APPENDIX 8

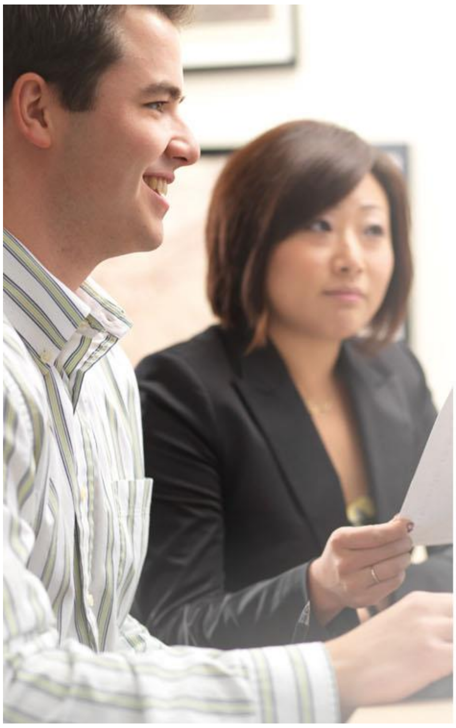
AMEC SAFETY AND ENVIRONMENTAL IMPACT EVALUATION




Fingleton White

Aviation Fuel Pipeline

Safety and Environmental Impact Evaluation



AMEC Environment & Infrastructure UK Limited

January 2015

Report for

Mary White,
Bridge Street Centre
Portlaoise
Co. Laoise
Ireland

Main Contributors

Jack Davy
David Craig
Laura Hodgson

Issued by

....
David Craig

Approved by

....
Diego Lisbona

AMEC Environment & Infrastructure UK Limited

Windsor House, Gadbrook Business Centre, Gadbrook Road,
Northwich, Cheshire CW9 7TN, United Kingdom
Tel +44 (0) 1606 354 800
Fax +44 (0) 1606 354 810

Doc Reg No. 35873 Final Report 14379i4

s:\e&i\projects\35873 rk fw dublin pipeline\d - design\final issue\superceded\35873 final report 14379i4.docx

Fingleton White

Aviation Fuel Pipeline

Safety and Environmental Impact Evaluation

AMEC Environment & Infrastructure UK Limited

January 2015

Copyright and Non-Disclosure Notice

Third-Party Disclaimer

Document Revisions

No.	Details	Date
1	Draft Report 14215i1	2/6/2014
2	Draft Report 14215i2	27/6/2014
3	Final Report 14379i1	October 2014
4	Final Report 14379i2	October 2014
5	Final Report 14379i3	November 2014
6	Final Report 14379i4	January 2015

Executive Summary

Purpose of this Report

This report describes an analysis on the safety and environmental impacts of the proposed aviation fuel pipeline from Dublin Docks to the Airport using the June 2014 design basis. The table below compares the projected and design flow cases with the use of either no or two Section Isolation valves and with the option of road tanker transport. This table summarises the failure frequencies and spill sizes.

	200mm Pipeline		**Road Tanker Transport**	
	No intermediate Section Isolation valve(s)	**Two intermediate Section Isolation valves at 4.5 and 11km**	**Projected** **1500 Ml/yr**	**Max Capacity** **2700 Ml/yr**
Total Failure Frequencies	1 in 5,130 years*	1 in 5,130 years*	1 in 57 years	1 in 32 years
Failure Frequencies (yr^{-1})	1.95×10^{-4}	1.95×10^{-4}	0.017	0.031
Average Spill Rate (litres/yr)	37	14	51.1	91.9
Maximum Spill size (litres)	278,702	103,128	38,000	38,000

* For breakdown in failure frequencies, see table below

Variances in available historical data indicate that the frequency of road tanker incidents could be up to a factor of ten higher than tabulated above which would also increase the average spill rate by a factor of ten (l/yr). This is discussed in detail in the conclusion of section 4. This would suggest that with the high number of journeys under the maximum capacity case an accident leading to a release could occur every 3 to 4 years rather than every 32 years. If a fire occurred in the port tunnel that leads to the airport it would generate smoke and toxic fumes and could easily pose a risk of asphyxiation leading to fatalities. Road transport also poses a significant risk of injury or fatality from the road traffic accident itself as well as any loss of containment events. The tabulated road tanker spill rates are derived from data for multi-compartment and single compartment tanker barrels and may be an under-estimate for the Aviation fuel which is transported in single compartment vehicles from Dublin Port to Dublin Airport.

The failure frequencies in the table above correspond to all failure modes, that is to say no distinction is made between the worst case rupture scenario and a small corrosion hole with a release rate so low as to be almost undetectable. Based upon further analysis of the EGIG data and grouping of the scenarios by three hole sizes representing 100%, 1% and 0.01% of cross sectional area, it is possible to derive probability ratios for each of these events. Almost half (49%) of previous recorded failures were in the smallest category, while a further third (36%) were in the middle category and only 15% were in the larger category of release. This is likely to be conservative as it does not account for the extra protection from third party damage which account for nearly 70% of rupture scenarios. The predicted failure frequencies for each scenario are shown in the table below.

The table above comparing the use of no or two Section Isolation valves shows a reducing Average Spill Rate as more section valves are introduced. In practice it is likely that the leak would be identified before these substantial volumes were released. The leak should be detected by the on-line monitoring but could also be identified by inspection and public observation (smell / visual). The maximum spill size of a pipeline with 2 Section Isolation Valves is less than 3 times that for a road tanker but the release frequency (all releases sizes) is approximately a factor of 90 times lower than that for a road tanker. It is therefore concluded that the optimum solution for transfer of aviation fuel is by a pipeline with two Section Isolation valves. This option has both a low likelihood of a release and also limits the potential volume released. However, in selecting an option due consideration should also be given to the consequences of a release as the assessment should be based on the environmental risk and not purely on release frequencies or volumes.

	Minor leak (Pinhole)	Major leak (hole)	Full bore rupture
Failure frequency	1 in 10,577 years	1 in 14,292 years	1 in 34,903 years

The present information is sufficient to conclude that there is a sound basis for proceeding to detailed design and construction planning for the pipeline. The frequency and size of spills have been minimised by adopting risk reduction strategies from the previous studies. The measures that need to be in place before commissioning the pipeline have been detailed above and it is normal practice for these to be developed during detailed design and construction.

The average spill rate for the pipeline is less than for road tankers. The maximum spill size of a pipeline with two Section Isolation Valves is less than three times that for a road tanker but the release frequency (all releases sizes) is lower by approximately a factor of 90. Thus pipeline transport is more attractive at the projected capacity and much more attractive at the design capacity. In summary, although the average spill size from the pipeline is higher than by tanker, the failure frequency is very much lower giving a much reduced risk.

This report together with the Environmental Impact Statement (EIS) provided fulfil the requirements of IS EN14161:2011Petroleum and natural gas industries - Pipeline transportation. Information on this is provided in Appendix C.

Contents

1. Introduction

1.1 General Introduction

Fingleton White proposes the installation of a 200 mm nominal diameter aviation fuel pipeline from Dublin Port to Dublin Airport. This report presents the safety and environmental impact evaluation of a release of fuel in terms of quantity and frequency for this proposal. The risks associated with transferring the same volume of fuel using road tankers is presented for comparison.

1.2 Purpose of Report

This report has been produced for Fingleton White as part of the planning submission for a 200 mm pipe line carrying aviation fuel from Dublin Port to Dublin Airport

1.3 Previous Work

AMEC E&I UK Limited produced previous reports for Fingleton White on the likelihood of leaks from the aviation fuel pipeline and their potential size in January 1999 (Reference 1) and a Safety and Environmental Impact Evaluation in December 1999 (Reference 2). These reports were part of Fingleton White's previous planning application for a 150mm diameter pipeline. Updated Safety and Environmental Impact reports were also produced in 2004 (13042CA001Ri0), 2007 (20736CB002) and 2011 (11037i1, January 2011 and 11532i1 in November 2011).

1.4 Organisation of the Report

The report has been organised as follows:

1.4.1 Detailed Route and Operation of the pipeline

The route and specification of the pipeline and the hazards from the medium transferred (Jet A-1 aviation fuel) are described in 2.1, 2.2 and 2.3. The relevant parts of the operating plan are discussed under the Safety Case Section 5. The details of the operating procedures can only be determined at a later stage of the project (prior to commissioning) but the recommended scope of the safety requirements for these is defined in Section 5.4.

1.4.2 Alternative use of Road Tanker Transport

The option to use Road Tankers as an alternative to operating a pipeline has been assessed. The analysis is summarised in Section 4.

1.4.3 Protective Measures

The protective measures proposed for the pipeline are described in Section 2.4 and the quantified benefits from them are reported in Section 3.

1.4.4 Safety Case

The Safety Case has been referred to in the context of UK Regulations, although the UK Pipeline Safety Regulations only require a Major Accident Prevention Document (MAPD) for pipelines carrying "Dangerous Fluids". Currently the aviation fuel pipeline is not classified as a major accident hazard pipeline under these regulations. A Safety Case will be prepared, prior to commissioning, to demonstrate that the pipeline is designed and operated to reduce risks to a suitable level. The information available at present and the intention regarding information to be prepared prior to commissioning is described in Section 5.

In order to prepare the MAPD or Safety Case it is necessary to identify the potential hazards and their effects. In the context of aviation fuel, because it is being transported by pipeline at a temperature well below its flash point, the flammability risk is likely to be extremely low. The major impacts resulting from a release are environmental. These are covered in the formal EIS.

1.4.5 Detailed Emergency Plan

Similarly the detailed emergency arrangements cannot be finalised until the detailed design stage but the types of emergency and principles of response can be developed. These are described in Section 5.6.

1.4.6 Detailed Construction Plans

The final details of the construction plans will not be available until after the detailed route investigations and design are complete. AMEC E&I has been provided previously with examples of Fingleton White's standard documents and plans regarding pipeline construction and these are reviewed in Section 6.

2. Description of the Pipeline

2.1 Route

The pipeline runs from Dublin Port to Dublin Airport (Map Figure 2.1). The route can be divided into three sections based on topography.

- The northern section of the route, from the airport to the Malahide Road (R139) approximately 500 m after the Mayne River crossing, is between 40 and 58m AOD (Above Ordnance Datum), fairly flat lying with relatively little development in the northern end of this section and residential areas in the southern end of this section. The pipeline will pass under two surface watercourses (Cuckoo Stream and Mayne River) and the M1 Motorway in this section;
- The middle section of the route, between Malahide Road (R139) and Malahide Road (R107), is the flattest of the sections starting at 40 m AOD dropping to approx 25 m AOD, however there is a great deal of undulation in this section with rises and falls of 5 m. This section mainly runs through the residential areas of north Dublin and crosses 4 watercourses (Kilbarrick Stream and the Santry, Naniken and Wad Rivers); and
- The southern section of the route follows Malahide Road R107, Copeland Avenue, Howth Road, Clontarf Road, Alfie Byrne Road before crossing the Tolka River and continuing along East Wall road to the Dublin Port terminal. This section has a fairly steep topography over the first 2.5 km (25 m AOD – 2 m AOD) and a very flat final 2 km with a change elevation of approx 3 m.

2.2 Operating Conditions and Design Parameters

Table 2.1 Pipeline Specifications

Feature	Parameter value
Governing Code:	IS EN14161:2011Petroleum and natural gas industries - Pipeline transportation
Pipeline Length	14.4 km
Pipeline Diameter (nominal)	200 mm (8 inch)
Pipe Wall Thickness	12.7 mm
Design Pressure	40 barg
Maximum Allowable Operating Pressure (MAOP)	40 barg
Depth of Cover	1.2 m (nominal)
Physical Protection	700 mm lean mix concrete
Grade of Steel	L245 or API 5L Grade B
Corrosion Coating	3 ply polyethylene

Table 2.1 (continued) Pipeline Specifications

Feature	Parameter value
Product – Substance Carried	Jet A1 Aviation Fuel (Category B Substance[1])
Isolation Valves	1 Pumping, 1 receiving (including non-return valve) and up to 2 section isolation valves.
Current Annual Throughput	573 Ml per annum
Projected Annual Throughput	1500 Ml per annum
Design Capacity	2700 Ml per annum

2.3 Pipeline Hazards

2.3.1 Aviation fuel hazards

Aviation fuel is flammable and under certain conditions when mixed with air in a confined space, or within an area of congestion due to obstacles, could give damaging overpressures if ignited. The flash point of Jet A-1 aviation fuel is above 38ºC which is significantly above the ambient temperature of the pipeline meaning that the fuel will require application of heat to ignite it. (Flashpoint is the lowest temperature at which under certain standardised conditions a liquid gives off sufficient vapour to form an ignitable air/vapour mix). If leaks migrated to underground unvented voids then there is a potential for build up of vapours and potential explosion if a strong ignition source and a heat source was also present but it is considered that these conditions will never normally occur for this pipeline. This hazard is considered in Section 3.2 but it should be noted that the pipeline is not adjacent to nor does it run across any basements.

It has a Specific Gravity between about 0.78 and 0.84 and so would float on any free water surface. Spilled fuel could cause harm to waterside flora and be detrimental to water quality.

[1] Refer to IS EN14161:2011 Table 1.

The physical and hazardous properties of Jet A-1 Fuel used in this study are given below.

Table 2.2 Physical and Hazardous Properties of Jet A1 Fuel

Property		Range	Assumed For This Study
Boiling Point	(ºC)	150 - 300	
Auto-ignition Temperature	(ºC)	>220	
Flash Point	(ºC)	> 38	
Vapour Pressure	bar	< 0.001 @ 20ºC	
Vapour Density	(Air = 1)	>5	
Flammability Limits (Vapour in Air)		LFL 1% v/v UFL 6% v/v	
Liquid Relative Density		0.78 - 0.84	0.81

Historically the main cause of pipeline leaks is third party damage, caused by excavations for other underground services or construction. In some areas on cross country pipelines deep ploughing has the potential to cause damage but this would not apply to the proposed, urban route. Corrosion has also been the cause of oil products pipeline failures even where the fluids conveyed are nominally non-corrosive and corrosion protection has been provided. The third largest category of leaks is due to mechanical failure of pipelines due to construction faults or material defects. The data on historical failures and the effects of mitigation measures are presented in section 3.1.

There are also hazards during construction due to the presence of other underground services. The installation procedure will have to recognise the other hazards of street works, including gas pipelines, electrical cables and other buried utilities, rail crossings, working over or in water, confined spaces (trenches and pits). These issues are reviewed in Section 6.

2.4 Protective Measures

2.4.1 Physical Protection

The depth of cover will be 1.2 metres. The trench will be backfilled with lean mix concrete, typically a depth of 700 mm. Marker tape will be installed in the lean mix to indicate the presence of a below ground utility / pipeline to a third party.

2.4.2 Cathodic Protection System

A cathodic protection system to the relevant standards (BS 7361-1:1991 and BS 12954:2001) will be installed to prevent external corrosion of the pipe.

2.4.3 Leak Detection

Computational Model

Leak detection measures will be provided by means of fortnightly walk surveys and by instrumentation monitoring.

Computational Model pipeline leak detection (CPM) with automatic shutdown will be installed in compliance with API Recommended Practice 1130 (2007, Reaffirmed 2012) and German TRFL ("Technische Regeln für Fernleitungen" - Technical Rules for Pipelines) which requires two different leak detection methods.

The leak detection systems will be chosen from specialist leak detection vendors with a significant installed base and proven track record on similar fuel product pipelines in Europe and particularly the UK.

Leak detection system will utilise current best available technology fiscal grade, OIML approved Coriolis 0.1% uncertainty mass flow meters at both ends of the pipeline.

The two computational h models proposed are:

Negative Pressure Wave — API Method B.5. Analysis of the pressure and flow measurements to detect negative pressure and rarefaction.

Flow/Pressure Model — API Method B.4. Analysis of flow and pressure measurements using signature recognition to detect an imbalance anomaly which would indicate a leak. Flow/Pressure model will incorporate Mass Balance, Static Pressure (shut-in), and Leak Location functions

One leak detection model will also be capable of detecting leaks during transients e.g. starting up, shutting down and changing flow conditions

The anticipated performance figures for CPM leak detection are as follows:

Table 2.3 CPM Performance

Performance Criteria	Limit
Minimum detectable leak rate under static conditions	10 litres /hr
Minimum detectable leak rate under flowing conditions	1% of flowrate
Time to confirm 1% flowing leak	10 Minutes (approximately 500 litre loss)
Response time for a 5% flowing leak	2 minutes (approximately 500 litre loss)
Response time for 10% or greater flowing leak	1 minute (approximately 500 litre loss)
Leak location accuracy	+/- 100 metres

The leak detection system will be calibrated and validated using leaks simulated by drawing off fuel at the terminals and at intermediate points along the pipeline route (isolation valve chambers).

During normal operations it has been assumed that any leaks would be within the range of Best Industry Standard, i.e. 0.2 to 0.4% of flow rate.

External Leak Detection

External leak detection will comprise a slotted duct installed in the pipeline trench with a sensing cable installed in the duct. The duct will have 0.5mm wide slots to prevent it filling with silt.

At present, there are no proven external technologies for long pipelines in urban areas. Sensing technologies which are being developed are:

- Liquid Hydrocarbon Sensing Cable;
- Fibre Optic Cable;
- Vapour Sensing Tube; and
- Acoustic Emissions.

The liquid hydrocarbon sensing cables are known to be reliable at detection but subject to false alarm if the ground is contaminated with hydrocarbons. If an alarm is detected the cable can be drawn out for inspection. It may be that periodic replacement is tolerable or more than one technology may be employed.

The open channel Tolka river crossing is identified for this protection. Other river crossings on the route are in culverts or in a concrete open channel.

Valve Chamber Leak Detection.

Valve chambers will be equipped with liquid level sensors to detect and alarm flooding and hydrocarbon sensors to detect fuel leaks.

The pipeline may be protected from excessive leakage in the event of a rupture by the use of either one or two intermediate Section Isolation Valves. These would be initiated by the software leak detection system (Automatic Emergency Shut-down) and manually e.g. as a result of the visual inspection system along the route. The use of automatic Section Isolation Valves is reviewed in this report.

2.4.4 Section Isolation Valves

In accordance with the governing code (IS EN14161)

'Section isolation valves should be installed at the beginning and end of a pipeline and where required for

- Operation and maintenance;

- Control of emergencies;
- Limiting potential spill volumes.'

In this case the 200mm (8 inch) diameter pipeline at 14.4 km long would contain about 452 m^3, or about 300 tonnes of product. The annual throughput of the pipeline is projected to be 1500Ml/year which equates to a flow rate of approximately 50 l/s.

In order to evaluate the effectiveness of section isolation valves along the route three options are considered: No valves; one valve; Two Valves. The calculated benefits of the various options are included in Appendix B.

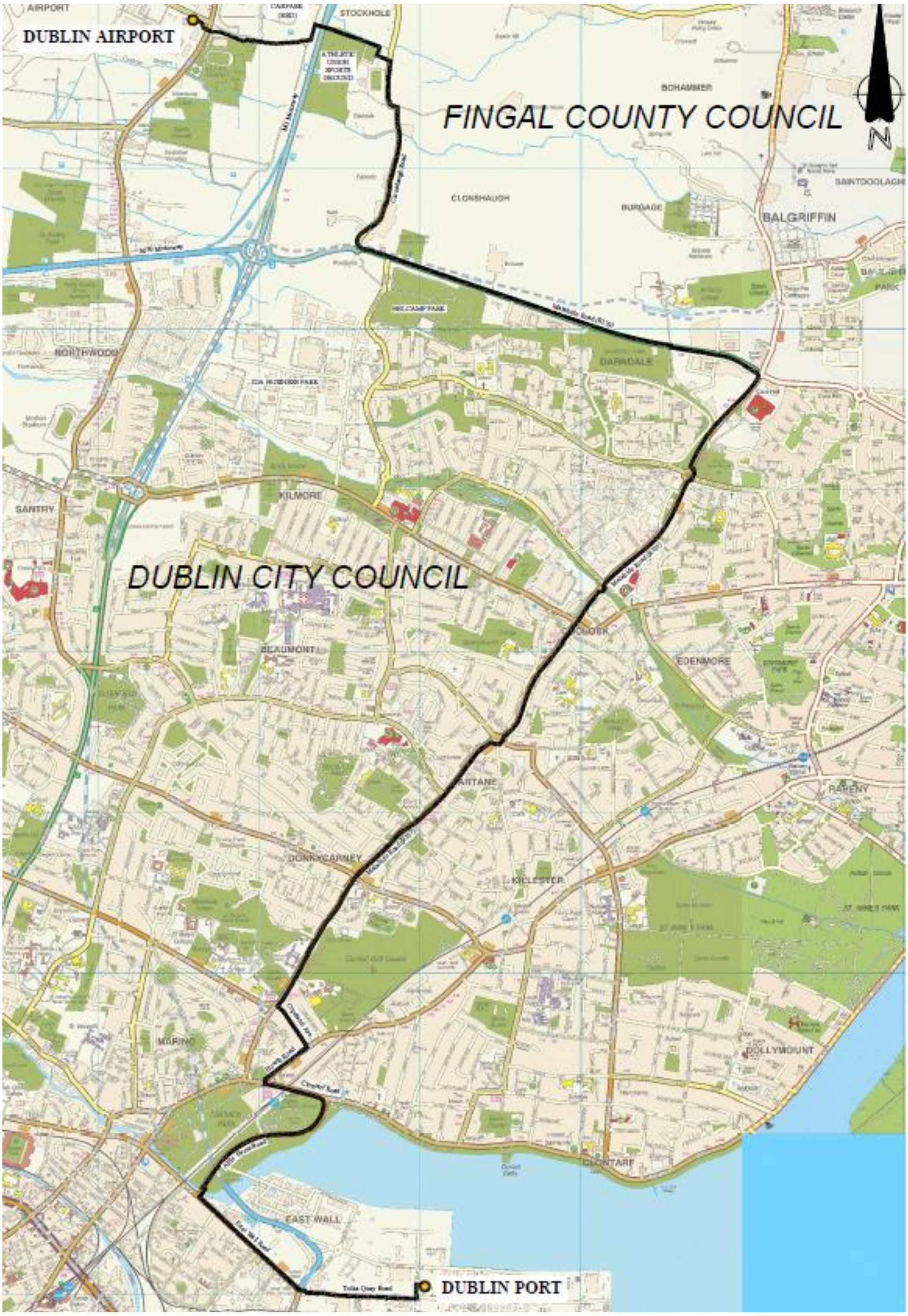
The location of these valves has to take into account, topography, ease of access and maintenance and security. Given all these considerations, the locations selected by Fingleton White are on Malahide Road (R107)about 400 m prior to the Wad river (4.5 km from Pumping Station) and again on Malahide Road (R139)approximately 500 m prior to crossing the Mayne River crossing (11 km from pumping Station). These two locations have enough space to safely accommodate the valve chamber. The pipeline ascends between the docks and the airport approximately 50m AOD, and this is spread fairly evenly over the route but the isolation valves are near the top of the two longest steep inclines and approximately splits the route into three to minimise potential release volumes.

Valves and their fittings are additional sources of potential leaks. Between each pair of Section Isolation Valves there will be provision for thermal expansion of the pipeline contents in case of temperature changes whilst the valves are closed. (As the pipe line is 1.2 m below the surface the ambient temperature will change only very slowly and the valves will rarely be closed). Thermal Relief valves will involve additional pipework and connections. There is obviously a balance between leakage from the line and leakage from additional Section Isolation Valves. A non-return valve will be installed at the Airport Terminus and will reduce the quantity lost still further, but does not affect the order of preference of the options.

2.4.5 Automatic Detection of Interference

In addition, the communications fibre optic control cable, laid on top of the pipe, will provide a means of detecting interference to the pipeline. Any disturbance to the pipeline will also break this cable which will automatically initiate an emergency shutdown of the pumps and closure of any Section Isolation Valves. This, together with the online leak detection, gives a very high reliability of detection of pipe damage and minimisation of the volume spilled.

Figure 2.1 Route Map



3. Risk Analysis

3.1 Frequency

The failure frequency analysis is based on updated failure data published by CONCAWE (2002, 2003, 2004, 2005, 2006, 2010, 2011 and now 2013 – references 3, 7 – 10, 12, 14 and 20). The highest causes of pipeline incidents by a factor of 3 is third party interference with corrosion in second place, mechanical failure third and then minor contributions from operational and natural hazards (CONCAWE, 2013).

The pipeline failure frequency data presented by CONCAWE covers the carriage of Crude Oil, Clean Products and hot oils. Aviation fuel is considered to be a clean oil product. Data has been collected from 1971 to 2012 (42 years) and covers a total of 842,366 pipeline km years. A subset of the CONCAWE data was selected to consider only pipelines carrying clean oil products and with a diameter equal to or less than 200mm. The summary of this analysis is detailed in Table 3.1. As this pipeline is continuously welded all flange failures have been excluded except those on the thermal relief. Section Isolation valves are fully welded. The only flanges present will be those which enable the thermal relief valve to bypass around the Section Isolation Valve (line nominal diameter of 25 or 50 mm) which will be at the valve stations where leaks can be contained in an impermeable area. Note that smaller diameter pipelines have thinner pipe walls and less structural resistance to interference and other damage. Therefore using the whole of this category for a 200 mm pipeline is conservative.

Table 3.1 Pipeline Failure Frequency Based on CONCAWE data (1971-2012)

Failure cause description	Diameter <=200 mm all recorded failures (# failures)	Diameter <=200 mm excl. flange failures (# failures)	Failure Frequency (km-1.yr^{-1})	Failure Frequency (14.4 km pipeline) (yr^{-1})
Mechanical Failure	34	31	3.68 X10^{-5}	5.30 X10^{-4}
Operational	4	3	3.56 X10^{-6}	5.13 X10^{-5}
Corrosion	44	43	5.10 X10^{-5}	7.35 X10^{-4}
Natural Hazard	1	1	1.19 X10^{-6}	1.71 X10^{-5}
Third Party Activity	88	88	1.04 X10^{-4}	1.50 X10^{-3}
Total	171	166	1.97 X10^{-4}	2.84 X10^{-3}

This data is conservative in that it does not take into account other specific mitigation measures such as depth of cover, pipeline wall thickness and additional protection measures for this pipeline. These are examined separately in the following sections on adjustment factors.

3.1.1 "Depth of Cover"

The CONCAWE failure data does not include information regarding depth of cover. However, the work of Jones and Gye (1991) (reference 5) has been used to consider how protective measures, e.g. depth of cover and pipe wall thickness, affect the risk of pipeline failure. They gave the variation of failure frequency at different depths of cover for 10.75" ethylene pipeline operating at 100 barg. By comparing these values, relative scaling for the variation of failure frequency with depth of cover was estimated. The original data and scale factors are detailed in Table 3.2 of Reference 2. This scale factor data was fitted with a polynomial regression to estimate other scale factors for different depth of covers as follows:

$$Scale = -0.0344\, depth^2 - 0.2789\, depth + 1.2799$$

Where: *Scale* Scale Factor (dimensionless)

Depth Depth of Cover (m)

In order to estimate the reduction of failure frequency owing to increasing depth of cover, it was assumed that a high percentage of small diameter pipelines considered in the CONCAWE data were at a standard depth of cover of 0.9 m. By applying the equation above, an estimate of the failure frequency of the pipeline for different depths of cover can be made.

3.1.2 Pipeline Wall Thickness

Jones and Gye (1991) also mention the effect of pipeline wall thickness as a method of protection. However, this is not presented in terms of failure frequencies. EGIG (2011) (reference 4) presents a breakdown of failures arising from external interference and corrosion for different pipeline wall thicknesses. The failure data is based on European natural gas transmission pipelines.

The pipe specification has a wall thickness of 12.7 mm. For this thickness the reference number for the scale factors are given in Table 3.2. (There is a considerable reduction in failure rate for pipes over 10 mm in wall thickness).

Table 3.2 Failure Frequency (per 1000 km-yrs) for 10-15mm Wall Thickness (EGIG, 2011)

Wall Thickness	10 - 15mm
External Interference (per 1000km·yrs)	0.016
Corrosion (per 1000km·yrs)	0.001
Ext Int Scale Factor	0.129
Corrosion Scale Factor	0.019

The failure frequencies have in general continued to fall or remain approximately constant over time.

3.1.3 Protection from Third Party Interference

The majority of the route (95%) will be operating in a controlled urban environment. Any road opening activities will require a road opening licence with conditions to give notice to and liaise with other utilities. It is considered that more than 90% of the time, road works will be conducted with correct licenses and in line with them.

Along the whole route, the trench will be backfilled with lean mix concrete which will provide additional protection against third party (external) interference. This lean mix will typically be 700 mm deep and contain marker tape indicating the presence of a below ground utility. It is considered that this gives a significant level of protection to the pipe from external interference especially important over the 800 m section of which is not covered by a road opening license/similar permit.

Third party interference contributes around 50% to pipeline failure (Table 3.1). It has been assumed that these two additional protection measures will eliminate 90% of failures due to third party activities. It has been argued that modern percussion drilling methods mean that the concrete no longer provides adequate protection compared to the use of hand pneumatic drill as these crane mounted drills are much more powerful and mean you can be through the concrete and pipeline before the problem is identified. These drills are, however, used in controlled environments where there is a greater reliance on safe systems of work.

It is considered conservatively that necessity of a Road Opening License and protection with concrete will protect against 90% of external interference events with potential to damage the pipeline.

It can be seen that they reduce the total frequency of failure by approximately 45%, reducing the frequency of failure for this pipeline from 3.50 $x10^{-4}$ to 1.95 $x10^{-4}$ per year but they have no impact on the size of the resultant spill.

3.1.4 Additional Protection Measures

Other means of preventing failures of the pipeline are inspection and initial testing. Assuming that the entire pipeline will be inspected and pressure tested when installed, 80% of failures due to material defects have been excluded from the final failure frequencies presented. In addition cathodic protection, installed along the pipeline, allow 90% of the failures due to corrosion to be excluded.

Details of failure frequencies calculated are contained in Table 3.3. A set of calculations, which changed variables depth of protection; corrosion protection; installation inspection; external interference and wall thickness), are provided in Appendix A. This data is for reference.

Data from EGIG (reference 4) has been used to distribute the pipeline failure frequency into hole size giving the following results:

Table 3.3 Failure Frequency with hole size

	Pinhole	Hole	Rupture	
Split (ratio)	0.489	0.362	0.148	
Failure rate	1 in 10,577 years	1 in 14,292 years	1 in 34,903 years	for a 14.4 km pipeline

3.1.5 Valve and Flange Failure Frequencies

The special design of valves and flanges (Ring Type Joints – RTJ) to be adopted should result in reduced leak rates and frequencies from these points. It has been assumed that the special flanges and gaskets will eliminate the major leak scenario i.e. 10% cross section equivalent area (CSA) and reduce the minor leaks i.e. 1% CSA by 90%. The assumed frequencies are thus:

Table 3.4 Additional Failure Frequencies (leaks per year)

	Valve	Flange	Thermal Relief
Major Leak	0	0	$4.10 X10^{-5}$
Minor Leak	6.50×10^{-5}	5.00×10^{-6}	3.63×10^{-4}

However, in calculating the release volumes (Appendix B) these leaks have been ignored. The pipeline is fully welded with the exception of 3 flanges on the small (25mm or more likely 50mm) thermal relief line around the section isolation valves. If a leak occurred at these flanges it would be slow and contained in the valve chamber. The leak should be detected by the on-line monitoring but could also be identified by inspection, public observation (smell / visual) or it would be picked up rapidly by the detection system in the valve chamber. The line would then be drained down before a significant release outside the valve chamber could occur. Any release into the valve chamber is into a contained area with no significant environmental impact – the chamber itself has sealed walls and floor. Hence, it should be excluded from the volumes calculated in Appendix B. This argument applies to minor section isolation valve leaks (e.g. via the valve spindle) and any leaks on the thermal relief valve.

It should be noted that the release from a 50mm RTJ (1mm hole) at 5 bar is 0.01 kg/s (0.008 l/s) (reference 17). The detailed design of the valve chamber has not been undertaken at this point in the project, but they are anticipated to be around 3.15m^3 in volume. It is thus likely to take around 100 hours to fill up the valve chamber. It is highly likely that this will be identified before the leak becomes more substantial especially if automatic leak detection is installed in each chamber.

3.1.6 Total Pipeline Failure Frequencies

The frequency data above have been used to calculate the frequencies for the complete pipeline (Table 3.5 below). This includes all major and minor leaks from valves, flanges and thermal relief.

Table 3.5 Failure Frequencies for Complete Pipeline

Pipe Failure Frequency (yr^{-1})	Total Valve, Flange and Thermal Relief Failure Frequencies (yr^{-1})	Total Failure Frequency for Complete 14.4km Pipeline (yr^{-1})
1.95×10^{-4}	5.64×10^{-4}	7.59×10^{-4}

Note that in Appendix B only pipeline releases are considered – valve, thermal relief and flanges releases are into the valve chamber and so are controlled. In Appendix B only the pipe failure frequency is relevant.

3.2 Consequences

Initial flow rates from leaks in the pipeline have been calculated for a 40 barg maximum operating pressure. Using the 40 barg pressure in the release calculation in Appendix B gives the worst case release rates and so demonstrates the benefits of the pipeline even under worst case conditions. The table below provides release rates at various pressures. Once the leak has been detected, the pumps and all Section Isolation Valves close and hence the outflow will be driven by gravity, at a lower rate. The rate of release will depend on the pressure in the pipe, while the volume depends on the location of the release in relation to any Section Isolation Valves (as discussed in Appendix B). The release rate will be determined by the head (i.e. height) of liquid. For simplicity it is assumed that outflows in the 0 – 4.5km section have backflow driven by 4.2 bar; 4.5 - 11km by 2.7 bar, and km 11 - 14.4 by 1.5 bar (as liquid head above release reduces). The range of release rates is tabulated below.

Table 3.6 Variation of Pipeline Leak Rate (l/s) with Pressure

Pressure	40barg (MAOP)	25 barg	5 barg	4.2 barg	2.7 barg	1.5 barg
Pipeline diameter (mm)	200 (8 inch)	200 (8 inch)	200 (8 inch)	200 (8 inch)	200 (8 inch)	200 (8 inch)
Failure Size						
Full Bore Rupture	1851	1463	654	607	486	358
Major Leak (10% CSA)	185	146	65	61	49	36
Minor Leak (1% CSA)	19	15	7	6	5	4

MAOP is Maximum Allowable Operating Pressure

The leak volumes presented in Appendix B do not use the figures above –a conservative simplifying assumption is made that all the material above a leak will at some point come out the pipeline. The figures above could be used to estimate how long it would take for the leak to occur. However, this calculation has not been undertaken as it gives no real added benefit. In practice it is likely that the leak would be identified by the supervisory systems before substantial volumes were released.

A potential hazard could arise if a leak found a pathway to an underground void or basement where vapour could accumulate and form a flammable atmosphere. However, the flash point of Jet A1 aviation fuel, above 38ºC, is well above ambient temperatures, therefore it is extremely unlikely that an explosive atmosphere of aviation fuel vapour may accumulate in a basement. Ignition of the vapour would require both heating and an ignition source. The pipeline is not adjacent to nor does it run across any basements.

4. Comparison with Road Tankers

4.1 Introduction

This section of the report assesses the risk of transporting fuel from Dublin Port to Dublin Airport via Road Tanker in comparison to a Pipeline. The figures compare the latest pipeline design basis and the new road route from the port to airport using the port tunnel (see Fig 2.1). The pipeline failure frequencies and the latest road traffic statistics have been reviewed and included in this report.

Since the previous planning application the port tunnel has come into operation. The accident frequency data for the tunnel is assumed to be the same as for the open road (ref 13, 23.26). However, although the material is transported below its flash point, there could be a fire in event of an accident caused by an ignition or heat source generated during the incident. Any fire in the confined space of the tunnel would generate smoke and toxic fumes and could easily pose a risk of asphyxiation leading to fatalities. As a result, the impacts of a fire in the tunnel are potentially more severe than that on the open road. In addition to the risk from the loss of material which is quantified below, there is the additional risk of injuries and fatalities from road traffic accidents. Although this is a risk accepted by all road users on a daily basis, it may nevertheless be a higher risk than that posed by the pipeline. This risk is obviously avoided by use of a pipeline.

4.2 Road Tanker Failure Frequency

The UK Health and Safety Commission (HSC, 1991) (Reference 11) investigated the risks of transporting dangerous substances by road as part of a study, specifically the transport of non-explosive hazardous materials such as motor spirits, chlorine, ammonia and LPG. The representative tanker capacity for motor spirits was 20-25 tonnes.

Causes for tanker failure considered in the study include puncture or tanker damage from collision or rollover and failure or mal-operation of tanker equipment. The frequency and size of spills are based on 25 motor spirit incidents over 4 years, 1.3 million journeys per year, details of these incidents are contained in Reference 11 (or Appendix B of reference 1). Therefore, 25 failures out of 5.2 million journeys, i.e. 4.8×10^{-6} failures per journey. Given the projected airport demand of 1500 Ml per annum, or 39,500 loaded tanker journeys per annum (tankers carry 38,000 litres), the failure frequency of a road tanker is 0.19 per year.

The data on motor spirit accidents can be analysed further to examine spill size and distance travelled rather than journeys made (reference 13, 23.6.6):

Table 4.1 Spill Frequency Values for Each Size (per Tanker·km)

15 kg < Spill < 150 kg	150 kg < Spill < 1500 kg	Spill > 1500 kg
1.9×10^{-8}	1.4×10^{-8}	0.24×10^{-8}

It should be noted that the above statistical analysis was conducted on data from both multi product tankers and single product tankers. Multi product tankers have up to six individual compartments per tanker whereas single product tankers such as the aviation tankers used in Dublin have one single compartment. Had the data related exclusively to single compartment tankers it is likely that the released volumes would have been higher due to less containment but as the failure mechanisms (e.g. puncture, crack on barrel, equipment failure etc) would remain the same the data would not change dramatically. Use of this data in the calculation is conservative.

The maximum potential leak size from the single compartment tankers used for the transport of aviation fuel is the full tanker volume of 38,000 litres.

Using this data then gives (assuming conservative values for the spill volume):

Table 4.2 Releases of various sizes per Tanker Distance Travelled (1500Ml/yr)

Spill Size (kg)	150	1500	25000	Total
Spill frequency (/km)	1.95×10^{-8}	1.40×10^{-8}	2.40×10^{-9}	
Number spills / year	0.009	0.007	0.001	0.017
Spill Volume (kg) /year	1.41	10.37	29.63	41.4
Spill Volume (l) /year				**51.1**

Number of Journeys	39,500	per year	Average spill size (kg)	2400
Distance travelled	12.5	km (When vehicle full of product)	Average spill size (l)	2950

The number of spills per year using this data is only 0.017 compared to 0.19 when using the data on the number of journeys. Reference 13 (Table 23.36) gives a release frequency for Urban multi-lane (divided) roads in the US (1992 report) of 0.48×10^{-6} /km (0.77×10^{-6} / mile) which in this case gives an annual frequency of 0.238 per year suggesting that the 0.017 figure is low by a factor of ten. This demonstrates the range of values for the same parameter, depending on the source data (with in turn depends on the different sources of raw data, how they have been analysed, assumptions made and ultimately how the results are presented).

The data used in the HSC study is based on information from 87 haulage companies in the United Kingdom. The Road Safety Authority in Ireland reported that, based on 2012 statistics the rate of road deaths in Ireland is 3.7 per 100,000 population (reference 6 and 19) whilst that in the UK is 2.8 per 100,000 population (references 15 and 16). This would suggest that, in general, a serious road transport accident is slightly more likely in Ireland and that the failure frequency rates could be adjusted upwards. However, the tanker route is essentially motorway. The data for Ireland demonstrates that a disproportionate number of fatal accidents occur on rural roads (>70%) and this results in evaluated figures. As a result the UK data has been used without any adjustment as this is likely to represent the route from the port to the airport.

At the Design capacity of 2700Ml/yr the number of full tanker journeys would increase to 71,000 per year giving the following results:

Table 4.3 Releases of various sizes per Tanker Distance Travelled (2700Ml/yr)

Spill Size (kg)	150	1500	25000	Total
Spill frequency (/km)	1.95×10^{-8}	1.40×10^{-8}	2.40×10^{-9}	
Number spills / year	0.017	0.012	0.002	0.031
Spill volume (kg) /year	2.53	18.64	53.25	74.4
Spill volume (l) /year				**91.9**

Number of Journeys	71,000	per year	Average spill size (kg)	2400
Distance travelled	12.5	km (When vehicle full of product)	Average spill size (l)	2950

The comparison with the pipe line is summarised below:

Table 4.4 Road Traffic Pipeline Comparison - Average Spill Size and Spill Rate for the Pipeline and Road Transport

	Pipeline (2 Section Isolation Valves)	Irish Road Transport	
Pipeline Diameter (mm)*	200 (8 inch)		
Wall Thickness (mm)*	12.7		
Depth of Cover (m)*	1.2		
Pipeline Pressure (barg)*	40 (MAOP)		
Projected Throughput (Ml per year)	1500 / 2700	1500	2700
Average Spill Size (m^3)	74.8	2.950	2.950
Failure Frequency (yr^{-1})**	1.95×10^{-4}	0.017	0.031
Average Spill Rate ($m^3\ yr^{-1}$)	0.014	0.051	0.092
Maximum Spill size (m^3)	103.1	38.0	38.0

The spill frequency and release values for the pipeline are unchanged with the increase in flow rate.

The transport failure frequency could be under-estimated by as much as a factor of ten (which would also increase the average spill rate by a factor of ten). The average spill rate for the pipeline is less than for road tankers. The maximum spill size of a pipeline with two Section Isolation Valves is less than three times that for a road tanker but the release frequency (all releases sizes) is lower by approximately a factor of 90. Thus pipeline transport is more attractive at the projected capacity and much more attractive at the design capacity. In summary, although the average spill size from the pipeline is higher than by tanker, the failure frequency is very much lower giving a much reduced risk.

5. Safety Case

5.1 Development of a Safety Case (Safety Evaluation)

It is understood that there are no relevant regulations in Ireland that require a pipeline safety case but consideration should be given to following the requirements of the UK Pipeline Safety Regulations. These require the preparation of a Major Accident Prevention Document (MAPD) for Pipelines which are classified as Major Accident Hazards. However this pipeline would not fall into this category as the vapour pressure of kerosene (Aviation Fuel) is less than 1.5 barg at 20 ºC, so it is not classified as a Dangerous Fluid.

It is important to recognise that, although there should be a safety management system in place to cover the whole life cycle of the pipeline, from design to decommissioning the details of future arrangements cannot be specified in detail at the outset. As stated in the guidance to the UK Pipeline Safety regulations: "It is recognised that, for example, at the concept design stage it may not be practicable to describe future management procedures for controlling risks to people during the operation of the pipeline".

5.2 Safety in Design

5.2.1 General Design considerations

The pipeline will be designed, constructed, tested, commissioned and operated in accordance with IS EN14161:2011Petroleum and natural gas industries - Pipeline transportation. These requirements have been compared to this report and the EIS and a summary of the results provided in Appendix C.

It must be ensured that the pipeline is designed to take account of its operation regime, the conditions under which the aviation fuel is to be conveyed and the pipeline environment.

Therefore the pipeline will have to be designed so that it is safe within the range of operating conditions. The design and maximum operating pressures for the pipeline is 40 barg. The aviation fuel will be transported at ambient temperature.

The nature of the aviation fuel such as its abrasive and chemical effects on the materials of construction for the pipeline should be taken into consideration. Furthermore, the pipeline will need to be compatible with the physical as well as chemical actions of the pipeline environment. The potential for ground movements will have to be taken into account during the detailed design, but this is expected to be extremely small. Ground movement and vibration should not be a sensitive issue for straight run pipe with no fittings. There will be considerable tolerance to movement, enhanced by laying the pipe in sand. Steel pipe particularly at the 12.7 mm wall thickness can also tolerate considerable unsupported free spans.

Mechanical failures of pipelines occur when stresses in the system exceed allowable limits. Hence, the pipeline design will need to take into account the foreseeable thermal and mechanical stresses and strains to which the pipeline may be subjected to during its operation as well as the forces that arising during its construction.

The pipeline design and its routing take into consideration the flammable properties of the aviation fuel. The routing is given in section 2.1 and the hazards of the fuel are presented in Section 2.3. The proposed protective measures for the pipeline have already been outlined in Sections 2.4. In addition the need to facilitate examination and maintenance of the pipeline has been accounted for in the design for the pipeline by providing suitable access at the required locations. Requirements for suitable and safe access for in-service inspections have also been considered in the design with the provision for pig traps at the pumping and receiving stations. .

5.3 Safety in Construction

It needs to be ensured that the pipeline is fabricated, constructed and installed in accordance with its design. Design considerations such as the location of the pipeline, the depth of cover and additional protection measures at vulnerable locations should be followed during its installation. This should cover the procurement process, auditing, certification and keeping of records.

There are a number of different pipeline construction techniques and it will be necessary to make sure that they are appropriate for the routing and ground conditions. Because of the frequency of existing services along the pipeline route, an “open cut” method will be used to construct most of the proposed aviation fuel pipeline. Safe operating procedures will therefore have to be developed for all the construction and installation activities and these have been described in Section 6.0.

The pipeline’s fitness for purpose will have to be proved before it comes into operation. Pressure testing; for instance, can be done by introducing a fluid, normally water, during the pre-commissioning programme. Other activities that would be carried out before the pipeline is brought into use would include, for instance, flushing or cleaning.

There needs to be a safety management system in place for the pipeline design and construction for its safe operation and use. This should cover, for example, the criteria for selection of contractors and the procedures for ensuring that the pipeline has been properly designed and constructed.

5.4 Normal Operating Procedures

The aviation fuel pipeline will have to be operated and controlled within its safe operating limits if it is to be operated in a safe manner. For instance, its design pressure is 40 barg and the maximum operating pressure is 40 barg. However, the pipeline will be proof tested to 1.5 times its design pressure i.e. 60 barg well beyond its maximum allowable operating pressure to ensure its integrity. The design velocity is 2.9 m/s which is within the allowable range (minimum and maximum velocities are 1 and 3 m/s respectively).

The majority of underground pipeline failures occur from third party excavations. Therefore such activities will have to be closely controlled and detailed plans of the pipeline routing made available so that the risk of such incidents is minimised. Appropriate pipeline markings should be provided.

5.5 Inspection, Monitoring and Leak Detection

As stated above, the detailed pipeline design should consider the requirements for suitable and safe access and operation for in-service inspections. Inspection of the pipeline should be undertaken such that the pipeline's fitness for purpose is not adversely affected.

On-line inspection of the pipeline will be achieved by "pigging". This is a non-destructive method of detecting defects in the metal wall of the pipeline. The "pig" (pipeline inspection gadget) will be conveyed through the pipeline, propelled by the fuel, continually monitoring the condition of the wall. The most common defect that the pigging operation should identify is corrosion, but mechanical damage and material defects can also be identified. The information received can then be used to make judgements on intervals between further inspections, what should be covered and how.

There are essentially two main categories for leak detection. Visual inspection would rely on the presence of the aviation fuel in the surrounding ground or in a watercourse. This information could be obtained from routine surveillance or indeed from members of the public. The second category involves the use of technology. In the UK, for instance, pipeline Safety Notices have required the application of SCADA system based leak detection for a number of years. There are a number of techniques available for monitoring a pipeline condition in this way and it will be necessary to assess the relevance of those that are available for the aviation fuel pipeline. One such example is Pressure Point Analysis which can detect small leaks and, in suitable configurations can identify the location of the leak. (This is extremely useful for providing rapid emergency repair to small leaks).

This has been covered in section 2.4.

5.6 Emergency Procedures

The Pipeline Safety Regulations in the UK require a local authority to prepare emergency plans for pipelines that have the potential to cause a major accident while the pipeline operator should establish emergency procedures. Whilst it is recognised that the operator is unlikely to be in a position to have fully developed their emergency procedures at design stage, this section does put forward the principles of emergency response that need to be considered and adopted where necessary. It is therefore essential that there is close co-operation between the pipeline operator and local authority in drawing up an emergency plan.

Firstly, it must be understood that the risk of a pipeline failure can be reduced, but can never be eliminated. The analysis of hazards associated with the pipeline has been addressed in Section 3.0 and includes an analysis of the failure frequencies. This information, together with assessment of environmental impacts (in the EIS) should be used in formulating the emergency procedures in order to ensure that it is appropriate for the breadth and magnitude of potential emergencies that could arise.

An emergency plan will be developed to provide an additional safeguard so that in the unlikely event of a major accident involving a loss of containment from the pipeline, the impact on the public's health and safety as well as the environment is minimised.

The objectives of the emergency plan are that it has a straightforward and clear structure so that everyone concerned understands the principles of its operation. They also include identification of measures to contain the effects of the emergency and to ensure that the management system clearly sets out the organisation, roles and responsibilities and arrangements to be established. Good communication between the pipeline operator and emergency services is essential for the plan to be effective.

The risks and consequences and methods for dealing with the pipeline failure will vary along its length. For example, the most significant environmental impact has been identified to arise from an aviation fuel leak at a river crossing and leakage prevention measures should therefore be given priority at these crossings. Management of an emergency in built up areas would involve traffic control to keep people away from the area and to prevent them from congregating at the scene thereby putting themselves at risk. Hence the plan needs to be sufficiently flexible to provide emergency response at any location along the pipeline route and at any time.

In principle, the emergency plan should be developed to respond to credible pipeline failures, but be flexible enough to take into account other more severe events that may be considered as being extremely unlikely. Therefore the emergency plan may include provision for the evacuation of a considerable number of people.

The emergency plan for a major accident hazard of the aviation fuel pipeline should incorporate responses such as control of the emergency location and an assessment of the actual and potential consequences of the emergency. The procedures and means of alerting the relevant authorities, organisations and the general public should be included in the plan together with measures for minimising the impact of the pipeline failure and restoring to normal conditions.

In the UK, the Pipeline Safety Regulations require pipeline operators to carry out an emergency exercise to test their emergency procedures or sections of them and may involve the local emergency services. As stated previously, communication is one of the most important elements of the emergency procedures and plans and so it is important to check on the lines of communication to ensure that they are kept up to date.

Minor leaks may be repaired by a specialist team using, for example, pipeline clamps. This would avoid the contents of an entire section of pipeline being released. Arrangements for call-out of the team and stocks / mobilisation of specialist equipment need to be planned.

6. Construction

6.1 Construction Management Plan

The construction method has been outlined in the Construction Management Plan. This has described suitable methods of trench excavation and noted the hazards from existing services and trench collapse. Appropriate methods such as hand excavation in the vicinity of other services and trench supports have been defined. The pipeline will be subjected to rigorous inspection before installation in the trench including 100% radiography of welds and Holiday Testing of the pipe coating. A minimum length of the trench will be left exposed at the end of each days working. The hazards of street works in high density traffic have been identified and provision made for working outside the peak traffic hours at busy sections (with suitable environmental constraints to minimise disturbance).

6.2 Health & Safety Plans for Construction

The detailed plan for this project will need to address the method of working in congested streets, with high traffic density and in close proximity to the public. Particular hazards from working in or over water, near gas and electrical services have already been recorded.

The plan will need to identify and define the precautions for machinery, plant and vehicle storage, maintenance and refuelling areas. These should be on impermeable surfaces with kerbs and drains to collect any contaminated run-off and allow it to be disposed of safely. Similarly any contaminated solid material will require a storage area, where it can be contained (packaged if necessary) before transport to suitable disposal facilities.

Commissioning of the pipeline will require special materials and equipment. These should be kept within a safe area. Again this should be impermeable with facilities for capturing any spills.

It is normal that these details have not been completely specified at this stage of a project but it would normally form part of the final stages of detailed design or confirmation of arrangements by the successful Contractor. Detailed risk assessments for construction work would be developed that systematically identified the risks involved and how they would be managed.

7. Conclusions

A comparison of the various options is tabulated below.

	200mm Pipeline			Road Tanker Transport	
	No intermediate Section Isolation valve(s)	**Single intermediate Section Isolation valve at 4.5km or 11km**	**Two intermediate Section Isolation valves at 4.5 and 11km**	**Projected Design 1500 Ml/yr**	**Max Capacity 2700 Ml/yr**
Failure Frequencies	1 in 5,130 years	1 in 5,130 years	1 in 5,130 years	1 in 57 years	1 in 32 years
Failure Frequencies (yr^{-1})	1.95×10^{-4}	1.95×10^{-4}	1.95×10^{-4}	0.017	0.031
Average Spill Rate (litres/yr)	37	25 / 27	14	51.1	91.9
Average spill size (litres)	193,524	128,778 / 138,834	74,795	2,950	2,950
Maximum Spill size (litres)	278,702	276,426	103,128	38,000	38,000

Variances in available historical data indicate that the frequency of road tanker incidents could be up to a factor of ten higher than tabulated above which would also increase the average spill rate by a factor of ten (l/yr). This is discussed in detail in the conclusion of section 4. This would suggest that with the high number of journeys under the Design case an accident leading to a release could occur every 3 to 4 years rather than every 32 years. If a fire occurred in the port tunnel that leads to the airport it would generate smoke and toxic fumes and could easily pose a risk of asphyxiation leading to fatalities. Road transport also poses a significant risk of injury or fatality from the road traffic accident itself as well as any loss of containment events. The tabulated road tanker spill rates are derived from data for multi compartment and single compartment tanker barrels and may be an under-estimate for the Aviation fuel which is transported in single compartment vehicles.

The table above shows that the use of no, one or two Section Isolation valves give a reducing Average Spill Rate as more section valves are introduced. Releases from the section valves, flanges and thermal relief valve do not significantly contribute to the spill rate and maximum spill size and are excluded. The leak could be identified by online leak detection; inspection, public observation (smell / visual) or it could be picked up rapidly if some form of spill detection was present in the valve chamber. The maximum spill size of a pipeline with 2 Section Isolation Valves is less than 3 times that for a road tanker but the release frequency (all releases sizes) is approximately a factor of 90 times lower. It is therefore concluded that the best option is the use of two Section Isolation valves which have both a low likelihood and also limit the volume released. However, in selecting an option due consideration should also be given to the consequences of a release as the assessment should be based on the environmental risk and not purely on release frequencies or volumes.

The present information is sufficient to conclude that there is a sound basis for proceeding to detailed design and construction planning. The frequency and size of spills have been minimised by adopting risk reduction strategies from the previous studies. The measures that need to be in place before commissioning the pipeline have been detailed above and it is normal practice for these to be developed during detailed design and construction.

This report together with the Environmental Impact Statement (EIS) provided fulfil the requirements of IS EN14161:2011Petroleum and natural gas industries - Pipeline transportation. Information on this is provided in Appendix C.

8. References

1. Entec 1999, Report L7045 D99029, "Safety evaluation of an aviation fuel pipeline versus road haulage, Dublin", January 1999.

2. Entec 1999, Reference: 02723 Final Report: "Aviation Fuel Pipeline - Safety & Environmental Impact Evaluation", December 1999.

3. CONCAWE (2002); "Western European Cross-Country Oil Pipelines, 30-year Performance Statistics", report no 1/02.

4. EGIG (2011); "8th EGIG Report 1970-2010 Gas Pipeline Incidents", report EGIG 11.R.0402.

5. Jones, D.A. and T. Gye (1991); "Pipelines Protection - How protective measures can influence a risk assessment of pipelines", *Pipe Protection Conference*, Cannes, 23 - 25 September.

6. Road Safety Authority, Ireland, "Road Collision Facts 2012".

7. CONCAWE (2003); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages - 2001", report no 1/03.

8. CONCAWE (2004); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages - 2002", report no 7/04.

9. CONCAWE (2005); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages - 2003", report no 3/05.

10. CONCAWE (2006); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages - 2004", report no 3/06.

11. HSC (1991); Major Hazard Aspects of the Transport of Dangerous Substances, Reports and Appendices, HSC, HMSO, London.

12. CONCAWE (2010); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages in 2008 and since 1971", report no 4/10.

13. Lees (2012); "Loss Prevention in the Process Industries", Chapter 23 Transport; Fourth Edition.

14. CONCAWE (2011); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages in 2009 and since 1971", report no 3/11.

15. UK Office of National Statistics, Annual Mid-year Population Estimates, 2011 and 2012: United Kingdom.

16. Reported Road Casualties in Great Britain: Main Results 2012 Statistical Release, Department for Transport, 27 June 2013.

17. Institute of Petroleum, Area Classification Code, IP 15, 2005. Tables C6 and C9(a).

18. IS EN14161:2011Petroleum and natural gas industries - Pipeline transportation.

19. CSO - Central Statistics Office, Population and Migration Estimates, Population and Migration Estimates April 2013, 2013.

20. CONCAWE (2013); "Performance of European Cross Country Oil Pipelines: Statistical Summary of Reported Spillages in 2012 and since 1971", report no 12/13.

9. Drawings

Fingleton White Limited Drawing list.

1. 0362-D-07-C-0002-Rev0 (Port Tunnel) 100614
2. 0362-D-07-C-0006-Rev0 (M1 Motorway) 160614
3. 0362-D-10-G-0001-Rev0 (Recommended Route – Ground Profile) 220414
4. 0362-D-07-C-0005- Rev0 (Cuckoo Stream) 160614
5. 0362-D-07-C-0003-Rev0 (Santry River) 160614
6. 0362-D-07-C-0004-Rev0 (Mayne River) 160614
7. 0362-D-01-G-0001-R0 (Pipeline Route) 100614
8. 0362-D-07-C-0001-R0 (Tolka River) 160614
9. 0362-D-12-E-0007-R0 (Dublin Port Seveso Sites) 120614

Appendix A
Pipeline Failure Frequencies

Table A1 Failure Frequency Reduction from Additional Protection, assuming an 80% reduction in material faults

Description	Depth of Cover (m)	Inspection during construction	External Interference (Factor)	Corrosion (Factor)	Thin Wall Thickness (0 - 5 mm)					
					Third Party Interference	Corrosion (Ext. and Int.)	Mechanical Failure	Operational	Natural Hazard	Total 14.4 km pipeline (yr-1)
Basic CONCAWE Data (excluding flange failures)	0.9	10%	100%	100%	5.70E-03	1.72E-03	5.30E-04	5.13E-05	1.71E-05	8.02E-03
Basic CONCAWE, 80% material defects excluded	0.9	100%	100%	100%	5.70E-03	1.72E-03	1.06E-04	5.13E-05	1.71E-05	7.59E-03
standard depth, 100% inspection, no external protection	0.9	100%	100%	100%	5.70E-03	1.72E-03	1.06E-04	5.13E-05	1.71E-05	7.59E-03
standard depth, 100% inspection, with external protection	0.9	100%	10%	100%	5.70E-04	1.72E-03	1.06E-04	5.13E-05	1.71E-05	2.47E-03
1.2m cover, 100% inspection, no external protection	1.2	100%	100%	100%	5.10E-03	1.72E-03	1.06E-04	5.13E-05	1.71E-05	7.00E-03
1.2m cover, 100% inspection, with external protection	1.2	100%	10%	100%	5.10E-04	1.72E-03	1.06E-04	5.13E-05	1.71E-05	2.41E-03
red. corr, standard depth, 100% inspection, no external protection	0.9	100%	100%	10%	5.70E-03	1.72E-04	1.06E-04	5.13E-05	1.71E-05	6.04E-03
red. corr, standard depth, 100% inspection, with external protection	0.9	100%	10%	10%	5.70E-04	1.72E-04	1.06E-04	5.13E-05	1.71E-05	9.16E-04
red. corr, 1.2m cover, 100% inspection, no external protection	1.2	100%	100%	10%	5.10E-03	1.72E-04	1.06E-04	5.13E-05	1.71E-05	5.44E-03
red. corr, 1.2m cover, 100% inspection, with external protection	1.2	100%	10%	10%	5.10E-04	1.72E-04	1.06E-04	5.13E-05	1.71E-05	8.56E-04

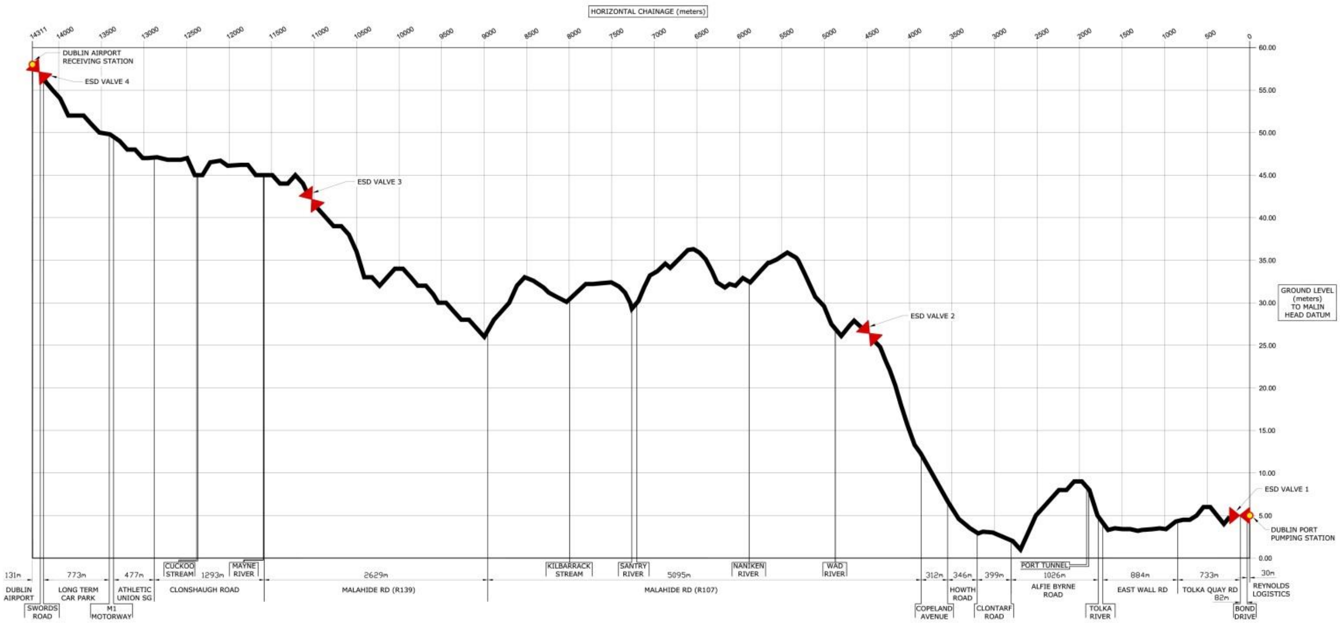
Description	Depth of Cover (m)	Inspection during construction	External Interference (Factor)	Corrosion (Factor)	Thin Wall Thickness (0 - 5 mm)					
					Third Party Interference	Corrosion (Ext. and Int.)	Mechanical Failure	Operational	Natural Hazard	Total 14.4 km pipeline (yr-1)
Basic CONCAWE Data (excluding flange failures)	0.9	10%	100%	100%	1.51E-03	7.35E-04	5.30E-04	5.13E-05	1.71E-05	2.84E-03
Basic CONCAWE, 80% material defects excluded	0.9	100%	100%	100%	1.51E-03	7.35E-04	1.06E-04	5.13E-05	1.71E-05	2.42E-03
standard depth, 100% inspection, no external protection	0.9	100%	100%	100%	1.51E-03	7.35E-04	1.06E-04	5.13E-05	1.71E-05	2.42E-03
standard depth, 100% inspection, with external protection	0.9	100%	10%	100%	1.51E-04	7.35E-04	1.06E-04	5.13E-05	1.71E-05	1.06E-03
1.2m cover, 100% inspection, no external protection	1.2	100%	100%	100%	1.35E-03	7.35E-04	1.06E-04	5.13E-05	1.71E-05	2.26E-03
1.2m cover, 100% inspection, with external protection	1.2	100%	10%	100%	1.35E-04	7.35E-04	1.06E-04	5.13E-05	1.71E-05	1.04E-03
red. corr, standard depth, 100% inspection, no external protection	0.9	100%	100%	10%	1.51E-03	7.35E-05	1.06E-04	5.13E-05	1.71E-05	1.75E-03
red. corr, standard depth, 100% inspection, with external protection	0.9	100%	10%	10%	1.51E-04	7.35E-05	1.06E-04	5.13E-05	1.71E-05	3.98E-04
red. corr, 1.2m cover, 100% inspection, no external protection	1.2	100%	100%	10%	1.35E-03	7.35E-05	1.06E-04	5.13E-05	1.71E-05	1.60E-03
red. corr, 1.2m cover, 100% inspection, with external protection	1.2	100%	10%	10%	1.35E-04	7.35E-05	1.06E-04	5.13E-05	1.71E-05	3.83E-04

Description	Depth of Cover (m)	Inspection during construction	External Interference (Factor)	Corrosion (Factor)	Thick Wall Thickness (10 - 15 mm)					
					Third Party Interference	Corrosion (Ext. and Int.)	Mechanical Failure	Operational	Natural Hazard	Total 14.4 km pipeline (yr-1)
Basic CONCAWE Data (excluding flange failures)	0.9	10%	100%	100%	1.94E-04	1.41E-05	5.30E-04	5.13E-05	1.71E-05	8.07E-04
Basic CONCAWE, 80% material defects excluded	0.9	100%	100%	100%	1.94E-04	1.41E-05	1.06E-04	5.13E-05	1.71E-05	3.83E-04
standard depth, 100% inspection, no external protection	0.9	100%	100%	100%	1.94E-04	1.41E-05	1.06E-04	5.13E-05	1.71E-05	3.83E-04
standard depth, 100% inspection, with external protection	0.9	100%	10%	100%	1.94E-05	1.41E-05	1.06E-04	5.13E-05	1.71E-05	2.08E-04
1.2m cover, 100% inspection, no external protection	1.2	100%	100%	100%	1.74E-04	1.41E-05	1.06E-04	5.13E-05	1.71E-05	3.62E-04
1.2m cover, 100% inspection, with external protection	1.2	100%	10%	100%	1.74E-05	1.41E-05	1.06E-04	5.13E-05	1.71E-05	2.06E-04
red. corr, standard depth, 100% inspection, no external protection	0.9	100%	100%	10%	1.94E-04	1.41E-06	1.06E-04	5.13E-05	1.71E-05	3.70E-04
red. corr, standard depth, 100% inspection, with external protection	0.9	100%	10%	10%	1.94E-05	1.41E-06	1.06E-04	5.13E-05	1.71E-05	1.95E-04
red. corr, 1.2m cover, 100% inspection, no external protection	1.2	100%	100%	10%	1.74E-04	1.41E-06	1.06E-04	5.13E-05	1.71E-05	3.50E-04
red. corr, 1.2m cover, 100% inspection, with external protection	1.2	100%	10%	10%	1.74E-05	1.41E-06	1.06E-04	5.13E-05	1.71E-05	1.93E-04

Appendix B
Pipeline Section Isolation Valve Analysis

Calculation of Annual Average Spill Volumes

In order to examine the effects of Section Isolation Valves a simple spreadsheet model was established. The results are presented at the end of this Appendix. The pipeline route is described in Section 2.1. Included below is a figure showing the elevation of the pipeline route and this has been used to divide the pipeline into sections (simplifying assumption a) and to estimate the leak potential from each section (simplifying assumptions f, g & h).



There are two major effects of installing Section Isolation Valves:

1. If operated promptly they can reduce the total quantity of fluid released from a leak in the pipeline.
2. They provide additional sources of leaks. As well as leaks through the valve stem, or failure of the valve body, there could be leaks from the flanges connecting the valve to the pipeline. These have been minimised by the use of weld end valves with fully welded bodies. If there are two or more Section Isolation valves then provision will have to be made for thermal expansion in the shut in sections with at least one connection per pair providing an additional potential leak pathway.

The following assumptions have been made in creating the model:

a) The pipeline may be divided into three sections:

- km 0 – 4.5 A relatively flat section for the first two kilometres through the docks area. The route crosses under the Tolka River and through to Alfie Byrne road. For the second half of this section, there is a relatively steep gradient, from 8 m AOD the pipeline drops to ~ 2 m AOD just before Clontarf Road, from this point over the next 2.25 km it rises to approximately 25 m AOD. If a release occurs it is assumed to drain half of the line (i.e. the line is assumed to be on a constant gradient, which is conservative, the likely average loss is more likely to be 1/3), it has been assumed that on average 50% of the line contents are lost for the first 4.5 km only;

- Km 4.5 – 11 This section of the route is undulating but rises from ~ 25 m AOD to ~ 42 m AOD just before the Malahide/Clonshaugh road junction. On this section the line could fail at any point and drain the material above it, the volume released would be reduced by the undulation but is conservatively assumed to be 50% of this section for larger releases. The location of a minor leak could significantly impact the percentage released, so has been assumed to reduce the release volume by half; and

- km 11 – 14.4 The northern portion of the route has some undulation but rises fairly steadily from 45 m AOD at the Mayne River and Cuckoo stream crossing to ~ 57 m at the Airport Receiving station. If a leak occurs on average only half the contents of the line between 11 and 14.4 km will drain out because of the slope.

b) If installed the Section Isolation valves will always operate within the assumed time of detection of leaks, 5 seconds for rupture, 30 seconds for a major leak (10% of pipeline cross section) and 3 minutes for a minor leak (1% of pipeline cross section).

c) We have assumed that the pump shutdown and isolation valve at the airport terminus will be operated at the same time as the intermediate Section Isolation Valve(s). The provision of a non-return valve at the airport will reduce some of the quantities released but the piping will need to be designed so that pigging can be performed.

d) The Section Isolation Valves are assumed to operate automatically. The provision of manually operated valves would provide additional leak paths and not significantly reduce the quantity leaked except in the case of minor leaks. (The response time from leak detection time to closure of the valve is likely to be 20 minutes or more).

e) If two valves are installed then a thermal relief connection may be required as discussed in 2.4.4. However, it has been excluded in these calculations as discussed in 3.1.4.

f) If a leak occurs in the line between 0 and 4.5 km then:

- With a valve at 4.5 km half of the line between 0 and 4.5 km will escape;

- With a single valve at 11 km all the line between 4.5 and 11 km will escape and 50% of the material between 0 and 4.5 km will be lost; and

- With no valve all the line will escape except the material trapped in undulations between 4.5 and 11 km assumed to be 50% and 50% of the line between 0 and 4.5 km.

g) If a leak occurs in the line between 4.5 and 11 km:

- With a single valve at 4.5 km, on average half the contents of the line between 4.5 and 11 km will escape, together with all of the contents of the line between 11 and 14.4 km. For minor leaks 25% of the material between 4.5 – 11 km and all the material between 11 and 14.4 km will be lost;

- With a valve at 11 km, on average half the contents of the line between 4.5 and 11 km will escape. For minor leaks 25% of the material between 4.5 – 11 km will be lost; and

- With no valve on average half the contents of the line between 4.5 and 11 km will escape and all the line above 11km will escape. For minor leaks 25% of the material between 4.5 – 11 km will be lost with all of the material from 11 to 14.4 km;

h) If a leak occurs in the line between 11 and 14.4 km with a valve at either 4.5 km or 11 km or indeed with no valve only half the contents of the line between 11 and 14.4 km will drain out because of the slope;

i) If a leak occurs in the downstream (uphill) flange of a valve then the whole of the contents of the pipeline section will drain out.

j) If a leak occurs in the upstream (downhill) flange of a valve then the leak will cease when the Section Isolation valve closes. Hence in any section only one flange or valve leak applies – the valve at the top of the section is assumed to be upstream.

The results are presented in terms of total quantity released on average each year, assuming the failure frequencies quoted in the text and second column of the spreadsheet.

Table B1 Release Volumes for options – Valve Chamber releases ignored.

Variable	Frequency (3) (/1000km years)	Release Rate (L/s) (1) Forward+Back	Back only	Time to detect (s)	Vol released before detection (L)	Vol released after detection: Leak at 0 - 4.5 km valve at 4.5 km (L)	Leak at 0 - 4.5 km valve at 11 km (L)	Leak at 4.5-11 km valve at 4.5 km (L)	Leak at 4.5-11 km valve at 11 km (L)	Leak at 11 - 14.4 km valve at 4.5 km (L)	Leak at 11 - 14.4 km valve at 11 km (L)	Total Volume Released: Release Volume per year (L / year) valve at 4.5 km (L)	valve at 11 km (L)
8in diameter pipeline at pressure of 40barg - Single Valve at Either 4.5 km or 11 km													
Distance						4.471	11.042	9.929	6.571	3.358	3.358		
Percentage in section which drains (FB / Major)						50%	50%	50%	50%	50%	50%		
Percentage in section which drains (Minor)						50%	50%	25%	25%	50%	50%		
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.00199	2008	1873	5	10041	70170	276426	208532	103128	52702	52702	4	4
Major leak	0.00486	187	187	30	5620	70170	276426	208532	103128	52702	52702	9	11
Minor leak	0.00657	19	19	180	3372	70170	276426	183319	51564	52702	52702	11	12
TOTAL	0.00019	/ year								Release Vol. per year		25	27
									Av spill size			128778	138834
Valves at both 4.5 km & 11 km													
Major)						50%		50%		50%			
Percentage in section which drains (Minor)						50%		25%		50%			
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.00199	2008	1873	5	10041	70170		103128		52702		3	
Major leak	0.00486	187	187	30	5620	70170		103128		52702		6	
Minor leak	0.00657	19	19	180	3372	70170		51564		52702		6	
TOTAL	0.00019	/ year								Release Vol. per year		14	
									Av spill size			74795	
NO VALVES													
Major)						50%		50%		50%			
Percentage in section which drains (Minor)						50%		25%		50%			
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.00199	2008	1873	5	10041	278702		208532		52702		6	
Major leak	0.00486	187	187	30	5620	278702		208532		52702		14	
Minor leak	0.00657	19	19	180	3372	278702		183319		52702		18	
TOTAL	0.00019	/ year								Release Vol. per year		37	
									Av spill size			193524	

(1) Assume maximum forward flow (no back pressure on pump) is 135 L/s (50% increase on normal maximum flow rate). Pump rate at future maximum pressure (40barg).
(2) Assume volume in 14.4 km pipeline is 452,000 litres
(3) Assume pipeline is protected with concrete and minimum depth of cover is 1.2 m

(4) Leak in km 0 - 4.5 have backflow driven by 4.2 bar; km 4.5 - 11 by 2.7 bar and km 11 - 14.4 by 1.5 bar (as liquid head above release reduces). This affects how quickly pipe will drain.
(5) Thermal relief, flange and valve leaks excluded.
(6) Isolation valve locations 4.471 km
11.042 km

amec

Table B2 Release Volumes for options – Valve Chamber releases included.

Variable	Frequency (3) (/1000km years)	Release Rate (L/s) (1) Forward+Back	Back only	Time to detect (s)	Vol released before detection (L)	Vol released after detection: Leak at 0 - 4.5 km, valve at 4.5 km (L)	Leak at 0 - 4.5 km, valve at 11 km (L)	Leak at 4.5-11 km, valve at 4.5 km (L)	Leak at 4.5-11 km, valve at 11 km (L)	Leak at 11-14.4 km, valve at 4.5 km (L)	Leak at 11-14.4 km, valve at 11 km (L)	Total Volume Released: Release Volume per year (L / year), valve at 4.5 km (L)	Release Volume per year (L / year), valve at 11 km (L)
8in diameter pipeline at pressure of 40barg - Single Valve at Either 4.5 km or 11 km													
Distance						4.471	11.042	9.929	6.571	3.358	3.358		
Percentage in section which drains (FB /						50%	50%	50%	50%	50%	50%		
Percentage in section which drains (Minor)						50%	50%	25%	25%	50%	50%		
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.0020	2008	1873	5	10041	70170	276426	208532	103128	52702	52702	4	4
Major leak	0.0049	187	187	30	5620	70170	276426	208532	103128	52702	52702	9	11
Minor leak	0.0066	19	19	180	3372	70170	276426	183319	51564	52702	52702	11	12
Leak frequency from valve	/ million years												
Major leak	0	187	187	30	5620	0	0	311660	0	0	52702	0	0
Minor leak	65	19	19	180	3372	0	0	234883	0	0	52702	15	4
Leak from flange	/ million years												
Major leak	0	187	187	30	5620	0	0	311660	0	0	52702	0	0
Minor leak	15	19	19	180	3372	0	0	234883	0	0	52702	4	1
TOTAL	0.000273	/ year								Release Vol. per year		44	31
									Av spill size			160840	114597
Valves at both 4.5 km & 11 km													
Major)						50%		50%		50%			
Percentage in section which drains (Minor)						50%		25%		50%			
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.0020	2008	1873	5	10041	70170		103128		52702		3	
Major leak	0.0049	187	187	30	5620	70170		103128		52702		6	
Minor leak	0.0066	19	19	180	3372	70170		51564		52702		6	
Leak frequency from valve	/ million years												
Major leak	0	187	187	30	5620	70170		103128		52702		0	
Minor leak	130	19	19	180	3372	70170		51564		52702		23	
Leak from flange	/ million years												
Major leak	0	187	187	30	5620	70170		103128		52702		0	
Minor leak	30	19	19	180	3372	70170		51564		52702		5	
Leak from thermal relief conn.	/ million years												
Major leak	41	187	187	30	5620							0	
Minor leak	363	19	19	180	3372							1	
TOTAL	0.000757	/ year								Release Vol. per year		44	
									Av spill size			58576	
NO VALVES													
Percentage in section which drains (FB /						50%		50%		50%			
Percentage in section which drains (Minor)						50%		25%		50%			
Leak rate per m of pipeline	(/ 1000 km years)												
Full bore rupture	0.0020	2008	1873	5	10041	278702		208532		52702		6	
Major leak	0.0049	187	187	30	5620	278702		208532		52702		14	
Minor leak	0.0066	19	19	180	3372	278702		183319		52702		18	
TOTAL	0.000193	/ year								Release Vol. per year		37	
									Av spill size			193524	

(1) Assume maximum forward flow (no back pressure on pump) is 135 L/s (50% increase on normal maximum flow rate). Pump rate at future maximum pressure (40barg).
(2) Assume volume in 14.4 km pipeli 452,000 litres
(3) Assume pipeline is protected with concrete and minimum depth of cover is 1.2 m
(4) Leak in km 0 - 4.5 section have backflow driven by 5 bar; km 4.5 - 11 by 1.5 bar, and km 11 - 14.4 by 0.5 bar (as liquid head above release reduces). This affects how quickly pipe will drain.
(5) Thermal relief only required if there are two block valves. After detection no loss occurs on assumption block valve closes.
(6) Isolation valve locations 4.471 km
11.042 km

The table above includes the releases in the valve chambers. It has been included as it demonstrates that although the inclusion of section valves has a strong benefit, there is also a small negative effect. The frequency of releases increases and this results in the average release volume per year increasing. However, as these additional releases are small, the average spill size is also much reduced. The figures above are very conservative because they do not take into account that small releases into the valve chamber will be identified and resolved before they become large releases. The likelihood of release from a valve has been minimised by the use of weld end valves with fully welded bodies.

Appendix C
Comparison of Safety Evaluation requirements in IS EN 14161 with this report and EIS

IS EN 14161 Annex A Requirement		AMEC Report selection	Other sections of the EIS.
A.3.Definition of the scope of the evaluation	a) the reason for performing the evaluation and the case specific objective	Sections 1.1, 1.2	Section 2
	b) a definition of the pipeline	Sections 2.1, 2.2	Section 3
	c) a definition of the environment, e.g. human habitation and activities near the pipeline		Section 7
	d) identification of the measures that can be practical and effective in removing or mitigating adverse effects on public safety	Section 2.4	Sections 8 to 17
	e) a description of assumptions and constraints governing the assessment	Assumptions/Constraints are discussed where they arise through sections 2-4	Section 6
	f) identification of required output		Section 2
A.4.Hazard identification and initial evaluation	a) design, construction or operator error	Section 3.1 Appendix A	
	b) material or component failure	Section 3.1 Appendix A	
	c) degradation due to corrosion or erosion, leading to loss of wall thickness	Section 3.1 Appendix A	
	d) third party activity	Section 3.1 Appendix A	
	e) natural hazards	Section 3.1	Sections 8 to 17

		Appendix A	
	f) fatigue and design life	Section 3.1 Appendix A	
A.5.2 Frequency Analysis	a) use of relevant historical data	Section 3 Section 4	
	b) synthesis of event frequencies using techniques such as failure mode and effect analysis	Section 3 Section 4 Appendix B	
	c) judgement	Section 3	
A.5.3 consequences analysis	a) the nature of the fluid	Section 3.2	
	b) pipeline design	Sections 2.2, 3.2	
	c) buried or above ground topography	Sections 2.3, 3.2	
	d) environmental conditions		Section 7
	e) likely size of hole or rupture	Section 3.2	
	f) mitigating measures to restrict loss of containment	Section 3.1	
	g) the mode of escape fluid	Section 3.2	
	h) dispersion of fluid and probability of ignition	Section 3.2	
	i) possible accident scenarios following a fluid loss	Section 3.2	
	j) level of exposure and estimated effect	Release effects are primarily environmental – potential effects to Seveso sites are in Appendix E, no other human exposure effects calculated.	Sections 8 to 17
A.5.4. Risk Calculation	a) curtailment of the assessment because the failure frequency or consequences of the hazard are insignificant	Not applicable – releases and frequencies estimated.	

	b) continuation with the detailed evaluation of the risk level	Release volumes and frequencies estimated	
	c) any individuals who might be present along the route	Release effects are primarily environmental – potential effects to Seveso sites are in Appendix E, no other human exposure effects calculated.	Section 8
	d) if appropriate, any large groups of people that might be present along the route	As A.5.4c above	Section 8
A.6. Review of Results	a). Individual risk	As A.5.4c above	Section 8
	b). Societal risks	As A.5.4c above	Section 8
A.7 Documentation	a) table of contents	Page vii-viii	Page i
	b) summary	Page v-vi	Section 1
	c) objectives and scope	Section 1	Section 1 to 3
	d) safety requirements	Section 5	
	e) limitations, assumptions and justification of hypotheses	Addressed as they arise throughout	
	f) description of system	Section 2	Section 3
	h) analysis methodology	Sections 3 and 4	Section 5 and 6
	i) hazard identification results		
	j) models description with assumptions and validation	Appendix B	
	k) data and their sources	Section 8	
	m) effect on public safety	As A.5.4c	
	n) sensitivity and uncertainties	Section 7	
	o) discussion of results	Section 7	Section 18
	p) conclusion	Section 7	Section 18

	q) references	Section 8	Section 19

Appendix D
Risk to Dublin Port Tunnel

Introduction

The Dublin Tunnel is a dual carriage road tunnel connecting the M50 with Dublin Port harbour. It runs for 5.6 km and is the longest urban road tunnel in Europe.   The proposed pipeline route crosses the tunnel once.

The tunnel itself is consists of two carriageways, northbound and southbound, each being two lanes wide. The length of the tunnel is bounded by two diaphragm walls; these extend from below the base of the tunnel to the surface offering lateral protection. The tunnel itself is set 2.86 m below the road. There are three membrane layers providing waterproofing external to the walls of the tunnel. Comprehensive details of the tunnel route and construction can be found in App D2.

Pipeline Description

The pipeline will run under Alfie Byrne Road and will cross above the Dublin Port Tunnel at the same point that Alfie Byrne Road does, approximately 100 m Northeast of the Tolka River crossing. At the point of crossing the tunnel, the pipeline will be approximately 1.4 m beneath the surface of the road which will leave approximately 1.4 m of clearance between the pipeline and the highest point of the tunnels outer protective layers.

As there are two diaphragm walls, the area in which a leak could impact the tunnel is reduced to the length of pipeline contained within the walls, conservatively the length of pipe has been measured from the outer side of either wall. This means the length of pipeline actually at risk is reduced to 27.13 m resulting in a predicted leak frequency of 3.7 $x10^{-7}$ $year^{-1}$. Further details of the pipeline are shown below in 0362-D-07-C-0002.

Impact

As can be seen in App D3, there are three layers on the outer of the tunnel. The PVC layer will provide waterproofing of the tunnel. While it will not react, kerosene may cause this layer to soften over an extended period of time; the exact effect is not known and will depend on the composition of PVC and kerosene as well temperature and water content in the soil.

While the risk is hard to quantify, any rupture would be detected fairly rapidly by the systems described above in Section 2.4.3 and intervention steps would be taken to isolate and clean up. This means even if the leak was in this area, the exposure time of the kerosene on the outer wall of the tunnel would be relatively short (several hours to a few days). If the leak were of a medium size (≥1% of flow rate), it is still likely to be detected automatically in line with Table 2. If a very small leak were to occur, if it remained below the detection rate for both static and flow conditions, there could be a gradual build up of kerosene in the soil over the tunnel. If this build up were to remain there for an extended duration, this could potentially lead to the PVC perishing and a small amount leaching into the tunnel. This would likely lead to detection of the leak before a significant pool could form in the tunnel. As the kerosene has a relatively high flash point and therefore hard to ignite; it is likely that any leak into the tunnel would make the road surface slippery with a potential for traffic accidents rather than reaching flammable concentrations.

Conclusion

As can be seen the frequency of the pipe failing in the area that could affect the pipe is extremely low at $3.7x10^{-7}$ $year^{-1}$.

The consequences from the event are hard to determine but it is not considered that there is likely to be any major safety risk to occupants of the tunnel.

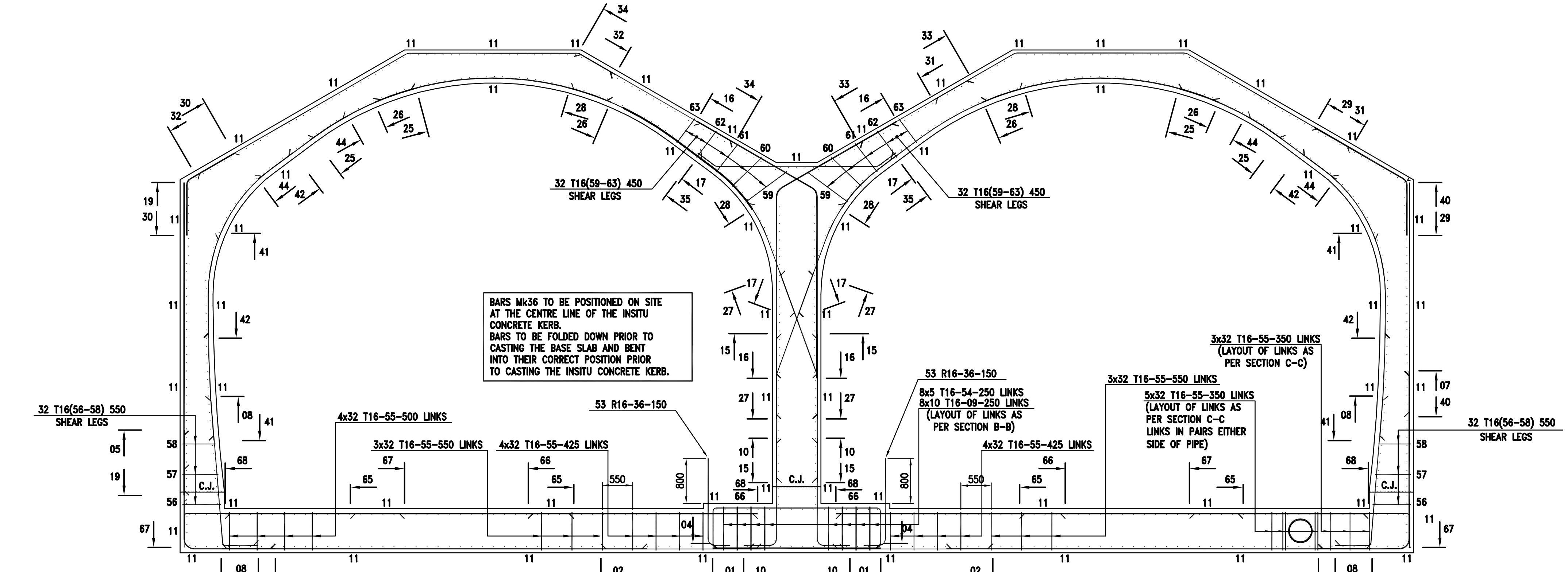
D2 Tunnel Details

DO NOT SCALE FROM THIS DRAWING

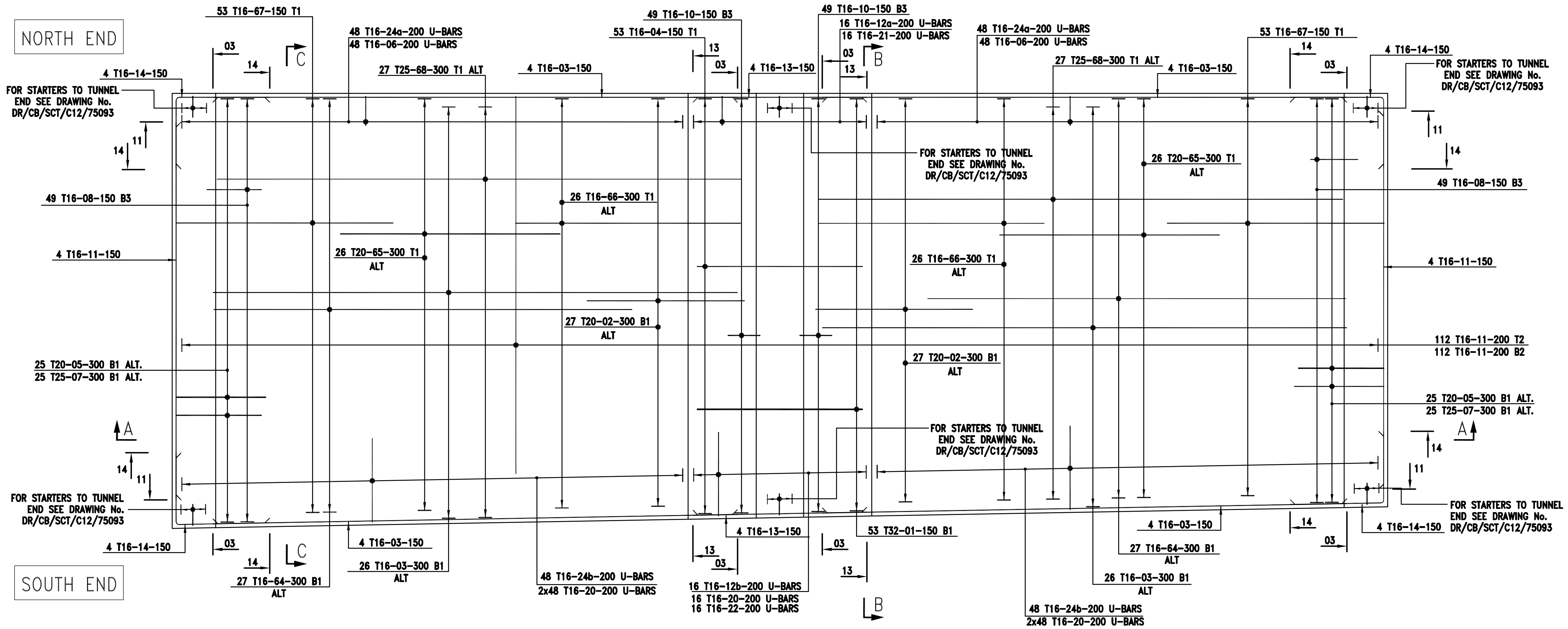
AS BUILT

Changes have been made to the 'For Construction' drawing.
This drawing should be read in conjunction with Field Change Request number(s)

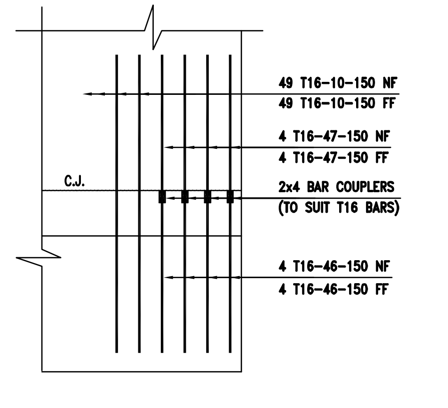
FCR/MI/PRO/19162/01/R	Removal of starber bars for verge works
FCR/MI/PRO/C12/21033/01/C	Backfilling of the 375 dia pipe



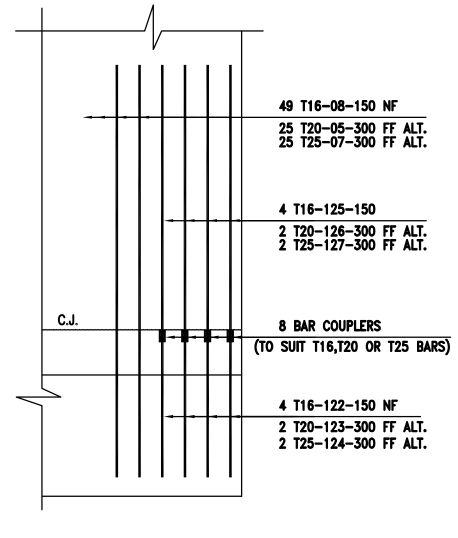
SECTION A–A
SCALE = 1:50



PLAN ON BASE SLAB
SCALE = 1:50



DETAIL OF INTERNAL WALL REINFORCEMENT AT SOUTH END OF SHUTTER
SCALE = 1:25



DETAIL OF EXTERNAL WALL REINFORCEMENT AT SOUTH END OF SHUTTER
SCALE = 1:25

NOTES:

1. THIS DRAWING IS FOR INFORMATION PURPOSES ONLY.
2. THIS DRAWING TO BE READ IN CONJUNCTION WITH DRAWING No's. DR/CB/SCT/C12/75091, DR/CB/SCT/C12/75092, DR/CB/SCT/C12/75093, BENDING SCHEDULE No. RS/CB/SCT/C12/75094 & GENERIC DRAWING No. DR/CB/PRO/C12/75491.
3. NOMINAL COVER TO REINFORCEMENT TO BE 45mm TO ALL EXTERNAL TUNNEL FACES AND 60mm TO ALL INTERNAL TUNNEL FACES.
4. ALL REINFORCEMENT TO BE HIGH YIELD TYPE 2 DEFORMED BARS COMPLYING WITH THE REQUIREMENTS OF SPECIFICATION CLAUSE 1712.
5. CUTTING AND BENDING OF REINFORCEMENT SHALL COMPLY WITH THE REQUIREMENTS OF BS 4466 (1989) AND SPECIFICATION CLAUSE 1713.
6. MINIMUM TENSION REINFORCEMENT LAP LENGTHS (UNLESS NOTED OTHERWISE):
   T40 – 1700
   T32 – 1400
   T25 – 1100
   T20 – 925
   T16 – 800 (LAP 550 BM 12a, 12b, 24a, & 24b)
   T12 –650
7. LEGEND:
   T1 – TOP BAR TOP LAYER
   T2 – TOP BAR 2nd LAYER
   B1 – BOTTOM BAR BOTTOM LAYER
   B2 – BOTTOM BAR 2nd LAYER
   B3 – BOTTOM BAR 3rd LAYER
   NF – NEAR FACE
   FF – FAR FACE
   EF – EACH FACE
   ALT. – ALTERNATELY PLACED
8. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.

Mark Chd By	Date	By	Rev.
03 DGP	NOV '06	ADF	AS BUILT CHANGES ADDED
02 DGP	AUG '06	JJP	AS BUILT CHANGES ADDED

Project: DUBLIN PORT TUNNEL

NISHIMATSU MOWLEM IRISHENCO

Haswell Consulting Engineers

Carl Bro Intelligent Solutions

HBI HAERTER AG

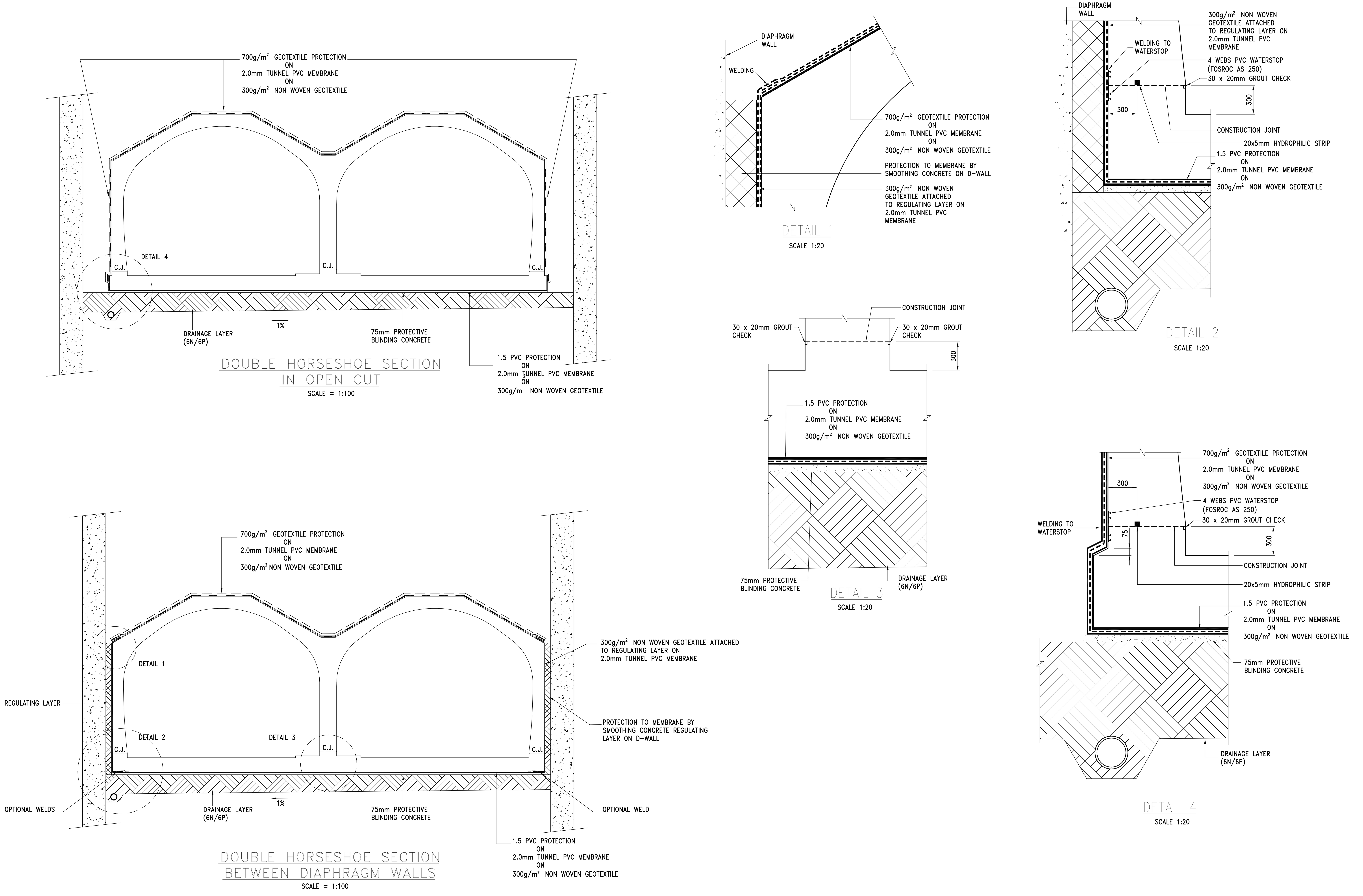
NRA NATIONAL ROADS AUTHORITY An tÚdarás um Bóithre Náisiúnta

Client: Dublin Corporation
Bárdas Átha Cliath

Title: HWD 2.2 (CB)
SOUTHERN CUT & COVER
RC DETAILS SCT-TH39b
SHEET 1 OF 4

Scale: AS SHOWN
Dn. JAO | Date 14/2/03 | Chd. | Passed
Project No. 841469.07
Drawing No. DR/CB/SCT/C12/75090/03/X
Original Drawing Size : 594 x 841 – A1

DO NOT SCALE FROM DRAWING



NOTES:

1. TO BE READ IN CONJUNCTION WITH G.A. DRAWING No's DR/CB/SCT/C12/75200/05/C & DR/CB/SCT/C12/75201/05/C DR/CB/SCT/C12/75202/04/P
2. FOR DETAILS OF MOVEMENT JOINTS REFER TO DRAWING No DR/CB/SCT/C12/75204/05/C.
3. ALL EXPOSED CORNERS TO HAVE A 25 x 25mm CHAMFER
4. ALL WATERPROOFING TO BE UNDERTAKEN IN ACCORDANCE WITH APPENDIX 20/2
5. ALL DIMENSIONS ARE IN MILLIMETRES.

Mark Chd By	Date	By	Rev.
06 DGP	JULY. '06	JJP	AS BUILT CHANGES ADDED
05 CH	MAY '02		GENERAL REVISIONS
04 CH	MAR. '02	J.A.O.	GENERAL REVISIONS
03 CH	FEB. '02	J.A.O.	GENERAL REVISIONS
02 CDH	NOV. '01	J.A.O.	DIMENSION ADDED, STATUS UPDATED

Project: DUBLIN PORT TUNNEL

NISHIMATSU MOWLEM IRISHENCO

Haswell Consulting Engineers

Carl Bro Intelligent Solutions

GCG HBI HAERTER AG

NRA NATIONAL ROADS AUTHORITY An tÚdarás um Bóithre Náisiúnta

Client: Dublin Corporation Bárdas Átha Cliath

Title: HWD 5.2.3 (CB) SOUTHERN CUT AND COVER SCT-TH31 TO SCT-TH37 WATERPROOFING DETAILS

Scales: As Shown

Drn: JAO Date: 22/10/01 Chd: DCE Passed: ARW

Project No. 841469.07

Drawing No. DR/CB/SCT/C12/75205/06/X

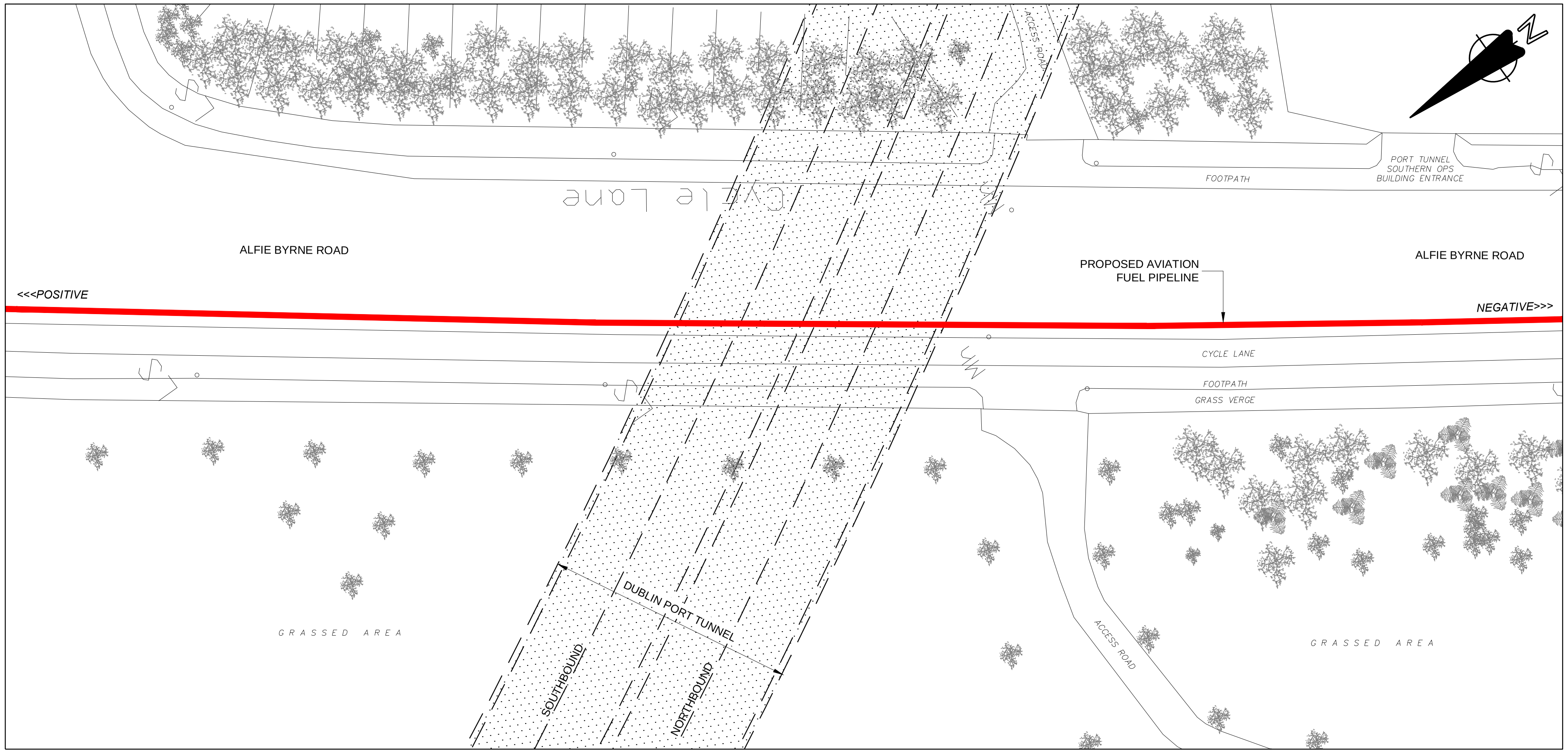
Original Drawing Size : 594 x 841 – A1

AS BUILT

Changes have been made to the 'For Construction' drawing.
This drawing should be read in conjunction with Field Change Request number(s)

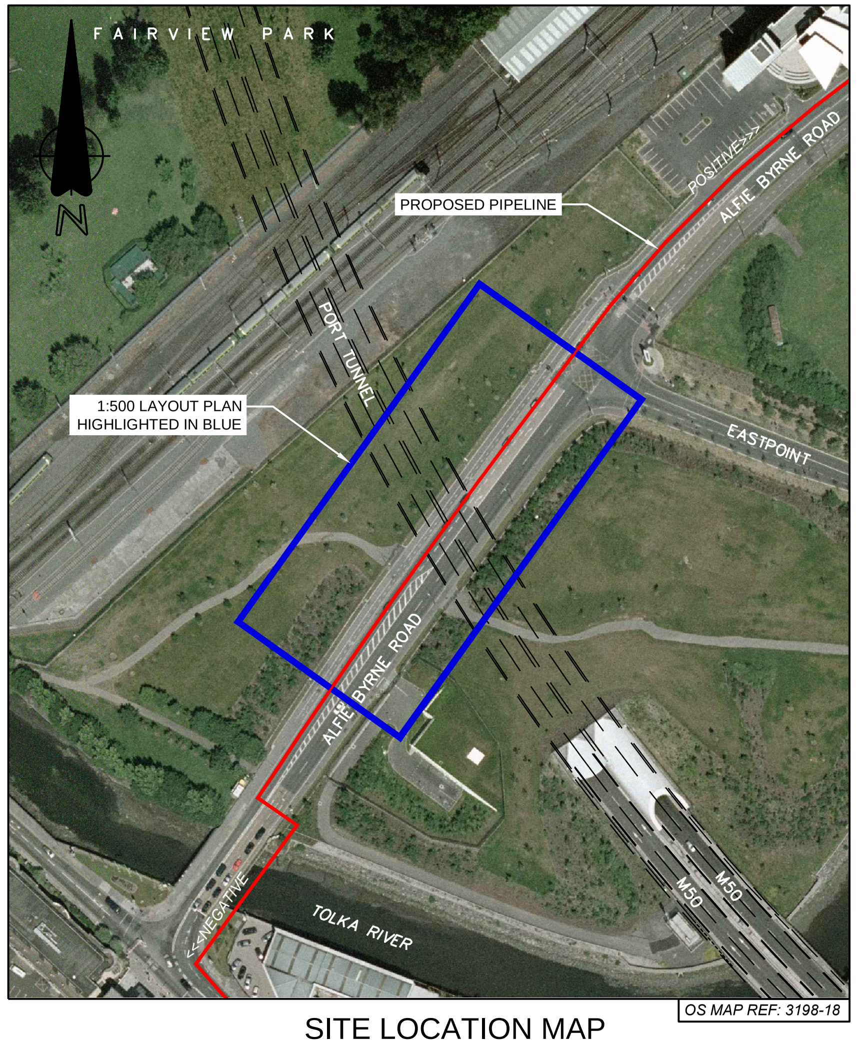
FCR/MI/PRO/C/19069/01/R	Remove the grout check from kickers of the walls

D3 Pipeline Design



LAYOUT PLAN

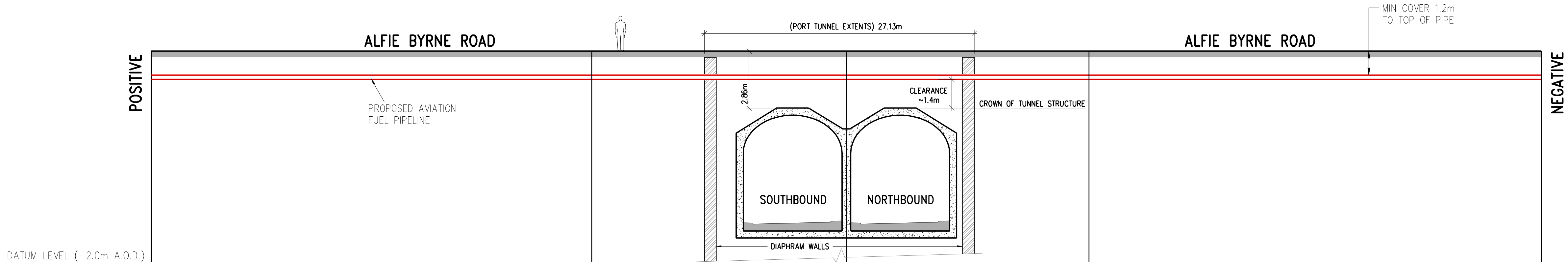
Scale 1:500



SITE LOCATION MAP

REFER STRIP MAP 0362-D-02-G-0008

Scale 1:2500



GROUND LEVEL (m A.O.D.)	8.79	8.79	8.79	8.79	8.79
TOP OF PIPE LEVEL (m)	7.59	7.59	7.59	7.59	7.59
COVER (m)	1.20	1.20	1.20	1.20	1.20
CHAINAGE (m)	1994.3	1950.0	1924.4	1900.0	1854.5

PROFILE ALONG CENTRE LINE OF PIPE

Scales Horizontal 1:500 Vertical 1:250

Legend:

Map Index:

APPROVALS	
A	ENGINEER
B	PROJECT MANAGER
C	PROJECT DIRECTOR
Revision	0

REV	REVISION	REV.BY	A	B	C
0	PRELIMINARY ISSUE	RMD 16/06/14			

APPROVED

Fingleton White
Bridge Street Centre
Portlaoise
Co. Laois
Ireland
T:(00353)(0)57 866 5400
www.fingleton.ie

On Behalf of: INDEPENDENT PIPELINE Co. Ltd.

Project: AVIATION FUEL PIPELINE

DUBLIN PORT TUNNEL CROSSING

Scale: 1:500/A3

Drawing Number: 0362-D-07-C-0002

Status: ISSUED

Sheet 1 Of 1

Appendix E
Risk to Dublin Port SEVESO Sites

Introduction

Dublin Port is a nationally important hub for the distribution of petroleum products in Ireland. There are several Seveso sites, both upper and lower tier sites. There are five lower tier Seveso sites along with seven upper tier sites. While the pipeline does not cross over or through any of these sites, it does pass near to one and follows the outer wall of one of the lower tier sites on Tolka Quay Road for approximately 300 m. This can be seen below.

It is assumed that the current Seveso sites are designed and operated in a safe manner, so an event on one of these sites impacting the pipeline has been discounted.

Consequence

The most plausible domino event is a pool fire escalating to a neighbouring site. This is unlikely as it is a fully welded pipeline buried at a depth of 1.2 m beneath a significant concrete layer and a road surface so that it would be unlikely to form a significant pool on the surface. This area of the route is relatively flat, so it is not known what section of pipeline could cause a large surface pool that affects the site but it is unlikely to extend much beyond the extremity of the site. This means the section of pipe from which a release could affect the neighbouring Seveso site is ~300 m. It should be noted that this is a lower tier site. This leads to an unignited failure frequency of 4.1 $x10^{-6}$ per year.

To reach the surface in sufficient quantities, it is considered that there would need to be a significant leak, therefore minor leaks can be excluded from the frequency above as it is not considered that they could cause sufficient levels of kerosene at ground level to form a hazard. This would reduce the frequency by approximately 50% (based on Table 3.3).

The kerosene handled by the pipeline has a flash point between 38 and 55°C. The highest temperature recorded in Ireland since records began (1881) was 33.3°C[2] recorded in 1887, the 20th century high was 32.5°C reached in 1976. Neither of these record highs were recorded in Dublin. So there is unlikely ever to be naturally occurring release conditions that would lead to a flammable release, however there is potential to make the road surface slippery and subsequent hazards that arise from that.

For an ignited event to occur, there would need to be an external heat source applied to the kerosene. This could be related to the cause of release e.g. cutting equipment or it may be completely separate e.g. vehicle collision and fire. Without additional data collection, this would be difficult to quantify, but it would be conservative to assume the presence of an ignition source of such strength is sufficiently unlikely to reduce the risk by two orders of magnitude.

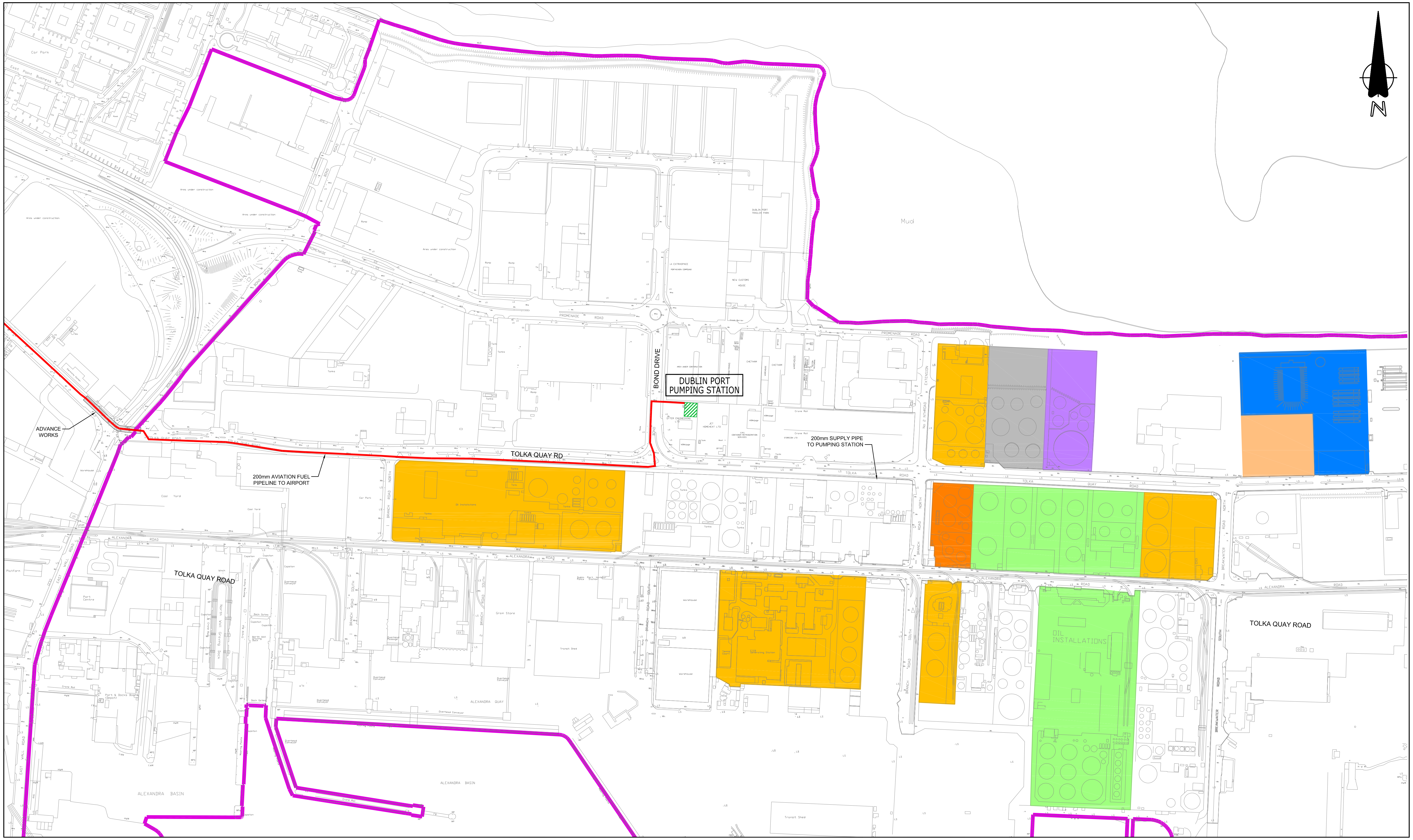
While the risk above is low it still neglects the likelihood of releases forming a pool, intervention before the pool reaches a significant size (the area at risk is visible from the pumping station), leak detection causing an auto shut-

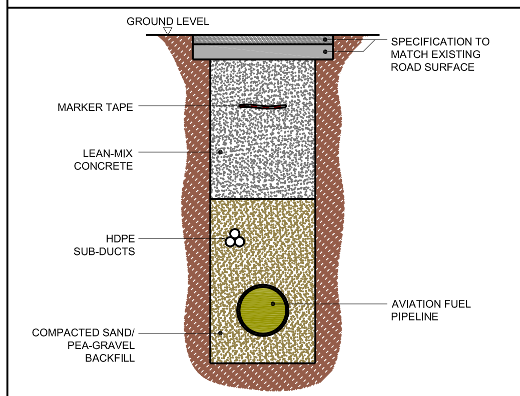
[2] Irish Meteorological Service Online, Climate of Ireland – Temperature, http://www.met.ie/climate/temperature.asp, Accessed 24/06/2014

off, firefighting efforts and assumes that every ignited release will impact the neighbouring Seveso site and that their thermal relief/firefighting systems will fail to protect them.

Conclusion

While the stated frequency is 4.1 $x10^{-6}$ per year it excludes other factors such as leak size, ignition probability or emergency response so the risk should be considered to be broadly acceptable. “Broadly acceptable” is the term typically used by the HSA to define the lowest risk threshold used in various forms of risk assessment.

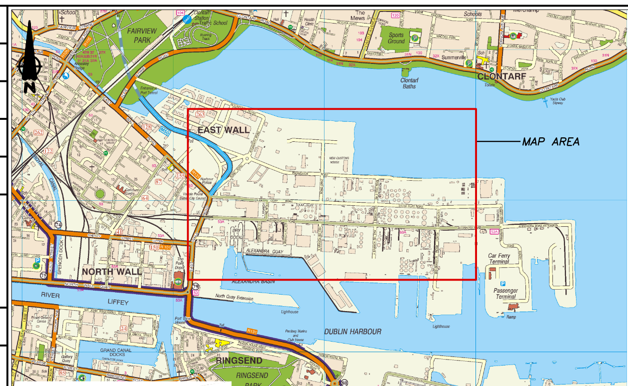




TYPICAL SECTION THROUGH PIPELINE

ALL DIMENSIONS IN METRES (u.o.s.)	
LENGTH OF PIPE WITHIN DPC ESTATE	846m
DIAMETER OF PIPE	200mm
OPERATING PRESSURE	40 BAR
PIPELINE WALL THICKNESS	12mm
REVISION:	0
O.S. MAP Ref.	3198-23, 24, 25, 3264-03, 04, 05

"Includes Ordance Survey Ireland data reproduced under OSi Licence number AR0002011. Unauthorised reproduction infringes OSi & Government of Ireland copyright."
© Ordance Survey Ireland 2011



MAP KEY (@1:50,000)

KEY
- 200mm PIPE ROUTE
- DPC ESTATE
- Seveso Upper Tier Sites
  - ESSO JFT
  - TOP Yrd 2
  - Indover
  - Color Gas
  - Dublin Waste to Energy
  - NORA
  - Topaz - Foreplay Yard 1
  - Topaz - Foreplay Yard 2
- Seveso - Lower Tier Sites

PROJECT

AVIATION FUEL PIPELINE

TITLE

SEVESO SITES IN DUBLIN PORT ESTATE

SCALE:	1:5000/A3
DATE:	12.06.14
DRAWN:	R.McDonnell
CHECKED:	K.Moore
APPROVED:	M.Lennon

CLIENT
INDEPENDENT PIPELINE Co. Ltd.

Fingleton White
Bridge Street Centre
Portlaoise
Co. Laois
Ireland
TEL: (00353)(0)57 866 5400 FAX: (00353)(0)57 866 5444
E-Mail: info@fingleton.ie www.fingleton.ie

DRAWING NUMBER
0362/D/12/E/0007