoke and liquid movement is treated as millions of particles that have different behaviors and are interdependent, meaning one particle affects another which changes the trajectory. In addition, there are common factors such as gravity, smoke density and wind direction that affect all particles that the model incorporates.

The dynamic models were based on actual historic fire events. In most cases multiple historical events were analyzed to understand and accurately recreate the incident as a dynamic model located in Burnaby.

The Burnaby Tank Farm dynamic model that generated smoke relied on wind rose data for Burnaby. It shows the prevailing wind direction and speed which indicates the great majority of the time (about 67%) the wind is from the south and the average speed is about 5 mph. This became the basis for the smoke direction and velocity.



Burnaby Wind Rose

The scenario worksheets were developed from information available at the time of writing. In the case of the Burnaby Tank Farm, the Trans Mountain Fire Pre-Plan document provided information to compare with industry best practices. The heat maps were developed using ALOHA, developed by the USA Office of Emergency Management, EPA guidelines and the Emergency Response Division, NOAA.

In the case of the Westridge Marine Terminal there was no publicly available Fire Pre-Plan document so the work sheets were developed using industry best practices that could be used at a later date to compare once such a document is provided. The same ALOHA model was used to create the heat maps.

The heat maps are provided as guidance and should not be considered precise. Large industrial fires and their radiant heat is affected by numerous factors including prevailing winds, weather, terrain or elevation, height of fire, type of fuel etc.… Consequently, the heat maps (or bubbles shown in the 3D static models) offer guidance only and it's recognized that other models and actual events could have different results. The heat maps provide a sense of the radiant heat emitted and are subject to local prevailing conditions.

4.0 HISTORICAL FIRE EVENTS

The section involves identifying historical tank fire related events with photos to help the reader understand the types of events that have happened elsewhere and that could happen at Burnaby / West Ridge Marine Terminal given the right circumstances. The events are listed in order of escalation from low to high.

4.1 Rim Seal Fires

In any type of tank where there is a roof that floats on the fuel, there is a possibility of a "Rim Seal Fire "– a fire in the small area between the roof and the tank shell. This would not normally be considered a serious fire unless it escalates to something larger. Below is an example of a rim seal fire started by a lightning strike.

Hengyuan refinery – Malaysia

4.2 Dike (or Bund) Fire

With fixed roof tanks such as the Jet tanks at Westridge or floating roof tanks with an outer roof such as those at Burnaby there are a number of potential fire types, the most serious being large dike area fires, roof lift off from an internal explosion leading to a full surface fire and, in the case of crude oil tanks, a boilover if not extinguished quickly and efficiently.

Dike (or Bund) area fire:

The dike, also called bund, is the area surrounding a tank intended to contain any spillages from the tank or associated pipework. Below are some examples of dike fires and their results.

Izmit, Turkey August 1999

The tank fire above was not contained to the single tank. Tanks within shared containment can spread the fire to adjacent tanks.

Infrastructure around the tanks (including fire water / foam piping) can be damaged during a dike fire thereby affecting the ability to apply water / foam.

4.3 Roof Lift Off

When there's a flammable vapor in the space between the flammable liquid and the fixed outer roof it can ignite causing an explosion that separates the fixed roof above from the cylindrical shell that forms the tank. Below are examples of a roof lift off.

Wynnwood, USA 2007

The above picture shows a fixed roof separation at the frangible roof / sidewall joint at the moment of ignition. This connection is designed to fail and allow the roof to separate. Without the weak frangible seam, the explosive forces could lift the entire roof connected to the cylindrical shell and failure at the bottom would allow immediate and complete loss of containment.

Crockett, California 2019

In the picture above, complete roof separation is clearly seen after blowing off the tank moments earlier. Note that any equipment that was roof-mounted is gone in seconds. An earthquake the previous day is the suspected cause of the fire when the internal roof was hung up and then released when the liquid level changed.

4.4 Full Surface Fire

A full surface fire can occur in floating roof tanks when the roof sinks exposing the whole surface of the fuel – or in the case of a tank with only a fixed roof when the roof is blown off.

The picture above is a full surface fire example at a diesel fuel storage tank. Israel 1997

With Burnaby lying in close proximity to a major fault line, the probability of a serious incident increases and over the year there have been several incidents leading to catastrophic damage at oil storage facilities including:

Hokkaido, Japan- 2003

4.5 Boilover

A boilover occurs when a full surface fire in a crude oil tank develops a hot zone within the burning fuel. This increases in depth until it reaches any water in the tank (normally at the bottom of the tank). The water turns to steam creating a massive eruption that forcefully ejects the burning crude into the air. In the past such events have been described as “Like a Flaming Niagara”. There is no proven method to prevent a boilover in a crude oil tank full surface fire except to extinguish the tank fire before the hot zone can build up. Best industry practice targets extinguishment of a full surface fire within 2 hours.

The Amoco Milford Haven boilover, 1983

Nigeria 2002

Nigeria 2002 – Note crude flowing outside bund

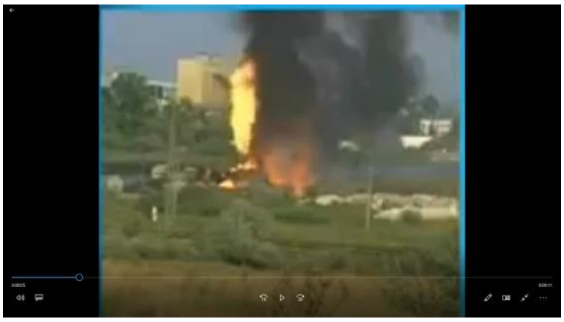
Tacoa, Venezuela December 1982

The above boilover event in Tacoa, Venezuela killed more than 150 people as the tanks were on a hillside and burning fuel engulfed lower areas.

4.6 Boiling Liquid Expanding Vapor Explosion (BLEVE)

The WMT has near-shore facilities including light condensate / propane storage. A BLEVE occurs when a fuel such as propane or butane, which is normally a gas at ambient temperatures and pressures is stored under pressure so that it becomes a liquid. If the pressure vessel is subject to fire it can burst, and the fuel is released, rapidly becoming gaseous as it boils off. When ignited this causes a massive fireball known as a BLEVE – Boiling Liquid, Expanding Vapour Explosion.

It is a short-lived event but can have massive consequences through radiant heat and shrapnel damage as the tank explodes.



The picture above shows a fire surrounding a rail car of propane. Note the relief valve is releasing propane at high pressure as a result of the fire around the tank that ignites.

The tank car ruptures releasing propane that flashes / boils immediately. Note the un-ignited propane to the left that appears as a white fog.

The propane ignites causing rapid air expansion / explosion

4.7 Fires at Jetty

The WMT has three berths with multiple loading arms at each berth. Loading rates vary but can exceed 100,000 Barrels per hour. Loading arms or their piping have failed resulting in fires or oil spills on the water that can affect shipping and the environment.

Pipe break on the tanker at the loading arm- Jet Fuel

Loading arm releasing jet fuel onto the tanker


Tanker loading arm fire can spread beyond the tanker itself.

5.0 BURNABY TANK FARM

5.1 Key Points of Concern / Fast Facts

A study has been carried out in accordance with international practices for tank farm hazardous scenario evaluation. It is recognized that the incidents are low probability, but they have all happened and can be considered more likely at Burnaby as it is in a high frequency earthquake zone.

A balanced technical approach has been taken of events that could occur at Burnaby as examples of possible incidents. These are not the only potential scenarios, and several escalation factors would lead to the same consequences.

The following points have been identified during this assessment:

- Serious concerns have been identified regarding quantification of firefighting resources on site. They do not appear to conform with industry standards (National Fire Protection Association) and basic errors have been made with respect to foam and water requirements.
    - Foam concentrate calculated quantities incorrect by 50%
    - Firewater quantities and flow rates insufficient for major scenarios.

- Based on the site topography and manpower levels, it is doubtful if the necessary resources for large scenarios could be deployed safely on-site even if they were available.
    - Smoke and heat exposure to responders.
    - Potential for catastrophic boil over during deployment.

- Whilst relying on external specialist responders for major accident scenarios it is very doubtful if they could be deployed within a timeframe to minimise potential for escalation to catastrophic events.
    - Numbers and competencies of responders critical.

- The fuel type could result in phenomena known as Vapour Cloud Explosions (VCEs) or Boilovers, both of which could result in major catastrophic damage inside and outside the fence.
    - Devasting consequences and multiple off-site fatalities have occurred with these incident types elsewhere.

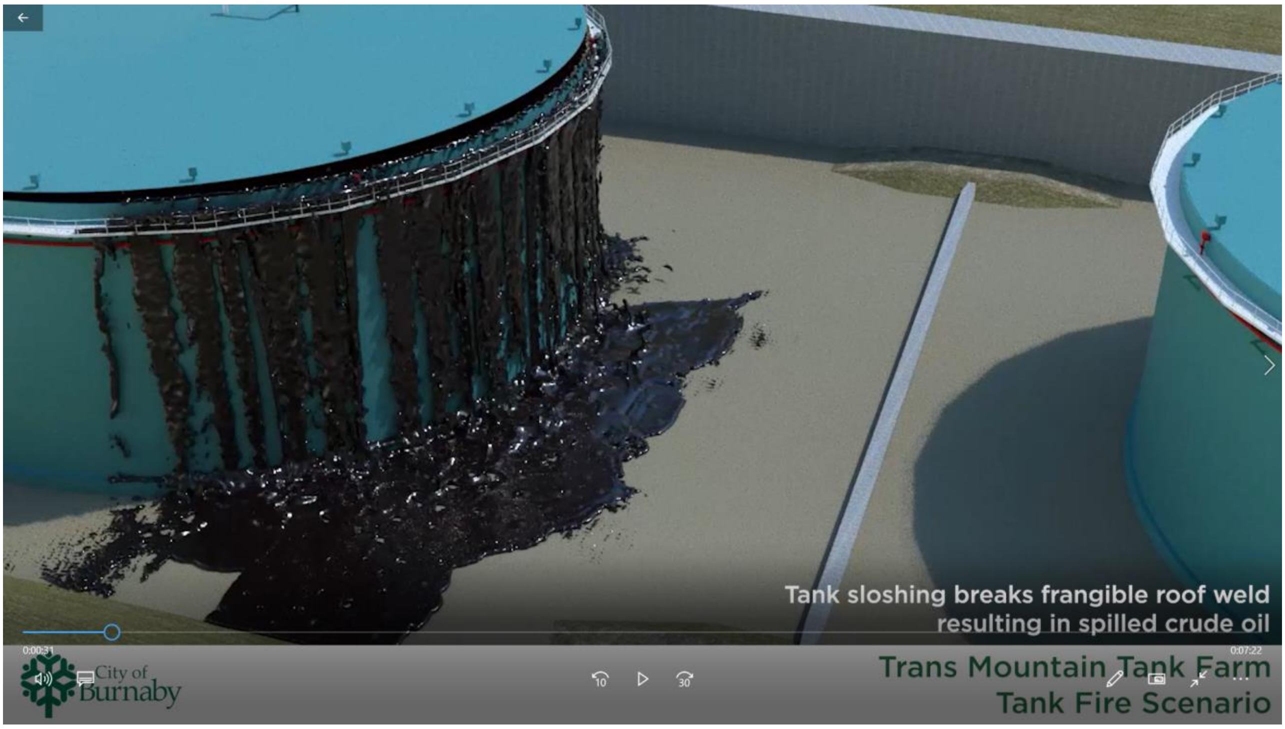
- Any major scenario on site could lead to public panic in the area jeopardizing access and evacuation routes and resulting in considerable additional pressure on emergency resources.
    - Emergency Services will require clear access for search and rescue and controlled evacuation priorities.

- The short and long term societal, economic, and environmental damage locally and regionally will be extensive.
    - Real estate value reductions.
    - Long term loss of local businesses.
    - Environmental pollution.

- There are potential short and long term health effects including to eyes and lungs as a consequence of the compounds produced by combustion, especially for those with respiratory issues.
    - Particulate matter – soot composed primarily of elemental carbon.
    - Gases, such as carbon dioxide, carbon monoxide, nitrogen oxides, sulphur oxides.
    - Volatile organic hydrocarbons.

- The foam currently used on site contains chemicals known as PFAS which are facing increasing regulatory controls worldwide, due to their "forever" nature and long-term environmental consequences.
    - Potential ground and water contamination.

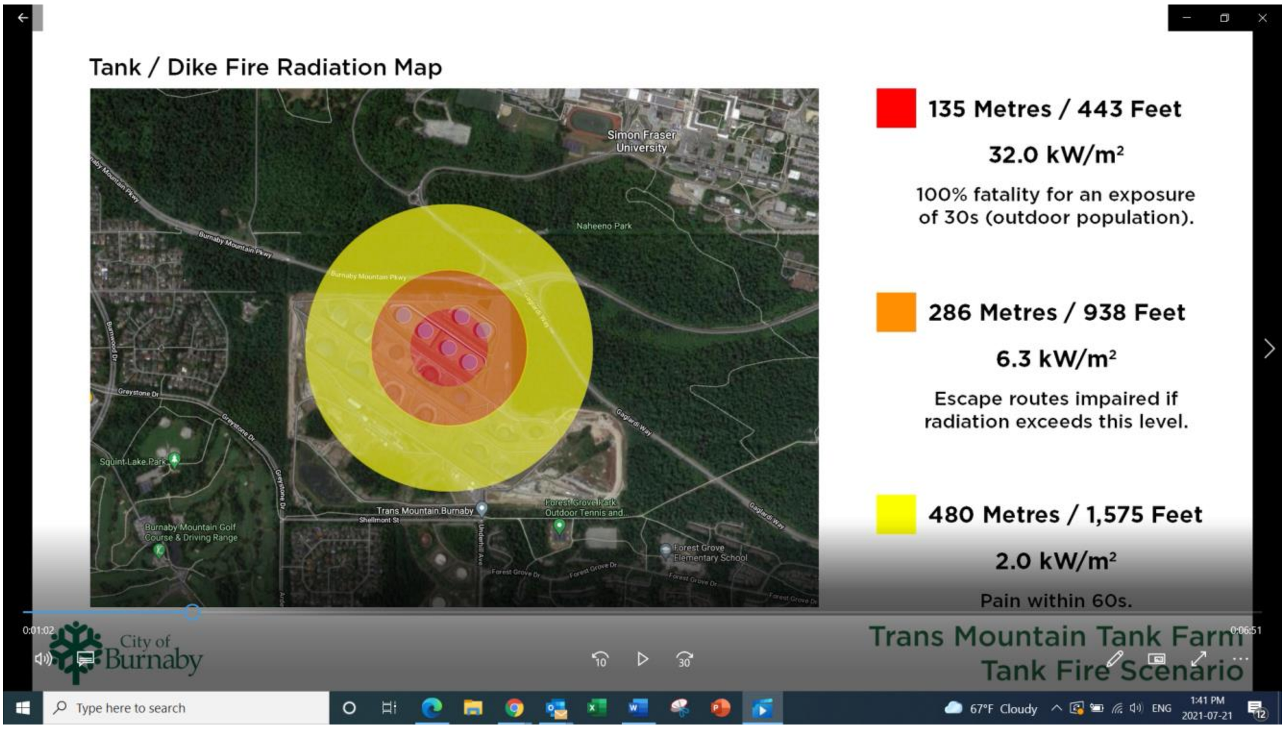
5.2 Burnaby Tank Farm - Example Event



Seismic generated sloshing causes frangible roof seam failure with oil spilling out of tank. The internal roof is undulating and strikes the external roof's underside and periphery causing the internal roof to sink. The friction caused by roof collisions ignites the oil vapors.

A bund (dike) fire is started as well as fire in the space between internal and external tank roofs.

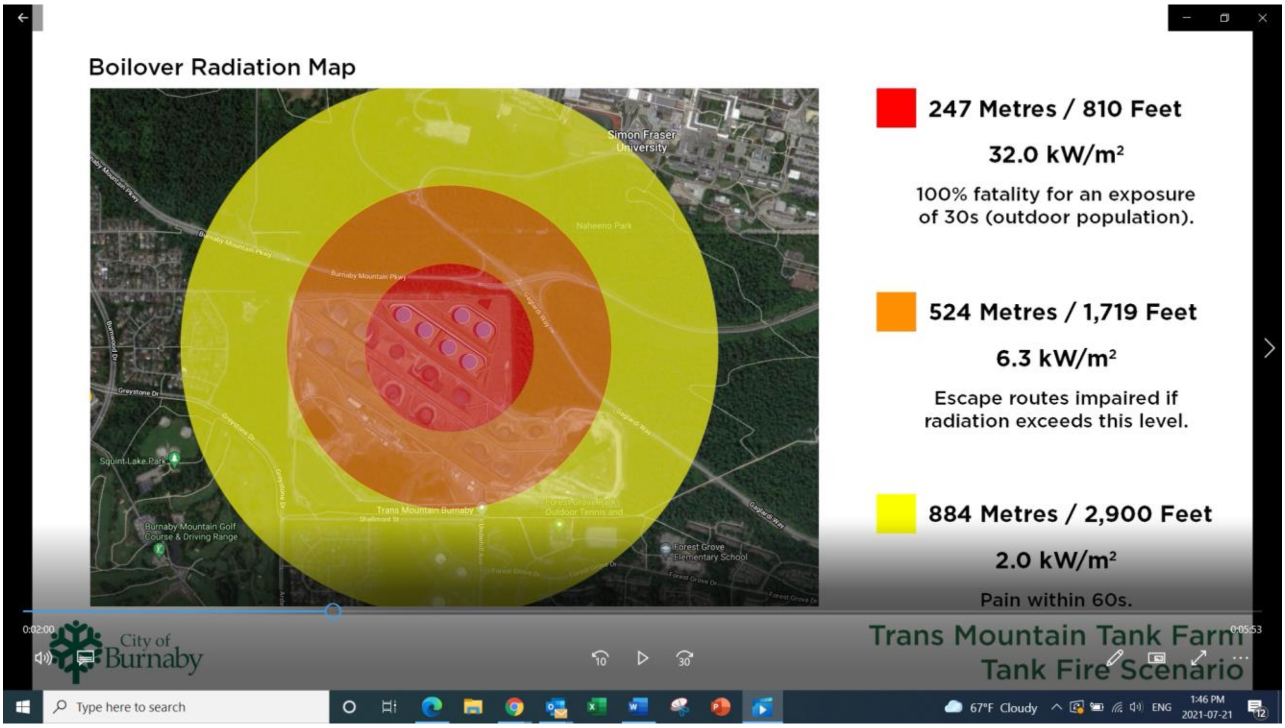
Above: A dike and full surface fire that if not extinguished could lead to a boilover.



Above: The radiant heat from a dike and tank fire can extend beyond the fence line.

Above: An internal fire / explosion can cause the roof to lift off.

Full surface fire and dike fire or boilover that could lead to a wildfire in the surrounding treed areas. Note that multiple tanks in the vicinity are also at risk.



Above: The radiant heat from a boilover can extend far beyond a fence line.

Above: The radiant heat can ignite trees in the area.

5.3 Burnaby Tank Farm - Static & Dynamic Models

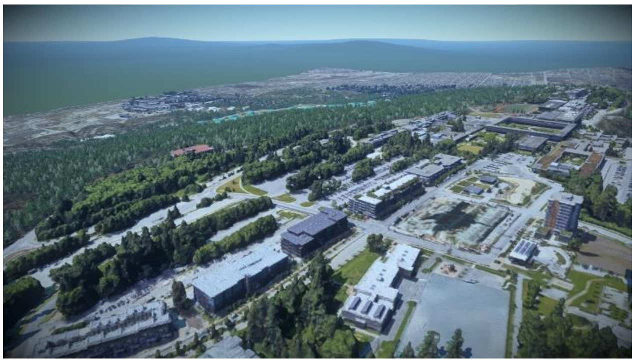
Burnaby Tank Farm

A static model was created using public information on the Burnaby Tank Farm. After completing the static model dynamic effects with added to simulate it according to historical events.

Each number represents the view from each respective location and towards the Burnaby Tank Farm.

Burnaby Tank Farm - Static and Dynamic Models (Side by Side)

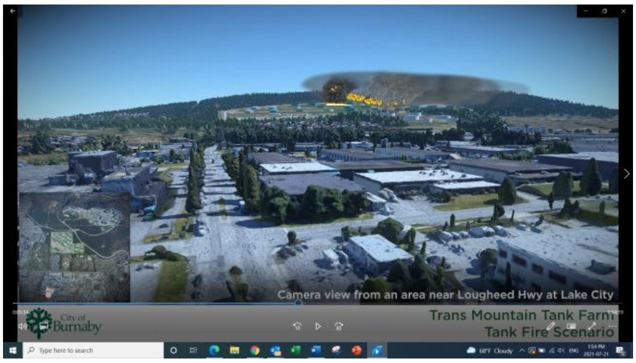

View #1- Overhead. The dynamic model view on right includes the tank and dike fire and the wildfire started from the radiant heat.



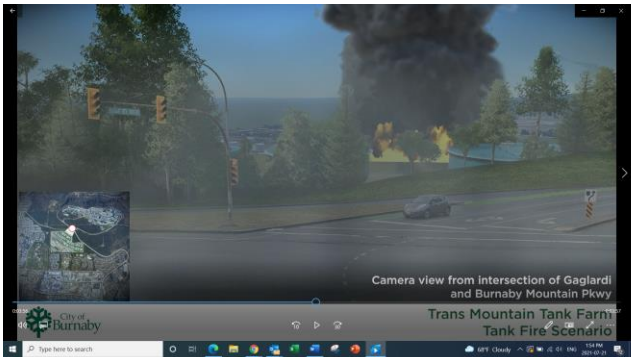

View #2 – Univer-City. The dynamic model view on the right is taken above the tank fire smoke plume.


View #3 – Forrest Grove Elementary School camera view. Static view on the left and dynamic model on the right.

View #4 – Burnaby Mountain west of tank farm.



View #5 – Lougheed Hwy @ Lake City Overpass.



View #6 – Gaglardi / Burnaby Mountain Intersection. The wildfire smoke obscures the view of the tank fire.

5.4 Burnaby Tank Farm Heat Map- 3D Bubble

Burnaby Tank Farm and full surface fire heat map- Red Zone.

Burnaby Tank Farm and full surface fire heat map- Orange Zone.

Burnaby Tank Farm and full surface fire heat map- Yellow Zone.

6.0 Westridge Marine Terminal

6.1 Key Points of Concern / Fast Facts

A study has been carried out in accordance with international practices for tank farm and jetty area hazardous scenario evaluation. It is recognized that the incidents are low probability, but they have all happened and in particular can be considered more likely at Westridge Terminal as it is in a high frequency earthquake zone.

Note that the assessments that have been carried out are based on limited information available from the Terminal itself, including no information on the existing Fire Hazard Management system

A balanced technical approach has been taken of events that could occur at Westridge Terminal as examples of possible incidents. These are not the only potential scenarios, and several escalation factors would lead to the same consequences.

The following points have been identified during this assessment:

- Whilst relying on external specialist responders for major accident scenarios it is very doubtful if they could be deployed within a timeframe to minimise potential for escalation to catastrophic events.
    - Numbers and competencies of responders critical.

- There is a Propane vessel located within the Vapour Recovery Unit, which could result in phenomena known as Boiling Liquid Expanding Vapour Explosion (BLEVE), which could result in major catastrophic damage inside and outside the fence.
    - Devasting consequences and multiple off-site fatalities have occurred with this incident type elsewhere.

- Any major scenario on site could lead to public panic in the area jeopardizing access and evacuation routes and resulting in considerable additional pressure on emergency resources.
    - Emergency Services will require clear access for search and rescue and controlled evacuation priorities.

- The short and long term societal, economic, and environmental damage locally and regionally will be extensive for some scenarios.
    - Real estate value reductions.
    - Long term loss of local businesses.
    - Environmental pollution.

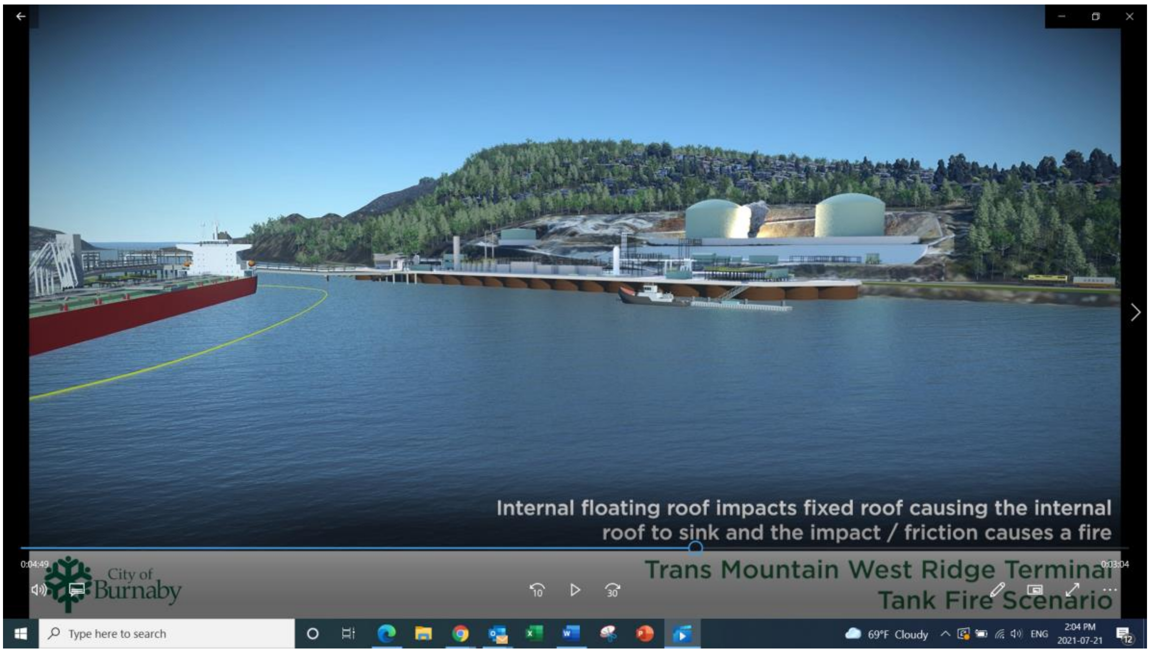
- There are potential short and long term health effects including to eyes and lungs as a consequence of the compounds produced by combustion, especially for those with respiratory issues.
    - Particulate matter – soot composed primarily of elemental carbon.
    - Gases, such as carbon dioxide, carbon monoxide, nitrogen oxides, sulphur oxides.
    - Volatile organic hydrocarbons.

- The foam currently used could contain chemicals known as PFAS which are facing increasing regulatory controls worldwide, due to their “forever” nature and long-term environmental consequences.
    - Potential ground and water contamination.

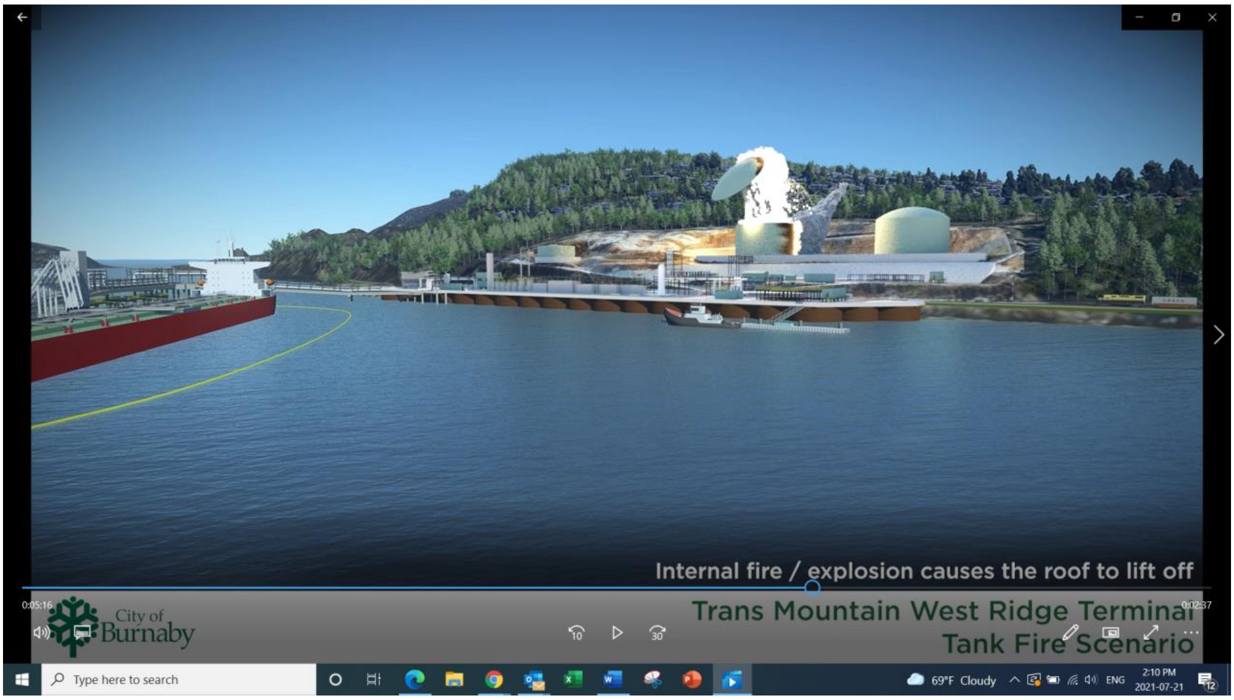
- A spill at the jetty, if unignited, could result in a significant incident to the environment, which may have long lasting impacts to the local wildlife.
    - The emphasis should be placed on identifying and containing the spill.

6.2 Westridge Marine Terminal – Example Event

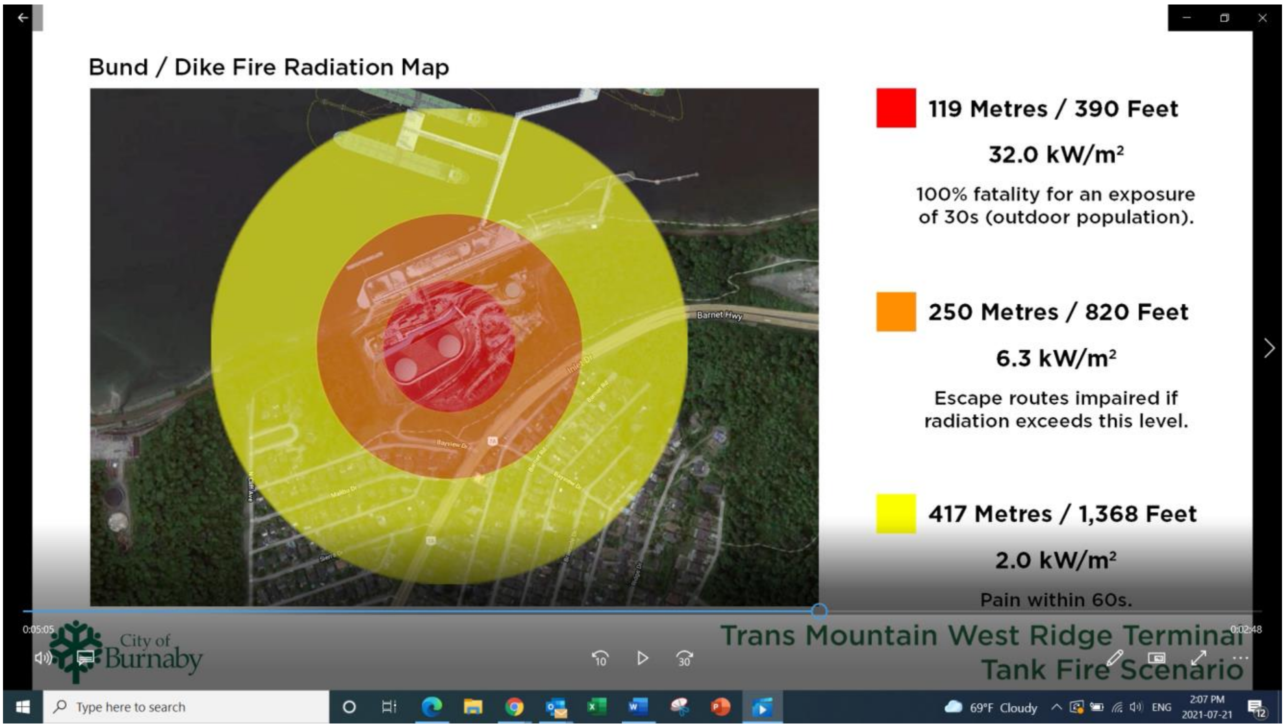
In the picture above a seismic event caused the liquid to fracture the frangible roof joint leading to a leak into the dike area that finds an ignition source.



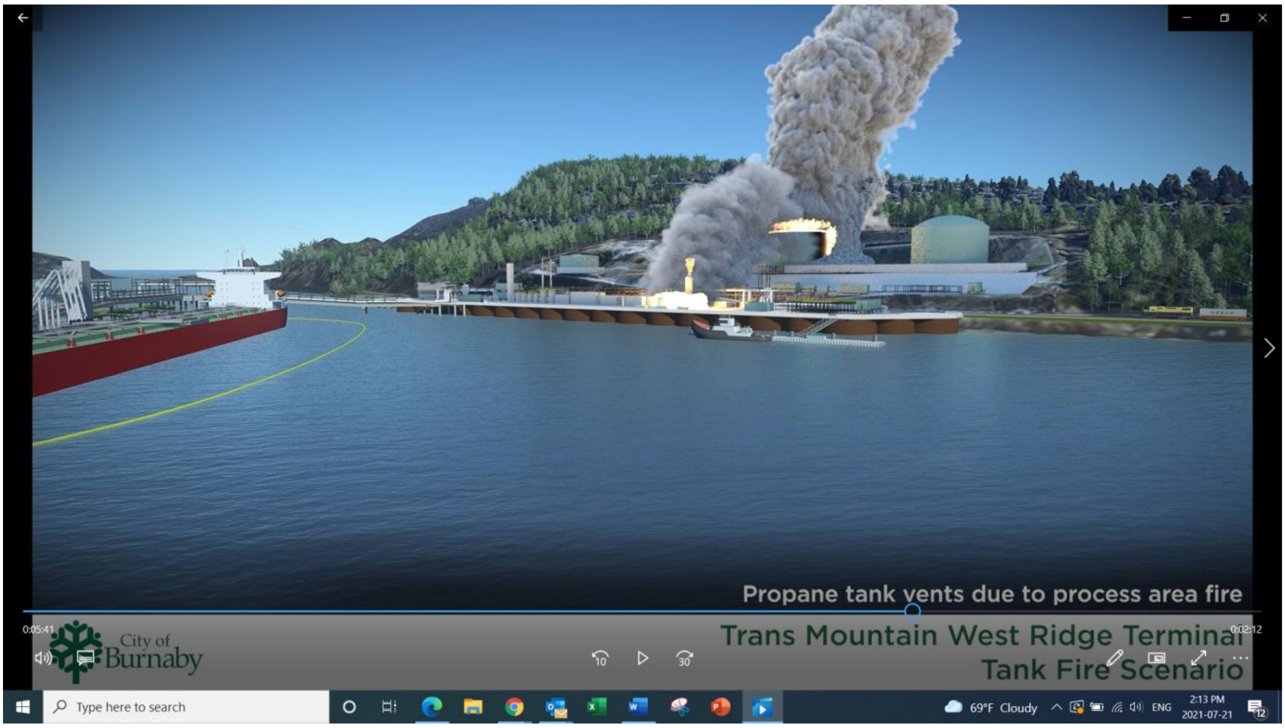
If the tank is equipped with an internal floating roof, it can be the cause of a fire when it contacts the fixed roof during large wave sloshing but there are other sources of ignition as well.



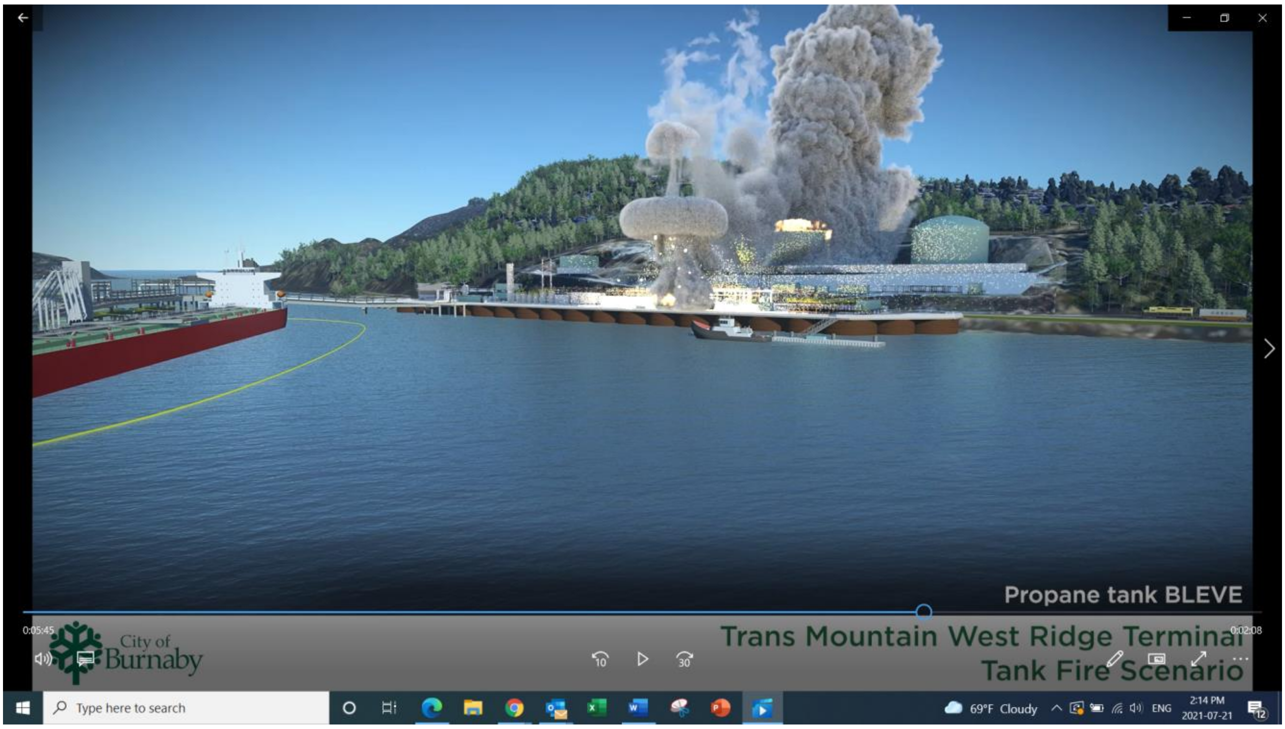
Above: The fixed roof can lift off if the vapors beneath it ignite and cause an explosion.



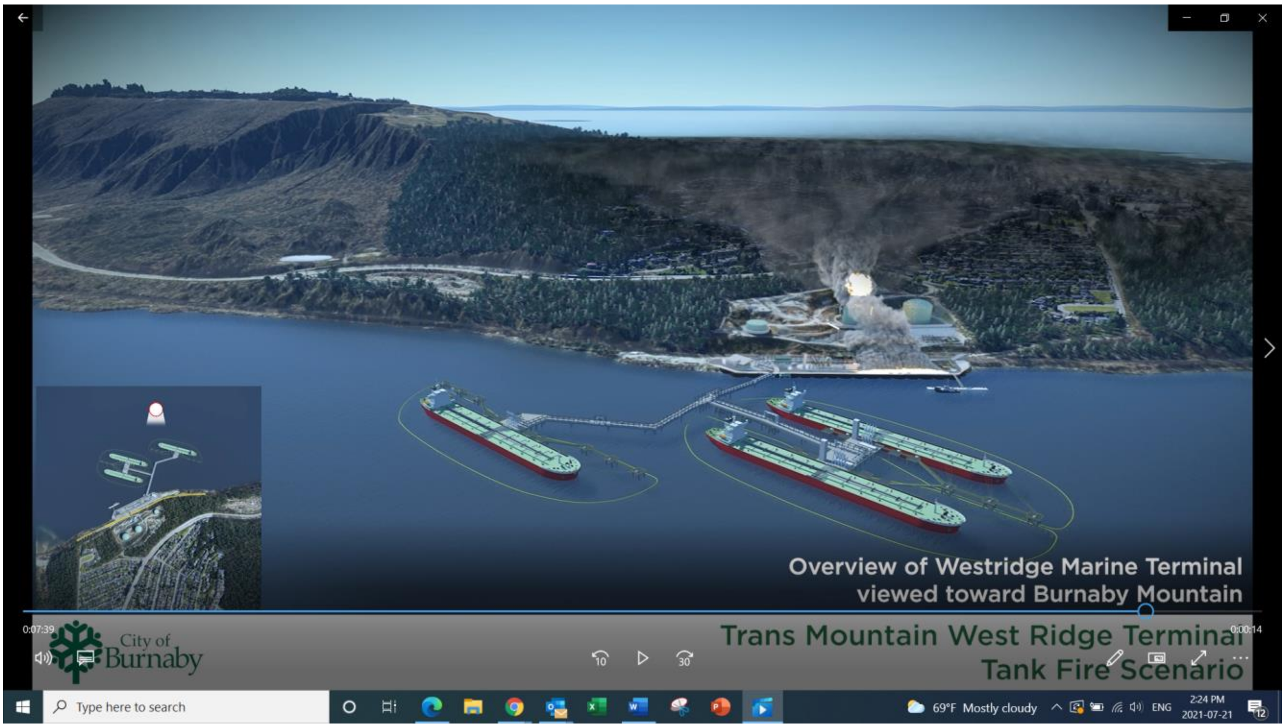
The radiant heat from a tank and dike fire can extend beyond the fence line.



Above: The roof blows off and lands in the process area causing a leak which ignites, and the heat can cause pressure vessels e.g., propane to vent.

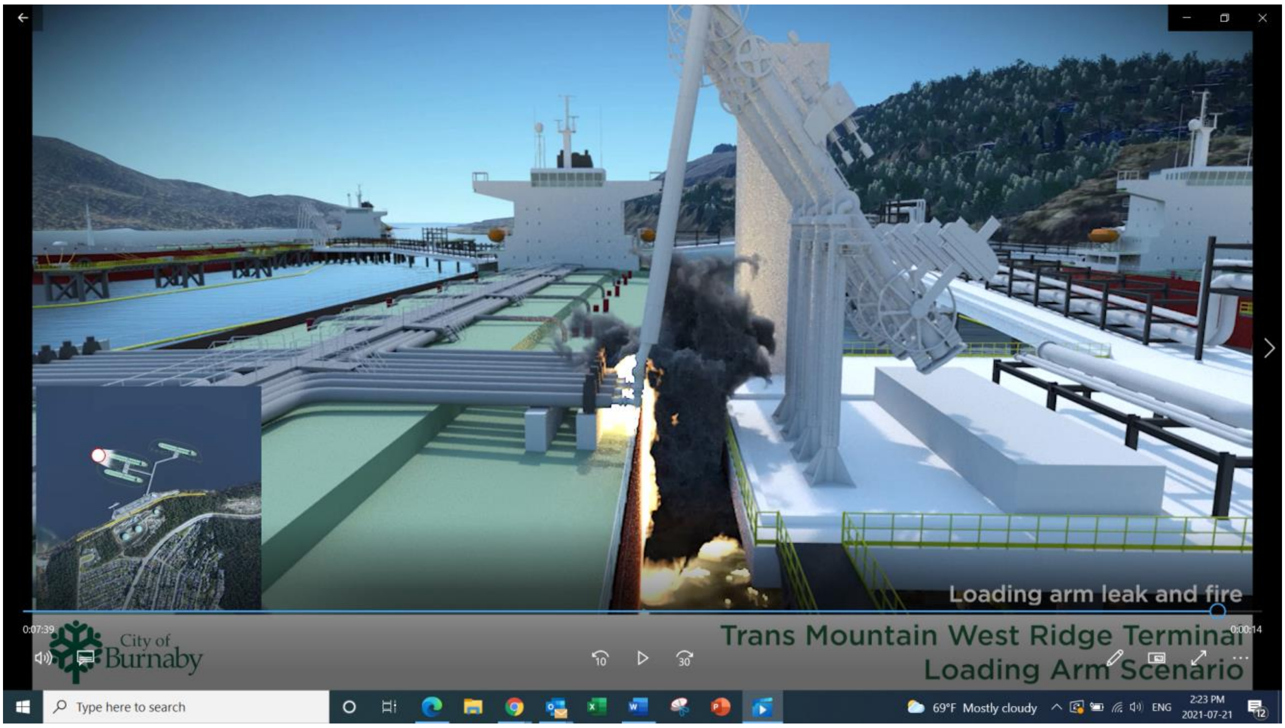


In the above picture a BLEVE of the propane tank occurs.



An aerial view of the fire of the Westridge Marine Terminal waterfront.

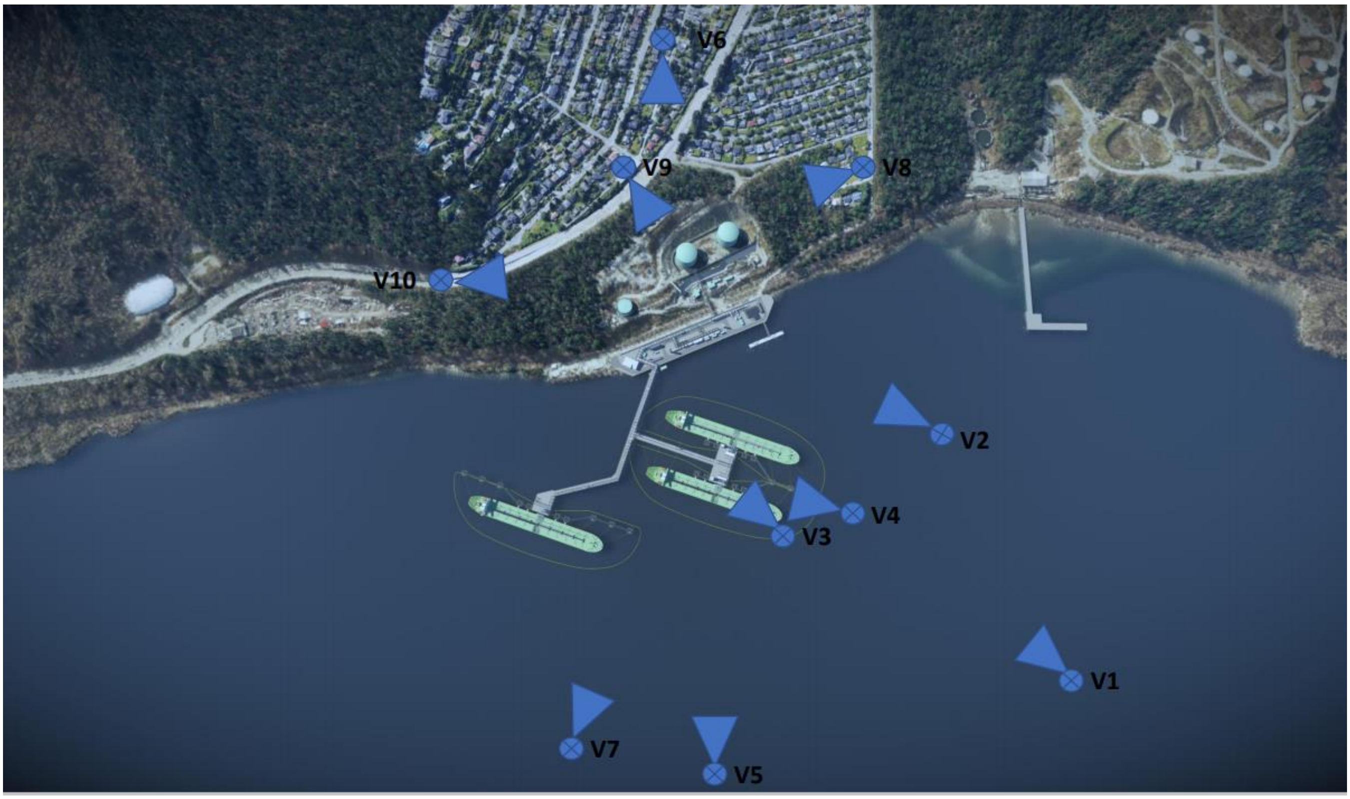
The picture above shows a loading arm leak and fire.



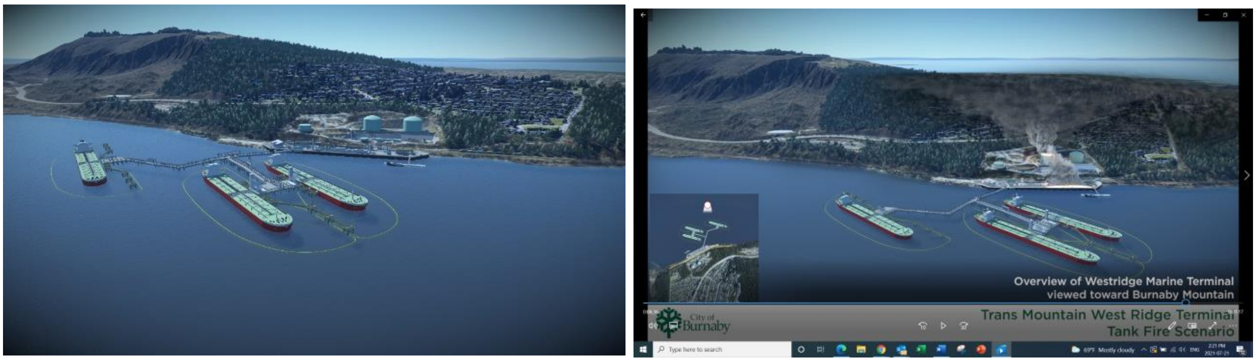
In the above picture the fire is between the tanker and the berth.

6.3 Westridge Marine Terminal – Static and Dynamic Models

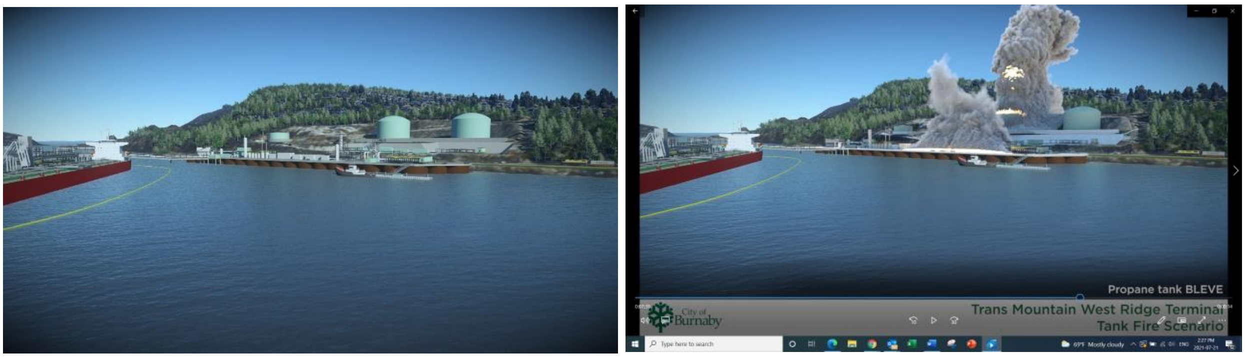
A static model was created using public information on the Westridge Marine Terminal. After completing the static model dynamic effects were added to simulate a historical fire event. Both the static and dynamic model screen shots were taken and placed side by side for comparison.



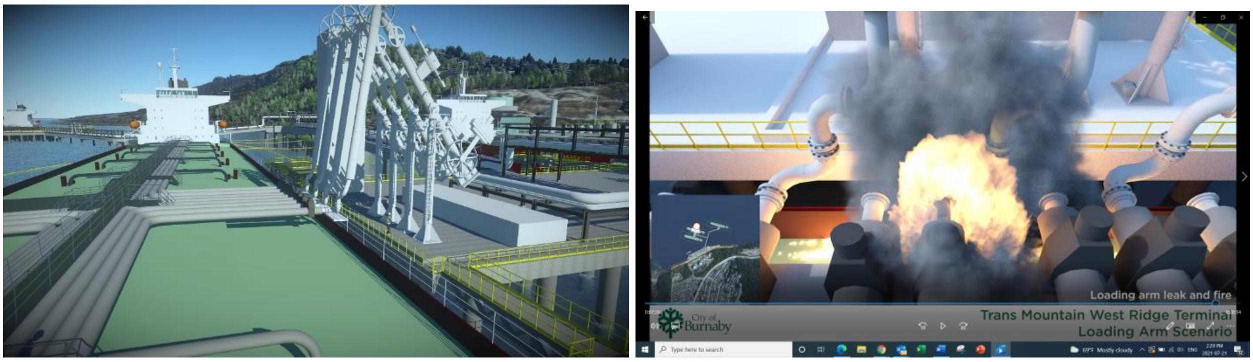
Each number represents the view from each respective location and towards the Westridge Marine Terminal.



View #1- Overview of Westridge Marine Terminal. Dynamic model on right shows fire event on the WMT waterfront.



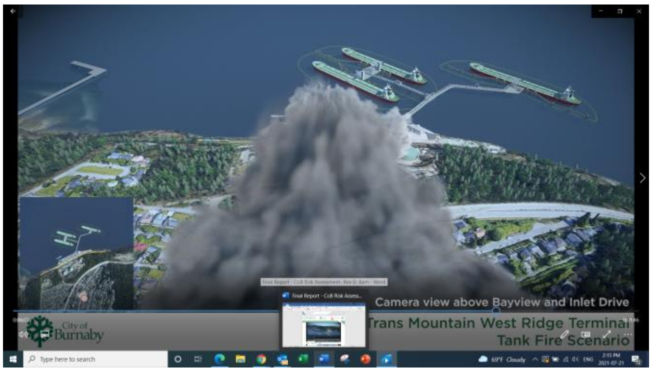
View #2- Water view of WMT waterfront. Dynamic model on right shows after propane tank BLEVE



View #3 – View from tanker. Note that the view was adjusted in the dynamic model to view the leak / fire.

View #4- View from a position between the berth and tanker. Dynamic model on right shows oil leak onto water with fire.

View #5- Alternate overview.



View #6- View from an area above Bayview and Inlet View Drive.

View #8- View from an area near N. Cliff Ave.

View #9- Street level view near Bayview and Inlet Drive.

View #10- View near Barnet Hwy.

6.4 Westridge Marine Terminal Heat Map – 3D Bubble

Three scenarios shown with heat map bubbles showing approx. radiant heat intensity at various distances.

East tank dike and full surface fire heat map- Yellow Zone.

East tank dike and full surface fire heat map- Orange Zone.

East tank dike and full surface fire heat map- Red Zone.

APPENDIX A-1: BURNABY ENRGCONSULTANTS REPORT

The Old Rectory, Mill Lane
Monks Risborough, Bucks, HP27 9LG, UK
Company Registration: 7698749

Burnaby Risk Assessment Project
Fire Scenario Worksheets
May 2021

Reference	**Prepared by**	**Checked by**	**Approved by**
Burnaby Risk Assessment Project	M. Plastow	Dr. N. Ramsden	Dr. N. Ramsden
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Burnaby Risk Assessment Project	M. Plastow	Dr. N. Ramsden	Dr. N. Ramsden
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Version: Issue REV C	10 May 2021	10 May 2021	10 May 2021
Burnaby Risk Assessment Project	M. Plastow	Dr. N. Ramsden	Dr. N. Ramsden
Version: Issue REV D	21 July 2021	21 July 2021	21 July 2021

Executive Summary

This document has been prepared to review a number of potential hazardous scenarios at the Burnaby Terminal site (Rim Seal Fire, Full Surface Fire, Bund (dike) Fire and Vapour Cloud Explosion). These Scenario Worksheets (SW) have been completed in accordance with the recommendations in the Energy Institute Model Code of Safe Practice Part 19 – Fire Precautions at Petroleum Refineries and Bulk Storage Installations. When used as part of a risk-based Fire Hazard Management development process in accordance with this internationally recognised guidance, they would form the basis for Scenario Specific Emergency Response Plans.

The assessments and worksheets contained within this document represent a balanced technical opinion of events that could occur at the Burnaby tank farm. All of the scenarios discussed within this document have occurred somewhere within industry and there is limited scope to reduce the magnitude of these events if they occurred. It is recognised that the likelihood of these events is low and there are measures that can be taken to reduce that likelihood further, but they still all remain credible events. It should be noted that in the case of Burnaby the probability would be higher than the global average because of the earthquake frequency in the area.

Within this document, scenarios have been reviewed that could escalate given a set of circumstances. However, given the correctly designed, inspected, maintained, and tested procedures and equipment with competent and trained personnel, the probability of escalation can be reduced, but not eliminated completely.

Where possible, information has principally been taken from the Trans Mountain Tank Farm Tactical Analysis document, dated 01 May 2015 or the Burnaby Terminal Fire Pre-Plan dated 12/20. However, it is recognised that some of this information may not be accurate or up to date given potential infrastructure changes due to the expansion project at the facility.

These worksheets are intended to provide examples of potential scenarios at the Burnaby Tank Farm with associated consequences and proposed firefighting strategies. There are other scenarios and sets of circumstances that could lead to the same escalation result.

Contents

Notes on Scenario Worksheets

The following notes are intended to clarify their purpose:

- It is recognised that the scenarios have a relatively low probability, but similar incidents have occurred within the industry in all cases, including at facilities designed and operated in accordance with best industry practices.

- The consequences have been modelled for a specific scenario at one location at the facility. Of course, a similar scenario could occur at many locations within the terminal with similar consequences but possibly different timelines and probabilities. For example, if a full surface tank fire occurred in a tank nearer the boundary fence, then escalation to facilities and vegetation outside the fence would be more rapid.

- The assessments have been carried out based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to boilover. Other material is stored at the tank farm, which could have similar consequences. Refer to Appendix 5 of this document.

- Radiant heat calculations have been carried out using recognised software (ALOHA, developed by the USA Office of Emergency Management, EPA and the Emergency Response Division, NOAA), but it must be realised that all such models have fairly high inherent calculation tolerances. Equally, although radiant heat levels causing certain effects such as escalation to adjacent facilities are based on published figures, the actual radiation levels will depend very much on specific conditions such as tank contents, ambient conditions etc. during the event.

- In the event of a major incident resulting in flames and smoke, this will be visible to the general public, which could cause panic within the community. This is likely to generate a large amount of media interest and telephone calls, which could impact communication. This should be recognised and will need to be managed.

- Initial panic caused by a major incident could lead to an uncontrolled evacuation from the area by the general public. This could seriously hamper any relief efforts or evacuations.

- It must be recognised that with such varying potential conditions, precise strategies, and tactics to be deployed might vary considerably. Tank firefighting should not be seen as an exact science but rather one relying on the availability of specialist experienced and competent personnel to make decisions based on the unique set of circumstances for that specific event.

- Boilovers are mentioned as a potential escalation route. Extensive work carried out by the LASTFIRE Group has shown that there are no proven or validated methods of preventing a boilover during a full surface crude oil tank fire except fast extinguishment. A published response time of 2 hours is recommended for any fuel with boilover potential by this international group of oil companies.
- The number and location of monitors is not based on specific application rate calculations but based on experience of similar incidents and the fact that application by monitors is typically dependent on the capacity and range of monitors rather than the actual minimum quantity of water required.

- This document concentrates on the relatively immediate incident consequences. Such incidents elsewhere have resulted in massive long term consequential impact on the surrounding area, including contamination of drinking water sources, business loss, residential accommodation property value losses and long-term environmental damage.

Potential Escalation Mechanisms

Whilst certain escalation routes have been discussed it is important to note that some of the escalation stages could be the initial incident in their own right. For example, a full surface tank fire could be the initial incident rather than a rim seal fire leading to one.

These are not considered to be the only escalation routes for the final scenarios but examples of potential ones only.

Example escalation route a)

- Earthquake or mechanical damage to the rim seal.
- Leads to a loss of containment of hydrocarbon above the rim seal.
- If there is an ignition source this could lead to a fire in the rim seal.
- A rim seal fire should be suppressed by the existing semi fixed foam system installed on each of the rim seals.
- A rim seal fire is unlikely to escalate to a full surface fire in well maintained tanks although it has happened rapidly in cases where there is vapour in roof pontoons.

Example escalation route b)

- Earthquake or maloperation leading to product on the tank roof. (Note: incidents have occurred where the earthquake results in loss of tank contents from the tank by sloshing and breaking of the tank roof/shell joint, which is deliberately a weak joint.)
- Potential for the roof to sink.
- If there is an ignition source this could lead to a full surface fire.
- If rapid extinguishment is not possible, then the radiant heat from the full surface fire could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to other tanks, which could lead to further rim seal fires or full tank surface fires or bund (dike) pool fires.
- If the full surface is not extinguished within 2 hours, there is a risk of boilover which may occur anytime - it is effectively an unpredictable event as there are so many variables involved.
- The impacts of a boilover will be realised not only within the tank farm, but also outside the fence and, in particular, the vegetation around the site and potentially communities. Given the topography of the site, there is a risk to the local community to the South of the site, which is at a lower elevation.
- Without ignition, there is likely to be minimal safety and health impacts but there could be a business interruption and there will be a requirement to clean the material up.

Example escalation route c)

- Maloperation or mechanical failure of instrumentation leading to an overfill of the tank.
- Potential for a vapour cloud to form in the tank farm and with the congestion in and around the tank farm, there is a risk that a delayed source of ignition could result in a flash fire back to the tank or a vapour cloud explosion.
- This vapour cloud explosion and damage from overpressure could lead to other tank fires or multiple tank fires and therefore the escalation scenarios identified for a full surface tank fire are possible.
- The flammable liquid accumulating in the bund could find a source of ignition leading to a bund fire.
- If rapid extinguishment is not possible, then the radiant heat from the bund fire could impact the tank in the bund and other tanks located within 2 tank Diameters (dependent on wind conditions

and the impacts of differing elevations). This could lead to potentially additional bund (dike) fires if there is flammable material in the bund.

- There is significant vegetation located around the tank farm and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area and evacuation from it, including surrounding schools and residential property (including the university campus).
- Without ignition, there is likely to be minimal safety and health impacts, although the Dilbit crude does contain Hydrogen Sulphide (H2S) and Sulphur Dioxide (SO2) which the emergency response personnel need to be aware of and wear suitable Personal Protective Equipment (PPE), but there is likely to be a major business interruption and clean-up operation required. It should also be noted that suitable PPE may include breathing apparatus, which will make working conditions difficult, particularly if the event goes on for some time.

Concerns to be Addressed

Whilst resources have been quantified for specific situations, no comparison with actual equipment on site have been made. However, sight of some documentation has given concern if sufficient resources are available and if they conform to industry recognised standards. Even if sufficient resources are available, it is unclear whether they can be safely deployed in an appropriate time.

For example: The foam requirement calculations provided in the Burnaby Fire Pre-Plan suggest that they have not been carried out in accordance with the recognised standard - NFPA11. No allowance, as required by this standard for losses due to wind and thermal updraught have been included. This is a very serious omission – especially if it has been continued through to the upgrade phase. It results in insufficient foam, application equipment and waterflow to meet standard demands available of the facility. Mention is made of increasing application rates if losses are occurring, but this does not appear top have been considered in the calculations deriving the quantities of foam concentrate and foam solution required.

It is understood that a “Round the Pump” proportioner type is used for foam concentrate injection. Based on considerable experience worldwide, these are notoriously inaccurate at providing correct proportioning rate over any significant flow range – and in any case can cause long delays in the correct rate reaching application equipment when any flow change occurs for whatever reason.

Whilst monitor locations have been identified as typical possibilities, they should be taken as examples only as actual locations will depend on wind direction and speed and on the actual radiation levels impacting access for emergency response personnel.

Based on limited site knowledge, there would be concerns regarding the safety of deploying equipment to the required locations because of boilover potential. There is a risk due to smoke obscuration and radiant heat and availability of sufficient manpower to be able to position all necessary equipment within a reasonable time frame. The consequences of a boilover would be significant at any site, but at the Burnaby site, there is the added risk resulting from the topography of the site resulting in burning product flowing downhill.

It is necessary to check: the minimum required water quantities, rates, pressures, etc. against availability on site, given the upgrades being made.

The capacities on site for foam/water containment are not known – this is an important part of minimising environmental consequences of any incident along with necessary detailed preplanning for such events.

It is understood that the foam being used at the facility is a fluorinated foam, commonly known as PFAS. Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that includes PFOA, and PFOS. Both chemicals are very persistent in the environment and in the human body – meaning that they do not break down and they can accumulate over time. PFAS, which is known as a forever chemical, will also leave a long-term environmental impact. There is a drive to non-fluorinated foams globally and this should be considered by the facility.

Rim Seal Fire

SCENARIO WORKSHEET

TANK 95 - SCENARIO RIM SEAL FIRE

AREA	**BURNABY TANK FARM**
FACILITY	Storage tank 95[1]
FUNCTION	Dilbit (Bitumen plus condensate) Storage Tank
SCENARIO	A rim seal fire occurs where the seal between the tank shell and roof has lost integrity and there is ignited vapour in the seal area. The amount of seal involved in the fire can vary from a small, localised area up to the full circumference of the tank. Seal construction is a major factor in this. The flammable vapour can occur in various parts of the seal depending on the seal type. A rim seal fire should not escalate to a full surface fire in a well-maintained tank. However, if there is vapour in the pontoons then they can explode due to the fire thus creating roof instability and so lead to a full surface fire. A full surface fire is discussed within the full surface fire scenario worksheet.
MATERIAL	The material stored within the tank(s) is Dilbit[2]. Dilbit is a product resulting from the mixture of high viscosity bitumen with a low viscosity "condensate" that facilitates the flow of bitumen through pipelines.

In the case of a Dilbit spill, the condensate would evaporate, leaving the heavy bitumen behind. The publicised consequences of exposure to condensate after a spill or accident are as follows:

- Condensate is a colourless to straw-coloured liquid, with hydrocarbon odour, which readily vaporizes at atmospheric pressure, and it is extremely flammable.
- Its vapours are heavier than air.
- Short term health hazards from exposure to vapours include eye and skin damage, nausea and dizziness, and breathing difficulties.
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.
- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, special firefighting techniques like the use of foam, CO2, or dry chemicals are required.

[1] This assessment has been based on Tank 95, but a similar event could have been considered for any of the storage tanks. The consequences will essentially be the same, but tanks nearer the fence line or nearer buildings could have a different impact.

[2] The assessment has been based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to Boilover. Other material is stored at the tank farm, which could have similar consequences.

- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

LOCATION FOR SCENARIO

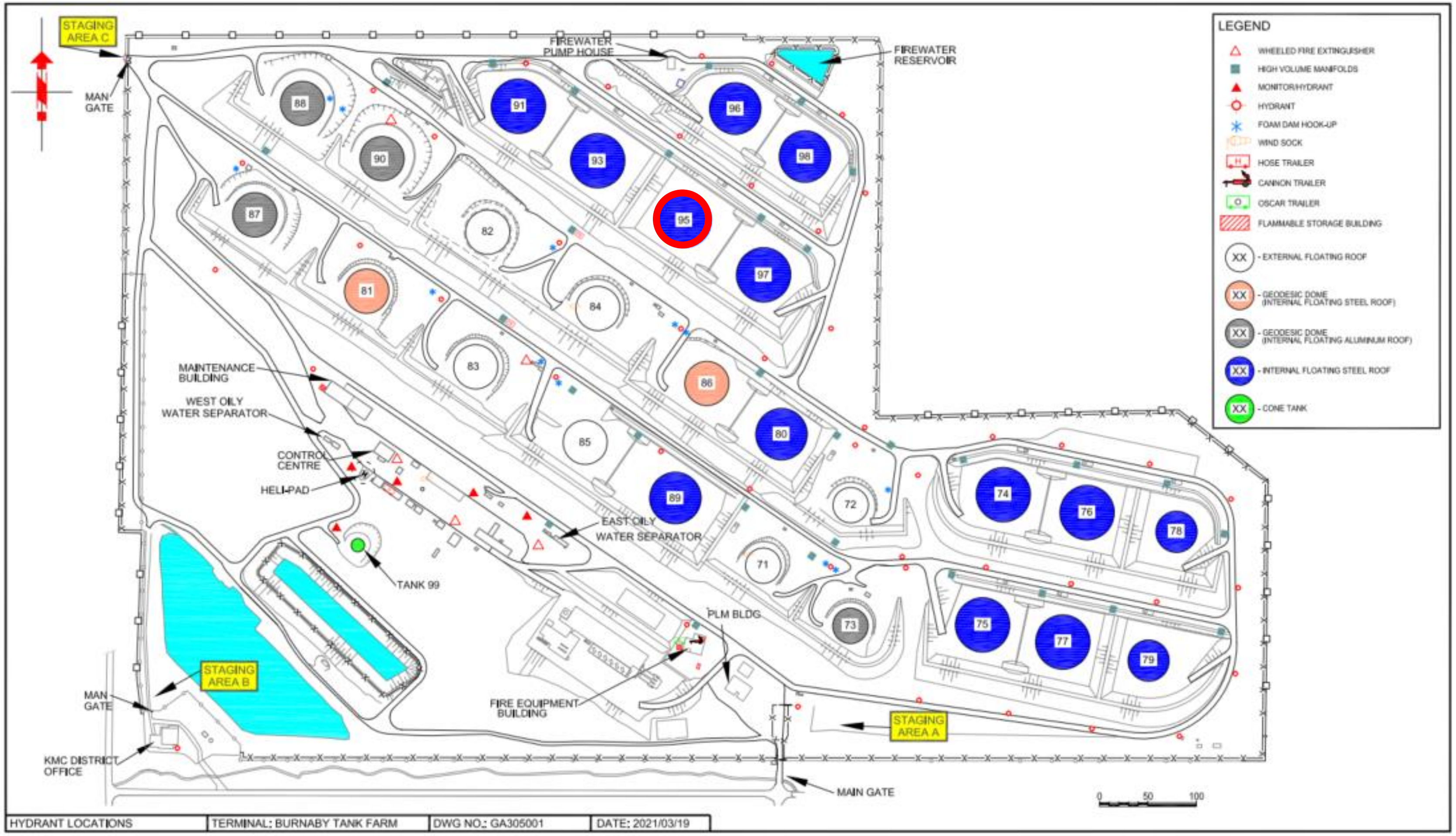
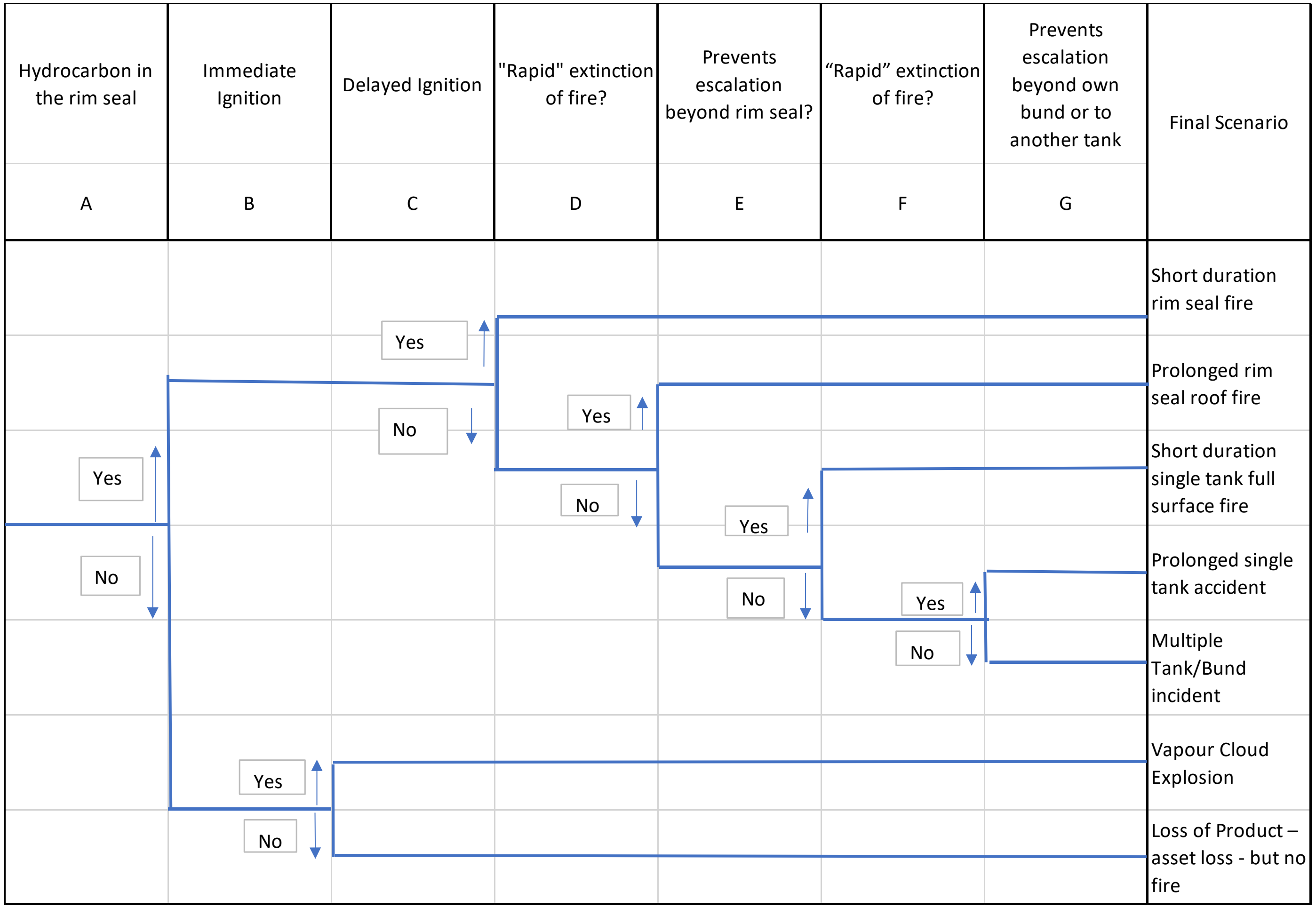


Figure 1: Partial plan of the site indicating the location of tank 95

POTENTIAL SCENARIOS

Below is an event tree for the rim seal fire starting with a loss of containment into the rim seal of the tank.



ESTIMATION OF RISK

The risk matrix (see below) has been provided as an example to represent the risk of the scenario. An estimate has been for the likely consequence assessed in terms of Safety or Environment or Financial. Only the initial scenario has been assessed and no account for escalation of the event has been included. Each organisation will have their own definitions of levels of risk and so for the purposes of this report, a generic set of definitions have been chosen.

A risk matrix can be used during risk assessment to define the level of risk by considering the category of probability or likelihood against the category of consequence severity. This is a simple mechanism to increase visibility of risks and assist management decision making.

For the scenario above (based on the existing prevention, control and mitigation measures that are believed to be in place), the scenario is assessed to be a relatively low level of risk to safety for the initial event, but that risk level is significantly increased based on the potential financial and environmental consequences.

An organisation can use a risk matrix to prioritise which scenarios should be addressed based on the level of risk estimated.

Risk matrices are included here to demonstrate the relative consequences as a guide, but it is recommended that the terminal undergoes a more detailed assessment to determine the level of risk for each scenario.

ESTIMATION OF RISK[3]

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

[3] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation.

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g. North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short-term complaints from neighbors (e.g. complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is not normally manned and has alternative exits available. A rim seal fire is unlikely to pose a major immediate life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the rim seal fire once the product is ignited. The Dilbit material is a high viscosity bitumen with a low viscosity "condensate", so there is likely to be a lot of thick and heavy smoke. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads, particularly as this is the only evacuation route from the University. However, providing the rim seal fire does not escalate to a full surface fire, there is unlikely to be significant amounts of smoke. The smoke is likely to cause panic in the local community and is likely to jeopardize the evacuation routes.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. The impact on adjacent tankage would depend on radiant heat and/or flame impingement, however the nearest tank is located at least 0.5D from tank 95.
Asset loss	Potential loss of, or damage to seal area, tank structure and piping.

Escalation Mechanisms

Note that it is unlikely that a rim seal fire will progress directly to a larger scenario, such as a full surface fire or a bund fire, providing the tank is well maintained and it is likely that the incident would need to progress to a full surface fire initially before escalating further.

Escalation time estimates

If there is vapour or product in the pontoons, then escalation could occur. If not, then it can be days or even weeks before escalation – although there would of course be severe seal and seal assembly damage if this was the case.

Post Escalation

Life safety	Operators should have evacuated from the vicinity immediately if a rim seal fire occurs. Escape routes within the tank farm are available and providing the rim seal fire is identified early enough it should make escape relatively easy. Escape would be more difficult if the rim seal fire progresses to a full surface fire, but this will take time to progress and will mean a number of safeguards and barriers have failed. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks. There is also the potential for toxic effects resulting from smoke fall out.
Environment	The smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident. The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm. Currently, it is understood that the facility is using PFAS, which is known as a forever chemical, which will also leave a longer-term environmental impact.
Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. A rim seal fire is likely to only impact a single tank and therefore business interruption is unlikely to be high.
Asset loss	Potential loss of a single tank, but if the incident is allowed to progress it could impact multiple tanks and a loss of piping/valves etc. Possible loss of more than one tank if escalation occurs.

Consequence Assessment

Heat Radiation – Rim Seal fire

Figure 2: Figure 2: Radiation map for a rim seal fire

Threat Zone

	Red	16 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	29 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	44 Metres	2.0 kW/m² = pain within 60 seconds

Boil Over

Refer to full surface fire scenario for further details on this scenario – note that the rim seal fire would need to progress to a full surface fire before it could escalate to a boilover.

Vapour Cloud Explosion

Vapour cloud explosions occur when a flammable cloud is released and allowed to form, which, after some delay finds a source of ignition generating high overpressures.

The main factors which influence the magnitude of gas or vapour explosions are:

- Degree of confinement of the gas cloud.
- Type of flammable gas.
- Level of turbulence in the gas cloud.
- Degree of congestion.
- Gas concentration.
- Ignition strength.

Detailed CFD modelling is recommended to determine levels of overpressure at a distance, which would be particularly important to determine potential impacts on buildings as this could have a significant impact on the emergency response activities. For "Search and Rescue" operations. The key criteria is to identify the formation of vapour at the earliest possible time to limit the release and therefor the potential for explosion.

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a rim seal fire scenario in the event that the semi-fixed system fails to operate, and it is felt necessary to cool the top of the tank.

Foam Cannon	Assuming a single foam cannon has the necessary capacity – 2-3 people would be required to monitor and manage its use.

The minimum number of people required to manage a rim seal fire event is 3 people, but realistically the semi-fixed systems should be operated and extinguish the fire without further manual intervention except to confirm full extinguishment. This does still require deployment of foam handlines as safety measures in most cases.

Full Surface Fire

SCENARIO WORKSHEET

TANK 95 – SCENARIO FULL SURFACE FIRE

AREA	**BURNABY TANK FARM**
FACILITY	Storage tank 95[4]
FUNCTION	Dilbit (Bitumen plus condensate) Storage Tank
SCENARIO	Full surface storage tank fire due to, for example, vapour space explosion and failure of tank roof. A fire of this magnitude (e.g., 56.4m diameter for Tank 95) could impact tanks in all directions. On the assumption that tanks need to be cooled that are 1 tank diameter upwind and 2 tank diameters downwind (with consideration given for the impacts of differing elevations), then the worst-case scenario is tanks 93 and 97 to the west and east respectively and tank 96 to the plant North. Tank 93 is separated from Tank 95 by 28.3m (0.5D) and is in the same bund separated by a small wall. Tank 97 is separated by 39m but is in a different bund. Tank 96 is further away and is uphill but is still less than 2 diameters away. Tank 84 is more than 2 diameters away and located downhill from Tank 95. It is possible that fuel surfaces could be exposed to greater heat levels and flame impingement as the tank on fire burns down. Escalation by 'fuel spread' is possible as the tanks contain Dilbit material (see below), so in the event of a tank full surface fire, this could escalate to a boil over.
MATERIAL	The material stored within the tank(s) is Dilbit[5]. Dilbit is a product resulting from the mixture of high viscosity bitumen with a low viscosity "condensate" that facilitates the flow of bitumen through pipelines. In the case of a Dilbit spill, the condensate would evaporate, leaving the heavy bitumen behind. The publicised consequences of exposure to condensate after a spill or accident are as follows:

[4] This assessment has been based on Tank 95, but a similar event could have been considered for any of the storage tanks. The consequences will essentially be the same, but tanks nearer the fence line or nearer buildings could have a different impact.

[5] The assessment has been based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to Boilover. Other material is stored at the tank farm, which could have similar consequences.

- Condensate is a colourless to straw-coloured liquid, with hydrocarbon odour, which readily vaporizes at atmospheric pressure, and it is extremely flammable.
- Its vapours are heavier than air.
- Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties.
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.
- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, special firefighting techniques like the use of foam, CO_2, or dry chemicals are required.
- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

LOCATION FOR SCENARIO

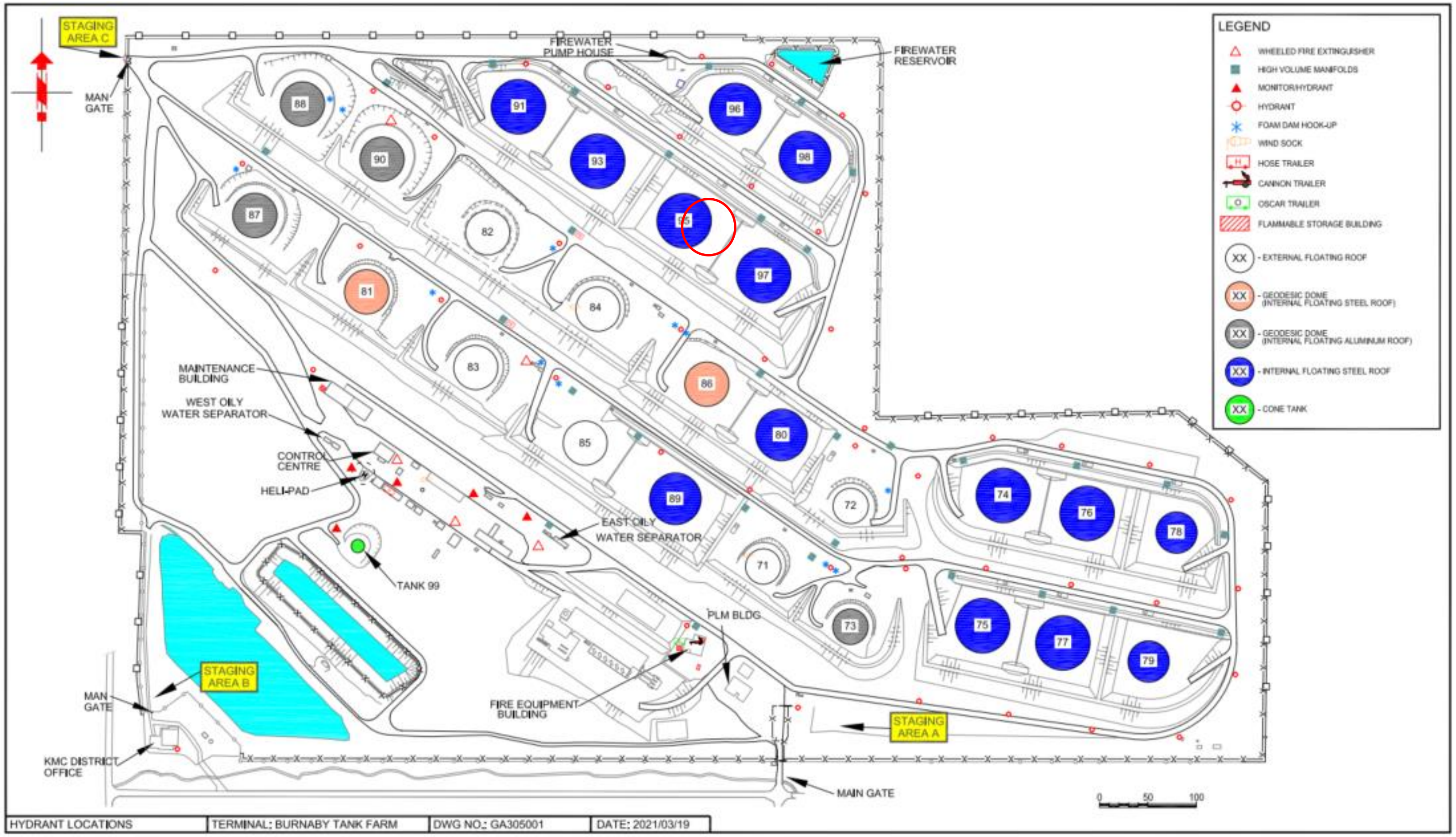
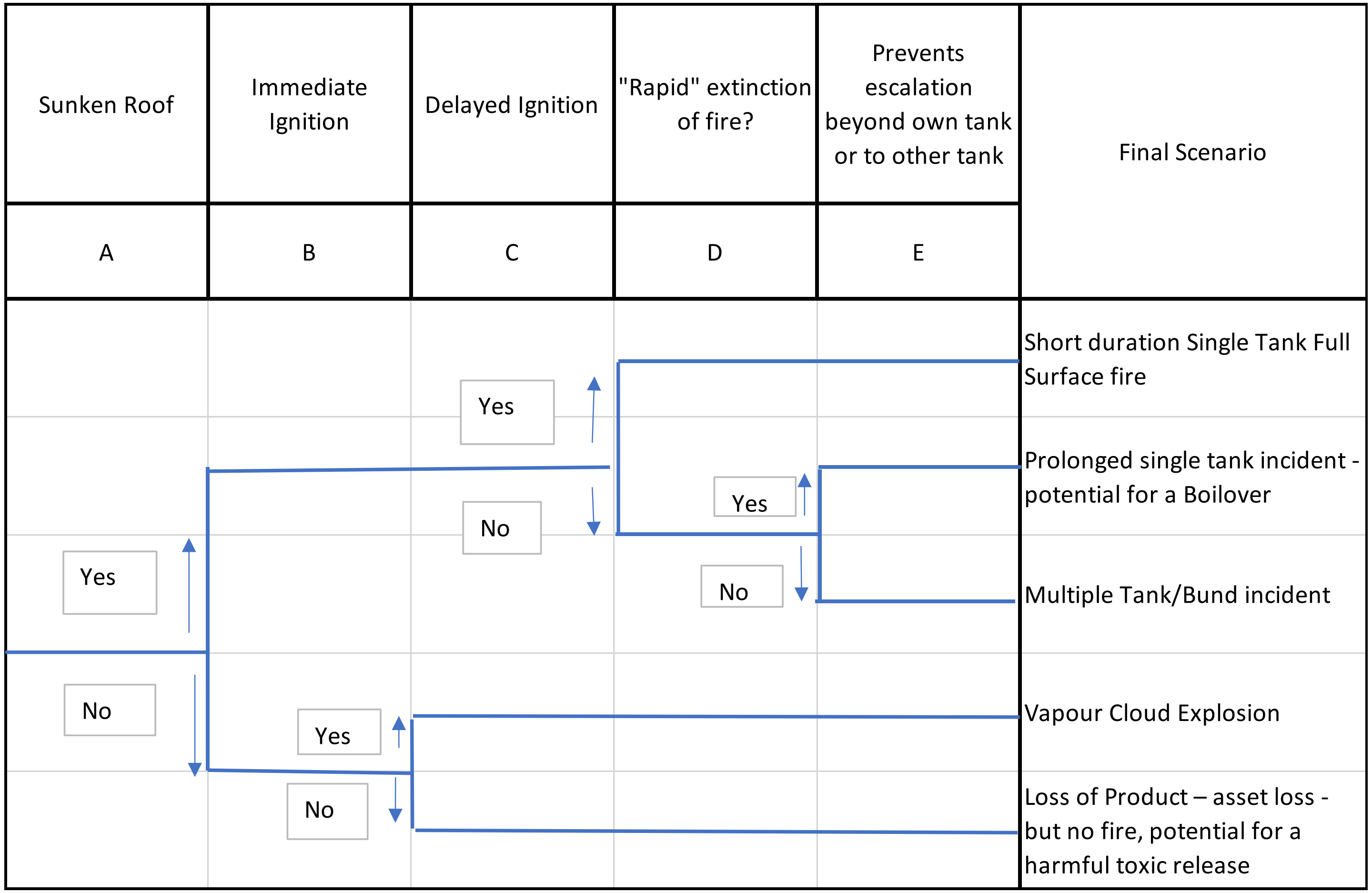


Figure 3: Burnaby Tank Farm Layout

POTENTIAL SCENARIOS

Below is an event tree for the full surface tank fire starting with a loss of containment from the tank onto the tank roof.



ESTIMATION OF RISK[6]

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities		8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

[6] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation. The assessment made above is based on industry in general, but there is a higher likelihood of earthquake in this region and so the risk of a sunken roof could be higher

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, eg. North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g. US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g. loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbors (e.g. complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is not normally manned and has alternative exits available. A tank fire is unlikely to pose a major immediate life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the fire once the product is ignited. The crude is a heavy end crude with some lighter condensate, so there is likely to be a lot of thick and heavy smoke. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads, particularly as this is the only evacuation route from the University and any evacuation is likely to be uncontrolled initially. The smoke is likely to jeopardize the evacuation routes by obscuration and radiant heat. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. The impact on adjacent tankage would depend on radiant heat and/or flame impingement, however the nearest tank is located at least 0.5D from Tank 95.
Asset loss	Potential loss of, or damage to tankage and piping.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to other tanks, which could lead to further rim seal fires or full tank surface fires or bund (dike) pool fires.

Given that the Dilbit material within the tanks is a mixture of high viscosity bitumen with a low viscosity "condensate", there is a risk that any release of the material, if not immediately ignited could cause a sufficiently large vapour cloud, that with delayed ignition escalates to a Vapour Cloud Explosion. The impact of a vapour cloud explosion through subsequent fires or the overpressure impacts could be multiple tank fires on the facility or impacts beyond the fence line either through direct flame impingement or radiant heat.

An alternative scenario that could result from a full surface fire is an escalation to a boilover given the nature of the Dilbit material or any other similar crude type material. A boilover could occur any time after a full surface fire has been ignited for 2 hours. In the event of a boilover, given the topography of the site, there is a risk that the burning product could flow down the hill and impact:

- Any emergency response people and equipment operating on the facility.
- Other tanks on the facility leading to further tank fires.
- Pipework, flanges, and valves on the facility, leading to additional hydrocarbons feeding the existing fire.
- Buildings and the control room on the site. This could have a major impact on the ability to manage the incident if the emergency control centre is located on the facility.
- Roads around the facility, for transporting people to or from the facility.
- Tank farms operated by other personnel.
- Local communities that are located downhill from the tank farm.
- Vegetation that could lead to forest fires and additional risk to people located outside of the tank farm.

Either a vapour cloud explosion or a boilover would represent a major risk to the whole of the site and to beyond the existing tank farm fence albeit via two different mechanisms. There is significant vegetation located around the tank farm and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area including surrounding schools and residential property (including university campus).

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m²	5-10 minutes
Spontaneous ignition of wood	40 kW/m²	Could be a very short time
Adjacent Tank	37 kW/m²	30-45 minutes

Personnel	32 kW/m²	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m²	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m²	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m²	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

In the event of a major bund fire one or more tanks will be exposed to radiant heat levels in excess of 8kW/m². Whilst this is unlikely to have an effect on firefighting strategies, more than one tank may be lost if the tank is allowed to burn down.

Post Escalation

Life safety

Operators should have evacuated immediately if a tank fire occurs. Escape routes within the tank farm are available but escape from the tank farm will be difficult as the only route is past the area of the tank farm that is on fire. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks, and there would be a risk from 'boilover'. There is also a high risk of toxic effects from smoke fallout or from toxic components within the Dilbit material (H_2S and SO_2).

In the event of a boilover or a vapour cloud explosion, this could have significant consequences on and off the tank farm site, potentially impacting a significant number of personnel.

Environment

Smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident.

The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm.

The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.

	The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems. Currently, it is understood that the facility is using PFAS, which is known as a forever chemical, which will also leave a longer-term environmental impact.
Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. A full surface fire is likely to cause major long-term disruption. The loss of the tank farm could impact the transport of hydrocarbons in the region and could lead to panic buying of gasoline and diesel with public perception that there could be a shortage of hydrocarbon products or that prices could rise.
Asset loss	Potential loss of tank(s) and loss of piping/valves etc. Possible loss of more than one tank if escalation occurs.

Consequence Assessment

Heat Radiation – Tank Fire

A tank fire has been modelled based on the dimensions of the tank and the material in the tank. Radiation at 3 levels have been modelled. This model can be used to assist emergency response teams determine safe locations for personnel and potential consequences for an incident of this magnitude.

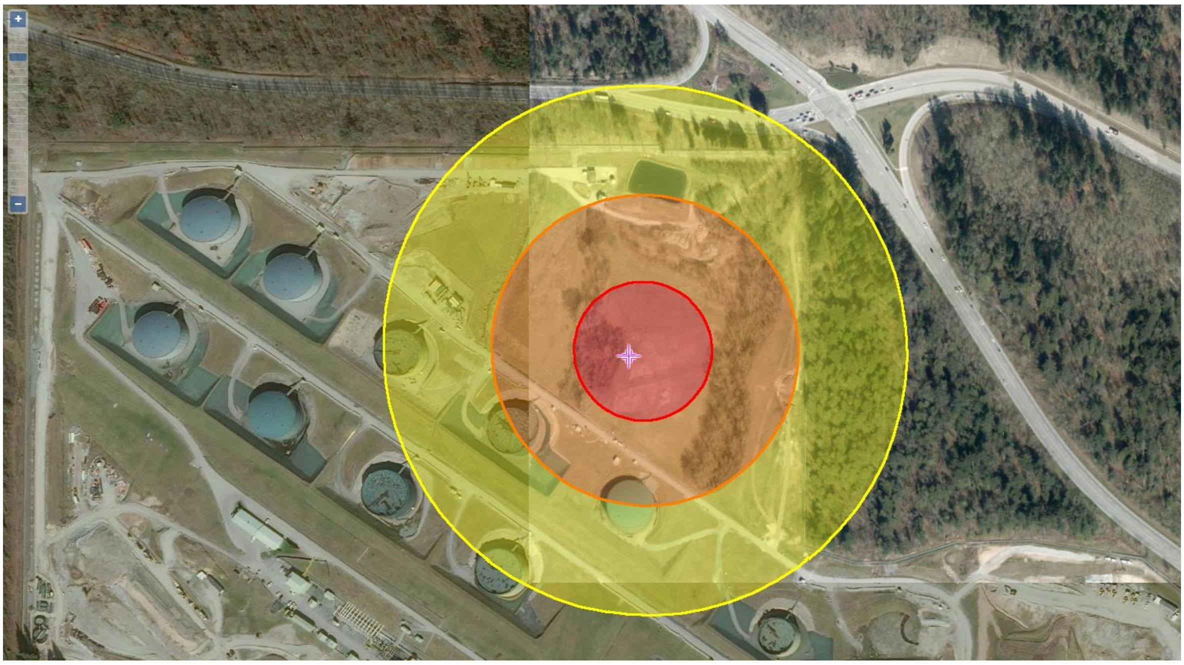


Figure 4: Radiation map for a full surface fire

Threat Zone

	Red	85.0 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	170.0 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	277.0 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

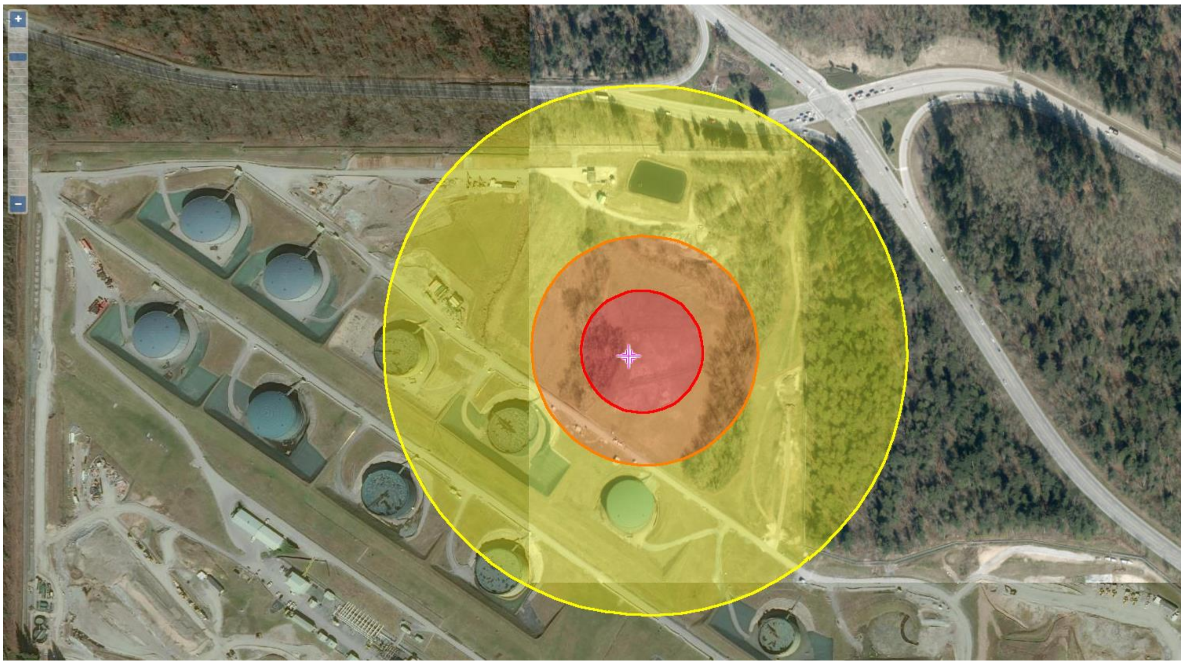


Figure 5: Radiation map for a full surface fire (40kW/m² and 12kW/m²)

	Red	75.0 Metres	40.0 kW/m² = Spontaneous ignition of wood
	Orange	129.0 Metres	12.0 kW/m² = Ignition of vegetation
	Yellow	277.0 Metres	2.0 kW/m² = pain within 60 seconds

Boil Over

NFPA define the boilover as: "An event in the burning of certain oils in an open top tank, when after a long period of quiescent burning, there is a sudden increase in fire intensity associated with expulsion of burning oil from the tank".

Empirical data indicates that impacts from a boil over can be realised 9 diameters from the source, so for Tank 95 which has a diameter of 56.4 metres, it can be anticipated that burning oil could be seen up to 500 metres from the tank.

The heat radiation map attached below has been modelled assuming a pool fire equivalent to 200 metres (4x the diameter of the tank). Note that the risk could be greater, but a 200-metre diameter pool fire was the largest fire that could be modelled using the software. This indicates that 100% fatality can be expected within 250 metres of the tank.

The biggest concern for the Burnaby site could be the topography of the site and the burning crude oil froth overflowing the secondary containment creating a fire ball and flowing down the hill.

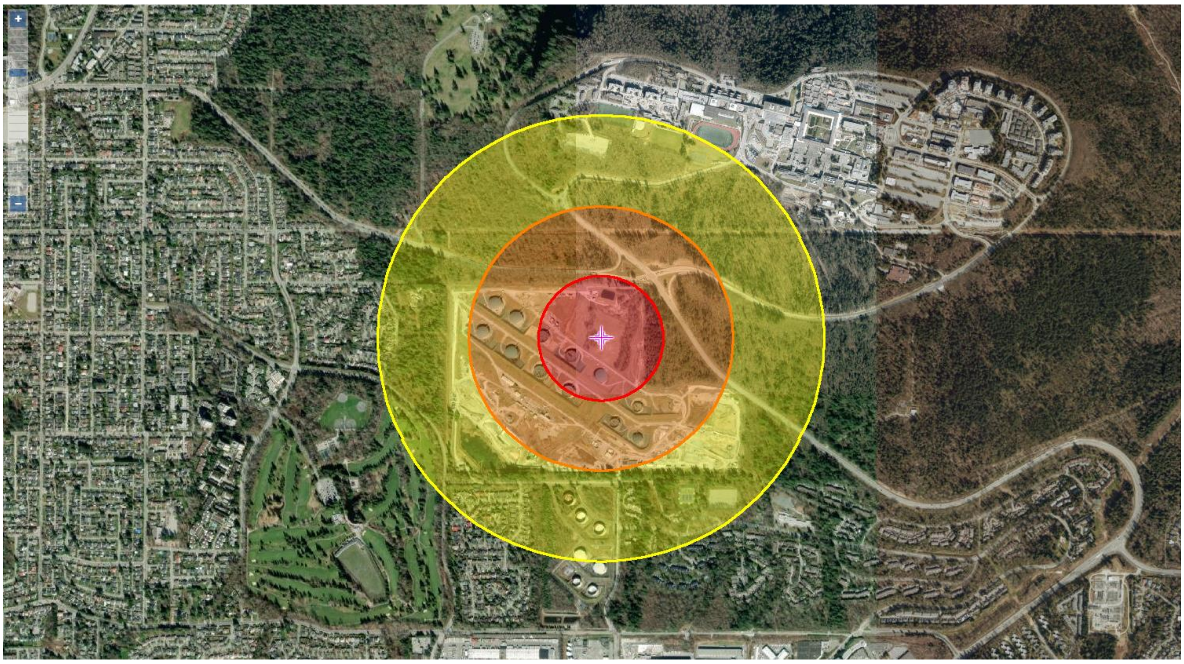


Figure 6: Radiation map for a Boilover from Tank 95

■	Red	247 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population
■	Orange	524 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	884 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

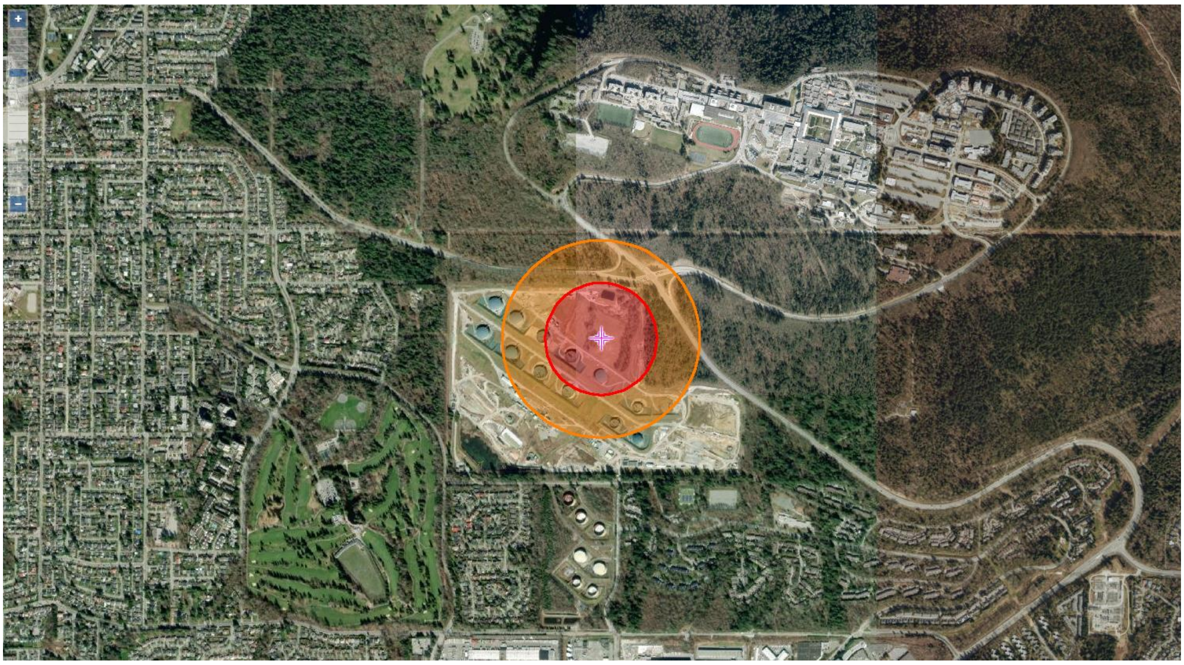


Figure 7: Radiation map for a Boilover from Tank 95 (40kW/m² and 12 kW/m²)

	Red	221 Metres	40.0 kW/m² = Spontaneous ignition of wood
	Orange	391 Metres	12.0 kW/m² = Ignition of vegetation

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario. It should also be recognised that these emergency response personnel are likely to need to wear breathing apparatus, which will place an additional burden on responses and the limitation to personnel for working for long periods of time.

Foam Cannon	Assuming a single foam cannon has the necessary capacity – 2-3 people would be required to monitor and manage its use.
Water cannons	It is recommended that 8 monitors need to be set up and managed for the duration of the water-cooling operation. Each monitor will need to be managed by a minimum of 2-3 people. For 8 monitors, this will require between 16 to 24 people.

The minimum number of people required to manage a full surface fire event is 18 people, but realistically the facility should be looking for 27 people to manage all of the equipment.

Partial Bund (Dike) Fire

SCENARIO WORKSHEET

TANK 95 – SCENARIO SMALL BUND (DIKE) FIRE

AREA	**BURNABY TANK FARM**
FACILITY	Storage tank 95[7]
FUNCTION	Dilbit (Bitumen plus condensate) Storage Tank Bund Fire
SCENARIO	Small bund (dike) fire. This fire is only within the small bund that contains Tank 95. A separate worksheet has been developed for a full bund fire that includes tanks 95 and 97. See figure 1 below that indicates the scenario on a map of the site. A fire of this magnitude (e.g., the dike area excluding the tanks is 3964m², which is equivalent to a pool fire with diameter 71m), could impact the tanks to the East and West of the dike, resulting in an escalation to additional fires and making mitigation efforts very difficult. Given the nature of the material stored within the tanks, there is a high risk of highly flammable vapours being released or a boil over if the contents of the tank are heated up from the bund fire.
MATERIAL	The material stored within the tank(s) is Dilbit[8]. Dilbit is a product resulting from the mixture of high viscosity bitumen with a low viscosity "condensate" that facilitates the flow of bitumen through pipelines. In the case of a Dilbit spill, the condensate would evaporate, leaving the heavy bitumen behind. The publicised consequences of exposure to condensate after a spill or accident are as follows: • Condensate is a colourless to straw-coloured liquid, with hydrocarbon odour, which readily vaporizes at atmospheric pressure and it is extremely flammable. • Its vapours are heavier than air. • Short term health hazards from exposure to vapours include eye and skin damage, nausea and dizziness, and breathing difficulties. • Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death. • Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.

[7] This assessment has been based on Tank 95, but a similar event could have been considered for any of the storage tanks. The consequences will essentially be the same, but tanks nearer the fence line or nearer buildings could have a different impact.

[8] The assessment has been based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to Boilover. Other material is stored at the tank farm, which could have similar consequences.

- In the case of ignition, special firefighting techniques like the use of foam, CO_2, or dry chemicals are required.
- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

LOCATION FOR SCENARIO

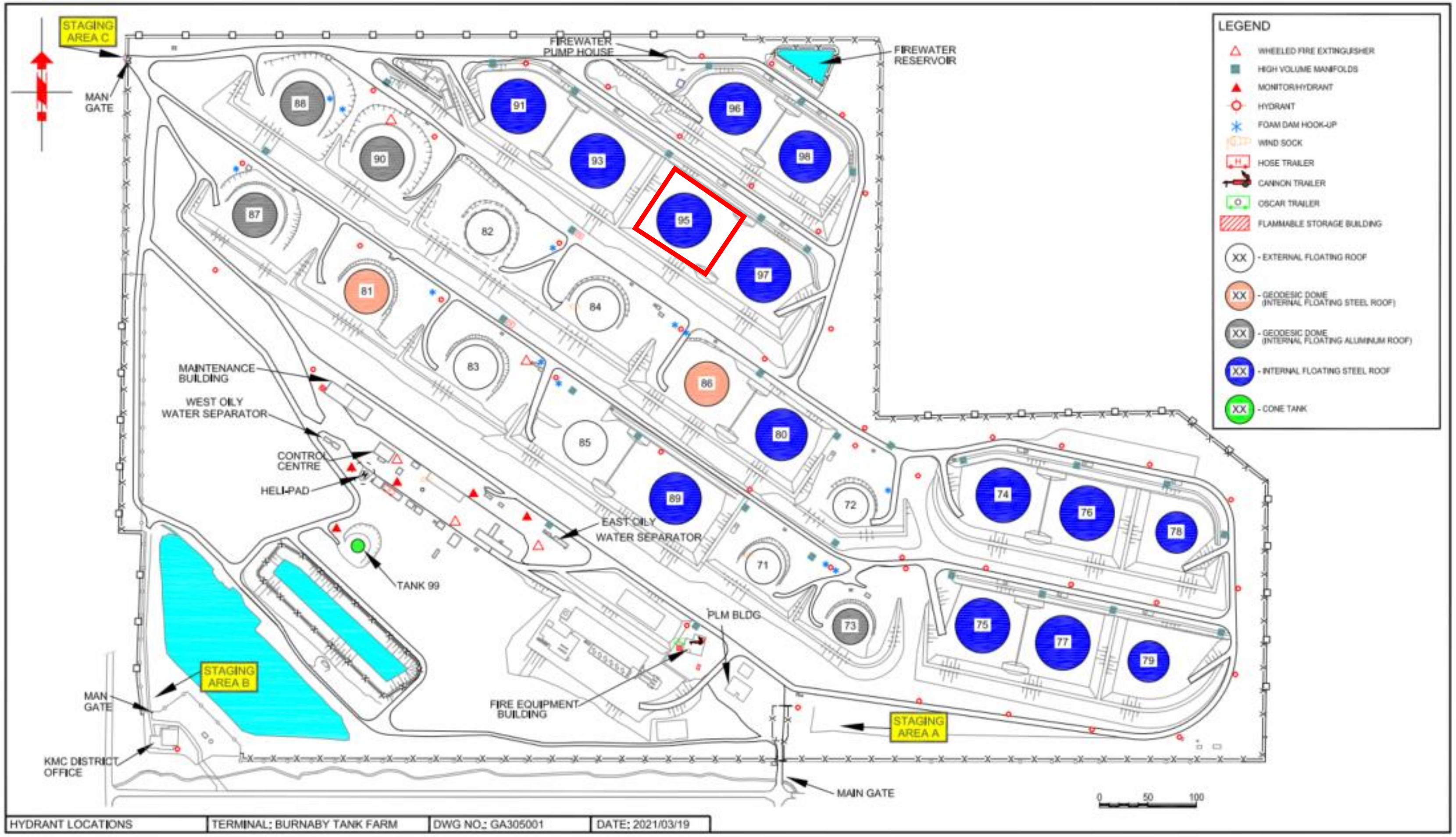
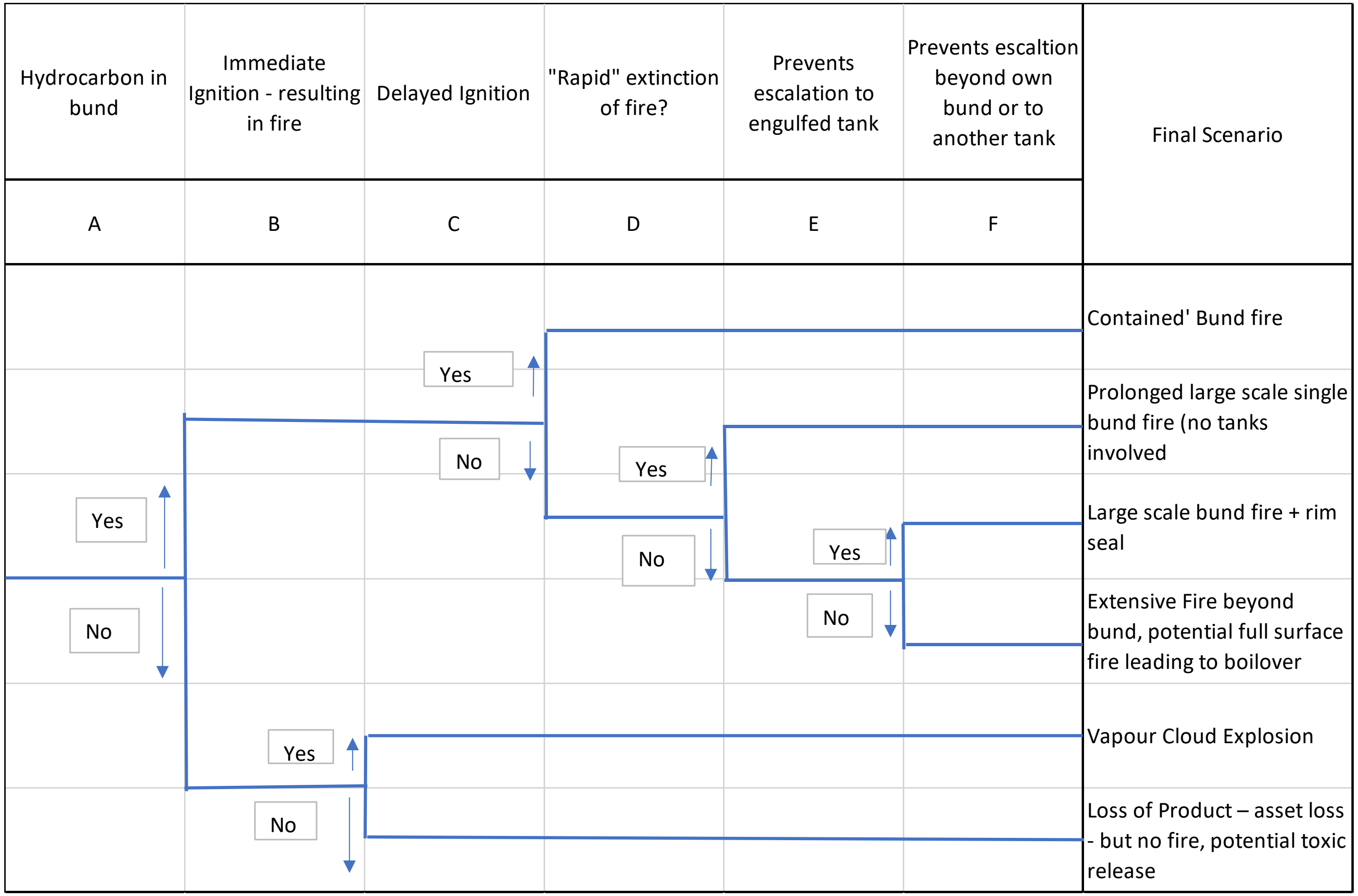


Figure 8: Plan of the tank farm indicating the bund area being assessed.

POTENTIAL SCENARIOS

Below is an event tree for the bund (dike) fire starting with a loss of containment into the bund (dike).



ESTIMATION OF RISK[9]

		1	2	3	4	5	6	7	8
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E	Major 1-2 fatalities	4	5	6	7 (green star, blue star)	8	9	10	11
F	High Impact H&S incident	3	4	5	6 (red star)	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Red star: **Health and Safety Risk** · Green star: **Environmental Risk** · Blue star: **Financial / Reputation Risk**

[9] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation. The assessment made above is based on industry in general, but there is a higher likelihood of earthquake in this region and so the risk of a sunken roof could be higher

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B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
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D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
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CONSEQUENCES

Immediate

Life Safety	The area is not normally manned alternative exits are available. A bund (dike) fire is unlikely to pose a major life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The Dilbit is a high viscosity bitumen with a low viscosity “condensate”, so there is likely to be a lot of thick and heavy smoke. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads, particularly as this is the only evacuation route from the University. The smoke is likely to cause panic in the local community and is likely to jeopardize the evacuation routes by obscuration and radiant heat. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. The impact on adjacent tankage would depend on radiant heat and/or flame impingement, however the nearest tank is located at least 0.5D from Tank 95, so direct flame impingement may not be an issue, but heat radiation will be.
Asset loss	Potential loss of, or damage to tankage and piping.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to other tanks, which could lead to further bund (dike) pool fires.

Given that the Dilbit material within the tanks is a mixture of high viscosity bitumen with a low viscosity “condensate”, there is a risk that any release of containment, if not immediately ignited could cause a sufficiently large vapour cloud, that with delayed ignition escalates to a Vapour Cloud Explosion. Alternatively, if the fire were allowed to continue, it could escalate to a full surface tank fire and then escalate to a boilover scenario given the nature of the Dilbit material. Refer to the full surface fire worksheet, where a detailed assessment of a boilover is discussed. Either of these two events would represent a major risk to the whole of the site and to beyond the existing tank farm fence albeit via two different mechanisms.

There is significant vegetation located around the tank farm and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area including surrounding schools and residential property (including university campus).

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

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(Above assumes no cooling or control actions)

In the event of a major bund (dike) fire one or more tanks will be exposed to radiant heat levels in excess of 8 kW/m². Whilst this is unlikely to have an effect on firefighting strategies, more than one tank may be lost if the tank is allowed to burn down.

Post Escalation

Life safety

Operators should have evacuated immediately if a bund (dike) fire occurs. Escape routes within the tank farm are available but escape from the tank farm will be difficult as the only route is past the area of the tank farm that in this scenario is on fire. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks. The risk from a boil over in this instance is low as it requires the tank being on fire. There is also a high risk of toxic effects from smoke fallout or from toxic components within the Dilbit material (H_2S and SO_2)

Environment	The smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident. A bund fire is likely to cause major long-term disruption although it is dependent on the extent and damage caused by the fire. The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems. Currently, it is understood that the facility is using PFAS, which is known as a forever chemical, which will also leave a longer-term environmental impact.
Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. A full surface fire is likely to cause major long-term disruption. Significant loss to the tank farm could impact the transport of hydrocarbons in the region and could lead to panic buying of gasoline and diesel with public perception that there could be a shortage of hydrocarbon products or that prices could rise.
Asset loss	Potential loss of tank(s) and loss of piping/valves etc. Possible loss of more than one tank if escalation occurs.

Consequence Assessment

Heat Radiation – Bund Fire

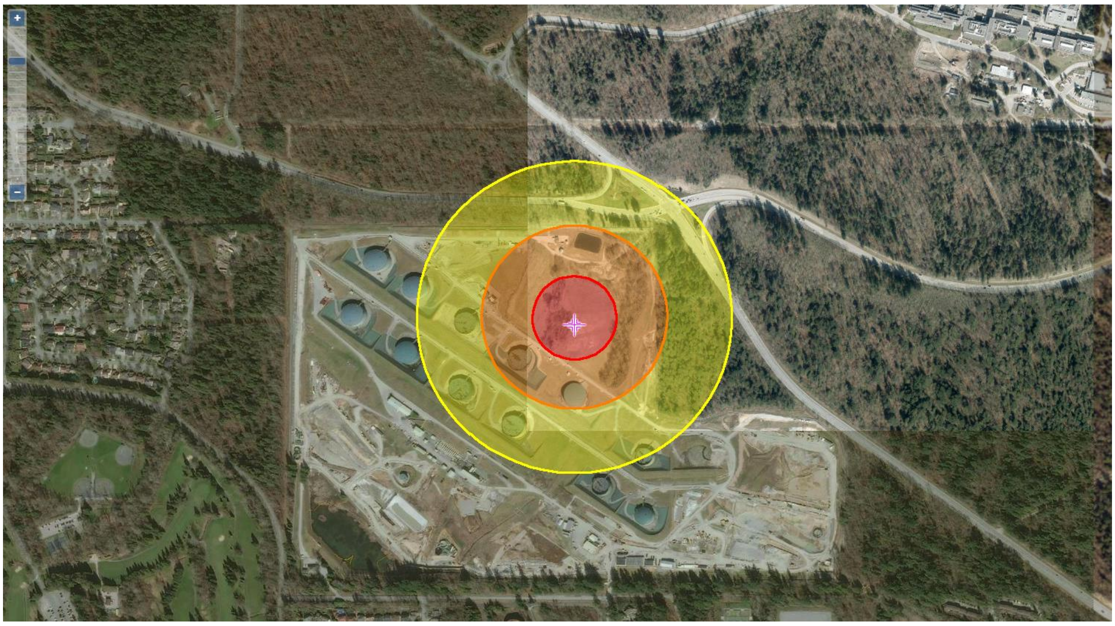


Figure 9: Radiation map for a bund (dike) fire

Threat Zone

(red)	Red	103 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
(orange)	Orange	210 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
(yellow)	Yellow	345 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

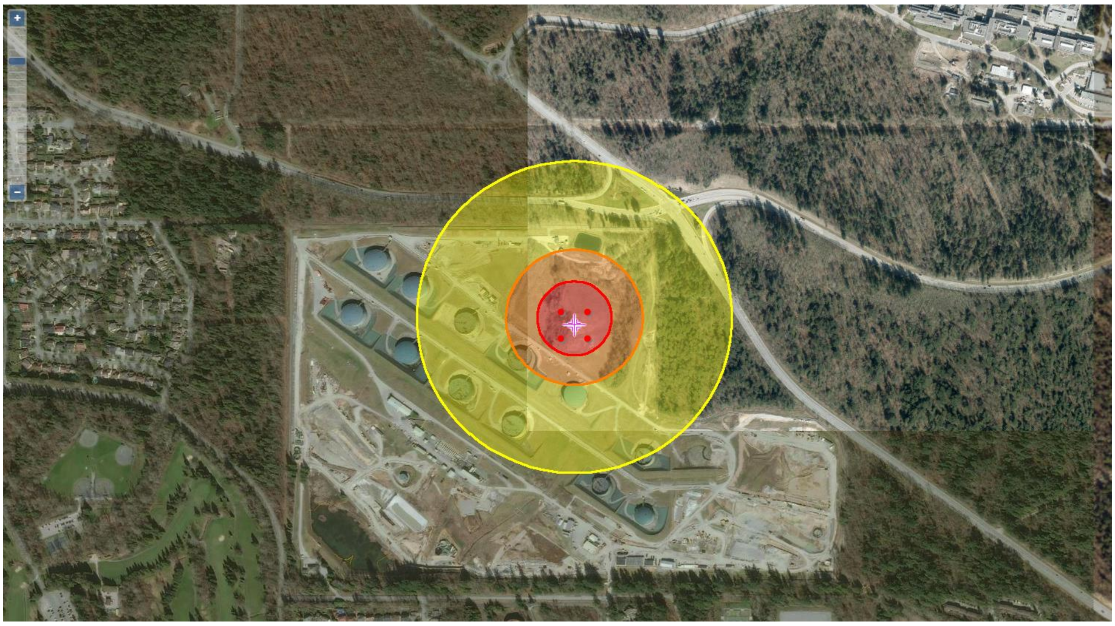


Figure 10: Radiation map for a bund (dike) fire (40kW/m² and 12kW/m²)

	Red	93 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	160 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	345 Metres	2.0 kW/m² = pain within 60 seconds

Boil Over

Refer to full surface fire scenario for further details on this scenario

Vapour Cloud Explosion

Vapour cloud explosions occur when a flammable cloud is released and allowed to form, which, after some delay finds a source of ignition generating high overpressures.

The main factors which influence the magnitude of gas or vapour explosions are:

- Degree of confinement of the gas cloud
- Type of flammable gas
- Level of turbulence in the gas cloud
- Degree of congestion
- Gas concentration

- Ignition strength

Detailed CFD modelling is recommended to determine levels of overpressure at a distance, which would be particularly important to determine potential impacts on buildings but would not significantly impact the emergency response activities. The key criteria is to identify the formation of vapour at the earliest possible time to limit the release and therefor the potential for explosion. Refer to scenario worksheet specifically for a Vapour Cloud Explosion.

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario. It should also be recognised that these emergency response personnel are likely to need to wear breathing apparatus, which will place an additional burden on responses and the limitation to personnel for working for long periods of time.

Foam Cannon	Assuming a single foam cannon has the necessary capacity – 2-3 people would be required to monitor and manage its use.
Water cannons	It is recommended that 9 monitors need to be set up and managed for the duration of the water-cooling operation. Each monitor will need to be managed by a minimum of 2-3 people. For 9 monitors, this will require between 18 to 27 people.

The minimum number of people required to manage a bund fire event is 21 people, but realistically the facility should be looking for 30 people to manage all of the equipment.

Full Bund Fire

SCENARIO WORKSHEET

TANK 95 – SCENARIO FULL BUND (DIKE) FIRE

AREA	**BURNABY TANK FARM**
FACILITY	Storage tank 95[10]
FUNCTION	Dilbit (Bitumen plus condensate) Storage Tank Bund Fire
SCENARIO	Full bund (dike) fire. The fire is in a bund that includes Tank 95 and Tank 97 to the north of the facility. There is a partial wall installed to separate the tanks, but this is not a full tank dike wall. The scenario discussed here is assuming that there is a full bund fire that encompasses both tanks. See figure 1 below. A fire of this magnitude (e.g., the dike area excluding the tanks is 8128m², which is equivalent to a pool fire with diameter 102m), could impact on the tanks to the North, South and East of the dike, resulting in an escalation to additional fires and making mitigation efforts very difficult. Not to mention, given the nature of the material stored within the tanks, there is a high risk of boil over.
MATERIAL	The material stored within the tank(s) is Dilbit[11]. Dilbit is a product resulting from the mixture of high viscosity bitumen with a low viscosity "condensate" that facilitates the flow of bitumen through pipelines. In the case of a Dilbit spill, the condensate would evaporate, leaving the heavy bitumen behind. The publicised consequences of exposure to condensate after a spill or accident are as follows: • Condensate is a colourless to straw-coloured liquid, with hydrocarbon odour, which readily vaporizes at atmospheric pressure, and it is extremely flammable. • Its vapours are heavier than air. • Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties • Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.

[10] This assessment has been based on Tank 95, but a similar event could have been considered for any of the storage tanks. The consequences will essentially be the same, but tanks nearer the fence line or nearer buildings could have a different impact.

[11] The assessment has been based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to Boilover. Other material is stored at the tank farm, which could have similar consequences.

- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, special firefighting techniques like the use of foam, CO_2, or dry chemicals are required.
- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

LOCATION FOR SCENARIO

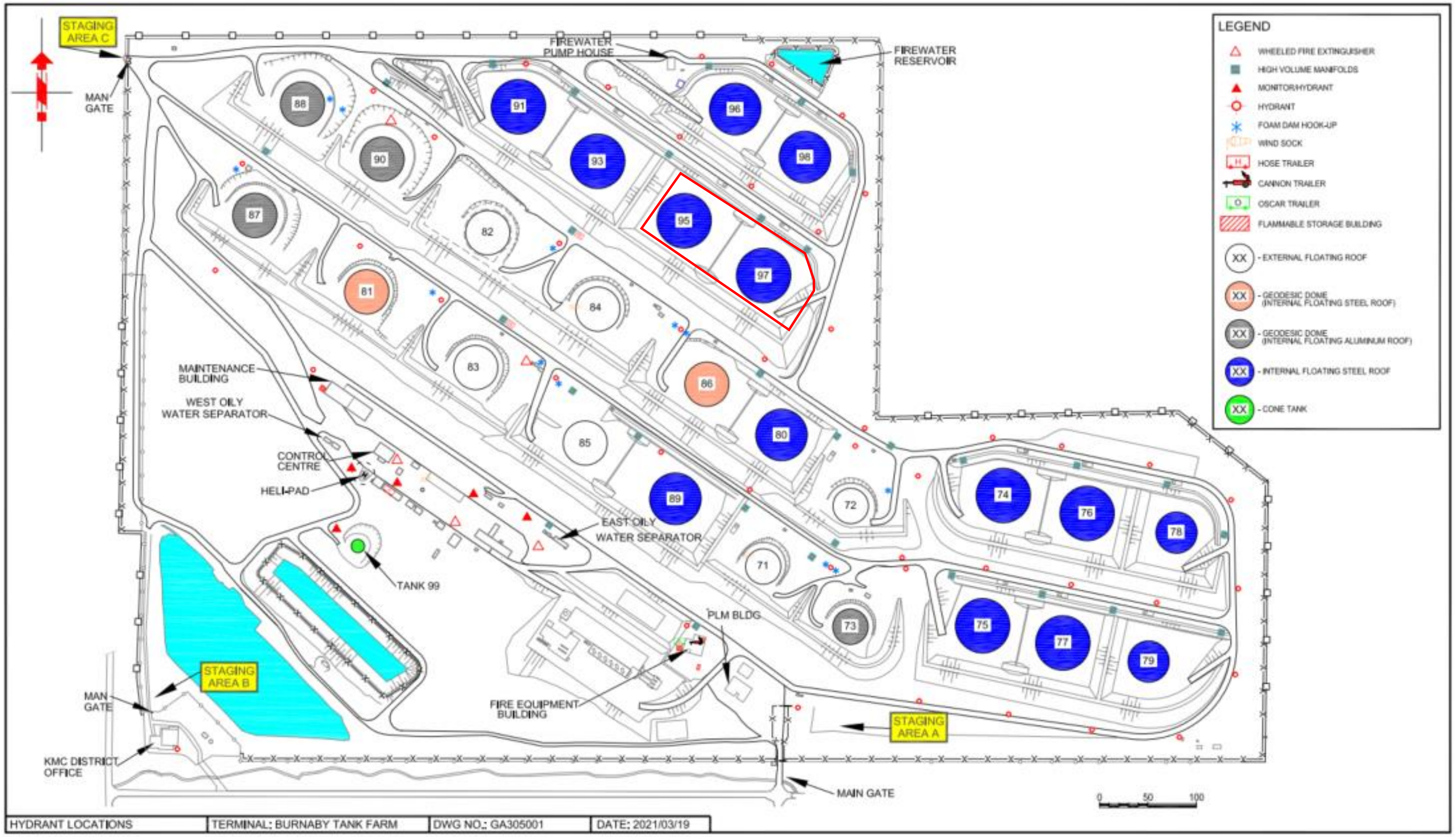
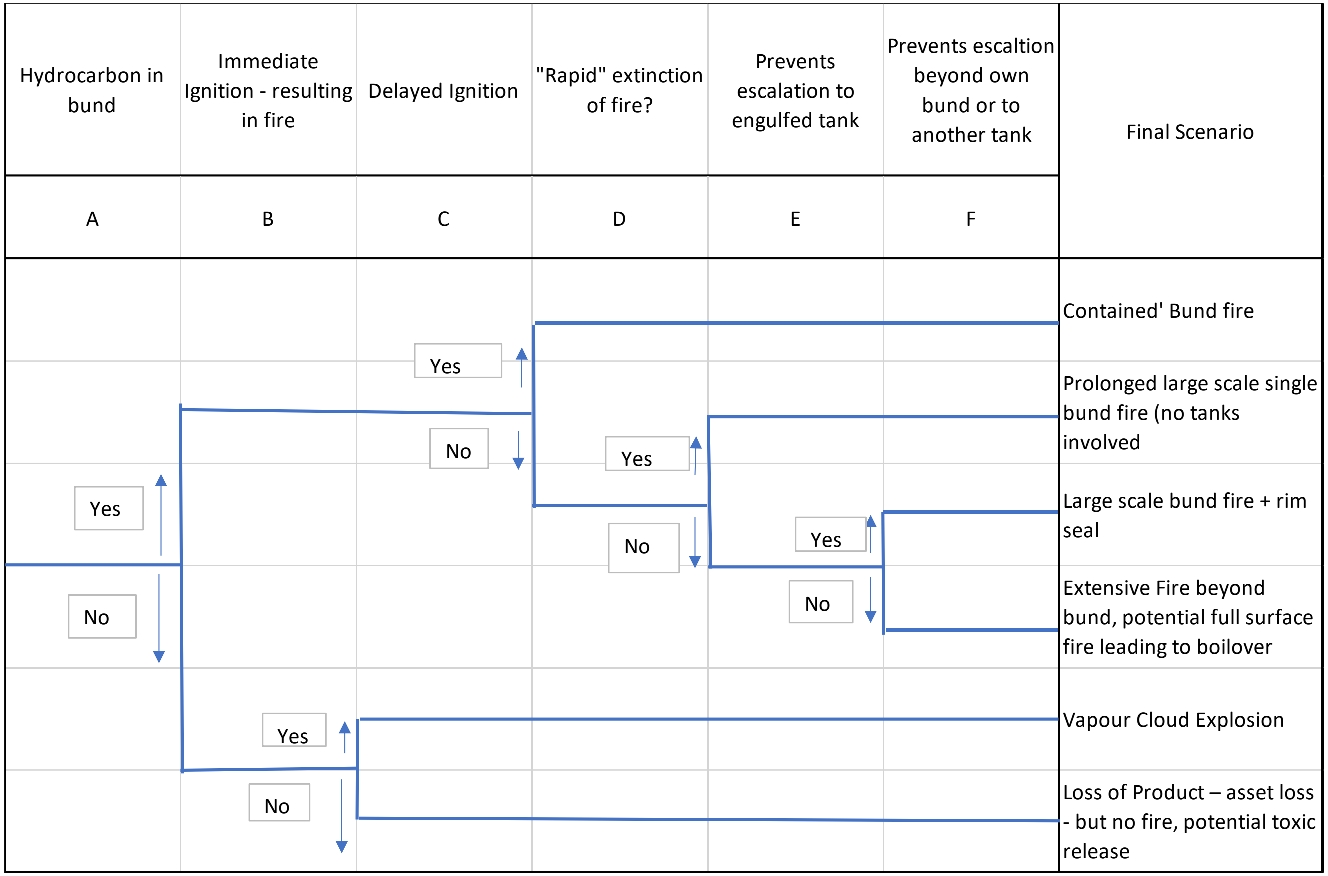


Figure 11: Partial plan of the tank farm highlighting Tank 95 and the bund

POTENTIAL SCENARIOS

Below is an event tree for the dike fire scenario starting with a loss of containment into the dike.



ESTIMATION OF RISK[12]

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities		8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

[12] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation. The assessment made above is based on industry in general, but there is a higher likelihood of earthquake in this region and so the risk of a sunken roof could be higher

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbors (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is not normally manned and has alternative exits available. A dike fire is unlikely to pose a major life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan. The crude may have toxic components (H_2S or SO_2), which would pose a life threat to personnel on and off the site. This would be highly dependent on wind direction, but plans should be in place to protect personnel.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The crude is a heavy end crude with some diluent, so there is likely to be a lot of thick and heavy smoke. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads, particularly as this is the only evacuation route from the University. The smoke is likely to cause panic in the local community and is likely to jeopardize the evacuation routes by obscuration and radiant heat. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. The impact on adjacent tankage would depend on radiant heat and/or flame impingement, however the nearest tank is located at least 0.5D from Tank 95.
Asset loss	Potential loss of, or damage to tankage and piping as a result of the fire.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to other tanks, which could lead to further bund (dike) pool fires.

Given that the Dilbit material within the tanks is a mixture of high viscosity bitumen with a low viscosity “condensate”, there is a risk that any release of containment, if not immediately ignited could cause a sufficiently large vapour cloud, that with delayed ignition escalates to a Vapour Cloud

Explosion. Alternatively, if the fire were allowed to continue, it could escalate to a full surface tank fire and then escalate to a boilover scenario given the nature of the Dilbit material. Refer to the full surface fire worksheet, where a detailed assessment of a boilover is discussed. Either of these two events would represent a major risk to the whole of the site and to beyond the existing tank farm fence albeit via two different mechanisms.

There is significant vegetation located around the tank farm and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area including surrounding schools and residential property (including university campus).

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Pipracks	200 kW/m^2	5-10 minutes
Spontaneous ignition of wood	40 kW/m^2	Could be a very short time
Adjacent Tank	37 kW/m^2	30-45 minutes
Personnel	32 kW/m^2	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m^2	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m^2	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m^2	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

In the event of a major bund fire one or more tanks will be exposed to radiant heat levels in excess of 8kW/m^2. Whilst this is unlikely to have an effect on firefighting strategies, more than one tank may be lost if the fire is allowed to burn down.

Post Escalation

Life safety

Operators should have evacuated immediately if a bund (dike) fire occurs. Escape routes within the tank farm are available but escape from the tank farm will be difficult as the only route is past the area of the tank farm that in this scenario is on fire. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks. The

	risk from a boil over in this instance is low as it requires the tank being on fire. There is also a high risk of toxic effects from smoke fallout or from toxic components within the Dilbit material (H_2S and SO_2)
Environment	The smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident. A bund fire is likely to cause major long-term disruption although it is dependent on the extent and damage caused by the fire. The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems. Currently, it is understood that the facility is using PFAS, which is known as a forever chemical, which will also leave a longer-term environmental impact.
Business interruption	Loss of multiple tanks or product line would reduce import/future export capability and cause back-up of cargo importing. Significant loss to the tank farm could impact the transport of hydrocarbons in the region and could lead to panic buying of gasoline and diesel with public perception that there could be a shortage of hydrocarbon products or that prices could rise.
Asset loss	Potential loss of tank(s) and loss of piping/valves etc. Possible loss of more than the two tanks that are installed within the bund if escalation occurs.

Consequence Assessment

Heat Radiation – Bund Fire

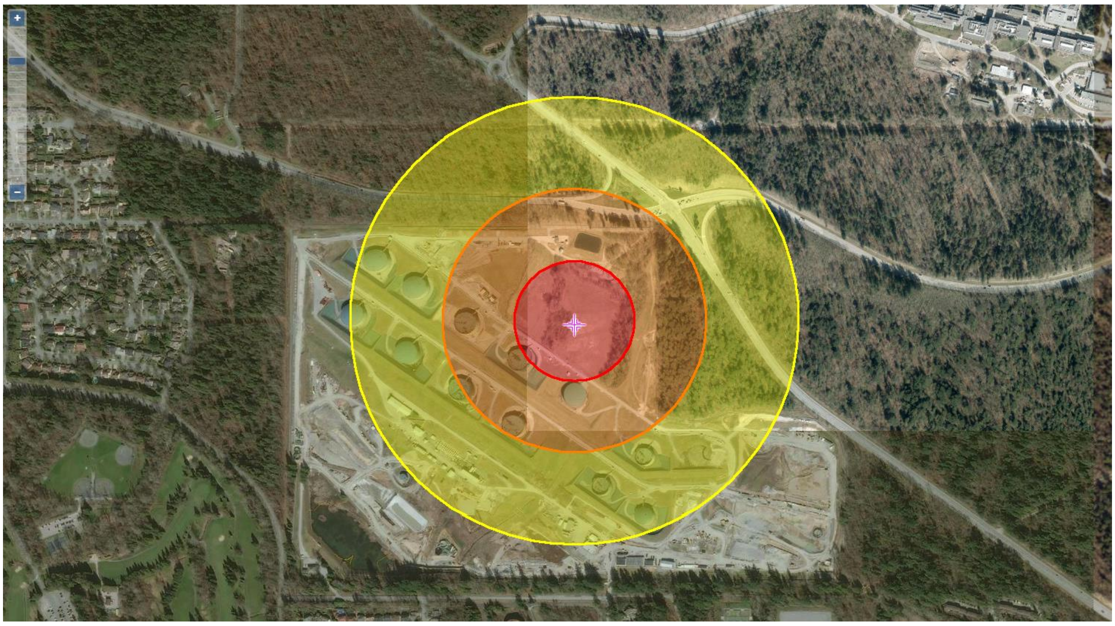


Figure 12: Radiation map for a bund (dike) fire

Threat Zone

■	Red	135 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population
■	Orange	286 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	480 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

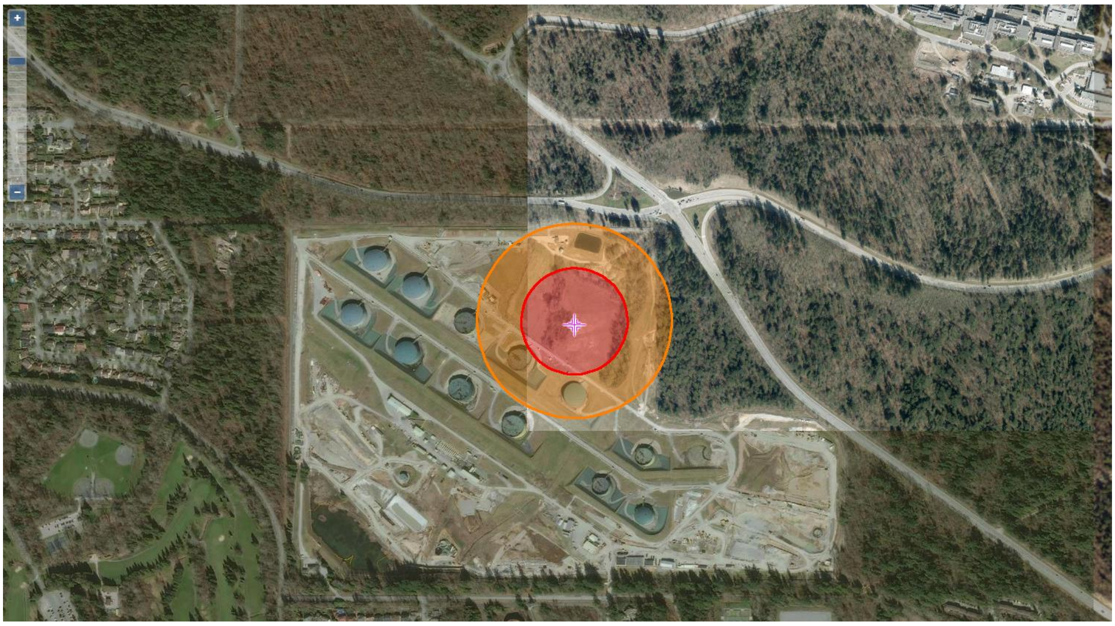


Figure 13: Radiation map for a bund (dike) fire (40kW/m² and 12kW/m²)

■	Red	120 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population
■	Orange	214 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	480 Metres	2.0 kW/m² = pain within 60 seconds

Boil Over

Refer to full surface fire scenario for further details on this scenario.

Vapour Cloud Explosion

Vapour cloud explosions occur when a flammable cloud is released and allowed to form, which, after some delay finds a source of ignition generating high overpressures.

The main factors which influence the magnitude of gas or vapour explosions are:

- Degree of confinement of the gas cloud.
- Type of flammable gas.
- Level of turbulence in the gas cloud.
- Degree of congestion.

- Gas concentration.
- Ignition strength.

Detailed CFD modelling is recommended to determine levels of overpressure at a distance, which would be particularly important to determine potential impacts on buildings but would not significantly impact the emergency response activities. The key criteria is to identify the formation of vapour at the earliest possible time to limit the release and therefor the potential for explosion. Refer to scenario worksheet specifically for a Vapour Cloud Explosion.

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario. It should also be recognised that these emergency response personnel are likely to need to wear breathing apparatus, which will place an additional burden on responses and the limitation to personnel for working for long periods of time.

Foam Cannon	Assuming a single foam cannon has the capacity based on the calculations above – 2-3 people would be required to monitor and manage its use.
Water cannons	Based on the calculations above, it is recommended that 9 monitors need to be set up and managed for the duration of the water-cooling operation. Each monitor will need to be managed by a minimum of 2-3 people. For 9 monitors, this will require between 18 to 27 people.

The minimum number of people required to manage a bund fire event is 21 people, but realistically the facility should be looking for 30 people to manage all of the equipment.

Vapour Cloud Explosion

SCENARIO WORKSHEET

BURNABY TANK FARM – SCENARIO - VAPOUR CLOUD EXPLOSION

AREA	**BURNABY TANK FARM**
FACILITY	Tank Farm
FUNCTION	Dilbit (Bitumen plus condensate) Storage Tank
SCENARIO	Vapour cloud explosions are an ever-present threat in major hazard sites including tank farms. They occur when a flammable cloud is released and ignited in a reasonably confined or congested environment which develops high flame speeds and overpressures, which can lead to damage to plant, buildings and equipment. The main factors that influence the magnitude of gas or vapour explosions are: • Degree of confinement of the gas. • Type of flammable gas. • Level of turbulence in the gas cloud. • Degree of congestion. • Gas concentration. • Ignition strength. Large scale explosions in tank farm sites have been experienced previously and result in high overpressures causing a significant amount of damage both on the tank farm and beyond. The most likely cause of this type of scenario would be a tank overfilling scenario as a result of maloperation or failure of instrumentation.
MATERIAL	The material stored within the tank(s) is Dilbit[13]. Dilbit is a product resulting from the mixture of high viscosity bitumen with a low viscosity "condensate" that facilitates the flow of bitumen through pipelines. In the case of a loss of containment of Dilbit, the condensate would evaporate, leaving the heavy bitumen behind. The publicised

[13] The assessment has been based on Dilbit material. It was chosen as it has the potential to form a VCE when released and could result in an escalation to Boilover. Other material is stored at the tank farm, which could have similar consequences.

consequences of exposure to condensate after a spill or accident are as follows:

- Condensate is a colourless to straw-coloured liquid, with hydrocarbon odour, which readily vaporizes at atmospheric pressure, and it is extremely flammable.
- Its vapours are heavier than air.
- Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties.
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.
- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, special firefighting techniques like the use of foam, CO_2, or dry chemicals are required.
- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

Location for Scenario

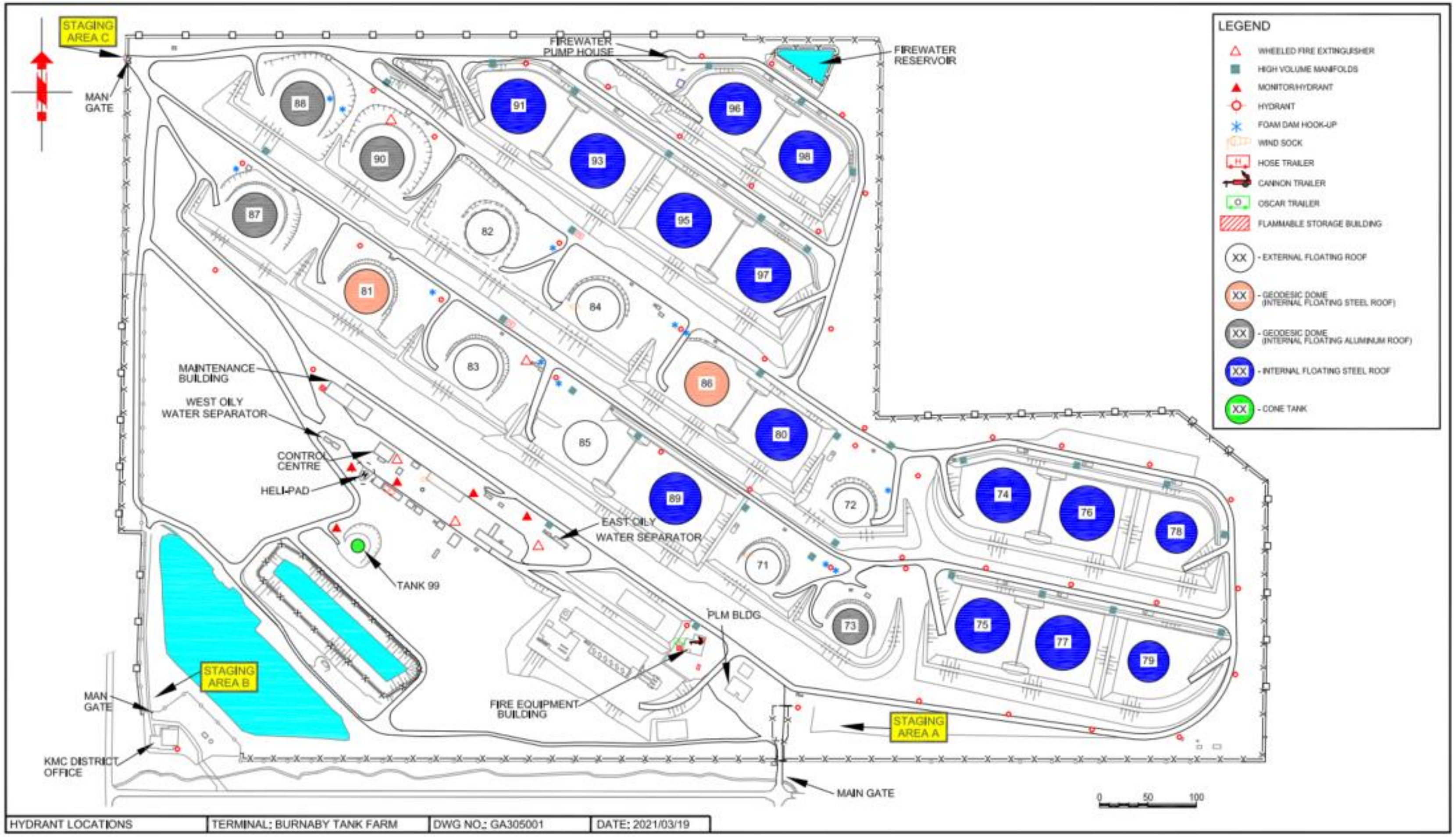
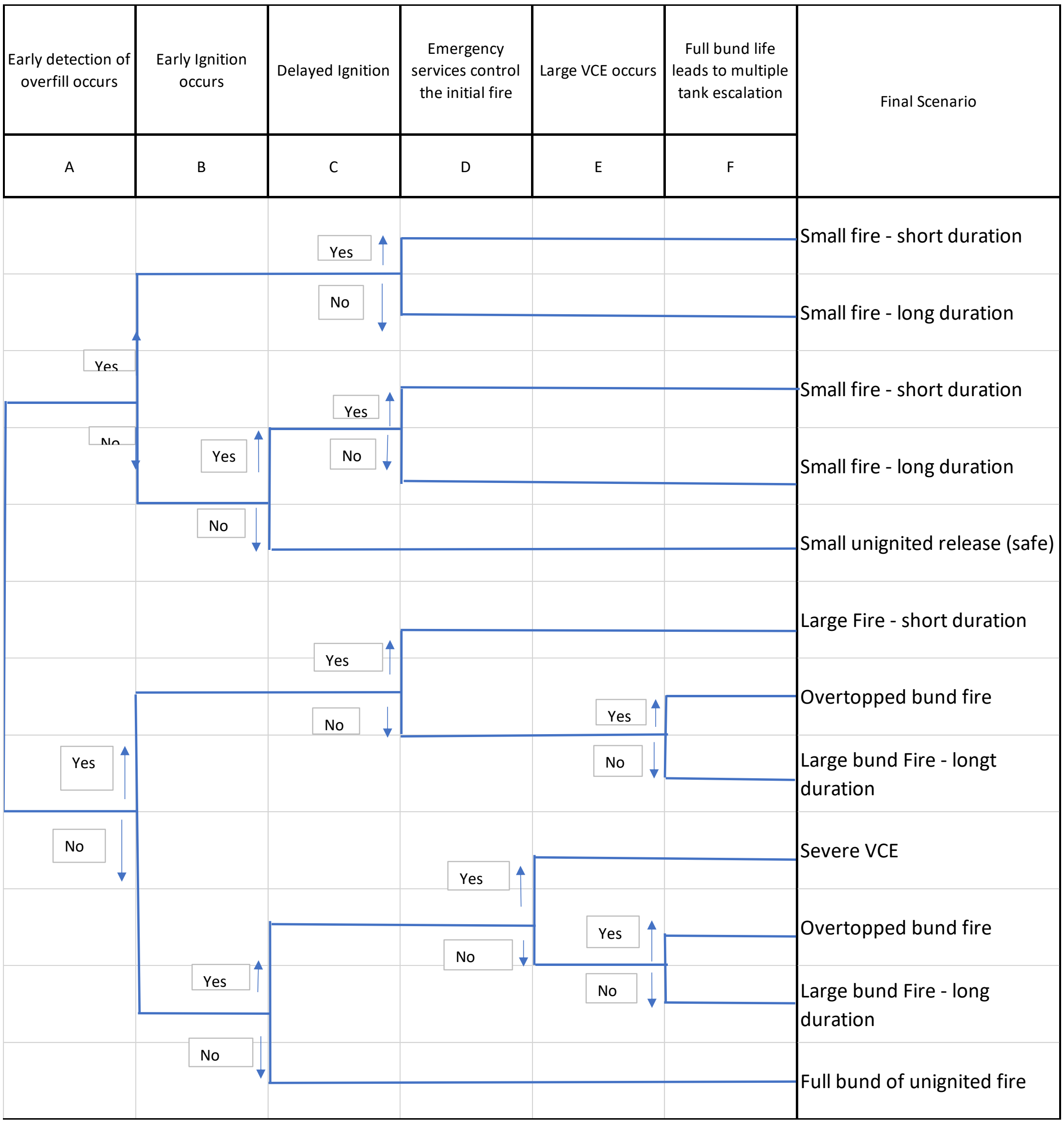


Figure 14: Plan of the tank farm

POTENTIAL SCENARIOS

Below is an event tree for a tank overfill scenario, which could lead to a vapour cloud explosion as one of the possible outcomes.



ESTIMATION OF RISK

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**$>10^{-6}$ to 10^{-5}/yr**	**$>10^{-5}$ to 10^{-4}/yr**	**$>10^{-4}$ to 10^{-3}/yr**	**$>10^{-3}$ to 10^{-2}/yr**	**$>10^{-2}$ to 10^{-1}/yr**	**$>10^{-1}$ to 1/yr**	**>1/yr**

Key

Health and Safety Risk

Environmental Risk

Financial / Reputation Risk

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short-term complaints from neighbors (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	A vapour cloud explosion has wide reaching consequences, so there is a high likelihood that there could be injuries or fatalities to people inside or outside the terminal fence. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	There is minimal environmental consequence from the initial flammable release, however there will be environmental consequences from any subsequent fires.
Business interruption	A vapour cloud explosion will have a dramatic impact on the operation at the tank farm. Some or all of the tank farm will be unavailable dependent on the scale of the explosion, limiting imports and exports for potentially a long term.
Asset loss	Potential loss of, or damage to multiple tanks and piping.

Escalation Mechanisms

When a flammable cloud finds a delayed source of ignition resulting in a vapour cloud explosion, there is a high likelihood that this will escalate to one or multiple tank fires or bund/dike fires.

Post Escalation

Life safety	Operators should have evacuated immediately if there is a large release of flammable material. Escape routes within the tank farm are available and providing the release is identified early enough it should make escape relatively easy. Once the flammable cloud has exploded there could be multiple large fires impacting a number of tanks and areas that would need 3rd party assistance to extinguish. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks. There is also the potential for toxic effects resulting from smoke fall out.

Environment	Smoke plume from resulting fires will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident. The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm. Currently, we understand that the facility is using PFAS, which is known as a forever chemical, which will also leave a longer-term environmental impact.
Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. A vapour cloud explosion is likely to impact much of the site so that it is unavailable for some time.
Asset loss	Potential loss of multiple tanks and a loss of piping/valves etc.

General Comments

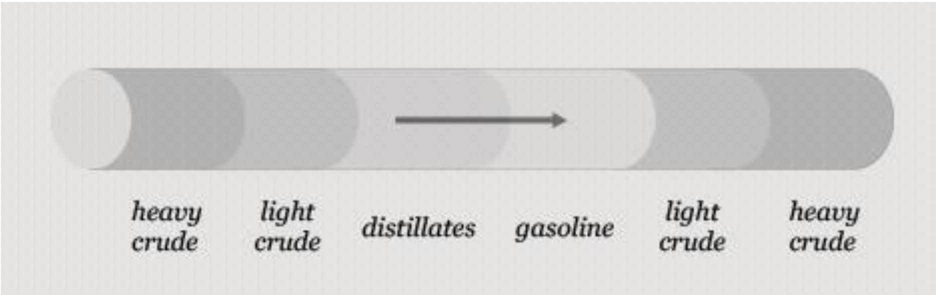
a) For tankage incidents, priority should be given to rapid call out of Trans Mountain Emergency Response Technicians (ERT's) and a designated on-call Third Party Response Contractor. The contractor provides 24/7 coverage with a minimum of four qualified firefighters. It is understood that the response time to a major incident could take 4 (four) hours.

Hydrocarbon Material at Burnaby

The Trans Mountain Pipeline transports crude oil, semi-refined and refined products in a series in the same pipeline. This process is known as "batching". Think of it as a "batch train," with one product following another product through the pipeline during a specific time period. It's like a series of rail cars carrying different products moving in a sequence along the 1,150-kilometre pipeline.

Trans Mountain is the only pipeline in North America that carries both refined product and crude oil in batches.

On any given day, the pipeline is used to move different grades or varieties of petroleum. Products moving next to each other in the pipeline can mix. This mixing – or product interface – is minimized by putting the products in a specific sequence.



PRODUCT DETAILS

The products currently shipped in the Trans Mountain pipeline:

Product Type	Example	Description
Refined petroleum	Gasoline or diesel	Refined
Synthetic crude	Processed bitumen	Semi-refined
Light crude	Conventionally sourced crude oil	Unrefined
Heavy crude	Diluted bitumen	Unrefined

Other than refined products, each of these general product types can be blended or pumped individually as requested by shippers – Trans Mountain's customers who own the products transported in the pipeline. Any product moved in the pipeline must meet tariff requirements, which include the requirement for products to adhere to technical specifications in order for them to be accepted for transportation in the Trans Mountain Pipeline system.

These rules specify that the product has:

- A maximum temperature of 38^o C.
- A maximum density of 940 kg/m3.
- A maximum viscosity of 350 cSt (centistokes) at Reference Temperature.
- Maximum impurities (basic sediments and water-abbreviated BS&W) of 0.5% of volume.
- Maximum Reid Vapour Pressure of 103 kPa (kilopascals).

Further information can be found at https://crudemonitor.ca/home.php

APPENDIX A-2: WESTRIDGE ENRGCONSULTANTS REPORT

ENRgConsultants

The Old Rectory, Mill Lane
Monks Risborough, Bucks, HP27 9LG, UK
Company Registration: 7698749

Burnaby Risk Assessment Project
Fire Scenario Worksheets
Westridge Terminal
June 2021

Reference	**Prepared by**	**Checked by**	**Approved by**
Burnaby Risk Assessment Project – Westridge Terminal	M. Plastow	Dr. N. Ramsden	Dr. N. Ramsden
Version: Issue Rev 0	02 June 2021	02 June 2021	02 June 2021
Burnaby Risk Assessment Project – Westridge Terminal	M. Plastow	Dr. N. Ramsden	Dr. N. Ramsden
Version: Issue Rev 1	21 July 2021	21 July 2021	21 July 2021

Executive Summary

This document has been prepared to review a number of potential hazardous scenarios at the Westridge Terminal site (Full Surface Fire (Jet fuel), Bund (dike) Fire (Jet fuel). Propane vessel BLEVE, Pool fire within the process area (leak of crude), and Pool fire on the sea (leak of crude)). These Scenario Worksheets (SW) have been completed in accordance with the recommendations in the Energy Institute Model Code of Safe Practice Part 19 – Fire Precautions at Petroleum Refineries and Bulk Storage Installations. When used as part of a risk based Fire Hazard Management development process in accordance with this internationally recognised guidance, they would form the basis for Scenario Specific Emergency Response Plans.

The assessments and worksheets contained within this document represent a balanced technical opinion of events that could occur at the Westridge Terminal. All of the scenarios discussed within this document have occurred somewhere within industry and there is limited scope to reduce the magnitude of these events if they occurred. It is recognised that the likelihood of these events is low and there are measures that can be taken to reduce that likelihood further, but they still all remain credible events. It should be noted that in the case of Westridge the probability of an event would be higher than the global average because of the earthquake frequency in the area.

Within this document, scenarios have been reviewed that could escalate given a set of circumstances. However, given the correctly designed, inspected, maintained, and tested procedures and equipment with competent and trained personnel, the probability of escalation can be reduced, but not eliminated completely.

These worksheets are intended to provide examples of potential scenarios at the Westridge Terminal with associated consequences and proposed firefighting strategies. There are other scenarios and sets of circumstances that could lead to the same escalation result.

Limited information on existing fire hazard management systems and processes have been provided for this assessment and so major assumptions have had to be made regarding its provisions. Nevertheless, the scenarios reviewed are based on actual incidents that have occurred in other locations similar to Westridge Terminal.

Notes on Scenario Worksheets

The following notes are intended to clarify their purpose:

- It is recognised that the scenarios have a relatively low probability, but similar incidents have occurred within the industry in all cases, including at facilities designed and operated in accordance with best industry practices.

- The assessments have been carried out based on either Jet Fuel material, for the tank and tank bund scenarios, or a crude oil, in the case of the process unit pool fire and a spill on the sea pool fire, and propane for a BLEVE scenario. These were chosen as materials that exist on the Westridge terminal.

- Radiant heat calculations have been carried out using recognised software (ALOHA, developed by the USA Office of Emergency Management, EPA and the Emergency Response Division, NOAA), but it must be realised that all such models have fairly high inherent calculation tolerances. Equally, although radiant heat levels causing certain effects such as escalation to adjacent facilities are based on published figures, the actual radiation levels will depend very much on specific conditions such as tank contents, ambient conditions etc. during the event.

- In the event of a major incident resulting in flames and smoke, these will be visible to the general public, which could cause panic within the community. This is likely to generate a large amount of media interest and telephone calls, which could impact communication. This should be recognised and will need to be managed.

- Initial panic caused by a major incident could lead to an uncontrolled evacuation from the area by the general public. This could seriously hamper any relief efforts or evacuations.

- It must be recognised that with such varying potential conditions, precise strategies, and tactics to be deployed might vary considerably. Tank firefighting should not be seen as an exact science but rather one relying on the availability of specialist experienced and competent personnel to make decisions based on the unique set of circumstances for that specific event.

- The BLEVE (Boiling Liquid Expanding Vapour Explosion) scenario that is described in the worksheet is an escalation scenario. It could happen as a result of an existing jet fire or as has been modelled in these worksheets, a pool fire in the process unit. Fire water and foam should be used to extinguish the pool fire, and this is assessed in the pool fire in the process unit worksheet. No calculations for quantity of water or foam have been completed due to the catastrophic nature of a BLEVE event.

- The number and location of water monitors is not based on specific application rate calculations but based on experience of similar incidents and the fact that application by monitors is typically dependent on the capacity and range of monitors rather than the actual minimum quantity of water required.

- This document concentrates on the relatively immediate incident consequences. Such incidents elsewhere have resulted in considerable long term consequential impact on the surrounding area, including contamination of drinking water sources, business loss, residential accommodation property value losses and long-term environmental damage.

- In the event of a major incident at the Westridge Terminal, this could have an effect on the local airport and businesses that rely on the airport unless there are other suitable plans in place.

- There is a railway line that runs through the terminal between the jetty area and the vapour recovery unit. This railway could be a source of ignition if vapours come into contact with the hot engine, but any incident could result in significant damage to the railway and could be impact local infrastructure and the transport of goods.

- In the case of a spill of crude oil to the sea, even if the oil is not ignited, this could have a significant environmental impact on the local wildlife and aquatic species in the area. Specialist clean-up crews and equipment are required in order to minimise the impact of an oil spill.

- In the event of a spill of crude oil to the sea, whether ignited or not ignited, there is an impact on vessels operating in the vicinity of the Westridge Marine Terminal that service nearby operations, such as the Parkland Refinery, Shell Terminal, Neptune Bulk Terminals, Suncor Energy and other industries operating in the Region that rely on materials entering through the terminal. Further impacts will be realised by:
-
    - Fishing rights
    - Impact on the city's program in using the waterfront for primary contact
    - Impact on leisure vessels

- No information is available on the type of construction of the jetty area, so it is not clear if a pool of crude oil could migrate under the jetty. In this case any fire could have serious implications on the equipment on the jetty and the ability for intervention from Terminal staff.

- No information has been obtained regarding the Fire Hazard Management Systems and processes that exist at the Westridge Terminal. Furthermore, it is assumed that the terminal is aligned with the latest ISGOTT (International Safety Guide for Oil Tankers and Terminals Sixth Edition) guide, although no assessment has been carried out as part of these worksheets

- These worksheets concentrate on the Fire Hazard Management system and active control systems, but no assessment has been made on the Process Safety management system in place at the Westridge Terminal. An independent evaluation is required to confirm that a Process Safety Management System is in place to manage the prevention of major incidents and accidents

Potential Escalation Mechanisms

Whilst certain escalation routes have been discussed it is important to note that some of the escalation stages could be the initial incident in their own right. For example, a full surface tank fire could be the initial incident rather than bund fire leading to one.

These are not considered to be the only escalation routes for the final scenarios but examples of potential ones only.

Example escalation route a)

- Earthquake or maloperation leading to damage to the product roof. (Note: incidents have occurred where the earthquake results in loss of tank contents from the tank by sloshing and breaking of the tank roof/shell joint, which is deliberately a weak joint).
- If there is an ignition source this could lead to a full surface fire.
- If rapid extinguishment is not possible, then the radiant heat from the full surface fire could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to other tanks, which could lead to further rim seal fires or full tank surface fires or bund (dike) pool fires.
- Without ignition, there is likely to be minimal safety and health impacts but there could be a business interruption and there will be a requirement to clean the material up.

Example escalation route b)

- Maloperation or mechanical failure of instrumentation leading to an overfill of the tank.
- The flammable liquid accumulating in the bund could find a source of ignition leading to a bund fire.
- If rapid extinguishment is not possible, then the radiant heat from the bund fire could impact the tank in the bund and another tank located within 2 tank Diameters (dependent on wind conditions).
- There is significant vegetation located around the Terminal and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area and evacuation from it, including surrounding schools and residential property.
- Without ignition, there is likely to be minimal safety and health impacts, but there is likely to be a major business interruption and clean-up operation required. It should also be noted that suitable PPE may include breathing apparatus, which will make working conditions difficult, particularly if the event goes on for some time.

Example escalation route c)

- Maloperation or mechanical failure leading to spill of material within the process area.
- The potential for a vapour cloud to form in the Terminal is low, but there is a real risk that a pool of crude oil could form in the process area. The amount of crude oil that could accumulate in the process area is dependent on early detection and then isolation of the source.
- The flammable liquid accumulating in the process area could find a source of ignition leading to a pool fire.

- If rapid extinguishment is not possible, then the radiant heat from the pool fire could impact the Propane tank that is installed. Under the right conditions this Propane tank could BLEVE leading to a significant escalation event that will impact people and equipment in the vicinity of the terminal, including any tankers that are moored.
- There is significant vegetation located around the Terminal and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area and evacuation from it, including surrounding schools and residential property.
- Without ignition, there is likely to be minimal safety and health impacts, although crude oil may contain Hydrogen Sulphide (H_2S) and Sulphur Dioxide (SO_2) which the emergency response personnel need to be aware of and wear suitable Personal Protective Equipment (PPE), but there is likely to be a major business interruption and clean-up operation required. It should also be noted that suitable PPE may include breathing apparatus, which will make working conditions difficult, particularly if the event goes on for some time.

Example escalation route d)

- Maloperation or mechanical failure leading to spill of material within the jetty area.
- The potential for a vapour cloud to form in the Terminal is low, but there is a real risk that a pool of crude oil could form on the sea depending on where the release is. The amount of crude oil that could accumulate is dependent on early detection and then isolation of the source.
- The most likely scenario is for a major environmental impact with the crude oil in the sea impacting local wildlife and aquatic species. This spill will require clean up and dispersal using specialist companies.
- An alternative is that the crude oil accumulates and finds a source of ignition leading to a pool fire on the sea.
- As the area around the tanker is typically boomed to contain any spills from the tanker, the fire will be contained, but may burn longer.
- If rapid extinguishment is not possible, then the radiant heat from the pool fire could impact the equipment on the jetty area or the tankers and personnel on the tankers that are moored at the jetty.
- There is significant vegetation located around the Terminal and through radiant heat, there is a risk of vegetation igniting, leading to forest fires that could impact the whole area and evacuation from it, including schools, residential property and businesses.
- Without ignition, there is likely to be minimal safety and health impacts, although crude oil may contain H_2S and SO_2 which the emergency response personnel need to be aware of and wear suitable PPE, but there is likely to be a major business interruption and clean-up operation required. It should also be noted that suitable PPE may include breathing apparatus, which will make working conditions difficult, particularly if the event goes on for some time.

Limitations to be Addressed

Whilst resources have been quantified for specific situations, no comparison with actual equipment on site have been made, as no information has been made available. Even if sufficient resources are available, it is unclear whether they can be safely deployed in an appropriate time.

The biggest risks are likely to be a result of a crude spill, whether within the confines of the process area or a spill to the sea. The amount of crude oil that could accumulate in the process area is dependent on early detection and then isolation of the source.

There is no indication on the construction of the jetty, so it is not clear if a release of oil could float beneath the jetty. The construction of the boom could impact the modelling that has been undertaken.

An assessment of the jetty and the jetty area should be undertaken against the latest ISGOTT (International Safety Guide for Oil Tankers and Terminals Sixth Edition) guide should be undertaken. It is the definitive reference for the safe operation of oil tankers and the marine terminals.

It is necessary to check the minimum required water quantities, rates, pressures, etc. against availability on site, given the upgrades being made.

The capacities on site for foam/water containment are not known – this is an important part of minimising environmental consequences of any incident along with necessary detailed preplanning for such events.

If the foam at the Westridge terminal is similar to the foam at the Burnaby Tank farm, this is likely to be a fluorinated foam, commonly known as PFAS. Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that includes PFOA, and PFOS. Both chemicals are very persistent in the environment and in the human body – meaning that they do not break down and they can accumulate over time. PFAS, which is known as a forever chemical, will also leave a long-term environmental impact. There is a drive to non-fluorinated foams globally and this should be considered by the facility.

Jet Fuel Bund / Dike Fire

SCENARIO WORKSHEET

TANK 202 – SCENARIO BUND (DIKE) FIRE

AREA	**WESTRIDGE TERMINAL**
FACILITY	Storage tank 202
FUNCTION	Jet Fuel Storage Tank
SCENARIO	Full bund (dike) fire. The fire is in a bund (dike) that includes tanks 202 and a second tank located to the west. Both of the tanks are located to the south of the terminal, separated from the jetty area by a Vapour Recovery Unit. The scenario discussed here is assuming that there is a full bund fire that encompasses both tanks. See figure 2 below. A fire of this magnitude (e.g., the dike area excluding the tanks is 5,460m², which is equivalent to a pool fire with diameter 83m), could impact on the vapour recovery area to the north of the storage tanks, potentially resulting in additional fires and making mitigation efforts very difficult. Note: A fire in a tank containing Jet fuel would not result in a full boilover although a much less severe thin film boilover might occur towards the end of burn out if unsuccessful extinguishing efforts resulted in water entering the tank.
MATERIAL	The material stored within the tank is Jet fuel. The publicised consequences of exposure to Jet fuel after a spill or accident are as follows: • Jet fuel is a colourless to straw-coloured liquid, with a characteristic hydrocarbon distillate odour. It is combustible, but not classed as extremely flammable as a liquid. • Its vapours are heavier than air. • Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties. • Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death. • Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks. • In the case of ignition, foam would be the agent of choice for a tank fire.

LOCATION FOR SCENARIO

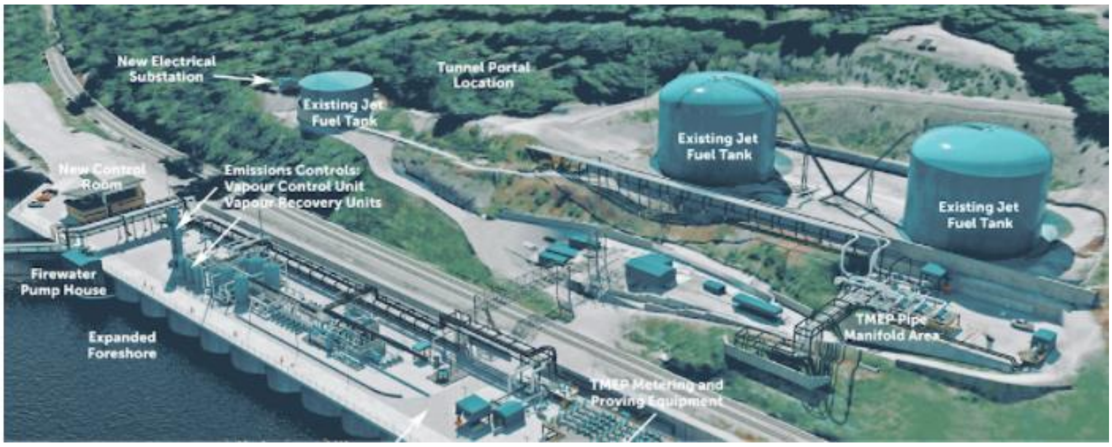


Figure 15: Image of the Westridge Terminal Site including the Jet Fuel Tanks

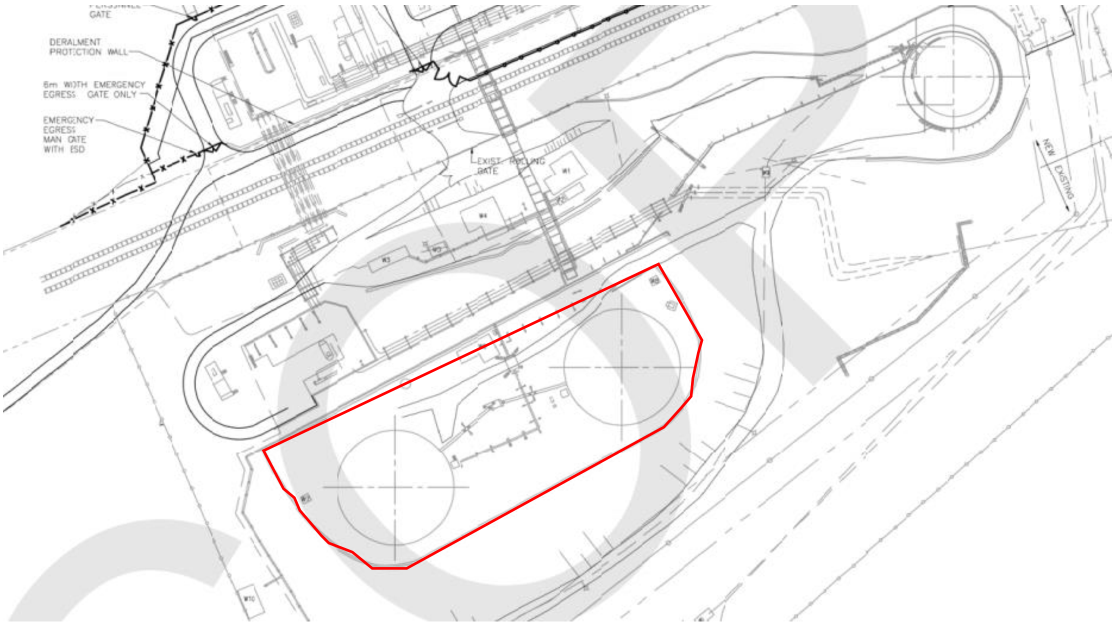
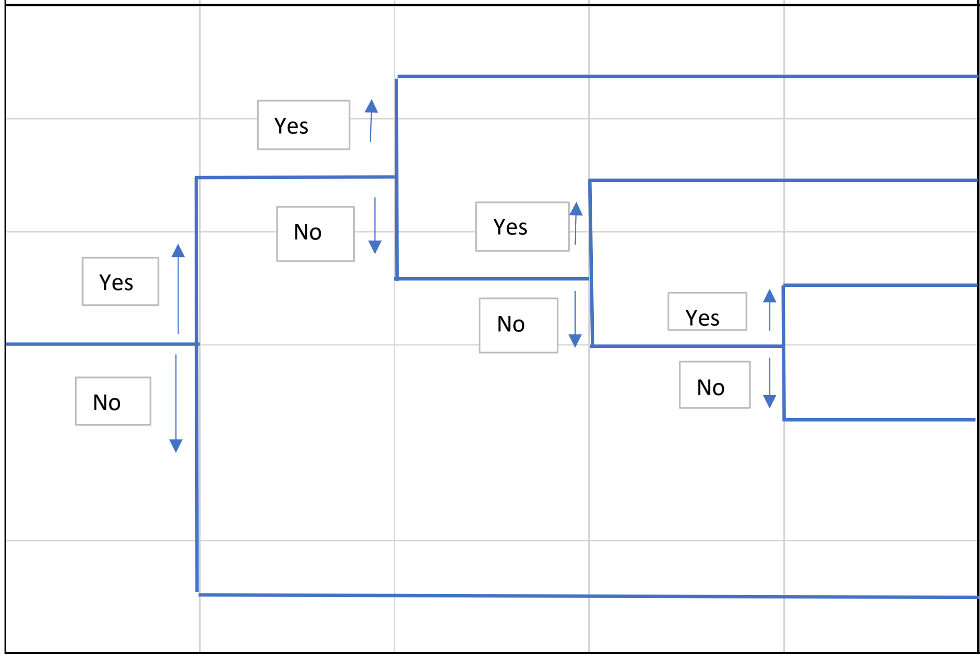


Figure 16: Partial plan of the Westridge terminal showing the Jet fuel storage tank

POTENTIAL SCENARIOS

Below is an event tree for the bund (dike) fire scenario starting with a loss of containment into the bund (dike).

Hydrocarbon in bund	Ignition - resulting in fire	"Rapid" extinction of fire?	Prevents escalation to engulfed tank	Prevents escaltion beyond own bund or to another tank	Final Scenario
A	B	D	E	F	
					Contained' Bund fire
					Prolonged large scale single bund fire (no tanks involved
					Large scale bund fire, escalting to tanks
					Extensive Fire beyond bund
					Loss of Product – asset loss - but no fire



ESTIMATION OF RISK

The risk matrix (see below) has been provided as an example to represent the risk of the scenario. An estimate has been for the likely consequence assessed in terms of Safety or Environment or Financial. Only the initial scenario has been assessed and no account for escalation of the event has been included. Each organisation will have their own definitions of levels of risk and so for the purposes of this report, a generic set of definitions have been chosen.

A risk matrix can be used during risk assessment to define the level of risk by considering the category of probability or likelihood against the category of consequence severity. This is a simple mechanism to increase visibility of risks and assist management decision making.

For the scenario above (based on the existing prevention, control and mitigation measures that are believed to be in place), the scenario is assessed to be a relatively low level of risk to safety for the initial event, but that risk level is significantly increased based on the potential financial and environmental consequences.

An organisation can use a risk matrix to prioritise which scenarios should be addressed based on the level of risk estimated.

Risk matrices are included here to demonstrate the relative consequences as a guide, but it is recommended that the terminal undergoes a more detailed assessment to determine the level of risk for each scenario

RISK MATRIX[14]

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

[14] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual, or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited "interest-group" outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbours (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is not normally manned and alternative exits away from the tanks are available. A dike fire is unlikely to pose a major life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads around the facility. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. There is unlikely to be an impact on the remaining storage tank outside of the bund as it is approximately 120 m from the bund. However, there is the potential for escalation to the process area which would have an impact on the business in addition to the unavailability of the two storage tanks impacted by the bund fire.
Asset loss	Potential loss of, or damage to tankage and piping as a result of the fire.

Escalation Mechanisms

A release of material into a bund (dike) if unignited may represent an asset loss but could also represent a significant environmental consequence depending on the amount of material released.

Given the nature of the Jet fuel material, it is unlikely that a release would result in significant quantities of flammable vapour being released from the dike, and therefore a Vapour Cloud Explosion is not considered credible.

In the event of a release with immediate ignition it could be a contained fire within the bund (dike) providing the fire response is set up quickly enough. However, failure of rapid extinguishment, could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the bund, or further escalation to the tanks contained within the bund, which could lead to tank fires or an escalation event in the vapour recovery area.

Given the composition of the Jet fuel material in the tanks, it is unlikely that the bund (dike) fire would escalate to a boilover event, although a much less severe thin film boilover might occur towards the end of burn out if unsuccessful extinguishing efforts resulted in water entering the tank.

There is significant vegetation located around the Westridge terminal and either through direct flame impingement or radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area.

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m^2	5-10 minutes
Spontaneous ignition of wood	40 kW/m^2	Could be a very short time
Adjacent Tank	37 kW/m^2	30-45 minutes
Personnel	32 kW/m^2	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m^2	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m^2	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m^2	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions).

In the event of a major bund fire one or more tanks will be exposed to radiant heat levels in excess of 8kW/m^2. Whilst this is unlikely to have an effect on firefighting strategies, more than one tank may be lost if the fire is allowed to burn down.

Post Escalation

Life safety

Operators should have evacuated immediately if a tank fire occurs. Escape routes within the Westridge terminal are available but escape from the tank farm will be difficult as the only route is past the area of the tank farm that is on fire. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the bund (dike).

A bund (dike) fire is likely to cause major long-term disruption although it is dependent on the extent and damage caused by the fire.

Environment	Smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident. The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm. The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. More significantly, the tanks store Jet fuel, so this could have a significant impact on the local airport and a resultant impact on businesses that rely on the airport to transfer people and equipment.
Asset loss	Potential loss of tank(s) and loss of piping/valves etc. Possible loss of more than one tank if escalation occurs.

Consequence Assessment

Heat Radiation – Bund Fire

A set of radiation modelling has been carried out for this scenario, assuming a pool area of 5,460m². The modelling has been carried out at 3 radiation contours 32kW/m² (fatality for human life if exposed to this level of heat for 30 seconds), 6.3kW/m² (which could impact escape routes and therefore impact the municipal team in their efforts and 2.0kW/m², which will result in pain within 60 seconds.

This scenario should be considered as an extreme case and the radiation contours a worst-case scenario, and the likelihood of an event of this magnitude is considered low.

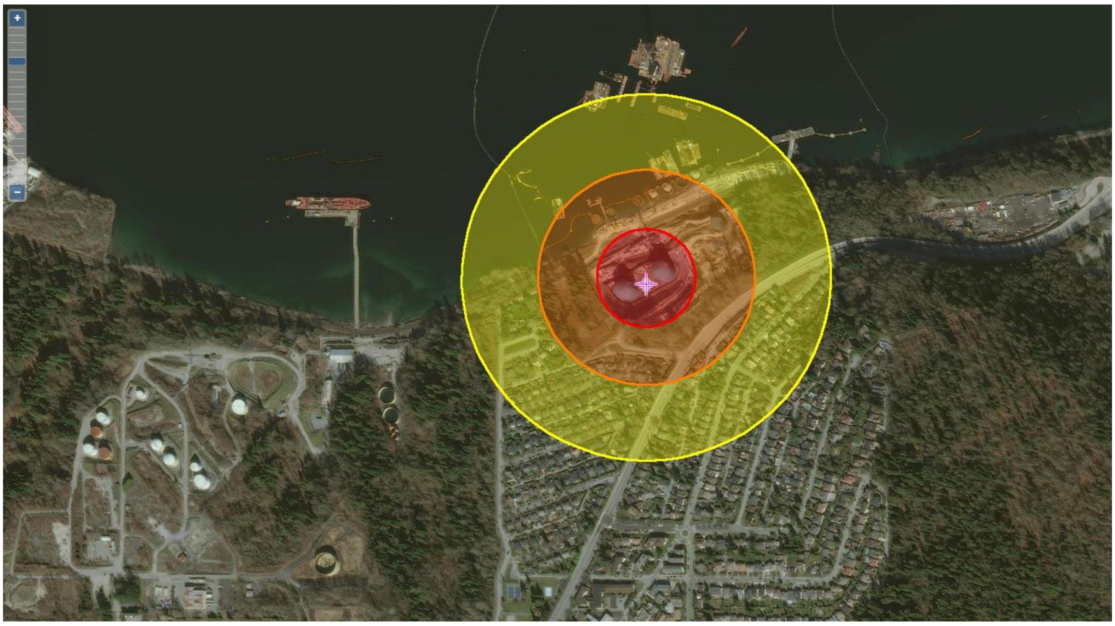


Figure 17: Radiation map for a bund (dike) fire at the Westridge terminal

Threat Zone

■	Red	119 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
■	Orange	250 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	417 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking specifically at the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

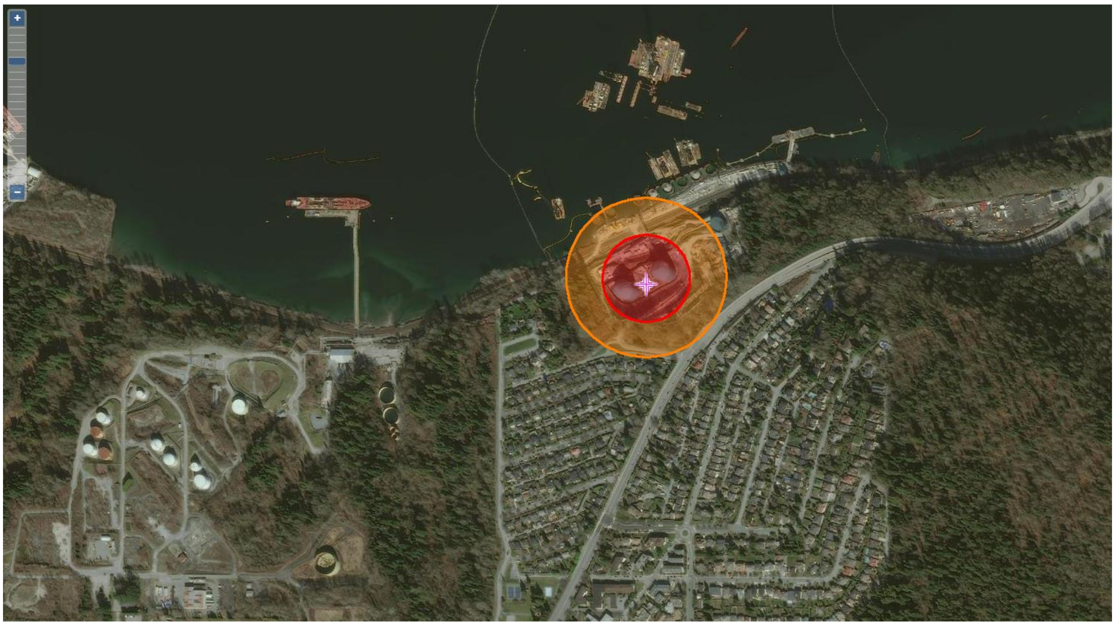


Figure 18: Radiation map for a bund (dike) fire at the Westridge terminal (indicating 40kW/m² and 12 kW/m²)

	Red	106 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	188 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	417 Metres	2.0 kW/m² = pain within 60 seconds

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario. It should also be recognised that these emergency response personnel are likely to need to wear breathing apparatus, which will place an additional burden on responses and the limitation to personnel for working for long periods of time.

Foam Cannon	Assuming a single foam cannon has the necessary capacity– 2-3 people would be required to monitor and manage its use.
Water cannons	It is recommended that 6 monitors are needed to be set up and managed for the duration of the water cooling operation. Each monitor will need to be managed by a minimum of 2-3 people. For 6 monitors, this will require between 12 to 18 people.

The minimum number of people required to manage a bund fire event is 14 people, but realistically the facility should be looking for 21 people to manage all of the equipment.

Jet Fuel Full Surface Tank Fire

SCENARIO WORKSHEET

TANK 202 – SCENARIO FULL SURFACE FIRE

AREA **WESTRIDGE TERMINAL**

FACILITY Storage tank 202

FUNCTION Jet Fuel Storage Tank

SCENARIO Full surface storage tank fire and catastrophic failure of tank. A fire of this magnitude (e.g., 39.3m diameter for Tank 202) could impact the storage tank to the west of tank 202 but is unlikely to impact tank 93 located to the east, as this tank is located more than 100 metres away and therefore more than 2 Diameters from the tank.

Tank 202 is located in the same bund as a second tank (refer to figure 6 below). A tank overfill or catastrophic tank failure could escalate to a bund fire impacting both tanks. Refer to worksheet scenario for a full bund fire.

It is possible that fuel surfaces could be exposed to greater heat levels and flame impingement as the tank on fire burns down. Escalation to the second Jet fuel tank is possible.

Note: A fire in a tank containing Jet fuel would not result in a full boilover although a much less severe thin film boilover might occur towards the end of burn out if unsuccessful extinguishing efforts resulted in water entering the tank.

MATERIAL The material stored within the tank is Jet fuel.

The publicised consequences of exposure to Jet fuel after a spill or accident are as follows:

- Jet fuel is a colourless to straw-coloured liquid, with a characteristic hydrocarbon distillate odour. It is combustible, but not classed as extremely flammable as a liquid.
- Its vapours are heavier than air.
- Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties.
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.
- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, foam would be the agent of choice for a tank fire.

LOCATION FOR SCENARIO

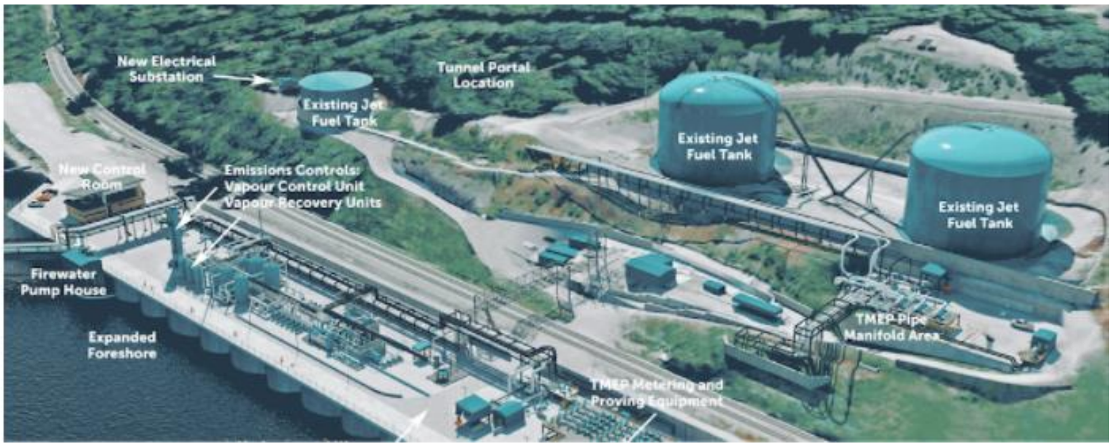


Figure 19: Image of the Westridge Terminal Site including the Jet Fuel Tanks

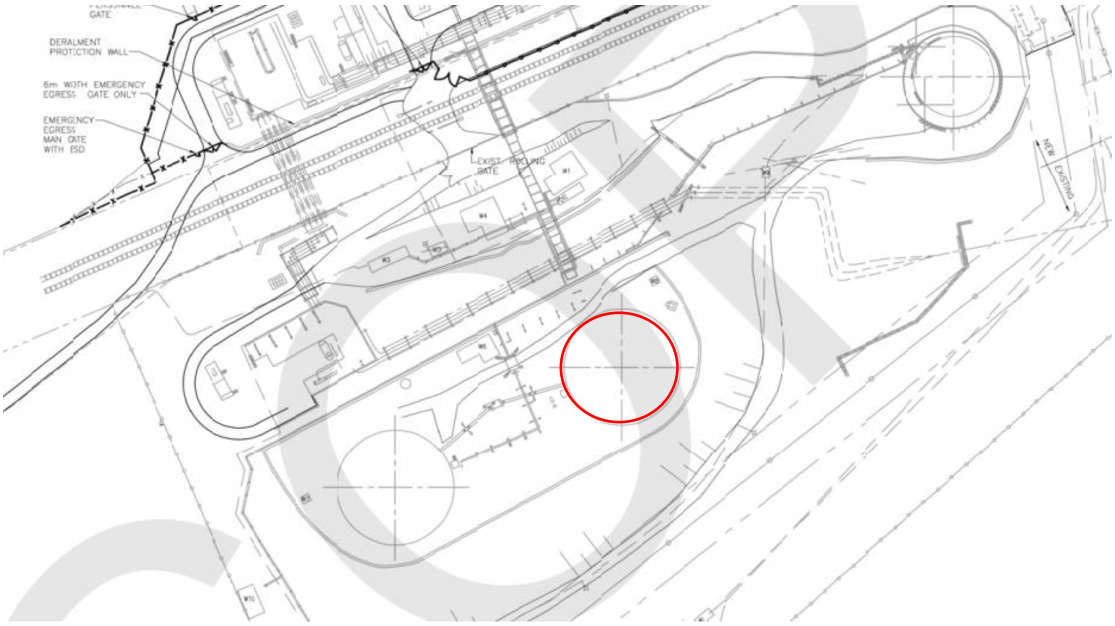
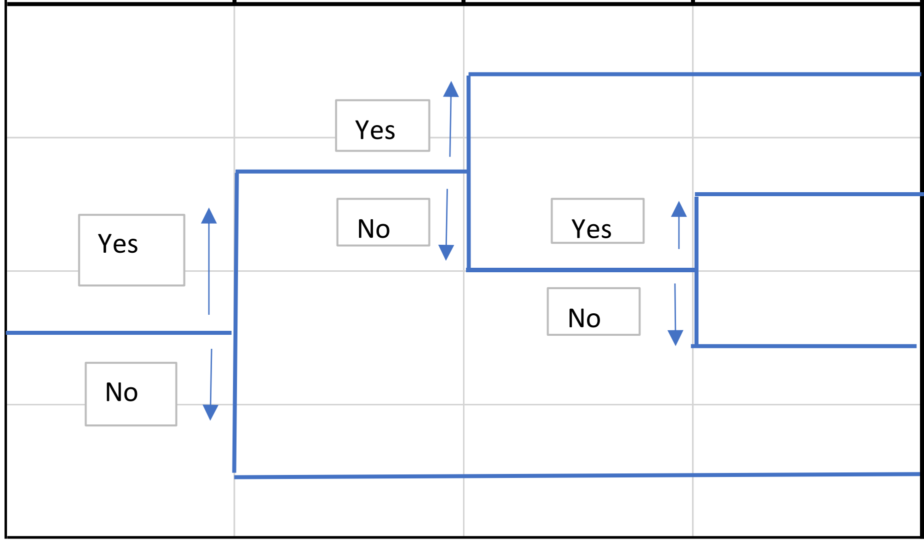


Figure 20: Partial plan of the Westridge terminal showing the Jet fuel storage tanks

POTENTIAL SCENARIOS

Below is an event tree for the full surface tank fire starting with a loss of containment from the tank onto the tank roof

Sunken Roof	Ignition	"Rapid" extinction of fire?	Prevents escalation beyond own tank or to other tank	Final Scenario
A	B	D	E	



Final Scenario
Short duration Single Tank Full Surface fire
Prolonged single tank incident - potential for a thin film Boilover
Multiple Tank/Bund incident
Loss of Product – asset loss - but no fire

ESTIMATION OF RISK[15]

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

[15] Note that the risk assessment is on a generic risk matrix and therefore definitions should be amended according to a specific organisation

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual, or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbours (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is not normally manned and alternative exits are available. A tank fire is unlikely to pose a major immediate life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the Westridge terminal evacuation plan.
Environment	Smoke pollution will occur from the fire once the product is ignited. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads around the facility. The smoke plume is likely to cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted. The impact on adjacent tankage would depend on radiant heat and/or flame impingement, however the nearest tank is located at least 1 tank diameter from tank 202
Asset loss	Potential loss of, or damage to tankage and piping.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the tank, or further escalation to the other storage tank resulting in a further tank fire or bund (dike) fire. There is also the potential risk that a fire in tank 202 could impact the proposed Vapour Recovery area.

Given the nature of the Jet fuel material, it is unlikely that a release would result in significant quantities of flammable vapour being released, and therefore a Vapour Cloud Explosion is not considered credible.

Given the composition of the Jet fuel material in the tanks, it is unlikely that the full surface fire would escalate to a boilover.

There is significant vegetation located around the Westridge terminal and through direct radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area.

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m^2	5-10 minutes
Spontaneous ignition of wood	40 kW/m^2	Could be a very short time
Adjacent Tank	37 kW/m^2	30-45 minutes
Personnel	32 kW/m^2	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m^2	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m^2	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m^2	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

In the event of a major bund fire one or more tanks will be exposed to radiant heat levels in excess of 8kW/m^2. Whilst this is unlikely to have an effect on firefighting strategies, more than one tank may be lost if the fire is allowed to burn down.

Post Escalation

Life safety

Operators should have evacuated immediately if a tank fire occurs. Escape routes within the Westridge terminal are available but escape from the tank farm will be difficult as the only route is past the area of the tank farm that is on fire. Oncoming fire personnel would be at risk from high radiant heat levels in the vicinity of the tanks.

A full surface fire is likely to cause major long-term disruption although it is dependent on the extent and damage caused by the fire.

Environment

Smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident.

The smoke particles could lead to long term health effects for vulnerable people living near or remote from the tank farm.

The smoke plume will cause panic in the local community and is likely to generate a large number of calls to the emergency services, which could overload communication systems.

Business interruption	Loss of a tank or product line would reduce import/future export capability and cause back-up of cargo importing. A full surface fire is likely to cause major long-term disruption to the facility. More significantly, the tanks store Jet fuel, so this could have an impact on the local airport and resultant impact on businesses that rely on the airport to transfer people and equipment.
Asset loss	Potential loss of tank(s) and loss of piping/valves etc. Possible loss of more than one tank if escalation occurs.

Consequence Assessment

Heat Radiation – Full Surface Tank Fire

Radiation modelling has been carried out for this scenario, assuming a pool area of 1,219m². The modelling has been carried out at 3 radiation contours 32kW/m² (fatality for human life if exposed to this level of heat for 30 seconds), 6.3kW/m² (which could impact escape routes and therefore impact the municipal team in their efforts and 2.0kW/m², which will result in pain within 60 seconds.

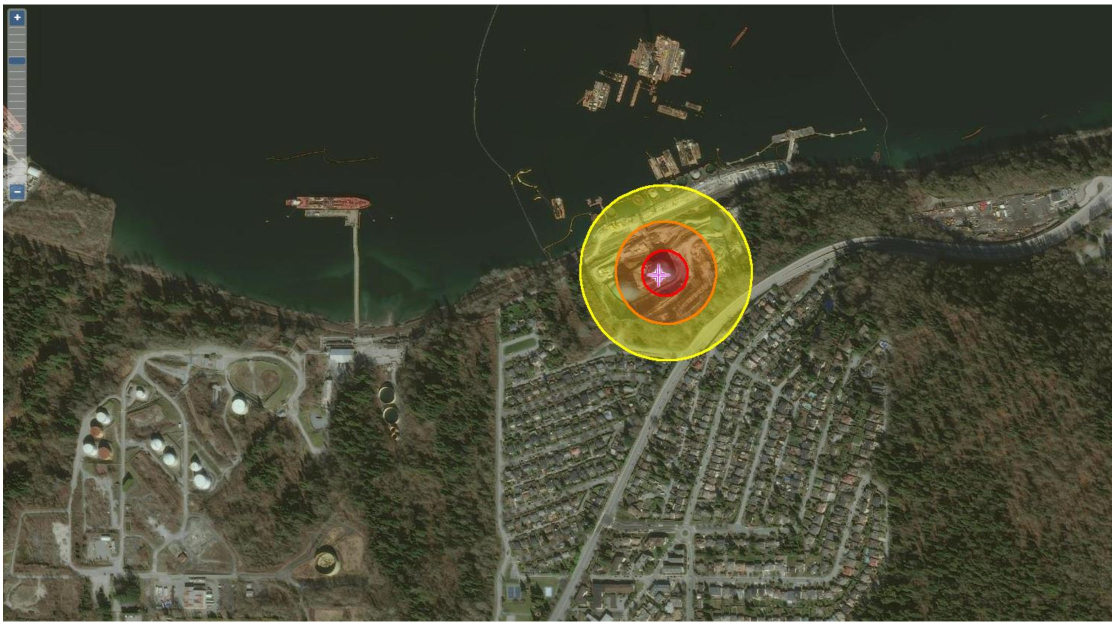


Figure 21: Radiation map for a full surface tank fire at the Westridge terminal

Threat Zone

	Red	63 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	127 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	205 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking specifically at the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

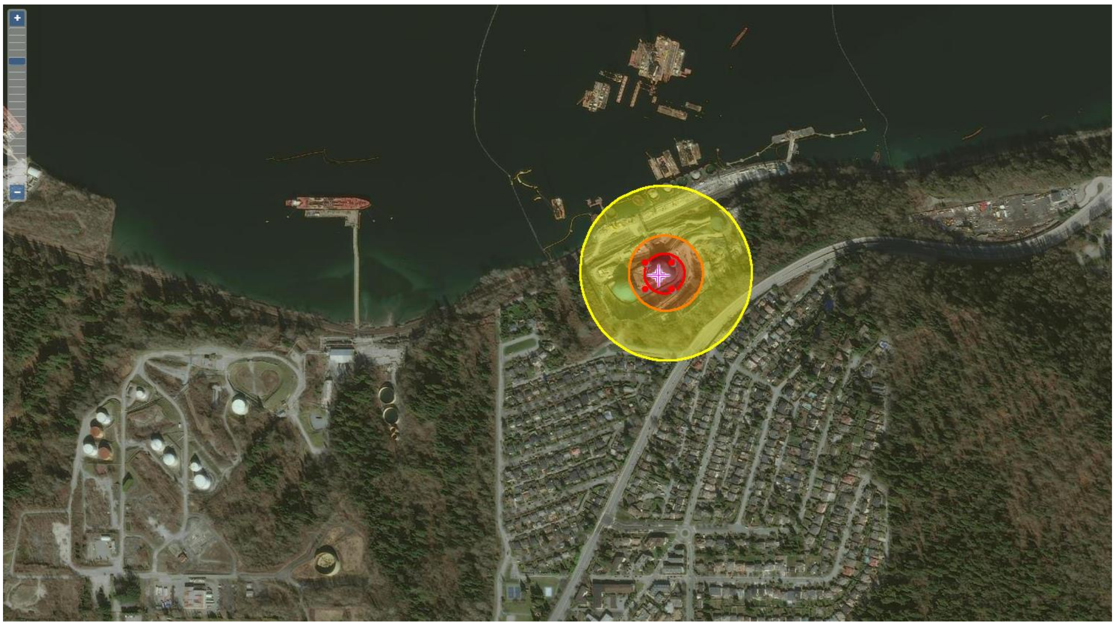


Figure 22: Radiation map for a full surface tank fire (40kW/m² and 12kW/m²)

	Red	56 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	97 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	343 Metres	2.0 kW/m² = pain within 60 seconds

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario

Foam Cannon	Assuming a single foam cannon has the necessary capacity– 2/3 people would be required to monitor and manage its use.
Water cannons	It is recommended that 6 monitors need to be set up and managed for the duration of the water-cooling operation. Each monitor will need to be managed by a minimum of 2/3 people. For 6 monitors, this will require between 12 to 18 people.

The minimum number of people required to manage a full surface fire event is 14 people, but realistically the facility should be looking for 21 people to manage all of the equipment.

Boiling Liquid Expanding Vapour Explosion (BLEVE)

SCENARIO WORKSHEET

SCENARIO PROPANE VESSEL BLEVE

AREA	**Westridge Terminal**
FACILITY	Propane Storage vessel
FUNCTION	Propane vessel BLEVE as an escalation event
SCENARIO	There is a propane vessel in the Vapour Recovery Unit at the Terminal and in the event of a hydrocarbon spill leading to a pool fire, there is a risk of BLEVE (Boiling Liquid Expanding Vapour Explosion). A BLEVE can occur on catastrophic failure of a vessel containing a pressure liquified gas, which is above its atmospheric boiling temperature. This type of explosion is very destructive of plant and equipment because they can result in missiles from the exploding vessel
MATERIAL	The material stored within the vessel is propane. Propane is a colourless, odourless gas. At atmospheric conditions it is a liquid at -42°C. • Propane is extremely flammable and under pressure may explode. • Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties • Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks • In the case of ignition, special firefighting techniques like the use of water spray or fog or dry powder • First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection

LOCATION FOR SCENARIO

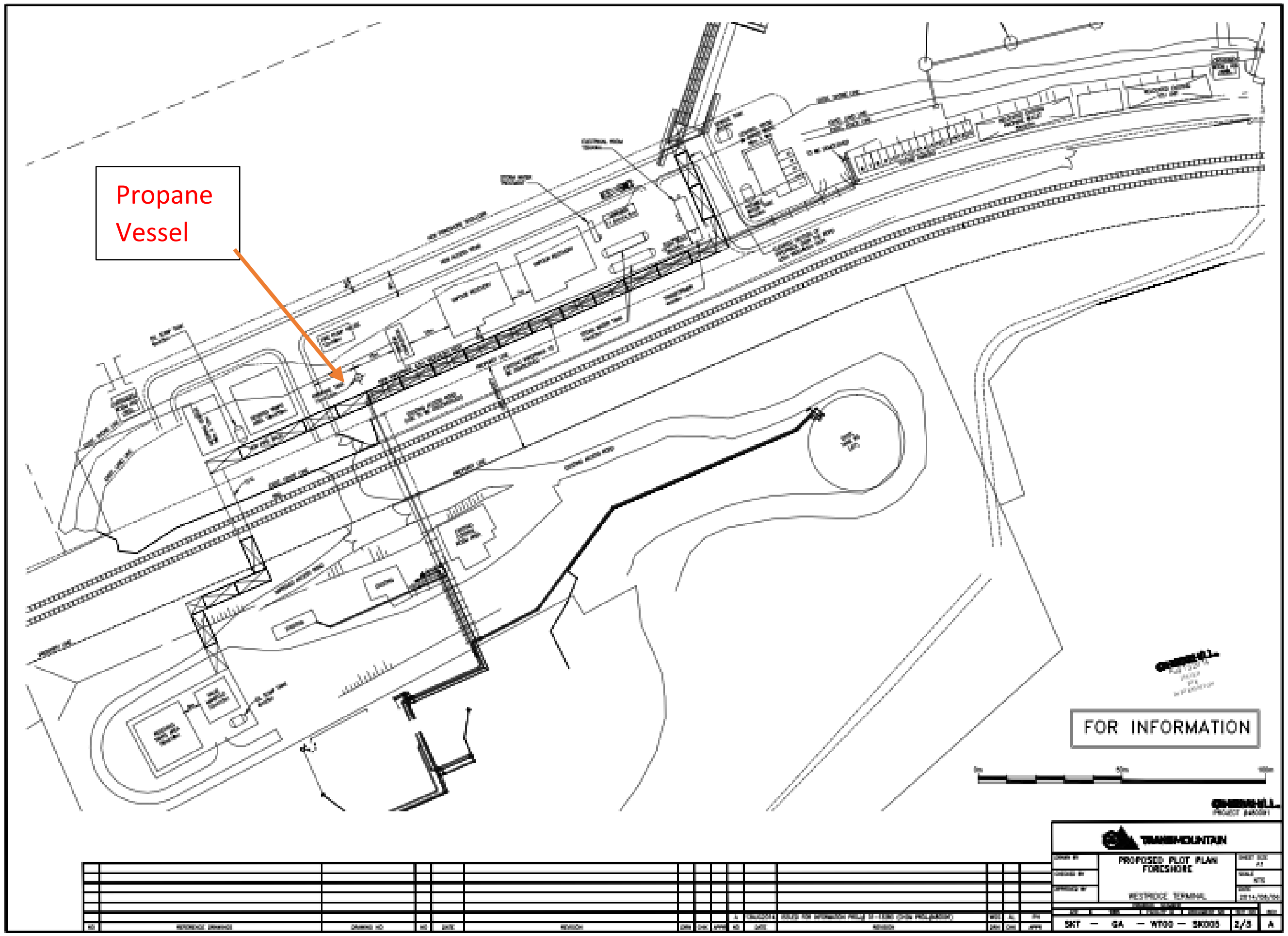


Figure 23: Plan of Westridge Terminal

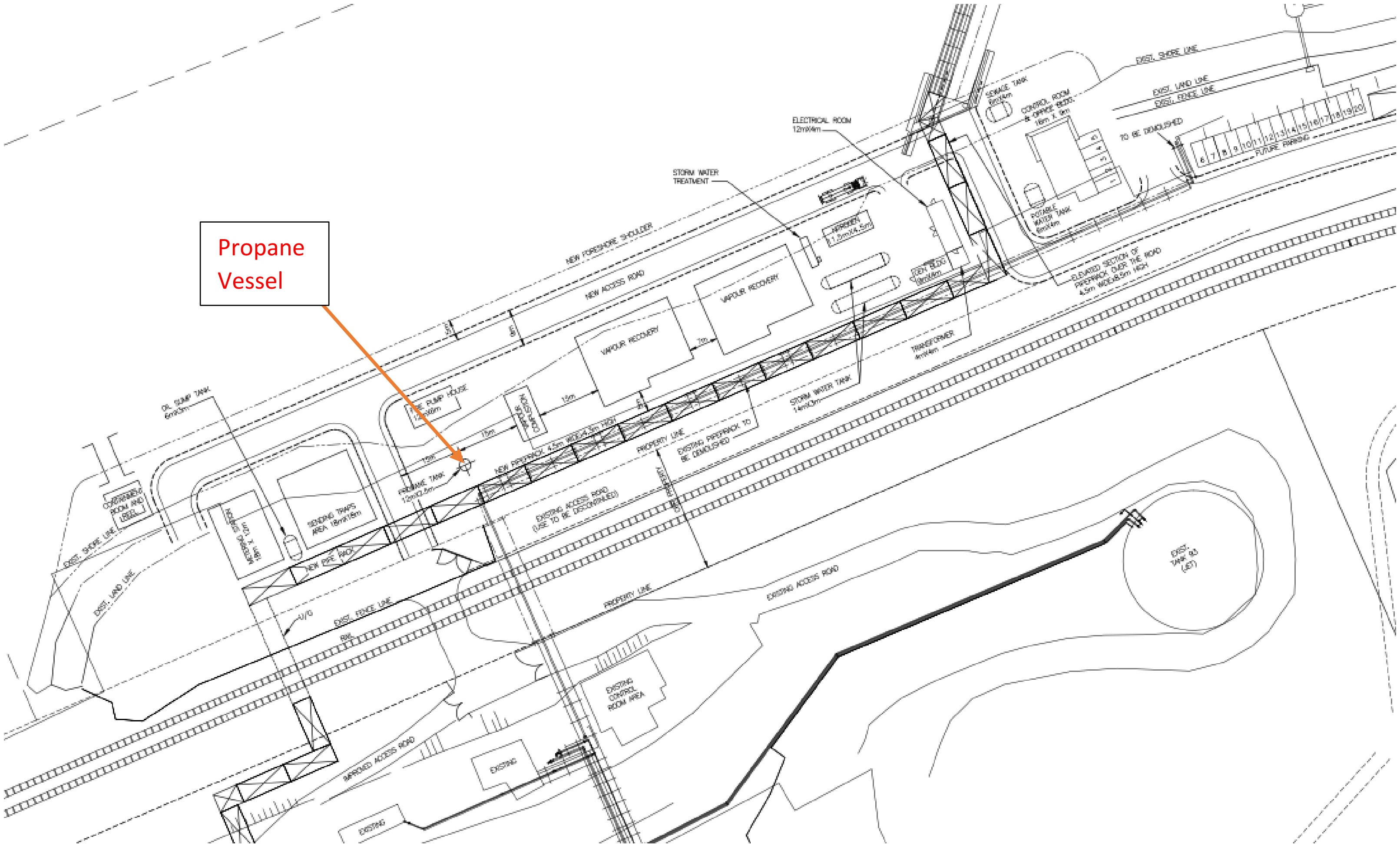
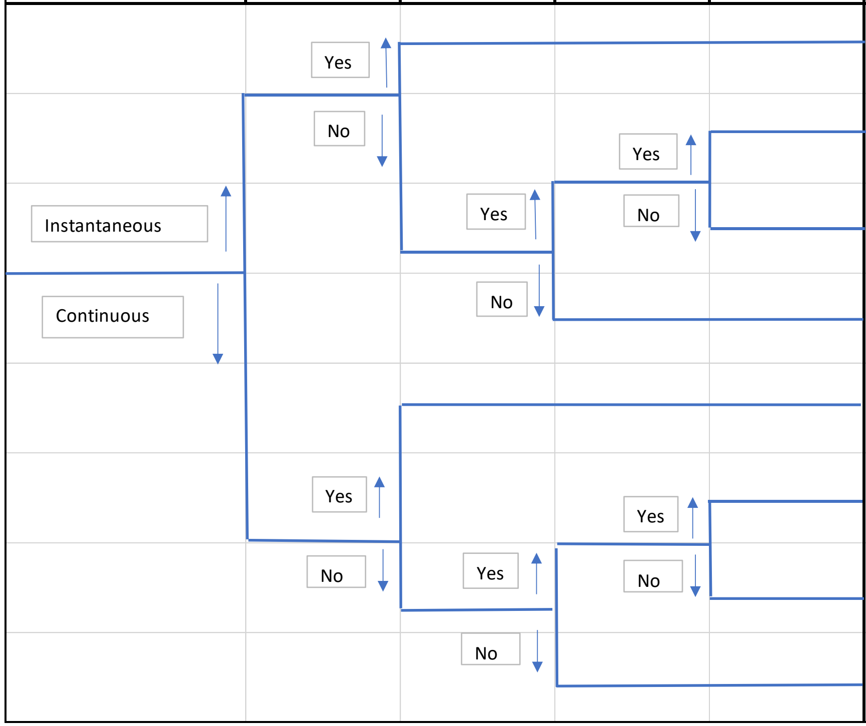


Figure 24: Plan of Westridge Terminal

POTENTIAL SCENARIOS

Below is an event tree for a process unit release, which could lead to a BLEVE amongst other scenarios.

Release of hydrocarbon	Release instantaneous	Immediate (direct) Ignition	Delayed Ignition	Confined vapour cloud	Event Combination	Final Scenario
	A	B	C	D		
					AB	BLEVE, fire pool
					$A\underline{B}CD$	Vapour Cloud Explosion
					$A\underline{B}CD$	Flash Fire / Pool fire
					$A\underline{BC}$	Pool of unignited hydrocarbon
					$\underline{A}B$	Jet / Pool fire
					$\underline{AB}CD$	Vapour Cloud Explosion
					$\underline{ABCD}$	Flash Fire / Pool fire
					$\underline{ABC}$	Pool of unignited hydrocarbon



ESTIMATION OF RISK

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual, or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited “interest-group” outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbours (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	A pool fire is unlikely to pose an immediate threat to life, however, if there is a risk of the scenario escalating to a BLEVE, then there is a real risk of injury or fatality to personnel on the facility. Once the initial loss of containment and pool fire has occurred, Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The smoke plume is dependent on wind direction, and could persist, limiting visibility on adjacent public roads.
Business interruption	During the initial fire, pumping movements would be shut down and loading would be halted.
Asset loss	Potential loss of, or damage to the vapour recovery area and the loading facilities at the jetty.

Escalation Mechanisms

The BLEVE is an escalation mechanism from a process pool fire or jet fire. Failure of rapid extinguishment of the pool fire could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the vapour recovery unit and further escalation to the propane tank leading to a BLEVE.

In the event of a loss of containment from the Propane vessel without an immediate source of ignition, there is a possibility that a flammable cloud could form which would lead to a potential vapour cloud explosion. Escalation to a Vapour Cloud Explosion would represent a major risk to the whole of the site and to beyond the existing tank farm fence.

There is significant vegetation located around the terminal and through radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area including surrounding schools and residential property.

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc.) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m²	5-10 minutes
Spontaneous ignition of wood	40 kW/m²	Could be a very short time
Personnel	32 kW/m²	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m²	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m²	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m²	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

Post Escalation

Life safety — Operators should have evacuated immediately if there was a process area pool fire. Oncoming fire personnel would be at risk from the BLEVE as an escalation event.

There is also the potential for escalation to any vessels moored at the jetty, which could have a significant impact to assets and people.

Environment — Smoke plume will continue and limit visibility on adjacent public roads. Firewater and foam runoff will have to be managed throughout the incident.

Business interruption — A BLEVE would lead to significant loss to the terminal and is likely to make it unavailable for some time before operations can be resumed. This could also result in limited supplies of Jet Fuel to the local airport, which could impose significant travel restrictions, which could have a consequential effect on business in the area.

Asset loss — Potential loss of loading facilities and the process area at the jetty.

Consequence Assessment

Heat Radiation – Propane Tank BLEVE

A BLEVE has been modelled based on the dimensions of the propane vessel. In the figure below, radiation at 3 levels have been modelled. This model can be used to assist emergency response teams determine safe locations for personnel and potential consequences for an incident of this magnitude

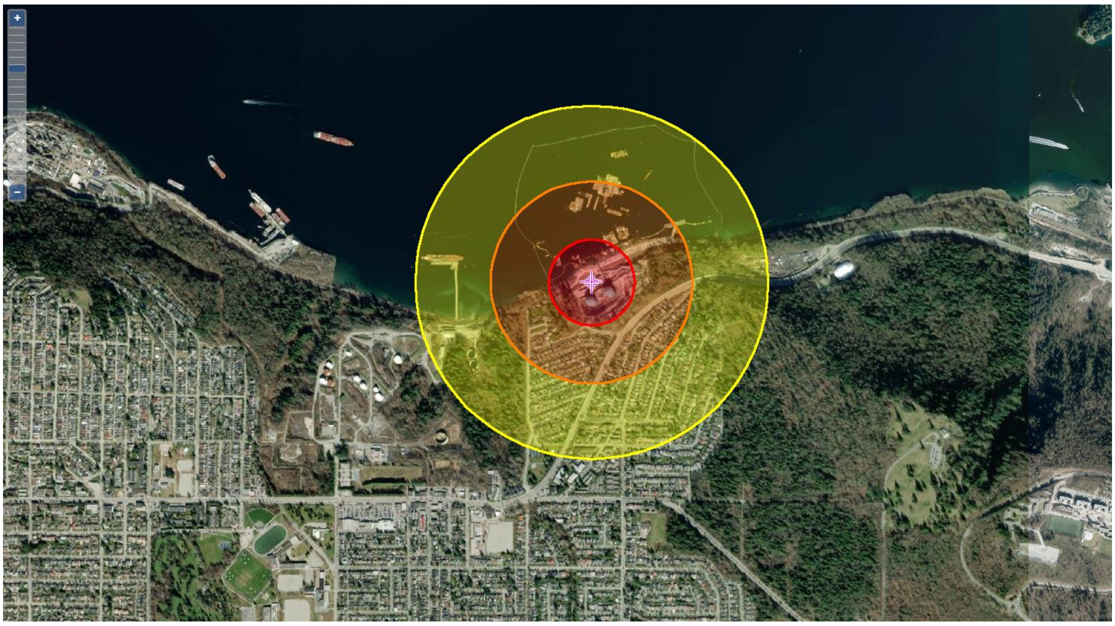


Figure 25: Radiation map for a BLEVE of the Propane vessel

Threat Zone

	Red	180 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	425 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	742 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

Figure 26: Radiation map for a BLEVE of the Propane vessel (40kW/m² and 12kW/m²)

	Red	158 Metres	40.0 kW/m² = Spontaneous ignition of wood
	Orange	307 Metres	12.0 kW/m² = Ignition of vegetation
	Yellow	742 Metres	2.0 kW/m² = Pain within 60 seconds

Liquid Release in the Process Area

SCENARIO WORKSHEET

SCENARIO - LIQUID RELEASE IN THE PROCESS AREA

AREA	**WESTRIDGE TERMINAL**
FACILITY	Westridge Terminal processing area
FUNCTION	Vapour recovery unit

SCENARIO

A leak of hydrocarbon material within the Vapour Recovery unit at the Westridge Terminal. At best, this leak of hydrocarbon remains unignited and therefore, the impact is an environmental release that requires clean up. However, if the hydrocarbon ignites immediately on release, the likely outcome is a jet fire. Any delayed ignition could result in a hydrocarbon pool fire or a hydrocarbon flash fire.

There is also a Propane vessel in the process area that could be impacted by a pool fire or jet fire and result in a BLEVE. Refer to separate worksheet on this scenario.

The potential size of the pool fire is dependent on a number of factors and assumptions and so the reality is the pool could be smaller or larger. The biggest factor on the size of the pool will be the early detection of a leak and the early closing of the ESD valve.

For this demonstration, the following assumptions have been made:

- Flowrate of crude oil = 100,000 US bbls/hour.
- Time to detect leak = 10 minutes.
- Time to close ESD valve = 30 seconds.
- Crude line Diameter = 36”.
- Distance from ESD to furthest berth = 100 metres.
- Assume line downstream of ESD is 50% full.
- Amount of crude in pool ~ 18,000 bbls (2,862m^3).
- It is estimated from the plot plan that the process units occupy an area of ~ 4,000m^2.
- This would result in a pool fire with an equivalent diameter of 71 metres.

MATERIAL

The material could be crude transferred from the Burnaby tank farm to the Jetty Area and it is this material that it is assumed that has leaked.

With crude, there is a potential for some of the material to evaporate, but most likely the material will remain as a liquid in the process area that on finding a source of ignition could result in a pool fire. The publicised consequences of exposure to crude after a spill or accident are as follows:

- Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties.
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.
- Sparking conditions must be avoided and being downwind during a fire greatly heightens associated risks.
- In the case of ignition, special firefighting techniques like the use of foam, CO_2, or dry chemicals are required.
- First responders must use chemical-resistant clothing, positive pressure breathing apparatuses, and eye protection.

LOCATION FOR SCENARIO

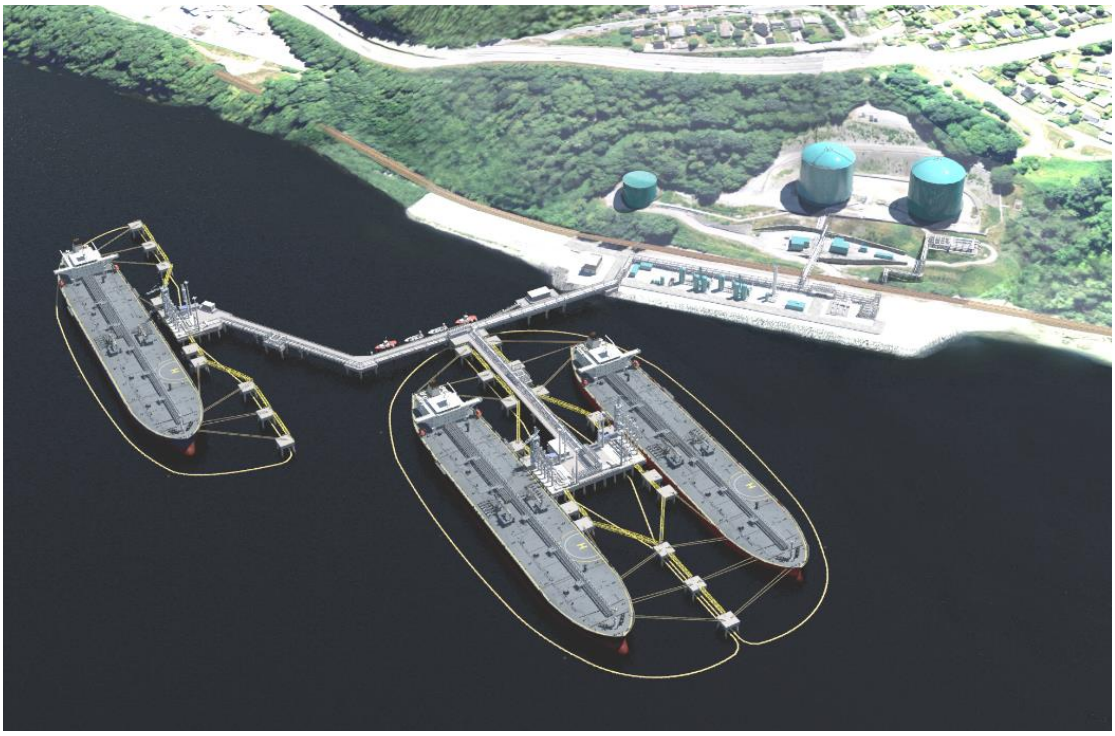


Figure 27: Image of the Westridge Terminal Site

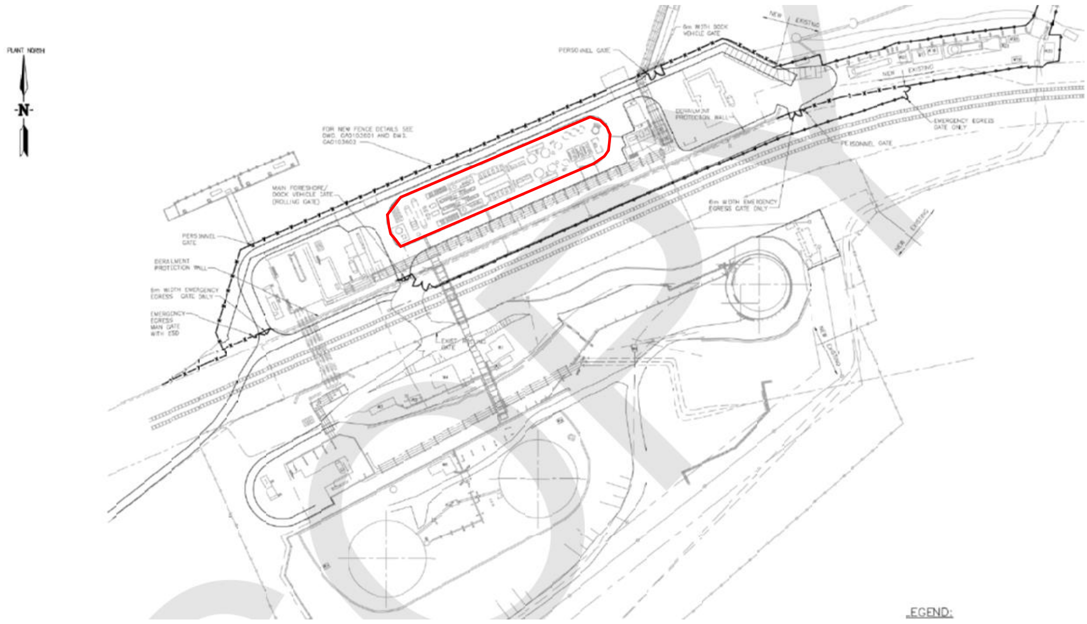
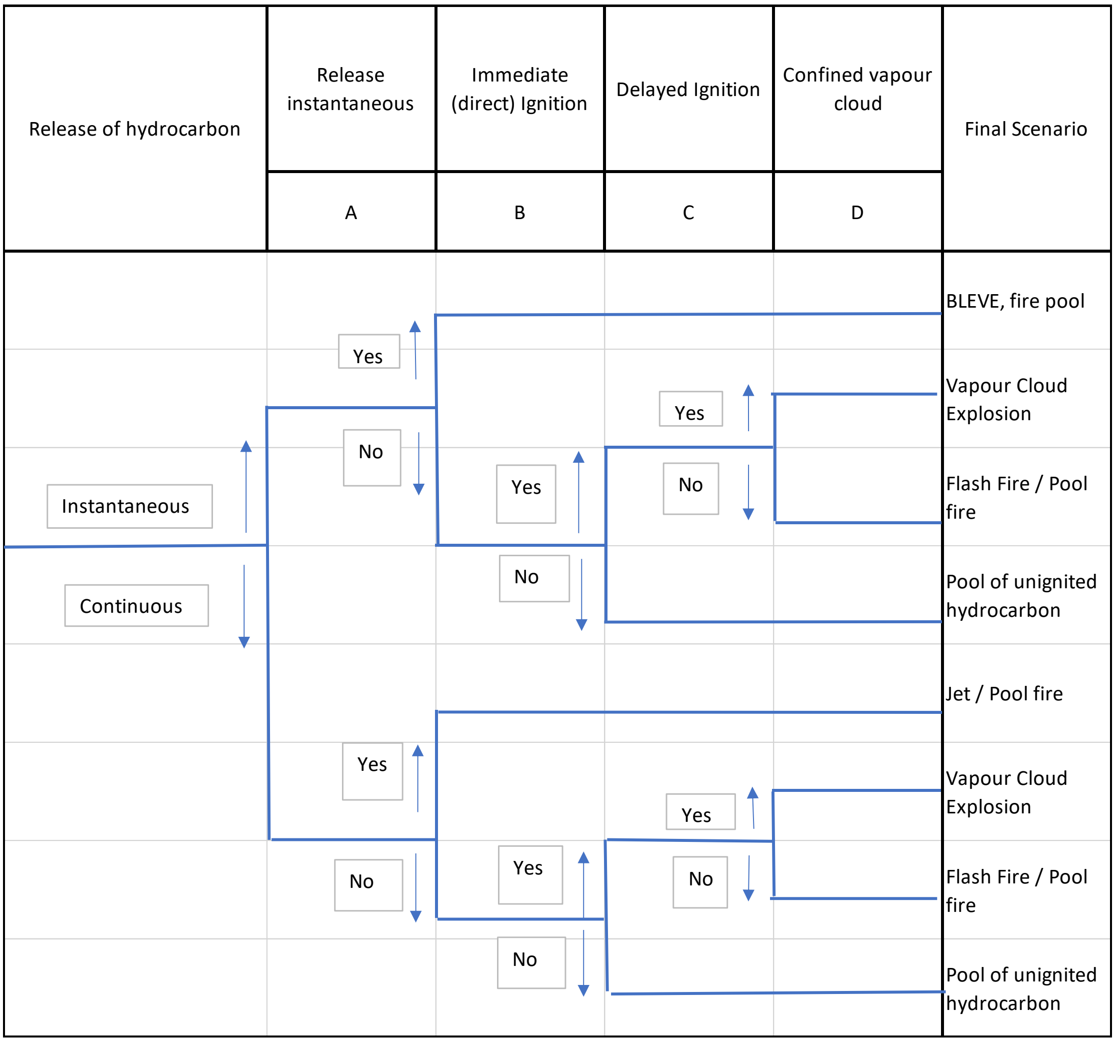


Figure 28: Westridge Terminal indicating the Process Area

POTENTIAL SCENARIOS

Below is an event tree for the Process Area fire



ESTIMATION OF RISK

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual, or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited "interest-group" outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbours (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The area is likely to be manned and there is a major immediate life safety threat to personnel on site. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the Westridge terminal evacuation plan.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The smoke plume is dependent on wind direction, and could persist, limiting visibility around the facility.
Business interruption	During the incident, pumping movements to or from the jetty would be shut down and loading and unloading would be halted. Depending on the severity of the incident and the damage to the plant would determine how long the facility would be unavailable.
Asset loss	Potential loss of, or damage to the vapour recovery unit and loading and unloading piping.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent structures by radiant heat. The radiant heat could result in failure of flanges in and around the process area, or further escalation, in particular to the Propane tank leading to a BLEVE. This scenario is addressed in a separate worksheet.

Given that there is likely to be a significant quantity of hydrocarbon vapour, as a result of the vapour recovery unit, there is a risk that a release could result in a large vapour cloud that fills the congested volume of the process area and results in a Vapour Cloud Explosion with subsequent overpressures impacting other plant and equipment. Any Vapour Cloud Explosion event could escalate beyond the Westridge terminal.

There is significant vegetation located around the Westridge terminal and most likely through radiant heat, there is a high risk of vegetation igniting, leading to forest fires that could impact the whole area.

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m^2	5-10 minutes
Spontaneous ignition of wood	40 kW/m^2	Could be a very short time
Adjacent Tank	37 kW/m^2	30-45 minutes
Personnel	32 kW/m^2	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m^2	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m^2	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m^2	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

Vapour Cloud Explosion Analysis

The main factors that influence the magnitude of gas or vapour explosions are:

- Degree of confinement of the gas cloud
- Type of flammable gas
- Level of turbulence in the gas cloud
- Degree of congestion
- Gas concentration
- Ignition strength.

Detailed CFD modelling is recommended to determine levels of overpressure at a distance, which would be particularly important to determine potential impacts on buildings but would not significantly impact the emergency response activities. The key criteria are to identify the formation of vapour at the earliest possible time to limit the release and therefor the potential for explosion. Refer to scenario worksheet specifically for a Vapour Cloud Explosion

Post Escalation

Life safety	Operators should have evacuated immediately if a process area fire occurs. Escape routes within the process area are available but escape from the terminal may be difficult. Oncoming fire personnel would be at risk from escalation events including Vapour Cloud Explosion and BLEVE.
Environment	Smoke plume may limit visibility around the terminal and at the jetty. Firewater and foam runoff will have to be managed throughout the incident.
Business interruption	Loss of the process area would reduce import/future export capability and cause back-up of cargo importing
Asset loss	Potential loss of vapour recovery area.

Consequence Assessment

Heat Radiation – Process Area Pool Fire

A set of radiation modelling has been carried out for this scenario, assuming a pool area of 3,900m². The modelling has been carried out at 3 radiation contours 32kW/m² (fatality for human life if exposed to this level of heat for 30 seconds), 6.3kW/m² (which could impact escape routes and therefore impact the municipal team in their efforts and 2.0kW/m², which will result in pain within 60 seconds.

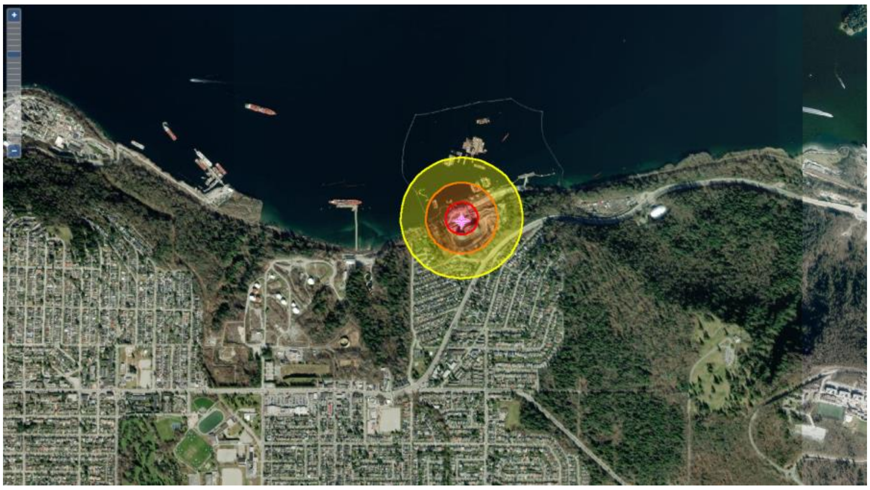


Figure 29: Radiation map for a process area pool fire

■	Red	103 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
■	Orange	208 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	343 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

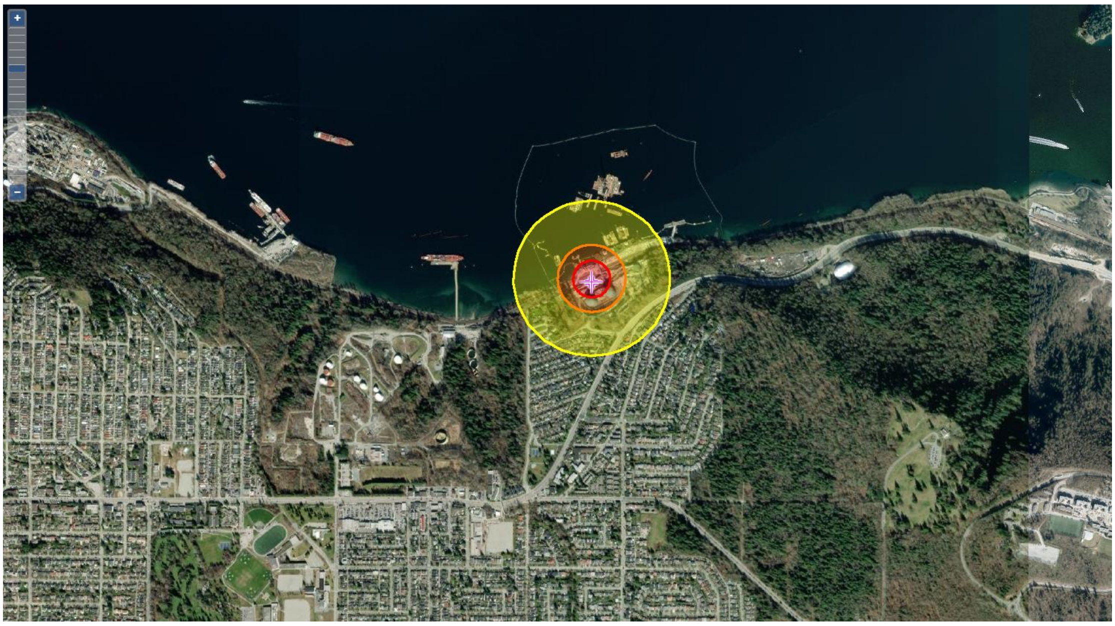


Figure 30: Radiation map for a process area pool fire (40kW/m² and 12kW/m²)

	Red	92 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	158 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	343 Metres	2.0 kW/m² = pain within 60 seconds

Manpower requirements

The following is the recommended manpower requirements that would be needed to manage a full surface fire scenario. It should also be recognised that these emergency response personnel are likely to need to wear breathing apparatus, which will place an additional burden on responses and the limitation to personnel for working for long periods of time.

Foam Cannon	Assuming a single foam cannon has the necessary capacity – 2-3 people would be required to monitor and manage its use.
Water cannons	It is recommended that 6 monitors need to be set up and managed for the duration of the water-cooling operation. Each monitor will need to be managed by a minimum of 2-3 people. For 6 monitors, this will require between 12 to 18 people.

The minimum number of people required to manage a bund fire event is 14 people, but realistically the facility should be looking for 21 people to manage all of the equipment.

Pool Fire on the Water

SCENARIO WORKSHEET

POOL FIRE ON THE WATER

AREA	**WESTRIDGE TERMINAL TANK FARM**
FACILITY	Westridge Terminal
FUNCTION	Crude leak resulting in a pool fire on the water

SCENARIO

A full bore rupture of the loading arm from a crude line within the Westridge terminal area. The most likely fire scenario is that there is a leak of hydrocarbon. At best, this leak of hydrocarbon remains unignited and therefore, the impact is an environmental release that requires clean up. However, if the hydrocarbon ignites immediately on release, the likely outcome is a jet fire. Any delayed ignition could result in a hydrocarbon pool fire or a hydrocarbon flash fire.

The potential size of the pool fire is dependent on a number of factors and assumptions and so the reality is the pool could be smaller or larger. If the tanker is surrounded by a boom, then the release area will be limited, which would result in smaller radiation circles, but the fire is likely to burn for longer. If the oil release is not boomed, then the fire area could be larger, but will be dispersed more and so the fire will not burn as long. The major contribution to the release is the flowrate of the product and the time to detection.

For this demonstration, the following assumptions have been made:

- Flowrate of crude oil = 100,000 bbls/hour
- Time to detect leak = 5 minutes
- Time to close ESD valve = 30 seconds
- Crude line Diameter = 36"
- Distance from ESD to furthest berth = 100 metres
- Assume line downstream of ESD is 50% full
- Amount of crude in pool ~ 9,200 bbls (1,463 m^3)
- Assuming that the pool has an average depth of 0.1 metres, the area of the pool could be 14,630 m^2
- This would result in a pool fire with an equivalent diameter of 136 metres

MATERIAL

The material could be crude transferred from the Burnaby tank farm to the jetty area and it is this material that it is assumed that has leaked.

With crude, there is a potential for some of the material to evaporate, but most likely the material will remain as a liquid on the surface of the water that on finding a source of ignition could result in a pool fire. The publicised consequences of exposure to crude after a spill or accident are as follows:

- Short term health hazards from exposure to vapours include eye and skin damage, nausea, and dizziness, and breathing difficulties
- Chronic or long-term effects can include cancer risk, effects on the nervous and/or cardiovascular system, seizures, and death.

LOCATION FOR SCENARIO

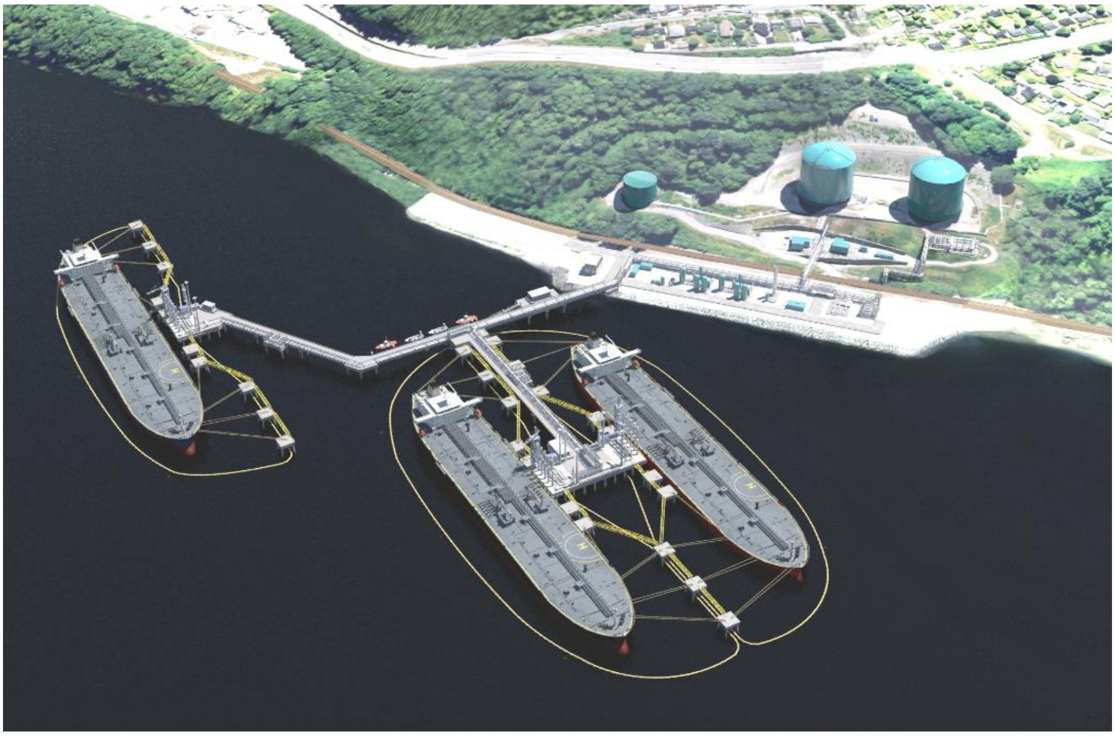
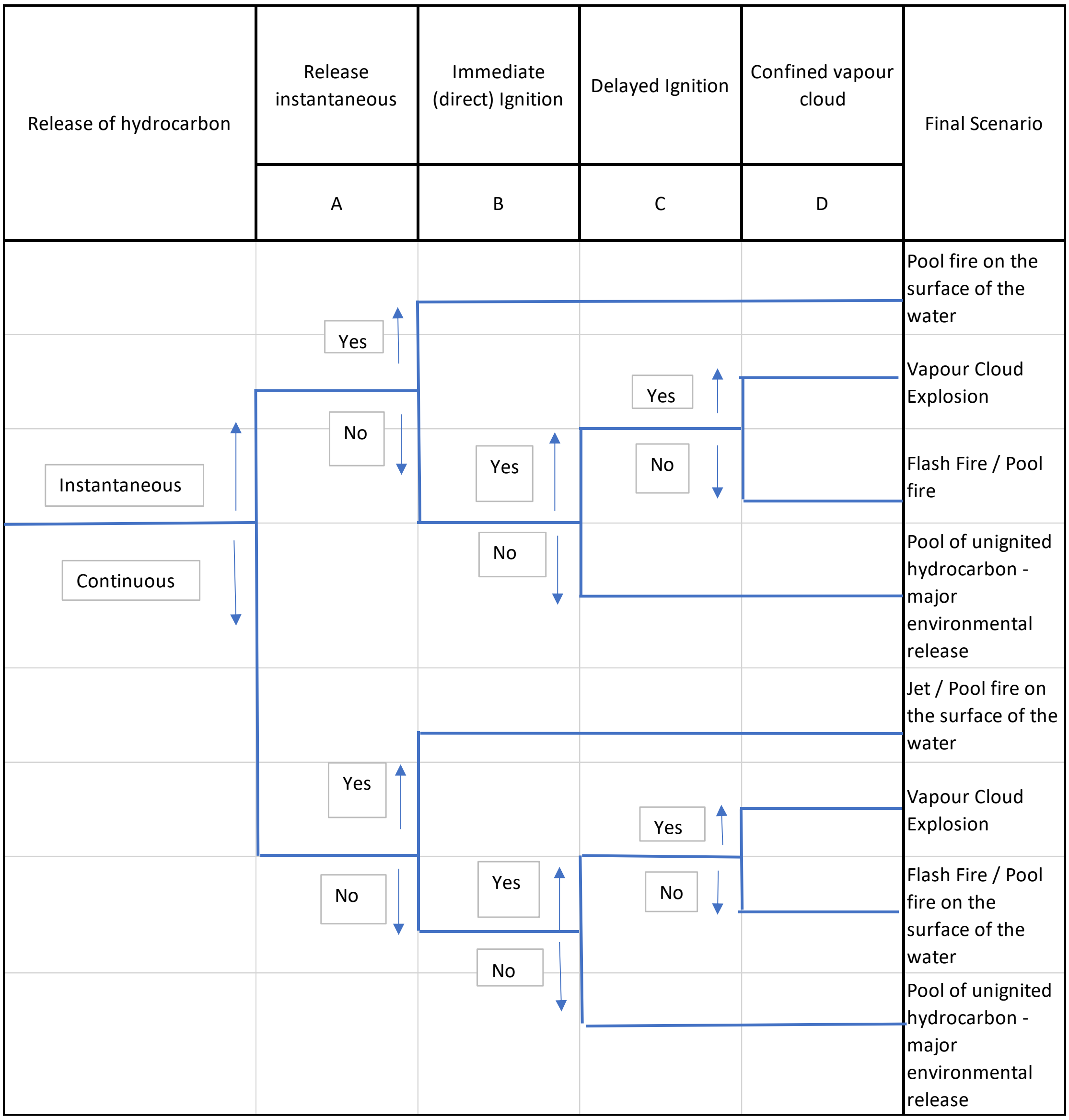


Figure 31: Plan of the jetty area

POTENTIAL SCENARIOS

Below is an event tree for the leak of crude oil to the sea.



Note that under the right set of circumstances, a delayed ignition event could result in a Vapour Cloud Explosion, however, there is little congestion and confinement at the jetty area and so a Vapour Cloud Explosion is considered to be very unlikely.

ESTIMATION OF RISK

		1	2	3	4	5	6	7	8
Severity Level		A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	Similar event has occurred somewhere in our industry	Similar event has occurred somewhere within the Organization	Similar event has occurred, or is likely to occur, within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	Event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
A	200 or more fatalities	8	9	10	11	12	13	14	15
B	Up to 50 fatalities	7	8	9	10	11	12	13	14
C	Catastrophic 10 or more fatalities	6	7	8	9	10	11	12	13
D	Very Major 3-10 fatalities	5	6	7	8	9	10	11	12
E	Major 1-2 fatalities	4	5	6	7	8	9	10	11
F	High Impact H&S incident	3	4	5	6	7	8	9	10
G	Medium Impact H&S incident	2	3	4	5	6	7	8	9
H	Low Impact H&S incident	1	2	3	4	5	6	7	8
Frequency		**10^{-6}/yr or lower**	**>10^{-6} to 10^{-5}/yr**	**>10^{-5} to 10^{-4}/yr**	**>10^{-4} to 10^{-3}/yr**	**>10^{-3} to 10^{-2}/yr**	**>10^{-2} to 10^{-1}/yr**	**>10^{-1} to 1/yr**	**>1/yr**

Key

Health and Safety Risk **Environmental Risk** **Financial / Reputation Risk**

RISK MATRIX DEFINITIONS

SEVERITY		HEALTH AND SAFETY	Environmental	Financial
A	Levels A-C maintain the visibility of risks with the potential for catastrophic impact even if their probability of occurrence is extremely low. The upper level of this framework is defined by the most severe level of impact ever seen in industry.	The potential for 200 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	Global outrage, global brand damage and/or affecting international legislation. **>$10 billion**
B		The potential for 50 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with extensive damage to a non-sensitive environment and which can only be remediated to a "satisfactory" / agreed state in a period of 2 - 4 years.	* Prolonged international media coverage. * Regional outrage, for example North America, Europe. * Regional brand damage. * Likely to lead to change of regulations at regional level. **$5 billion - $10 billion**
C		**Catastrophic health/ safety incident causing widespread fatalities within or outside a facility**. The potential for 10 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level.	Future event with widespread damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* International media coverage prolonged Regional media coverage. * Public outrage in major markets, e.g., North America, Europe. * Limited regional/ national brand damage. * Actual or threatened loss of privilege to operate (license suspension) for major operation in a significant market. * Likely to lead to change of national/ (state in USA) regulations. **$0.5 billion - $5 billion**
D		**Very major health/ safety incident** * The potential for 3 or more fatalities (or onset of life-threatening health effects) shall always be classified at this level. * 30 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of @ 1 year.	* Public outrage in other major markets where we have presence or aspiration. * Regional or prolonged local media coverage or severe national outrage. * Actual or threatened loss of License to Operate for affected business/site. * Likely to lead to change of regulations **$100 m to $0.5 billion**
E		**Major health/ safety incident** * 1 or 2 fatalities, acute or chronic, actual, or alleged. * 10 or more injuries or health effects to BP workforce, either permanent or requiring hospital treatment for more than 24 hours.	* Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of months.	* Localized or limited "interest-group" outrage in major market. *Public or investor outrage in non-major markets. * Significant enforcement action against one or more material assets in a significant market (e.g., US, Europe) **$5m -$100m**

SEVERITY	HEALTH AND SAFETY	Environmental	Financial
F	**High impact health/ safety incident** * Permanent partial disability(ies) * Several non-permanent injuries or health impacts. * DAFWC	Future event with localized damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Prolonged local media attention. * Other enforcement action against one or more material assets in other market (not US or Europe) with a foreseeable end date. **$500k-$5m**
G	**Medium impact health/ safety incident** Single or multiple recordable injury or health effects from common source/event.	Future event with immediate area damage to a sensitive environment and which can be remediated to a level which restores its environmental amenity in a period of days or weeks.	* Short term local media coverage. * Some disruption to day to day lives (e.g., loss of single road access less than 24 hours) * Fines or other penalties significant to a BU. **$50k -$500k**
H	Low impact health/safety incident. First aid. Single or multiple over-exposures causing noticeable irritation but no actual health effects.	* Future impact with immediate area damage to a non-sensitive environment and which can be restored to an equivalent capability in a period of days or weeks.	* Isolated and short term complaints from neighbours (e.g., complaints about specific noise episode) * Code of Conduct violation which does not lead to higher severity level consequence *No community notification required. **<$50k**

CONSEQUENCES

Immediate

Life Safety	The principal risk will be to Operators on the jetty and vessels in close proximity to the crude pool. There is unlikely to be a major risk to Operators in the short term, but if the fire is not extinguished quickly and the scenario escalates, then there could be a potential risk to the tanker personnel unless escape and evacuation routes are maintained. Water spray systems should be provided to assist and protect evacuation routes. Operator(s) would evacuate all non-essential personnel from the area and advise them to report to an appropriate muster point in accordance with the terminal evacuation plan.
Environment	Smoke pollution will occur from the pool fire once the product is ignited. The smoke plume is dependent on wind direction, and could persist, limiting visibility around the facility and on the tankers. Crude will spill into the sea, which could initiate a major accident to the Environment. The extent of this accident will depend on how quickly the leak is identified and stopped.
Business interruption	During the initial incident, pumping movements would be shut down and loading would be halted. The impact on adjacent tankers would depend on radiant heat and/or flame impingement, and whether other vessels were moored at the terminal at the time of the incident.
Asset loss	Potential loss of, or damage to the jetty and tankers.

Escalation Mechanisms

Failure of rapid extinguishment could see an escalation to adjacent equipment on the jetty or the tankers moored at the jetty by radiant heat. The radiant heat could result in failure of flanges in and around the jetty, which could lead to further releases and pool fires.

Escalation time estimates

Potential heat flux in the flame of a pool fire is in the order of 200 kW/m2. Potential radiant heat levels and escalation times (time to failure of pipeline/tankage, etc) may be:

Material	Radiant Heat	Exposure Time / Comments
Main Piperacks	200 kW/m²	5-10 minutes
Spontaneous ignition of wood	40 kW/m²	Could be a very short time
Adjacent Tank	37 kW/m²	30-45 minutes
Personnel	32 kW/m²	100% fatality for an exposure of 30s (outdoor population)
Ignition of vegetation	12 kW/m²	Could be a very short time dependent on the vegetation and how dry it is 1% fatality for an exposure of 30s outdoor
Heat impacts to internal and external roadways	6.3 kW/m²	Escape routes impaired if radiation exceeds this level, so could impact firefighting or access or egress
	2.0 kW/m²	Pain within 60 seconds and some authorities are limiting emergency response teams to this maximum heat radiation level at all times

(Above assumes no cooling or control actions)

Escalation is likely to be via the ship itself, either through extended fire duration at the manifold or through flammable liquids entering the ship via openings or doorways. Time to escalation is difficult to predict.

Post Escalation

Life safety — Tanker personnel and emergency responders would be impacted if the tanker becomes involved in the incident. Escape and evacuation routes within the jetty area are available and should be kept available at all times.

Environment — Smoke plume may limit visibility around the terminal and at the jetty. Firewater and foam runoff will have to be managed throughout the incident.

There is a significant risk from hydrocarbon that is unignited that spills to the sea. This loss of containment may or may not be boomed. This material will need to be dispersed and cleaned to prevent a major environmental consequence.

Business interruption — Loss of the jetty area or product line would reduce import/future export capability and cause back-up of cargo importing. This could have a major impact on the availability of the jetty, which in turn could have a major impact on local businesses including the nearby airport.

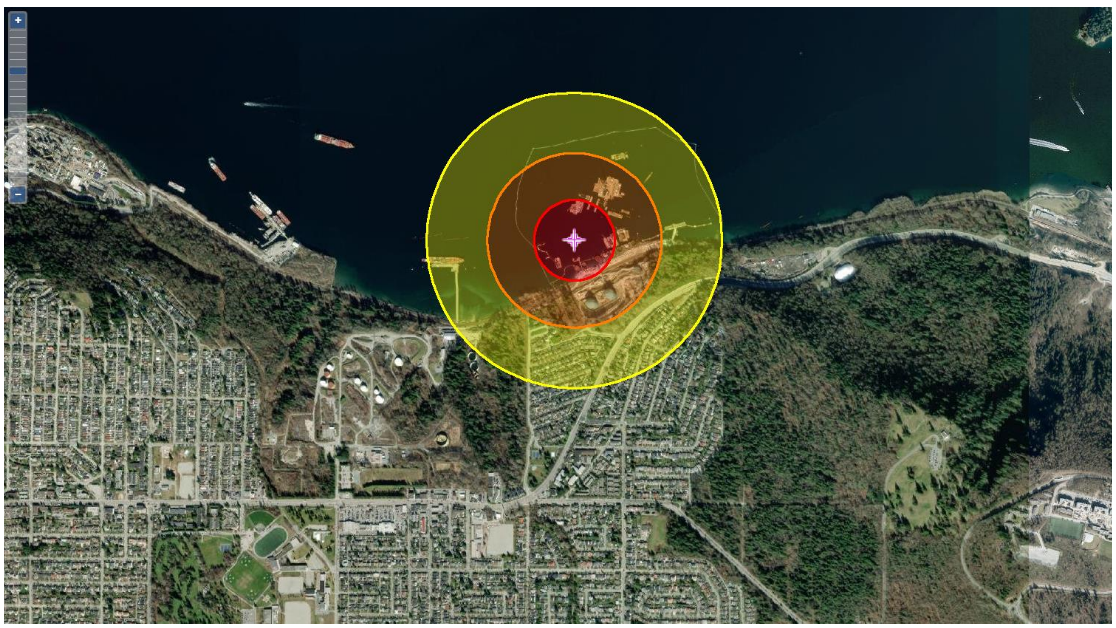
Asset loss	Potential loss or severe damage to the jetty and the jetty loading arms and loss of piping/valves and cabling.

Consequence Assessment

Heat Radiation – Pool Fire on the sea

A set of radiation modelling has been carried out for this scenario, assuming a pool area of 14,630m². This should be seen as a worst-case scenario and the emphasis should be on early detection and isolation to minimise the amount of oil spilled to the sea. The modelling has been carried out assuming that any release is boomed to prevent further spread.

The modelling has been carried out at 3 radiation contours 32kW/m² (fatality for human life if exposed to this level of heat for 30 seconds), 6.3kW/m² (which could impact escape routes and therefore impact the municipal team in their efforts and 2.0kW/m², which will result in pain within 60 seconds.

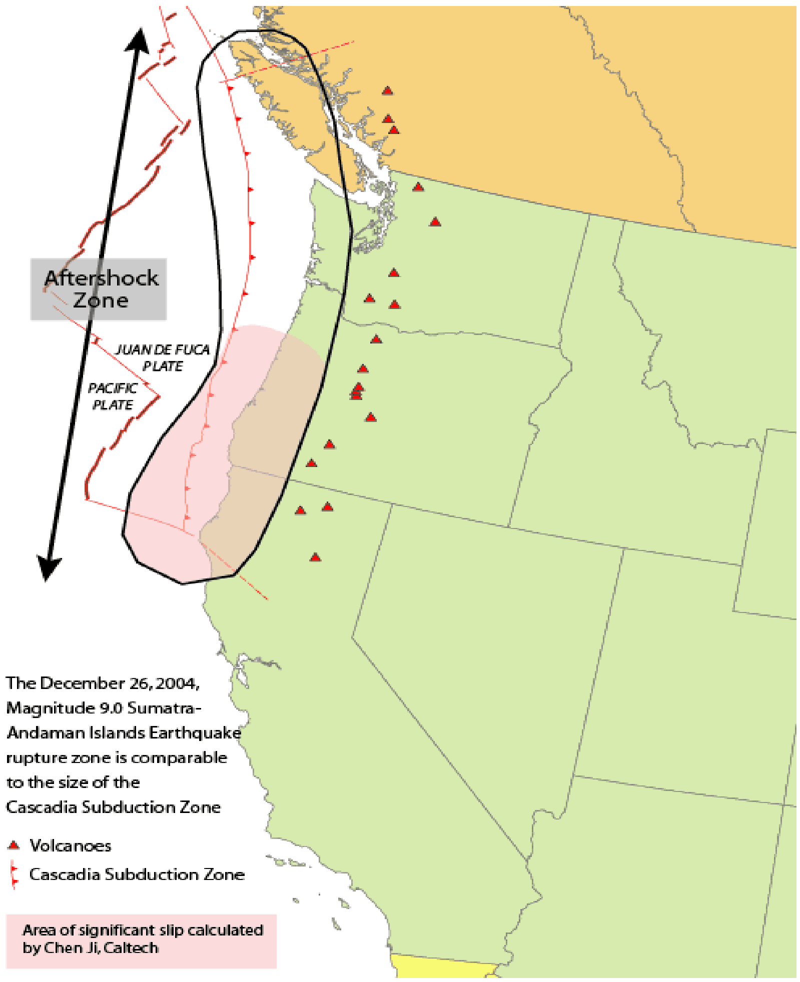


■	Red	169 Metres	32.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
■	Orange	366 Metres	6.3 kW/m² = Escape routes impaired if radiation exceeds this level
■	Yellow	622 Metres	2.0 kW/m² = pain within 60 seconds

A further set of modelling has been completed looking at specifically the objects that could be impacted that see radiation levels of 40kW/m² (wood self-ignition) or 12kW/m² (ignition of vegetation).

	Red	151 Metres	40.0 kW/m² = 100% fatality for an exposure of 30s (outdoor population)
	Orange	272 Metres	12.0 kW/m² = Escape routes impaired if radiation exceeds this level
	Yellow	622 Metres	2.0 kW/m² = pain within 60 seconds

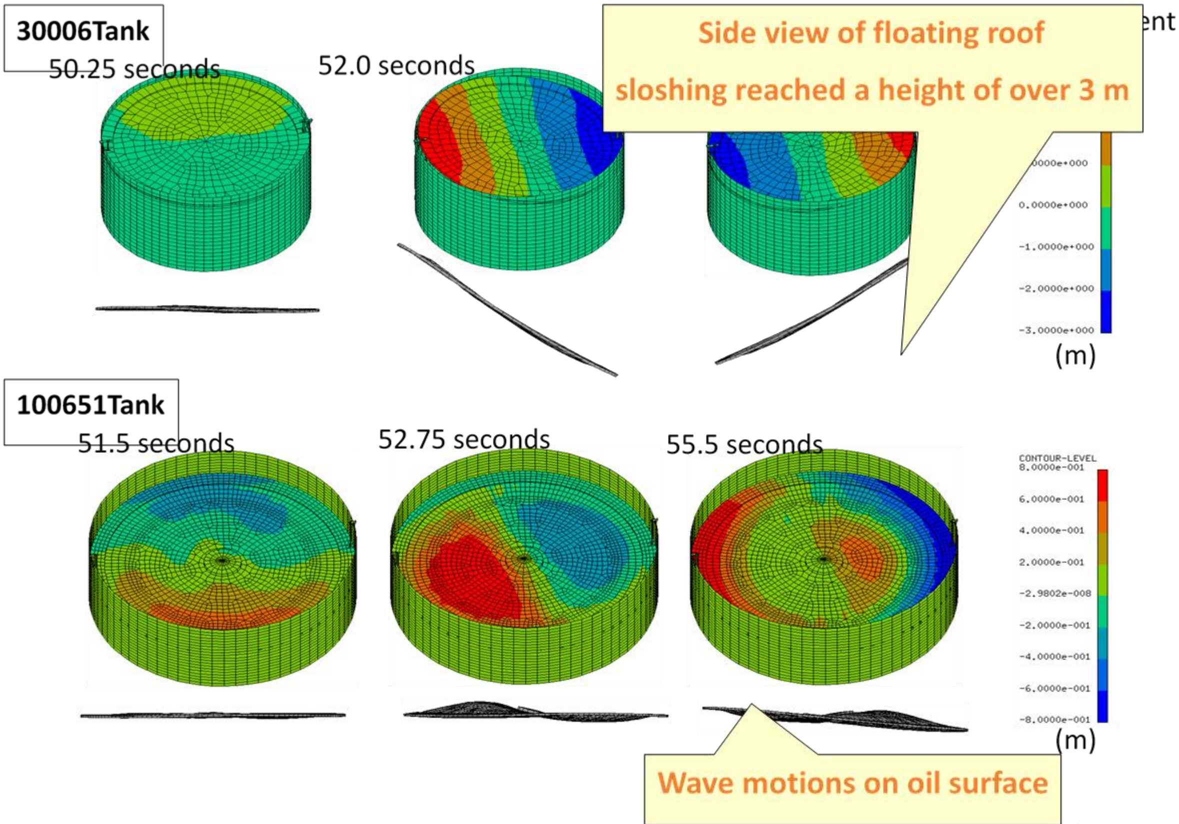
APPENDIX B: SEISMIC RISK TO BURNABY



In 2010, geologists predicted a 37% chance of an M8.2+ event within 50 years, and a 10 to 15% chance that the entire Cascadia subduction zone will rupture with an M9+ event within the same time frame.

Sources:
https://en.wikipedia.org/wiki/1700_Cascadia_earthquake
"A Major Earthquake in the Pacific Northwest Looks Even Likelier". The Atlantic. August 16, 2016.
Odds Are 1-In-3 That A Huge Quake Will Hit Northwest In Next 50 Years". Oregon State University. 24 May 2010.

APPENDIX C: SIMULATED SEISMIC SLOSHING IN TANKS- HOKKAIDO, JAPAN



Behavior of Floating Roof During Sloshing（Results of simulation）

Wave heights can exceed the clearance between internal and external roofs causing impact. The resulting impact can damage the floating roof leading to its' sinking. Metal to metal friction can ignite vapors leading to explosion and full surface fire.

What "Highest Level of Safety" Would Look Like

Basic Concepts for the "Highest Level of Safety"

- Control system auto ESD upon seismic threshold:
  - Auto ESD upon threshold of P waves or alert system
- Tank Design:
  - API 650 with Appendix E (Seismic Use Group 2)
  - Appendix I (for passive tank bottom leak detection)
  - Internal Floating Roof (IFR) type 5 steel with pontoons
  - Bladders in pontoons for added buoyancy
- Overflow Protection
  - Multiple detectors for liquid level and tilt with auto ESD
  - Separate and independent overflow detection per API 2350 with auto ESD
  - Specify ISA-84
- Secondary Containment:
  - Separate containment for each tank
  - Liquid level monitoring, hydrocarbon monitoring, and MOV
- Fluorine-free foam with performance based specification
  - Proven through large scale testing, not just small scale standard tests.

Basic Concepts for the "Highest Level of Safety"

- Fire Protection:
  - Rim seal (concurrent on every tank)
    - Rim seal fire detection with auto deployment
    - Compressed Air Foam (CAF) deployed within 2 minutes of detection
    - CAF hand lines located around top perimeter for spot application per NFPA 11 sec. 5.9
  - Full Surface Protection (concurrent on every tank)
    - IR detection of fire
    - Supplemental oversized CAF hand line foam protection per NFPA 11 sec 5.9
    - DryFoam continuous passive protection
  - Secondary Containment area (concurrent on every tank)
    - CAF deployed from fixed perimeter piping loop with fixed pourers and / or
    - DryFoam (depending on water supply or the ability of CAF to maintain suppression for evacuation)
  - Water supply to meet concurrent demands of full surface and secondary containment fires (DryFoam as appropriate where water supply is limited)
  - Hydrant spacing per NFPA 24 with large diameter outlets for back up response
  - Portable foam monitors and spares per risk assessment
- Protection at perimeter for radiant heat effects
  - Water spray or deforestation (may be mitigated with full surface and secondary containment protection)