9. WATER

9.1 Introduction

This section presents the results of the impact assessment process on the physical and chemical aspects of aqueous environment.. The impacts assessed are those which have the potential to change water quality. The biological aspects are dealt with in **Section 7**; the geological aspects are dealt with in **Section 8**.

9.2 Study Methods

A combination of methods was used to acquire information on the water environment.

For the oceanographical work, Metoc plc. were retained by Enterprise to carry out a desk study of the metocean conditions in the Corrib Field area and the western seaboard of Ireland. This desk study included wave, current, water level, wind and seawater properties.

This desk study was added to by the use of field data, which Enterprise had acquired on tidal currents in the field over a 12 month period, 15/10/98 to 26/10/99. Fugro GEOS acquired these data. Currents were also measured at various points along the proposed pipeline route over the period June/July 2000. Gardline Surveys acquired these data which included high frequency sampling, allowing near–bed wave motions to be assessed.

As part of the study, Metoc accessed the NEXT wave and current hindcast model data analysed by Statoil, a partner in the Corrib project. Metoc modified aspects of the model to more accurately describe the extreme wave heights.

Kirk McClure Morton were commissioned by Enterprise to implement a dispersion model of Broadhaven Bay.

In respect of water chemistry, samples were acquired from Broadhaven Bay and analysed for a range of metals, in order to determine the background levels in the environment.

9.3 Receiving Environment

9.3.1 General Description

The continental shelf (generally the area of less than 200 m water depth) off the western coast of Ireland is broad to the south and mid west of Ireland and relatively narrow to the north-west and south-west (**Figure 9.1**). The Corrib Field at a distance of 65 km offshore, is in an area of approximately 350 m water depth, a zone which can be termed the continental slope or continental margin.

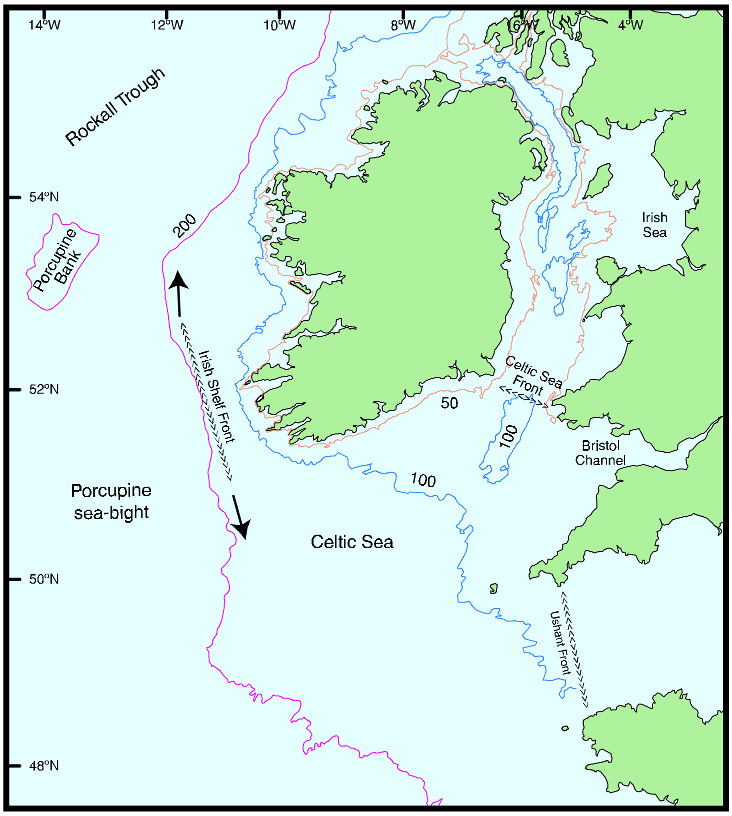


Figure 9.1: Bathymetry of the Irish Coast

The west of Ireland faces the North Atlantic Ocean, and waves travel undisturbed for thousands of miles before reaching the coastline. As the Gulf Stream fans out in the eastern Atlantic it creates the North Atlantic current. Weak, meandering eddies on the south-east periphery of the North Atlantic current form the predominant currents of the western coast of Ireland. Nearshore currents generally flow in a south to north direction around the coast of Ireland. Off the western coast the predominant surface and deepwater currents come from the south and south-west.

The divisions between the offshore Atlantic waters and the fresher coastal waters are marked by frontal regions, where temperature and salinity change rapidly over a small horizontal distance of about 10 km. These fronts play an important role in controlling the current patterns as described below.

Along the continental margin itself, the currents are dominated by the shelf edge current. This is predominantly a warm and saline poleward flowing current that has been observed at many locations along the NE Atlantic margin. Mean currents are between 5 – 20 cm/s, but instantaneous speeds can reach up to 50 cm/s at times. Off north-west Ireland, this slope current is very persistent, both throughout the water column and also in time, with relatively small seasonal changes evident in mean speeds. South of 53°N, however, more seasonality is observed in the currents, with reversals in the poleward flow measured principally during March-April and September-October.

On the shelf, water movements are dominated more by tidal currents, wind forced motions and by the fronts described above. Generally, tidal currents have a magnitude of between 10 – 30 cm/s on the shelf, decreasing to about 5 cm/s in the deeper water. The tide is dominated by the semi-diurnal (twice-daily) tide, but near the seabed of the continental slope to the north-west and south-west of Ireland the diurnal tide becomes stronger. Inshore of the fronts, the currents generally flow clockwise around the Irish coastline. Movement of the surface fronts may control these flows significantly. Over the outer shelf, currents are poleward in winter, up to 30 cm/s, but are weaker and more variable in summer, with little mean flow evident. In addition, recent measurements have highlighted the presence of bottom fronts around the inner shelf of the south, west and north-west of Ireland. These fronts can drive mean persistent currents clockwise around the coast, which are at times stronger (up to 25 cm/s) than the wind-forced currents.

9.3.2 Oceanographic Conditions in the Corrib Field and Along the Pipeline Route

The following section on oceanographic conditions in the Corrib Field and along the pipeline route is based on information presented in a report produced at the request of Enterprise by Metoc plc (Metoc, 2000).

9.3.2.1 Data Sources

Historical observations at a new exploration site are rarely available, therefore alternative data sources are generally limited to reviewing observations recorded by passing vessels (VOF data). The reliability, continuity, and coverage of these data tend to be intermittent, and this information is augmented in the Metoc report by the use of hindcast model. Theoretical calculations were used to derive wave conditions at shallow sites. Hindcast models are based on historical meteorological records, from which likely sea conditions are calculated using numerical models. These models enable sea conditions (water levels, wave height and direction, wind-driven currents etc.) to be calculated in much the same way as marine conditions are currently forecast, on the basis of meteorological conditions. Because historical meteorological records are quite comprehensive, cover wide areas, and are available for many years, this is often the most satisfactory method of obtaining a reliable statistical description of marine conditions.

For a given hindcast model, the known meteorological conditions over an extended period (typically 20 years or more) are run through the model to obtain marine conditions at regular intervals (typically every hour for currents and every three hours for waves). From these results, a statistical description of the likely conditions can be obtained. The hindcast models are generally validated against the VOF data.

Wave and Current Data Sources

The Metoc report is based on hindcast model wind, with wave, water level and current data taken from the North European Storm Study (NESS) Extended Hindcast Model (NEXT). The data obtained included extreme values and operating statistics from NEXT archives for grid points relevant to the project. The archives contain output from a wave model with a 30 km grid, and a current model with a 10 km depth-averaged grid. The model was run for the years from 1964 to 1995.

Enterprise has also obtained one year of current measurements from the Corrib Field (Fugro GEOS, 1999). Metoc performed extreme value analyses using speed frequency distributions extracted from the GEOS report.

Current meter data were obtained from the Corrib Field and at points along the proposed pipeline route during June/July 2000 which have been incorporated into Metoc's assessment of the model results and have allowed modifications to be made to the earlier data.

For Broadhaven Bay current metering was carried out in 2000 and 2001.

Sources for Water Levels and Sea Water Properties

Tidal levels were calculated along the pipeline route using standard tide tables and tidal atlases. Storm surge levels and extreme still water levels are based on the NEXT tide and surge model.

Seawater temperature and salinity profile data were obtained from large public-domain databases held by Metoc.

9.3.2.2 Wave Conditions

From the NEXT model, extreme significant wave height (Hs) values were obtained at three grid points (16159, 16160, 16106) as shown in **Figure 9.2**. The Metoc assessment includes validation of the NEXT data against other data sets, including satellite data, and some adjustments to the NEXT results for shallow water and directional sheltering effects.

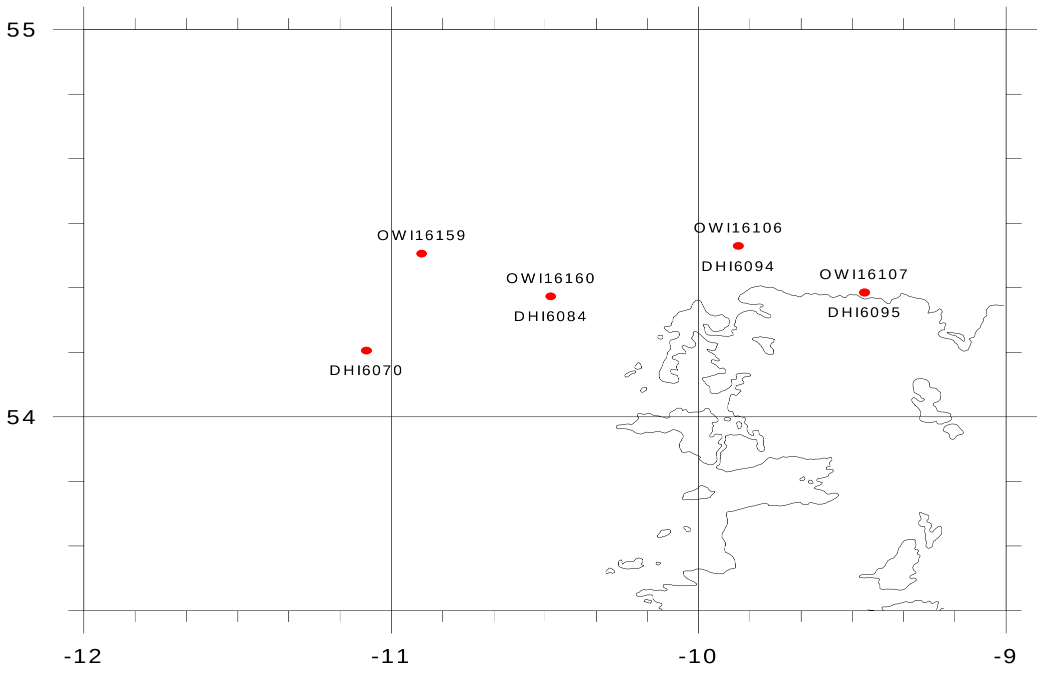


Figure 9.2: NESS/NEXT grid points

Greatest anticipated significant wave height at the proposed landfall site in Broadhaven Bay was 6.2 m, based on a water depth of 10 m. The TMA spectrum, a shallow water modification of the widely used JONSWAP spectral formulation, was used to estimate the worst sea state sustainable in shallow water (depth 10 m). TMA derives its name from the three of the sites, Texel, Marsden and Arsloe, used to collect shallow water data in the North Sea. JONSWAP is the widely used wave spectral formulation derived using data from the Atlantic ocean and the North Sea (the Joint North Sea Wave Programme). The exposure to waves from different directions within Broadhaven is shown in **Table 9.1**.

Table 9.1: Exposure of Broadhaven Bay to waves from various directions

Waves From	Mode of entry to Bay	Areas of Broadhaven affected
N	Direct	whole bay
NE	Direct	west and south shores
E	Refracted from Donegal Bay	western half
SE	-	-
S	-	-
SW	Refracted from Atlantic	eastern half
W	Direct	could affect whole bay
NW	Direct	whole bay

Extreme wave conditions for four of the NEXT points are provided in **Table 9.2** for the return periods 1 year summer, 10 year winter, 50 year winter and 100 year winter (Metoc, 2000). For all return periods the maximum significant waves are from the west.

Table 9.2: Significant wave heights (m) for different return periods at four points along the Corrib pipeline

Site	1 yr summer	1 yr winter	10 yr winter	50 year winter	100 year winter
DHI 6070	6.1	16.3	19.7	22.0	22.9
DHI 6084	5.8	14.8	16.9	20.1	20.9
DHI 6094	4.2	12.1	14.6	16.3	17.0
DHI 6095	3.9	8.4	10.1	11.3	11.8
B-H Bay, 10 m depth	2.2	5.2			6.2
Note: 100-year winter values are considered to also represent 100-year all-year conditions.					

9.3.2.3 *Current Flow Conditions*

As noted above, current measurements were available from the Corrib Field for a period of one year. Elsewhere along the route, extreme values and operating statistics were calculated from the NEXT model, with slight modifications by Metoc. The model grid points used (DHI model points 6070, 6084, 6094 and 6095) are shown in **Figure 9.2**. **Table 9.3** presents modelled extreme current speeds at four points along the pipeline route, at a height of 1 m above the seabed[1].

Winter extreme values are given for return periods of 1, 10, 50 and 100 years. Summer extreme values are given for 1 year only.

The measurements by Gardline Surveys during the summer of 2000 confirmed that the tidal streams off Erris Head are stronger than those at the outer shelf. The same relationship might not hold in extreme events.

[1] The data presented incorporate some adjustments by Metoc to the NEXT results to allow for local bathymetry, the proximity of coastlines and the difference between depth mean currents (as obtained from the model), and currents at 1 metre above the seabed. The Gardline Surveys data have contributed to this adjustment and have also helped to define the area over which each model grid point's values apply.

The model will not replicate slope current overspill or internal tides, but neither of these is considered likely to materially affect the area near the seabed. The model also will not accurately simulate accelerations past local obstructions such as headlands, which have been allowed for by directional scaling. The latter are not relevant in the more open ocean conditions.

Table 9.3: Current speeds (cm/s) for different return periods at four points along the Corrib pipeline at 1.0 m above seabed

Site	1 yr summer	1 yr winter	10 yr winter	50 year winter	100 year winter
Corrib Field	42 (N, NE)	42 (N, NE)	46 (N, NE)	49 (N, NE)	50 (N, NE)
150 m depth	40 (N, NE)	82 (SW,NE)	94 (SW,NE)	103 (SW,NE)	107 (SW,NE)
100 m depth	55 (NE)	82 (NE, E, SW)	94 (NE, E, SW)	103 (NE, E, SW)	107 (NE, E, SW)
B-H Bay	35 (NW)	37 (E, W)	42 (E, W)	44 (E, W)	45 (E, W)
Notes: Letters in brackets indicate which direction the current is towards. 100-year winter values are considered to also represent 100-year all-year conditions. At the Corrib Field the summer values are the same as winter because there are inadequate grounds to reliably quantify seasonal variations					

Flow patterns near Erris Head were noted to involve only one ebb and one flood tide per day (diurnal, instead of two tides daily (semi-diurnal). The observed currents may not, therefore, be purely tidal, but may have been influenced by the formation of coastal eddies. Within Broadhaven Bay the tidal streams run in and out of the inlets. The pattern is further complicated as small coastal eddies form inside Broadhaven Bay. Current flow paths generated from hydrodynamic modelling **(Section 9.6.1)** confirm this.

Hydrodynamic Model of Broadhaven Bay

In order to assess the tidal current conditions within Broadhaven Bay, Kirk McClure Morton were commissioned to implement a hydrodynamic model.

The hydrodynamic model **(Appendix 9.1)** indicates that in the offshore area, i.e., beyond Erris Head and Kid Island, the flood tidal stream tends to set to the north east, while the ebb runs in a generally south westerly direction. The south west going flow is predicted to begin at approximately 2 hours after high water Broadhaven and runs for circa 6½ hours. Similarly, the flood commences at approximately 9 hours after local high water and runs for around 6 hours. Peak speeds during both the flood and ebb tides are similar at approximately 0.5 m/s.

Within outer Broadhaven Bay, i.e., the open water area bounded to the north by a line between Erris Head and Kid Island but excluding the various inlets, the tidal flow regime is significantly weaker than offshore.

The model predictions indicate a noticeable reduction in the magnitude of the tidal currents moving southwards through this area. The relatively high tidal flows past Erris Head and Kid Island give rise to the formation of eddies or gyres during both the flood and ebb tide. This is in line with the indication on the Admiralty Chart of the occurrence of tidal overfalls in these areas.

Further into the outer Bay, the model predicts tidal currents to be very slack, particularly in the area around the entrance to Rossport and Sruwaddacon Bay, where tidal exchange appears to be very limited. Examination of the predicted flood and ebb tidal flow patterns within the outer Bay **(Figures 6 and 8, Appendix 9.1),** indicates that the main tidal stream flows to and from inner Broadhaven Bay along the Erris Head side of the Bay. During the ebb, there is some flow along the eastern shoreline towards Kid Island however this is weak during spring tides and almost non-existent during neaps.

The model predicts the onset of the ebb tidal flow from inner Broadhaven Bay i.e. the area south of a line between Gubacashel Point and Brandy Point, to commence around the time of high water Broadhaven while the ebb from Rossport begins approximately one hour later. Similarly, the flood tidal streams commence at 6 and 7 hours after local high water with the stream into inner Broadhaven Bay again occurs in advance of the flow into Rossport.

Within the narrow entrances to inner Broadhaven Bay and Rossport, significant tidal currents are predicted to occur, reaching speeds of well in excess of 1 knot. These tidal streams are particularly significant off Rossport Quay, where tidal streams of circa 2 m/s are predicted to occur.

The predicted tidal current speeds are broadly in line with the observations stated in the Irish Coast Pilot (Hydrogapher of the Navy, 1997). This document states that off Broadhaven Bay the NE going tidal stream begins at 3 hours after HW Galway and runs for approximately 6 hours, attaining a peak speed of approximately 1 knot. Similarly, this reference reports the flood tidal streams into the bays as commencing at 5 hours before HW Galway and the ebb at one hour after HW Galway. Thus since local high water occurs approximately 1 hour after high water at Galway, the timing of the tidal streams appears to be well represented in the model.

The flow paths for the different tidal conditions modelled are presented in **Appendix 9.1.**

9.3.2.4 Tidal Conditions

Water levels are presented as 'still water levels' (SWL), i.e., the mean water level exclusive of waves. The mean spring tidal range at Broadhaven is 3.0 m, while the range of neap tides is 1.4 m. The lowest astronomical tide (LAT) at Broadhaven is 0.0 m, while the highest astronomical tide (HAT) is 4.2 m.

Storm surge levels are meteorologically-induced changes in SWL. They arise as a result of barometric pressure changes and wind forces and can only be predicted with accuracy a few hours in advance. Values at three DHI model points along the pipeline route are presented in **Table 9.4** for winter (all-year) conditions for 1, 10, 50 and 100 year return periods. The values given in **Table 9.4** are still water levels relative to predicted tidal level.

Table 9.4: Extreme storm surge heights (m) for different return periods at three points along the Corrib pipeline route

Site	1 yr winter	10 yr winter	50 yr winter	100 yr winter
DHI 6070	0.5	0.6	0.7	0.7
DHI 6084	0.6	0.7	0.8	0.8
DHI 6094	0.7	0.8	0.9	0.9
The surge periods relate to a duration of 3 hours				

Total water level is the combined result of tidal and surge levels. For the same three DHI model points along the pipeline route, the total still water level for return periods of 1, 10, 50 and 100 years are presented in **Table 9.5**, relative to mean sea level. It can be seen that at the inshore stations, for a given return period, the extreme total level is somewhat below the highest tidal level plus equivalent surge level. This reflects the reduced probability of the joint occurrence of the extreme events.

Table 9.5: Extreme total water levels (m) for different return periods at three points along the Corrib pipeline route

Site	1 yr winter	10 yr winter	50 yr winter	100 yr winter
DHI 6070	2.3	2.4	2.5	2.6
DHI 6084	2.3	2.6	2.7	2.7
DHI 6094	2.4	2.7	2.8	2.8
The surge periods relate to a duration of 1 hour				

The values predicted by NEXT are considered reasonable, because they are consistent with the tidal levels (derived by Metoc based on Admiralty Tide Tables), and with the 50-year storm surge heights published by the UK Dept of Energy (Dept Energy, 1990).

9.3.3 Stratification and Water Quality

9.3.3.1 Stratification

Stratification of the water column (the stratification can be either on a thermal or a salinity basis) occurs during the summer months, unless very strong tidal mixing prevents this. Temperature differences between the surface and deeper water layers lead to the formation of a seasonal thermocline (a depth zone of marked rate of temperature change with depth). Due to the presence of this thermocline, mixing between the upper and lower layers of water is restricted and stratification occurs. Higher air temperatures maintain the temperature differences during the summer, continually warming the surface waters, while at depths there is no source of heat. Very strong winds can drive the surface waters downwards; this is termed “mixing”, and can result in the layers of water becoming “mixed”, with little differences in temperature with depth. Stratified layers can reform in the summer, but generally in autumn and winter the solar warming is not sufficient to maintain the thermocline. The stratified layer usually occurs at a depth of 50 – 60 m in nearshore regions (these being defined here as a distance of up to 20 miles off the coast) and at 80-100 m depth offshore.

Seawater Properties - general

In an average year surface water temperatures at the Corrib Field are likely to range from about 9°C in March to about 15°C in August. The range of temperatures is more limited at depth, with little variation expected below 100 m, where a temperature of close to 10°C is typical. Nearshore in April/May thermal stratification begins to develop, peaking in July, with bottom temperatures are often 5-6°C cooler than the overlying surface waters (Huang *et al*., 1991; McMahon *et al*., 1995). Stratification usually breaks down in September/October (McMahon *et al*., 1995).

Water surface salinities of approximately 35.1 parts per thousand (ppt) persist throughout the year in the Corrib Field. Below 100 m depth the salinity is approximately 35.4 ppt. Lower salinities could be found in the nearshore sections of the pipeline route.

9.3.3.2 Seawater Chemistry

The Corrib development, which falls within OSPAR Region III, covers a range of seawater environments from open Atlantic Ocean to nearshore tidal bays. Scientists from the Marine Institute have contributed to the OSPAR Quality Status Report 2000 for the Celtic Seas. The input was presented in a report entitled *Ireland's Marine and Coastal Areas and Adjacent Seas: An Environmental Assessment;* Boelens *et al*. (1999). This is a comprehensive document which covers the area designated as OSPAR Region III.

Data sets on marine chemistry have been studied. The west coast of Ireland in general, and more specifically, the areas affected by the Corrib development, are not well documented, since very few studies have been carried out in these areas.

Other data sets studied include that from the Monterey Bay Aquarium Research Institute (MBARI) Chemical Sensor Programme. In **Figure 9.3** data from the MBARI programme show typical concentrations for the 12 key metals in the sea, which are expected to be present in treated effluents containing produced water discharged from the Terminal.

In order to assess the impact of the Corrib development, it is important to be able to judge it against the existing conditions. The natural environment is dynamic and it generates internal contaminants as a result of natural geological processes such as volcanic activity, mudslides and earthquakes and other natural processes such as forest fires, flash floods and extreme tide or wind events. In addition, there are human inputs which have increased over the time that man has been active on the planet; more so since the advent of the industrial revolution. **Figure 9.3** details the natural concentration profiles of metals in the Atlantic Ocean.

In the assessment of the existing environment for the Corrib development, it will be seen that, at trace quantities, the existing environment already contains a number of contaminants, which are both natural and man made.

Inputs to seawaters

Rivers

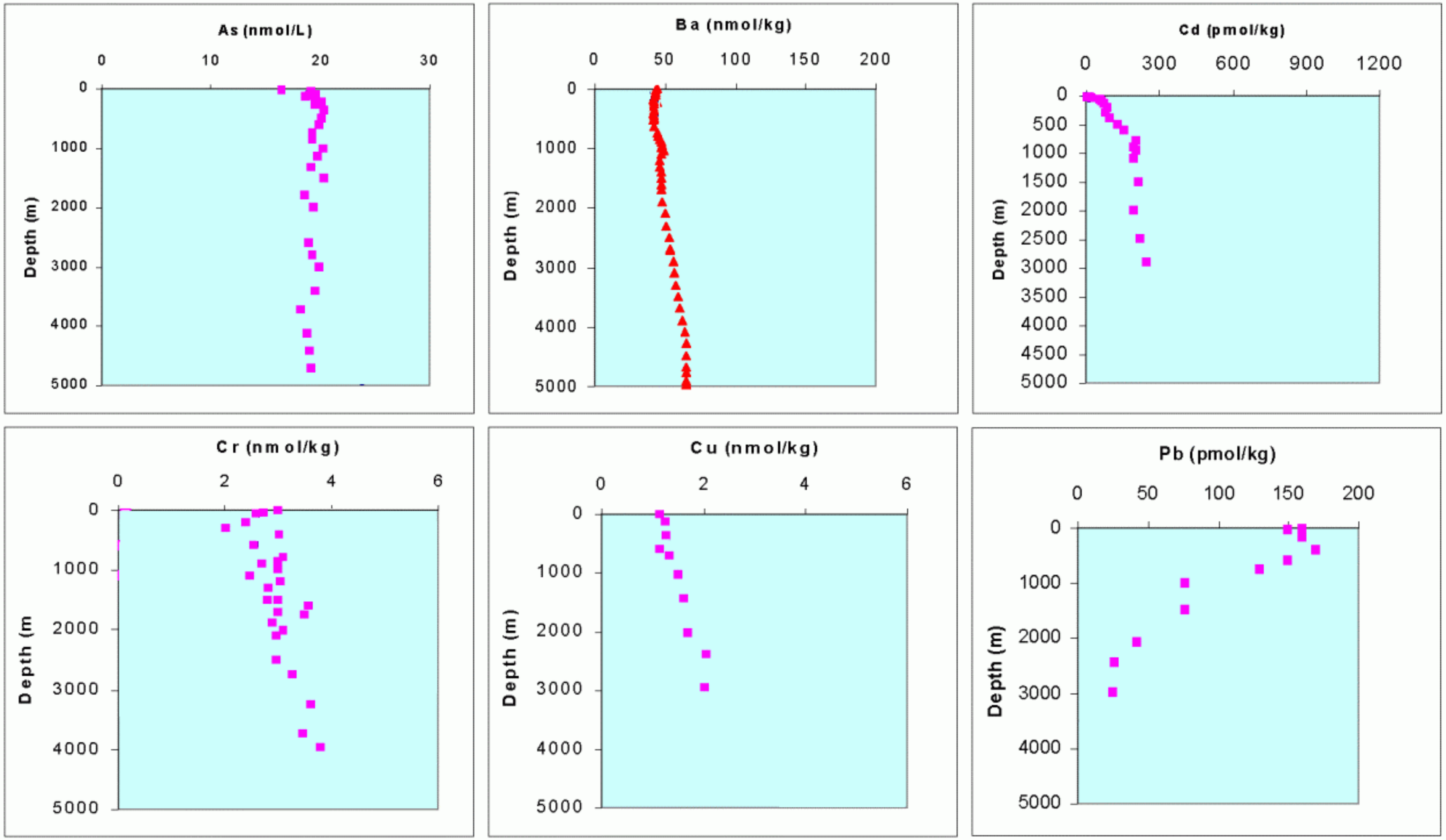
Background levels of metals that reflect natural geochemical weathering of soils are ever-present in Irish rivers. Elevated levels of metals occur in rivers that drain contaminated land. Using data from river catchments, the Marine Institute (Boelens *et al.*, 1999) estimated the input of metals into the Irish coastal waters for a number of years between 1990 and 1996 (**Table 9.6**).

Table 9.6: Estimated annual loads of 4 metals over 1990-1996 for the principal rivers discharging into the Atlantic

Metal	1990 tonnes	1992 tonnes	1993 tonnes	1994 tonnes	1995 tonnes	1996 tonnes
Copper	33.6	59.7	36.2	67.6	62.5	19.3
Zinc	235.8	498	165.4	183.4	418.5	138.4
Lead	26.5	23.4	4.5	14.5	16.9	7.6
Cadmium	1.14	0.45	0.37	0.54	0.46	0.77

In addition to the above metals, there are also nutrients entering the sea from rivers, including most notably nitrogen and phosphorus. Nitrogen inputs are perceived as being potentially damaging to coastal waters due to the limiting role of nitrate in marine primary production (stimulation of species which restrict primary production) in many areas (Boelens *et al.*, 1999). In Irish waters nitrate concentrations are generally lower than those found elsewhere in Europe. It could be assumed that, due to a decline in arable farming over the last 10 years in Ireland, there would be a net fall of riverine nitrate loads. In reality, the observed increase over this time period (**Table 9.7**) can partly be attributed to continuing increases in the use of nitrogen-based fertilizers. Other known sources of nitrates include rivers that receive sewage discharges and general farm run-off.

It is universally acknowledged that phosphorus is the main limiting nutrient for algal growth in freshwater, under most conditions. However, the limiting role of phosphorous in marine waters is less certain. Small changes in phosphorus levels can potentially lead to shifts in the trophic status of particular marine areas (McGarrigle, 1993). Phosphorus in rivers arises from the natural background weathering of soils, the decay of plants and inputs due to human activities, e.g., sewage plants and intensive agriculture. Although phosphorus has a generally low mobility in soils, there is a general increase in the input of phosphates in proportion to increasing soil reserves, which is evident in many catchments, due to declining water quality. Consequently, this is likely to increase marine inputs of phosphorus, particularly outside the growing season. Estimated phosphorus inputs to the marine environment from the principal rivers discharging into the Irish marine environment over the period 1990 – 1996 are provided in **Table 9.7**.


As (nmol/L)
0 10 20 30
Depth (m)
0 1000 2000 3000 4000 5000
Ba (nmol/kg)
0 50 100 150 200
Depth (m)
0 1000 2000 3000 4000 5000
Cd (pmol/kg)
0 300 600 900 1200
Depth (m)
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Cr (nmol/kg)
0 2 4 6
Depth (m
0 1000 2000 3000 4000 5000
Cu (nmol/kg)
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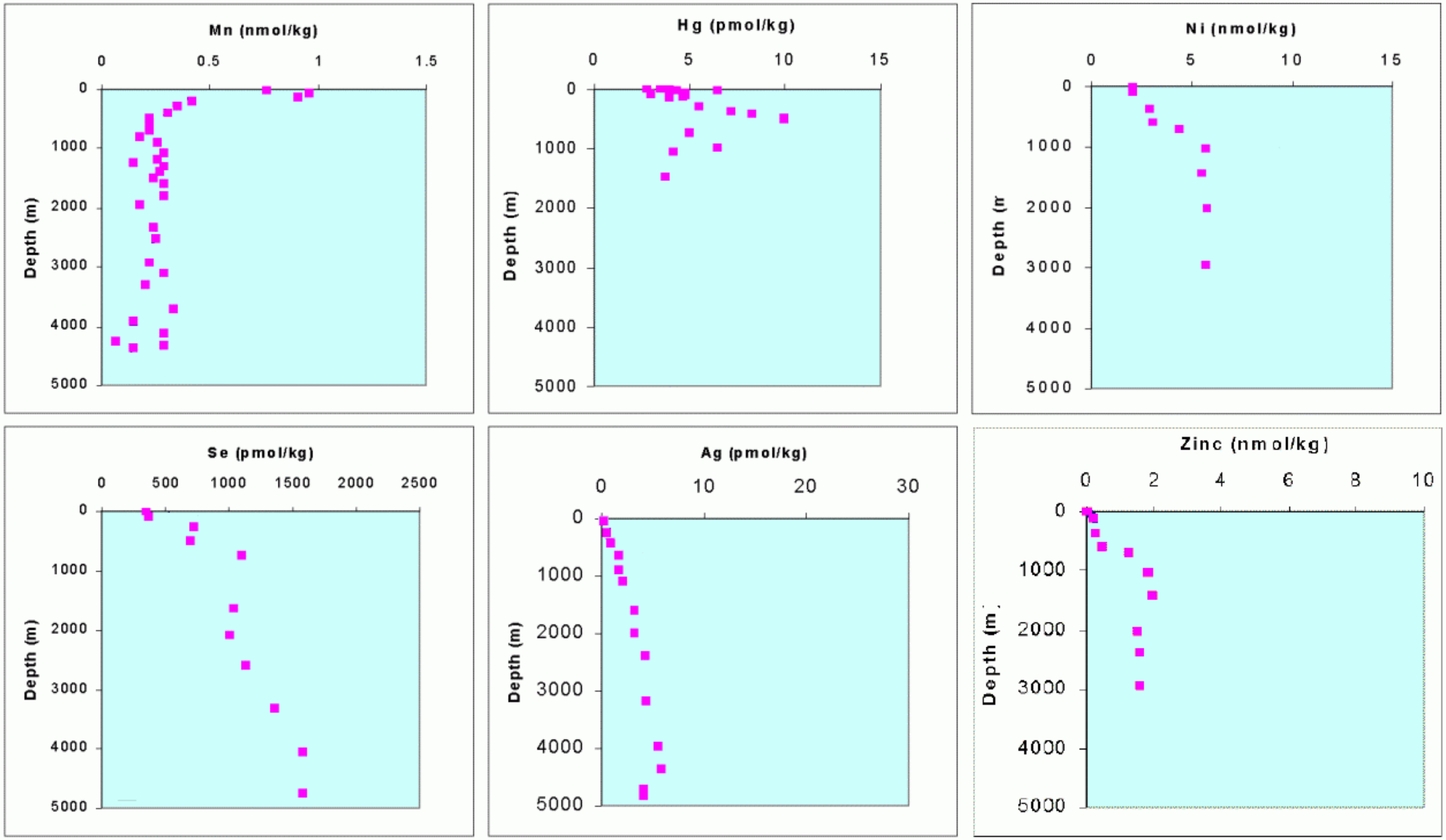
Depth (m)
0 1000 2000 3000 4000 5000



Source: Monterey Bay Aquarium Research Institute (www.mbari.org).

Figure 9.3: Depth profiles of background concentrations of various metals in the Atlantic Ocean

Table 9.7: Estimated annual loads of total nitrogen and total phosphorus over the period 1990 – 1996 for the principal rivers discharging into Irish marine areas

Marine area	1990 kt[1]	1991 kt	1992 Kt	1993 kt	1994 kt	1995 kt	1996 kt
Nitrogen							
Celtic Sea	35.77	37.80	24.05	38.63	46.51	41.61	50.30
Atlantic Ocean	35.86	30.56	27.45	27.79	32.96	27.29	35.90
Phosphorus							
Celtic Sea	1.127	0.868	1.085	1.730	2.526	1.191	2.220
Atlantic Ocean	1.153	0.993	1.057	1078	1.461	1.300	1.240

[1] kilotonnes

Trace organic contaminants are also a potential input from rivers. A project funded by the EU was conducted in 1993 (Cullen, 1994) on the organic compounds in Irish groundwater. The study identified volatile organic compounds (VOCs) as being the most abundant with benzene and chlorinated derivatives, chloroform, dichloromethane, hexachloro-butadiene, toluene and derivatives, xylene isomers and naphthalene are commonly detected. As sites were chosen on their proximity to pollution sources, the study recognised that the results may not be representative of general groundwater quality.

Atmosphere

Metals and other contaminants also enter the sea from the atmosphere. The atmospheric transport of metals is considerably quicker than in water, resulting in long-lived contaminants being rapidly transported around the globe. For Ireland, the prevailing wind direction is westerly and so atmospheric contamination is generally low, on a European scale, but not non-existent, as the atmosphere has a background of contaminants. When the winds swing to an easterly direction, the contaminant levels can increase dramatically, due to their passage over continental Europe. These easterly winds are also generally dry winds, preventing wash-out of contaminants when compared to the wetter westerly winds. Valentia and Turlough Hill both record the flux of contaminants, which are deposited from the atmosphere during dry and wet weather conditions (EMEP/CCC-Report 2/2000). These data can be extrapolated using atmospheric models to give depositional load estimates over the Irish Coastal area.

Table 9.8: Total annual inputs of various metals from the atmosphere and precipitation.

Metal	Precipitation (Turlough Hill, Ireland)	Precipitation (Valentia Observatory, Ireland)	Total input to OSPAR area III from atmosphere
	g/km²	g/km²	tonnes/yr
Arsenic	481	446	6.5
Cadmium	154	214	1.4
Chromium	481	446	7.3
Copper	1192	5258	10.8
Lead	1691	1301	152
Mercury*	115	107	~
Nickel	1057	891	47.5
Zinc	5055	95068	82.8
* measurements of mercury in precipitation at Turlough Hill and Valencia may not be reliable due to the high detection limits in the method of detection (EMEP/CCC, 2000)			

Nutrient deposition from the atmosphere is highly dependent on the wind direction. The wet westerly winds tend to have lower concentrations of nutrients compared to the dry easterly winds. Using ammoniacal compounds as an example, concentrations measured on the west coast of Ireland were up to 4 times less than those on the east coast (McGettigan & O'Donnell, 1995). The majority of atmospheric nitrogen is attributable to anthropogenic sources, and so a declining concentration from east to west is again experienced under most conditions. Atmospheric phosphorus deposition is thought to be responsible for the absence of oligotrophic lakes in the north of Ireland, and as a result, could present a large source of phosphorus to the sea. However, as some atmospheric phosphorus is recycled from the sea, the exact contribution of phosphorus from the atmosphere into marine areas is difficult to ascertain. Estimates of atmospheric deposition of various nutrients are provided in **Table 9.9**.

Table 9.9: Approximate annual atmospheric inputs of various nutrients into the Atlantic zone west of Ireland

Nutrient	Input
Ammonical compounds	0.25 gNH_4-N/m²/yr
Oxidised Nitrogen (Nitrate & Nitrite)	0.2 gNO_3-N/m²/yr
Total Nitrogen	0.175 gN/m²/yr
Phosphorus	20 mgP/m²/yr
Data taken from Boelens *et al*. (1999)	

Other inputs from the atmosphere include trace organic chemicals, such as petroleum hydrocarbons (PHCs) and Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), pesticides, and dioxins. These compounds are all deposited into the ocean from the atmosphere. Estimates for the west coast of Ireland are given **Table 9.10**.

Table 9.10: Estimates on the annual input of organic contaminants into the Atlantic zone west of Ireland

Contaminant	Input
PHCs	0.8 to 1.3 $mg/m^2/y$
PAHs	0.35 $mg/m^2/y$
PCBs	1.8 $\mu g/m^2/y$
Pesticides	0.9 $mg/m^2/y$
Dioxins	2.1 $ng/m^2/y$
Data taken from Boelens *et al*. (1999)	

Dumping

Disposal of sewage sludges and dredged sediments can give rise to measurable loads of contaminants. However, the wide-scale disposal of sewage sludge to the sea has ceased in most of Europe in recent years, due to the enactment by Member States of European Union legislation. However, many sewage outfalls serving small coastal communities still discharge untreated human waste to sea.

According to Boelens *et al*. (1999), there are no marine disposal sites close enough to the Corrib Field to influence background conditions there. However, in the coastal region of the pipeline route landfall, there are outfalls of untreated sewage.

Mariculture

Marine finfish and shellfish farming in Ireland have expanded considerably over the past 30 years. The expansion has been most pronounced on the western seaboard and to a lesser extent on the southern coast (Boelens *et al*., 1999). The cultivation processes involve pellet feeding and the use of chemotherapeutics. These activities introduce contaminants into coastal waters in the form of nutrients and other trace organic compounds.

Petroleum Hydrocarbons

Large spills from tankers are the most widely known form of marine pollution by petroleum hydrocarbons. However, to put this into context, it is notable that the total global estimate for inputs of petroleum from tanker spills in 1989 (568,000 tonnes; GESAMP, 1993) is dwarfed, compared with inputs resulting from hydrocarbon biosynthesis by phytoplankton (26,000 million tonnes/year) and atmospheric fallout from natural sources (100-4000 million tonnes/year) (Clark, 1992). There is little evidence of adverse ecological impacts from these latter sources and thus, attention tends to be focused on anthropogenic activities, such as tanker spills, and onshore and offshore petroleum installations.

From data presented in Boelens *et al*. (1999), the most significant losses of oil into the sea are operational losses rather than accidents. These authors also note that since the enactment of the MARPOL regulations (MARPOL 73/78 enacted through the Sea Pollution Act 1991), there has been a substantial reduction in oil inputs to marine environments in most categories. No specific data are available for operational losses of oil from shipping in Irish waters. Nevertheless, given the volume of traffic in the whole of Region III (150,000 merchant vessel transits and 13,000 tanker transits per year), it is considered that these inputs are likely to be significant (Boelens *et al.*, 1999).

Metals

Inputs from rivers, the atmosphere, disposal operations, and mariculture, all contribute to background concentrations of key metals. These background levels of metals increase significantly towards the coastlines, as shown in **Table 9.11**.

Table 9.11: Background concentrations for five key metals in the Ocean, Offshore and Estuarine Environments (OSPAR, 2000 Region III QSR)

Metal	Ocean	Offshore	Estuarine
	Concentration in µg/litre unless otherwise stated		
cadmium	0.05	0.01 – 0.03	0.03 – 0.1
copper	0.5	~	0.31
lead	0.03	~	0.12
mercury	0.1-0.4	0.2 – 0.5 (ng/l)	~
zinc	5	0.5	40

Seawater samples were taken from Broadhaven Bay in 2000 and 2001. These samples were analysed for the range of potential metals that might occur in the produced water. The results of these analyses are provided in **Table 9.12.**

Table 9.12: Measured background metal concentrations in Broadhaven Bay

Metal	2000 mg/l	2001 mg/l	Metal	2000 mg/l	2001 mg/l
antimony	~	0.001	**manganese**	0.014	0.056
arsenic	0.008	0.006	**mercury**	<0.0001	0.000041
barium	<0.01	0.00761	**molybdenum**	~	0.007
cadmium	<0.0001	<0.00004	**nickel**	0.005	0.005
chromium	0.001	0.003	**selenium**	0.042	0.0056
cobalt	~	0.001	**silver**	<0.001	<0.001
copper	0.011	0.018	**strontium**	6.66	~
calcium	401	~	**tin**	~	<0.001
iron	0.01	~	**vanadium**	~	<0.001
lead	<0.001	0.000864	**zinc**	0.005	0.032
magnesium	1280	~			

The measured concentrations in Broadhaven Bay tie in well with published data, with the exception of selenium and manganese. Selenium and manganese are found in higher concentrations than most other trace metals in seawater. One reason is because they form oxyanions upon contact with water. These oxyanions are readily soluble in water. Other transition metals tend to form insoluble colloids (very fine grained solids) in solution, and therefore exhibit lower concentrations in marine waters. Manganese exhibits a negative concentration gradient (concentration increases with proximity to the shore) which suggests a significant input to the coastal zone (e.g. by river runoff or diffusion from bottom sediments). By contrast, the opposite trend is the case for lead, leading to the suggestion that the lead input is largely atmospheric (Chester, 2000).

9.3.3.3 Broadhaven Bay

Broadhaven Bay is open to the west and north west. It has a total area of about 100 km^2. The outer limit of the Bay, taken as a line between Erris Head and Kidd Island, has water depths of around 50 m LAT. The Bay shelves towards the coast where the inner bays of Sruwaddacon, Broad haven and Ross Port create tidal reaches with drying banks, into which local rivers and streams flow.

Of the rivers and streams feeding the Bay, the largest is the Glenamoy. Flow recording for the Glenamoy River between 1978 and 1997 (EPA 2001 pers. com) shows the average daily flow as 2.96 m^3/sec. or about 255,000 m^3/day. Using the average rainfall data for Bellmullet of 1000 mm per year falling over the area of the Bay a similar volume of rain enters the Bay in the form of incident rainfall.

9.4 Characteristics of the Proposed Development

The five existing appraisal wells drilled and suspended in the Corrib Field will be completed and used as production wells, requiring three new production wells to be drilled. It is anticipated that these new production wells will be drilled between 2002 and 2007 (see **Section 3**).

A 20" gas pipeline will be constructed from the Corrib Field to the onshore Terminal. Well operations will be controlled from the Terminal, by an integrated electro-hydraulic control umbilical, which will lie alongside the pipeline.

In addition to the above, a water discharge pipe will be laid in Broadhaven Bay from the Terminal site. This will be installed at the same time, and in the same trench, as the gas pipeline. It is likely that the discharge pipeline will be "piggy-backed" onto the larger gas pipe.

9.5 Potential Impacts of the Proposed Development

The impacts described in this section are those which could potentially occur if no mitigation measures were in place, the mitigation measures and consequently reduced impacts are described in later sections.

9.5.1 Offshore

9.5.1.1 Drilling and Completion

The routine discharges generated during the proposed drilling and completion programmes by the Mobile Offshore Drilling Unit (MODU) and support vessels include the following waste water streams:

- open drainage waters:
  - deck drainage water from open drains of the rig and support vessels; and
  - rig wash.
- domestic waste waters discharged via the discharge caissons:
  - treated effluents from the sewage and grey water treatment systems of the rig and support vessels; and
  - macerated, putrescible food wastes from the rig and support vessels.
- service waters discharged via the discharge caissons:
  - treated effluents from the closed drainage systems on the rig;
  - laboratory sink drainage;
  - discharges from well clean-up and production test flaring;
  - ballast water; and
  - effluent from potable water makers.
- drilling muds and cuttings and cement discharged, either directly to the seafloor from the wellbore, or from the rig via the cuttings chute:
  - water-based mud (WBM) fluids retained on drill cuttings; and
  - drilled solid cement and excess slurry cement.

The well casing plan presented in **Section 2** is used as the basis for the estimate of drilling discharges. Volumes of other waste streams are estimated assuming maximum drilling and completion programme durations per well of 60 days and 25 days, respectively, and a personnel on board (POB) complement on the MODU of 90 and on each of the support vessels of 12.

Open Drainage Waters

The volume of water discharged from the open drainage system is dependent on the level of rainfall during the drilling programme. Rain water from open areas is directed to the open drains system and is not subject to treatment prior to discharge. This waste water is uncontaminated, and no impacts will result from its discharge.

Domestic Waste Water

The principal domestic waste water streams are the grey and black waters and putrescible galley wastes. Black water is the term used in the MARPOL regulations Annex 4 to describe sewage. Grey water usually refers to shower and washing water, although it is not defined specifically in the MARPOL regulations. The volume estimates per well for these waste streams are presented in **Table 9.13**.

Table 9.13: Domestic liquid waste water discharges for the future wells

Waste Streams	Generation Rate	Totals
MODU		
Sewage & Grey water	0.250 m^3 per person per day	9110 m^3
Putrescible Galley Wastes	0.0003 tonnes per person per day	10.94 tonnes
Service vessels (2)		
Sewage & Grey water	0.250 m^3 per person per day	1980 m^3
Putrescible Galley Wastes	0.0003 tonnes per person per day	2.38 tonnes
Based on the assumptions that there will be two service vessels operating in the Corrib Field for the duration of the drilling and completion programmes; three further wells are to be drilled; a worst-case assumption of three well tests and six wells to be completed after being suspended.		

Service Waters

The majority of drainage effluents are directed to the closed drainage system(s).

These system(s) are fitted with International Maritime Organisation (IMO) approved oil/water separator units, with an operational design maximum residual oil in water level for the discharge effluent of 15 ppm.

During drilling with WBM, drainage from the drill floor is normally directed for discharge to the sea, without passing through the oil/water separator, if it is uncontaminated. This effluent could contain surplus rig wash detergent.

It is estimated that approximately 3,000 litres of rig wash detergent concentrate is used during the 85 day drilling and completion programme. However, only a small proportion of this (approximately 10%) is directed for discharge to sea.

The mud laboratory sink drainage system onboard the rig is directed for overboard discharge. However, this sink is used for general washing only, so would contain only trace amounts of mud and mud chemicals. Mud samples are collected in a bucket and recycled back into the mud pits on the MODU.

Fire water and ballast water are discharged without treatment. Ballast water is normally uncontaminated. However, if a chemical system is used to inhibit biological growth, the ballast water may contain low concentrations of residual biocide.

A closed loop system is operated for the cooling water for the MODU. No discharge of cooling water is anticipated.

The waste stream from the potable water maker (desalination unit) is normally a brine solution. The effluent contains trace amounts of scale inhibitor, and periodic acid wash waters.

The impacts from discharge via the open drains and of domestic and service waters are expected to be negligible. The volumes are relatively low, and the open nature of the discharge area will enable rapid dilution to take place.

Drilling Muds and Cuttings

An estimate of the volume of WBM and cuttings generated per hole interval during the drilling programme is presented in **Table 9.14**. The cuttings from well sections I and II are discharged directly to the seabed from the top of the well. Cuttings from sections III and IV, drilled with low-toxicity oil based mud are taken to shore for disposal or recycling (see **Section 15**).

Table 9.14: Typical drilling fluid and cuttings discharges by hole interval for three future wells

	Section I (36") m^3 (tonnes)	Section II (17.5") m^3 (tonnes)	Total m^3 (tonnes)
Dry cuttings	156 (417)	282 (747)	438 (1164)
Mud on Cuttings	468 (561)	120 (144)	618 (705)
Assumptions: Washout: 36" well section washes out to 45.5" (60%), 17.5" washes out to 19.25" (21%). Rock density of approx 2.65 Mud and Cuttings from sections III and IV are returned to the shore			

A breakdown of the estimated discharge volumes for all drilling chemicals for the three future wells is presented in **Table 9.15**. A breakdown of the discharges per well section for an individual well is provided in **Appendix 9.2**. For WBM most of the chemicals used or discharged will return directly to the seabed. WBM is defined here as seawater with viscous mud sweeps. The sweeps are mixed with bentonite (naturally occurring clay material) to provide viscosity and good hole cleaning characteristics.

Table 9.15: Estimated drilling fluid chemicals discharge for the three future wells

Mud Chemicals	HOCNF Categ.	Total Material Left Downhole Kgs	Discharge to Sea Kgs	Total Returned to Shore[1] Kgs
BW Base Oil	SBM[2]	291,807	0	409,620
BW Emul Vis	SBM[2]	12,342	0	18,732
BW Kleemul 50	SBM[2]	14,796	0	20,184
BW Kleemul	SBM[2]	5,451	0	7,233
BW Emul Treat	SBM[2]	657	0	627
BW Emul Thin S	SBM[2]	0	0	0
BW Emul Lift	SBM[2]	294	0	711
BW Barite	E	242400	384948	356,880
BW Eco Tech	SBM[2]	2,529	0	885

Mud Chemicals	HOCNF Categ.	Total Material Left Downhole Kgs	Discharge to Sea Kgs	Total Returned to Shore[1] Kgs
Calcium Chloride	E	44,706	0	66,471
Caustic Soda	E	0	750	0
BW Eurogel	E	0	204,000	0
Xantham Gum	E	0	0	0
Lime	E	8,910	0	10,857
Soda Ash	E	0	3,000	0
CONTINGENCY CHEMICALS				
BW Defoam Green	E	0	0	0
Guargum	E	0	0	0
Hi Vis CMC	E	0	2,025	0
BW Emul Thin S	SBM	69	0	45
BW Envirowash2	D	0	17193	0
BW Nutplug	E	0	0	0
Calcium Chloride	E	0	0	0
Sandseal	E	2,583	1170	6,252
BW Metacarb	E	9549	13401	13,788
Delta P	E	0	0	0
Kwikseal	E	0	0	0
Sodium Chloride	E	234519	394935	0
Sodium Bicarbonate	E	0	0	0
Citric Acid	E	0	0	0
Mica	E	0	0	0
Ironite Sponge	E	0	0	0
COMPLETION FLUID				
Sodium Bromide	E	86442	210909	
Potassium Chloride	E	124059	221634	
BW Rheodrill D	E	0	1050	
BW Envirosolv 2	E	0	2310	
BW Envirocor 2	E	4404	6552	
Sodium Metabisulphite	E	363	612	
BW Biocide	E	519	873	
Rheopol R	E	42	633	
WELL CLEAN-UP ADDITIVE				
BW Envirofloc 2	E	0	3000	
SUPPLEMENTARY/PRODUCTION CHEMICALS				
Methanol	E	0	9444	
Monoethylene Glycol	E	0	18207	
CarboProp	E	106194	49245	

The estimates above are based on multiplying the discharges from well 18/25-3 by 3
[1] Material returned to shore for re-cycling or disposal
[2] Chemicals classified under HOCNF as SBM. These form part of the LTOBM formulation used in well 18/25-3 and probably future wells, there is no discharge of these chemicals

The use (and therefore the discharge) estimates presented in this EIS represent the worst case, especially for the contingency chemicals, with calculated maximum requirements being presented. Contingency chemicals are only used if drilling problems are encountered.

The potential impact of these mud discharges is seen as moderate without mitigation.

Cement

For the first two casings (the 762 mm (30”) Conductor casing and 508 mm (20”) surface casing), some excess cement slurry will be returned from the well bore directly to the seabed around the hole opening and the low pressure well head housing (LPWH), respectively.

For each casing string the cement volume used includes an allowance for building up a cement plug inside the casing to ensures that the cement provides a strong seal around the outside of the casing shoe. When drilling into the next interval, the hardened cement plug is drilled up. The drilled solid cement is then handled in the same way as the drill cuttings, either being returned to the seabed, or directed to the solids and mud handling equipment onboard the rig. This set material is essentially inert, with the additives fixed within the cement matrix.

A small amount of residual cement slurry will also be discharged during cement tank washout. The estimated volumes of excess slurry and drilled solids discharged to sea are included in **Table 9.16**. A breakdown of the estimated discharges per well section for an individual well is provided in **Appendix 9.2.**

The potential impact of these cement discharges is assessed as minor**.**

Table 9.16: Estimated cement slurry and drilled solids discharges for the three future wells

Cement Chemicals	Product ID.	HOCNF Categ.	Drilling[1]		Testing[2]	
			Material Left Downhole	Total Discharge	Material Left Downhole	Total Discharge
			Kgs	Kgs	Kgs	Kgs
Calcium Chloride	S-001	E	4,614	1,293	0	0
Sodium Chloride	D-044	E	5,615	2,971	9376	2880
Retarder	D-110	E	3,303	567	0	0
Barite	D-031	E	0	0	5532	20316
Bentonite		E	0	0	0	0
Surfactant	B-064	C	2,136	561	8444	2144
Cement Rugby Class G	D-907	E	635,916	28,074	196092	20136
Retarder	D-801	C	0	0	1120	484
Defoamer	D-175	E	666	171	776	248
Dispersant	D-145A	C	2,742	546	2104	604
Mudpush XL	D-149	B	0	0	140	348
Anti Settling Agent	D-153	E	0	0	752	216
Retarder	D-081	E	174	30	1000	0
Silica Flour	D-066	E	0	0	33008	1120
Extender	D-075	E	10,426	1,023	0	0
Mutual Solvent	U-066	E	0	0	0	0
Sea Dye		E	150	0	0	0
Gasblock	XE-903	D	0	0	30324	9360
UNIFLAC	D-168	E	8,346	3,084	0	0
Cement Additives						
Buffer	BF-10LE	E	0	0	2988	1653
Buffer	BF-7L	E	0	0	20910	5109
Surfactant	D-4G	D	0	0	0	114
Surfactant	D-4GB	E	0	0	11565	3114
Anti-foamer	FP-9L	B	0	0	744	177
Frac gel breaker	GBW-5	C	0	0	93	21
Water gellant	GW-4 AFG	E	0	0	22221	13392
Frac gel breaker	High Perm CRB	C	0	0	39	9
Biocide	XCIDE 102	D	0	0	1596	1344
Crosslinker	XLW-56	D	0	0	10500	2568
Gelling agent	XCD Polymer	E	0	0	0	87
Friction reducer	FRW-14	B	0	0	0	732
Corrosion inhibitor	CI-27	C	0	0	0	510

[1] Drilling discharges based on actual returns from well 18/25-3 multiplied by 3, actual drilling discharges from well 18/25-3 are provided in Appendix 2.1.
[2] Testing discharges based on actual discharges for well 18/25-3, multiplied by 3.

Well Testing Discharges

During well testing operations, any produced water separated from the reservoir fluids in the test separator will be either fed into the burner, or directed for discharge to sea. This separated fluid contains excess well clean-up chemicals at the start up of the testing operations. The only other discharge to water associated with the well testing operations is condensate drop out from the flare. Based on a burner efficiency of 99% for reservoir fluids, it has been assumed that there will be almost zero condensate carry over and therefore, zero condensate dropout on the sea surface during production test flaring. There are no well tests planned for wells 6, 7 or 8, but in the worst–case scenario, that well tests are carried out for all future wells, the impact is still considered to be negligible.

9.5.1.2 *Facilities Installation*

Estimates of the volume of black and grey waste waters, discharged from the vessel spreads during the Field facilities and the pipeline and umbilical installations, are provided in **Table 9.17**. Estimates have also been provided for galley wastes from the installation vessels. A breakdown of the discharges per vessel for both the facilities and pipeline installation operations is provided in **Appendix 9.2.**

Table 9.17: Black and grey water and galley waste production estimate during Field facilities and pipeline and umbilical installation

	Total mandays	Black and grey water (m^3)	Putrescible Galley waste (tonnes)
Field Facilities Installation	17,560	4,390	5.27
Pipeline and Umbilical Installation	25,185	6,296	7.56
Total	42,745	10,686	12.83

Assumptions:
Black and grey water is produced at a rate of 0.250m^3 per person per day
Putrescible Galley Waste is produced at a rate of 0.0003 tonnes per person per day

The potential impacts from discharge of black and grey water and galley wastes during installation of the field facilities, the pipeline and umbilical are considered to be negligible in general, possibly minor locally without the mitigation measures which are discussed in **Section 9.7**.

9.5.1.3 *Decommissioning*

Current international conventions (OSPAR 98/3) now require that all equipment above the seabed be removed to shore, where, if possible, it would be recycled. This would include removal of the wellheads to a depth of 3 m below the seabed, where the wells would be capped with cement. The infield flowlines and umbilicals would all be removed from the seabed and the manifold and PLEM would be retrieved.

Decommissioning of the infield facilities in accordance with the above convention will have some local and temporary impacts in the short term on the aqueous environment. Beyond that time there will be no further impact.

9.5.2 *Pipeline and Umbilical*

9.5.2.1 Installation

During the laying of the pipeline and umbilical, the potential impacts on the aqueous environment, in addition to the vessel discharges discussed above in **Table 9.17**, will be the generation of a small amount of suspended sediment as the pipeline is laid on the seabed. The trenching of the umbilical will also generate more suspended sediment. The finer fraction will stay in suspension for a longer period than the coarser fraction, which will more rapidly fall out of the water column and be re-deposited on the seabed. The potential impact is considered to be negligible over the entire route, but to be minor locally during umbilical trenching.

Hydrotesting and Commissioning

Once the pipeline has been laid on the seabed, it will be hydrotested to ensure that it has no leaks. Hydrotesting involves filling the pipeline with water and raising the pressure of the water to well above that which would normally be expected within the system. In order to eliminate the potential for corrosion of the pipeline during the hydrotest, oxygen scavenger and corrosion inhibitor are added to the water. A biocide is also added to reduce biological activity, and a dye is added to enable the location of any leaks during the test. There will be a complex pressure recording system to enable the identification of any reductions in pressure.

The volume of water used in the hydrotest will be approximately 18646 m^3 (92 km pipeline of 20” diameter pipeline). During hydrotesting, the water winning line will be fitted with filters and flotation devices in order to minimise sediment disruption and to stop marine organisms from being captured in the test water. Minimal concentrations of biocide (B1150 200 ppm), corrosion inhibitor (CP 1900 200 ppm), oxygen scavenger (OS2 155 ppm) and dye (fluorescein 25 ppm), will be added to the water. The discharge of hydrotest water will be via the subsea completion to achieve high levels of dilution. The umbilical will not require hydrotesting.

The water will be pumped into the pipeline by a vessel in the Corrib Field, and it will also be discharged in the Corrib Field. The hydrotest water will be discharged in the Field, at a distance of 65 km offshore. Potential impacts from the discharge of such a volume of water, containing small amounts of chemicals, is considered minor for the Corrib Field, due to the large dilution potential available.

In order to evacuate all the water from the pipeline after the hydrotest and prepare it for transporting gas from the field to the Terminal, a sequence of pipeline integrity gauges (PIGS) will be used to dry the line. These "swabbing" PIGs will be pushed through the pipeline from the Terminal to the Field using compressed nitrogen gas, the sequence will also push through the pipeline drying agents, such as glycol, to remove as much water as possible. The PIGs and chemicals will be recovered in the Corrib Field via a temporary pig-catcher, installed at the Corrib manifold.

The umbilical will be tested prior to installation. No discharges will result from commissioning of the umbilical.

9.5.2.2 Operation

Hydraulic Fluid

The hydraulic control fluid will be a 50:50 water:glycol mixture. In order to fully open or close all the valves on one christmas tree, approximately 14 litres of this glycol mixture would be discharged.

It is estimated that a maximum of 1,344 litres of the glycol mixture will be discharged per year (all valves operated monthly on each well), equivalent to 672 litres of glycol (HOCNF category E). The discharge of this fluid is expected to have a negligible impact upon the water quality in the Corrib Field.

Maintenance vessel operations

During the production life of the Corrib Field, there will be a requirement for vessels to carry out well maintenance and survey operations. For well maintenance a drilling rig would be required, with attendant vessels, while for other operations single (survey) vessels would be present. During the time they spend in the Corrib Field these vessels will be discharging black and grey water and galley waste. It is not possible to estimate accurately the frequency of maintenance operations, nor therefore the likely discharges. However, it can be assumed that these discharges will not be of the same order of those created during the facilities and pipeline installation operations, hence any impacts are expected to be negligible.

Sacrificial Anodes

Sacrificial anodes are designed to lose material to the surrounding water, in order to maintain an electrical potential across the pipework, which helps to prevent corrosion. The anodes will be an aluminium-zinc-indium based alloy. For the Corrib subsea development it is anticipated that 105 tonnes of anode will be required for the pipeline and 11 tonnes will be required for the subsea facilities. The anodes are generally positioned as collars around pipelines.

The typical percentage composition of these anodes is presented in **Table 9.18**.

Table 9.18: Typical composition of sacrificial anodes

Element	Composition (%)	Total tonnage for Corrib
zinc	4.0 (approx)	4.64 (approx)
indium	0.015 (approx)	0.0174 (approx)
iron	0.09 (max)	0.1044 (max)
silicon	0.20 (max)	0.232 (max)
copper	0.004 (max)	0.00464 (max)
others (each)	0.01 (max)	0.0116 (max)
others (total)	0.05 (max)	0.058 (max)
aluminium	balance	110.9 (min)

The tonnages of anode given above have been calculated in accordance with a DnV standard (DnV RP B 401), based on a long term test programme. The anodes will dissolve if an electrical reaction is able to occur between them and other parts of the pipework. Such a reaction (current) will only be able to take place if there are other parts of the pipework exposed to seawater. Normally, the epoxy pipe coatings prevent the metalwork coming into contact with seawater. However, it is possible that in some places the coatings could become damaged, and therefore the anodes could partially dissolve. The tonnages of anode to be used in the development are based on 2% of the pipework being exposed to seawater over a period of 30 years.

The potential impact if all the anodes were lost to sea would be negligible, due to the fact that the process would be extremely slow, allowing ample dilution of the metals in the sea.

It should be noted that sacrificial anodes are present on most types of ocean-going vessel, and that metal ions will be released from these anodes on an almost continual basis.

9.5.2.3 Decommissioning

The umbilical from the shoreline to the Field would be made safe, isolated and left in situ. The pipeline would be flushed, filled with water, capped and left in place. National Legislation, such as the Dumping at Sea Act, 1996, would also need to be complied with at the time of decommissioning. The potential impacts on the aqueous environment are considered to be negligible, if the requirements described above are followed. If the umbilical and the pipeline were to be retrieved, then there would be a minor impact associated with the generation of suspended sediment from seabed disturbance, as the facilities are lifted and removed.

9.5.3 Waste Water Outfall

In order to dispose of the wastewater from the Terminal, it is proposed to construct an outfall into Broadhaven Bay. The sources of water and the Terminal processes which lead to the production of waste water are described here.

9.5.3.1 Waste Water Sources and Constituents

This section addresses the waste waters that are generated from three main sources: rainwater, firewater and produced water. These are the only waste waters which will be routed to the sea outfall. Details of the Terminal process, including handling of other waste streams are described in the Terminal EIS.

Rainwater

Rainfall flow rates have been derived from local Met Eireann meteorological data. The maximum hourly rainfall has been assessed to ensure that the drainage system is of sufficient capacity to accommodate heavy rainfall. The maximum daily flow rate has been used to evaluate overall surge volumes within sumps.

All paved hydrocarbon processing areas have the potential to contaminate rainwater (from fuel spills or lubricating oil drips) therefore, drainage water from these areas will be routed to an open drain system, and treated in the tilted plate separator (TPS) and polishing unit, prior to discharge.

The tank bund areas will be managed to allow controlled flow to the TPS via the open drain system. This will ensure that any water coming from the bunds will be treated in the water treatment plant.

Firewater

Firewater is water which is held in the firewater pond, and will always be a mixture of clean rainwater and mains water. In the unlikely event of a fire, the firewater runoff from paved areas could become contaminated with fire fighting foam and with liquids present in the plant. Firewater runoff from paved areas will be carried in the open drain system, which is routed to the TPS for treatment, then to a secondary polishing unit, prior to being discharged to sea via the outfall.

Produced Water

Water is a by-product of natural gas production. The water originates from two sources: water which always exists as water vapour within the gas (water of condensation) and water which sometimes can come from the rock formation (formation water). The water vapour in the gas will condense out through cooling and expansion, as the gas is produced. Both of these waters contain naturally occurring elements. Due to the geochemical conditions in the reservoir, some of these naturally occurring elements are at concentrations higher than the receiving environment that is used to dispose of them.

Reservoir simulations carried out for the Corrib Field predict that formation water will be produced in very low quantities, see **Table 9.20**.

Produced water arrives in the Terminal with the gas. The combined produced water will contain naturally-occurring dissolved salts and metals, and small quantities of water of condensation. In the offshore production system, certain chemicals are added to the wellstream. These are dosing chemicals (methanol, corrosion inhibitor, scale inhibitor) that will require recovery from the effluent water stream. They will mainly be in the water phase, mixed with the produced water. They will be removed partly with the condensate, dependent upon the selected chemicals. The water treatment process will remove the majority of any chemicals that stay with the water phase. The reasons for use of the dosing chemicals are presented in **Section 2**.

The gas is separated from the liquid, and the water phase is processed to remove traces of hydrocarbon condensate, and to recover methanol. The water phase recovered from the methanol recovery unit is then passed through a treatment system before discharge through the outfall pipe.

A summary of all key constituents with the required Environmental Quality Standard (EQS) limits (see **Section 9.10.4.1**) is provided in **Table 9.19** and detailed in the following sections.

Dissolved Solids

The majority of dissolved solids are normally-occurring seawater or brine salts: chlorides, with some sulphates and bicarbonates of sodium, potassium, calcium and magnesium. There is no requirement to treat or remove these salts from the produced water, if disposal is to the coastal environment. There will be no impact from discharge of dissolved solids.

Suspended Solids

Preliminary analysis suggests that iron hydroxide solid scale will precipitate in early years, with calcium sulphate and carbonate precipitating in later years. The precipitation is predicted as the water of condensation and formation waters mix, before any treatment takes place in the Terminal. There is provision to remove potential scaling solids downstream of the slugcatcher in coarse filters. Provision of scale inhibitor is included within the methanol regeneration system and the suspended solids load is not expected to have any impact.

Heavy Metals

Heavy metals are known to be present in formation water. Facilities to remove heavy metals will be provided to meet EQS levels, prior to the discharge of the final treated effluent.

Methanol and Other Chemicals

It is anticipated that the methanol recycling system will enable an average of 96% of the methanol in the system to be recycled. Of the remaining 4%, the majority is carried over with the gas to the national grid. The remainder is removed in the water treatment plant which is designed to remove all substances to a concentration equivalent to the EQS levels.

Throughout the Field life the maximum methanol discharge is expected to be an average of 0.58 tonnes per year. The equipment installed at the Terminal for treating the produced water will achieve a methanol in water concentration of 15 ppm (parts per million).

Chemicals added during processing are expected to be primarily hydrate inhibitor (methanol) and corrosion inhibitor. Additional chemicals could be used occasionally comprising well completion muds, scale inhibitor, anti-foaming agents, lubricating oils and descaling fluids. The treatment of methanol and other chemicals to EQS levels is discussed in the Terminal EIS.

Methanol and other dosing chemicals in their undiluted form, if not treated at some point in the process, have the potential to create a moderate impact on the environment, depending upon the quantities, concentrations and point of release.

Corrosion Inhibitor

The corrosion inhibitor is injected at the wellhead and arrives in the produced water, from where it is removed by the water treatment plant. Corrosion inhibitors typically have an HOCNF rating of B. Current estimates are that 0.25 –0.5 litres of corrosion inhibitor will be required per MMscf gas produced (approximately 17 litres/million m^3) for the Corrib fluids, but this depends on reservoir pressure and the amount of water being produced.

Enterprise is currently carrying out studies to identify a corrosion inhibitor that will partition in the methanol. This will allow recycling of the corrosion inhibitor along with the methanol.

Final selection of any dosing chemicals will take account of the interaction between the various other chemicals and persistence in the aqueous phase will be minimised. A number of fluids may only be used for maintenance, but will be removed by the water treatment operations to ensure that the discharged water meets the EQS.

Condensate/ Aromatics

The design of the gas liquid separation facilities will limit the potential for bulk carry-over of hydrocarbon condensate in the aqueous phase. The hydrate inhibitor (methanol) is recovered from the aqueous phase by fractionation in a distillation column. This will tend to vaporise any components more volatile than water, leaving the aqueous stream relatively free of hydrocarbons. The hydrocarbons remaining will be those with a boiling point above 100^{o}C. Experience of other gas plants using methanol regeneration would indicate levels of residual oils and hydrocarbons prior to treatment as provided in **Table 9.19**.

Total organic carbon (TOC) is a measure of the total carbon loading of the discharge; it includes not only methanol and oil and grease, but also aromatics and organic acids (such as acetic acid). It is calculated based on the percentage of carbon in the compounds anticipated to be discharged.

The TOC is discharged in an "unoxidised" state (i.e. the compounds will react with oxygen in the water). Eventually the carbon in the compounds will be oxidised to carbon dioxide, thus the potential impact of the TOC discharge is the consumption of oxygen in the local seawater. It is estimated that the daily discharge of TOC will be approximately 8.2 kg.

In the ocean, organic carbon is recycled, primarily biologically, at relatively shallow depths. However, not all is recycled and it is estimated that perhaps 5% falls to the seabed and becomes mixed in the sediment column (Chester, 2000).

The impact from this discharge on the water quality of Broadhaven Bay will be negligible because of the high volume of well oxygenated water in the Bay.

The aim of the characterisation of the produced water stream is to identify and quantify the occurrence of any undesirable substance or quality of the wastewater.

Throughout the appraisal phase, samples of water have been taken from the wells. Most of these have been water of condensation. The engineering design of the Terminal has been based on these in combination with general industry produced water characteristics also considered was data from a formation water sample collected from the Avonmore well, which was a dry well drilled some distance away from Corrib. The produced water composition has been analysed and is described in **Table 9.19**. This is considered to present a conservative view on the produced water composition and provides a robust basis for the design of water treatment facilities. Current and future wells drilled in the Corrib Field will bring additional information on water properties. It is expected that these will largely fall within the range of concentrations predicted in **Table 9.19**.

The nature of natural gas production is such that it is considered prudent to design facilities for a typical range of inlet concentrations and that this be evaluated on an ongoing basis.

Table 9.19: Produced water compositions

		Inlet Concentration					Required Levels		Remarks
All values in mg/1		Condensed water from well 18/25-1	Formation water from well '27/5-1	Proposed Design Criteria from Enterprise	Design Basis	Worst Operational Level	EQS	Background	
Na	mg/1	1480	23050		23050	6736			
K	mg/1	58	3196		3196	823			
Ca	mg/1	1390	2059		2059	1553		401	
Mg	mg/1	155	737		737	297		1280	
Ba	mg/1	0.22	<0.4		0.4	0.26	0.5	0.01	95% compliance
Sr	mg/1	2.1	46.1		46.1	12.82		6.66	
Fe dissolved	mg/1	185	1		185	185			
Fe total	mg/1	215	76.8	20	215	215	1	0.01	Limits relative to dissolved iron
Cl	mg/1	4610	41200		41200	13525			
SO4	mg/1	340	4093		4093	1254			
HCO3	mg/1	195	127		195	195			
CO3	mg/1	0	0		0	0			
CH	mg/1	0	0		0	0			
NO3 as N	mg/1		-				50		
Ba	mg/1	2.1	4		4	2.56	2	0.01	
Al	mg/1	<0.2	<1.3		1.3	0.47	0.2		95% compliance
Si	mg/1	2.8	4.6		4.6	3.24			
P	mg/1	0.11	<1		1	0.33			
Li	mg/1	0.15	2.3		2.3	0.67			
CR 6+	mg/1		-						
Cr Total	mg/1	0.005	<0.1	0.5	0.5	0.028	0.100	0.001	
Mn	mg/1	3.1	2.7		3.1	3.1	0.300	0.14	
N	mg/1	0.26	15.7	1	15.7	4.02	0.100	0.005	Annual mean
Cu	mg/1	0.44	<0.01		0.44	0.44	0.050	0.011	
Zn	mg/1	25	<0.01	10	25	25	0.100	0.005	
As	mg/1	0.019	<0.1	0.5	0.5	0.039	0.050	0.006	
se	mg/1	0.02	<0.1		0.1	0.039	0.020	0.042	
Ag	mg/1	0.05	<0.1		0.1	0.062	0.010	<0.001	
Cd	mg/1	0.005	<0.01	0.05	0.05	0.006	0.005	0.0001	Total
Hq	mg/1	0.0085	3	0.05	1	0.737	0.0001	<0.0001	
Pb	mg/1	0.05	<0.05	0.5	0.5	0.05	0.001	<0.001	
pH @ 20°C	mg/1	4.8	7.4		7.4	4.8	6		Not more than 0.2 points from natural level in 95% of samples
	mg/1					5.4	9		
Resistivity	mg/1	1.145	0.0992		1.145	1.145			
SG @ 60°F	mg/1	1.019	1.0532		1.0532	1.027			
TDS	mg/1	8420	76000		76000	24886			
H_2 S	mg/1	0	0		0	0			
Oil,Fat,Grease(free)	mg/1	5	5	15	15	5	0.3		To protect aquatic life, not more than 0.3 mg/l for mineral oils
TOC Dissolved	mg/1	67		200	200	67			
Methanol	mg/1	50	50	150	150	50			Included with TOC
mrl oil Intcpts	mg/1								None expected included with TOC
mrl oil bioplant	mg/1								None expected included with TOC
Suspended Soils	mg/1	320			320				Visually neutral
Phenol	mg/1	5	5	10	10	5	0.0005		
Ammonia Total	mg/1	5	5		5	5	0.3		Amine residuals as ammonia
BTEX	mg/1	0.1	0.1	25	25	0.1	0.01		
Sn	mg/1						0.01		
Cyanide	mg/1						0.01		None expected
Organoalogens	mg/1								No freon refrigerant
BOD	mg/1								
COD	mg/1	274		500	500				
PAH	mg/1			1	1		0.0002		
Organic Acids	mg/1			30	30				
NPD	mg/1			0.5	0.5				

Notes:
The condensed water sample is probably contaminated with brine.
The formation water is taken from the Avonmore formation (approximately 20 km from the Corrib formation)

In **Table 9.19** a design basis water composition has been derived as a worst case, i.e. using the greatest concentration for each component from each of the inlet streams. This 'design case' composition ensures that the treatment plant can cope with all possible constituents of the produced water.

Within **Table 9.19**, a second composition, referred to as 'worst operational', is provided, based on a conservative mix of water of condensation and formation water. This composition is provided to allow a qualitative comparison with the design basis, such that a judgement can be made on the significance of any further test data.

9.5.3.2 Waste Water Flow rates

Table 9.20 provides a year by year tabulation of the anticipated water inflows into the Terminal. The flow rates for water of condensation and formation water represent the most likely production profile from the reservoir. Rainwater figures are given for normal and peak daily flow rates, based on maximum annual and maximum daily rainfall figures over a 43-year period. The maximum annual rainfall is provided as the peak daily 'averaged' rainfall (normal). Firewater figures are based on the maximum capacity of the firewater system. It is assumed that the peak rainwater and firewater flow rates will not coincide, though there is sufficient capacity within the facilities for coincidental occurrences.

Table 9.20: Water flow rates

Year	Condensed Water	Formation Water	Normal Rainwater	Peak Rainwater	Peak Firewater	Normal Total	Pump Operate	Peak Total	Pump Operate
	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	hrs/day	m³/h	hrs/day
2003	3.2	0.0	3.40	52.3	1200	6.6	1.9	55.5	16.2
2004	3.3	0.0	3.40	52.3	1200	6.7	2.0	55.6	16.2
2005	3.2	0.0	3.40	52.3	1200	6.6	1.9	55.5	16.2
2006	2.6	0.0	3.40	52.3	1200	6.0	1.8	55.0	16.0
2007	2.1	0.0	3.40	52.3	1200	5.5	1.6	54.4	15.9
2008	1.7	0.0	3.40	52.3	1200	5.1	1.5	54.0	15.7
2009	1.4	0.0	3.40	52.3	1200	4.8	1.4	53.7	15.7
2010	1.2	0.0	3.40	52.3	1200	4.6	1.3	53.5	15.6
2011	1.0	0.0	3.40	52.3	1200	4.4	1.3	53.3	15.6
2012	0.9	0.0	3.40	52.3	1200	4.3	1.2	53.2	15.5
2013	0.8	0.0	3.40	52.3	1200	4.2	1.2	53.2	15.5
2014	0.7	0.1	3.40	52.3	1200	4.2	1.2	53.1	15.5
2015	0.7	0.1	3.40	52.3	1200	4.2	1.2	53.1	15.5
2016	0.6	0.2	3.40	52.3	1200	4.1	1.2	53.1	15.5
2017	0.6	0.2	3.40	52.3	1200	4.2	1.2	53.1	15.5
2018	0.5	0.0	3.40	52.3	1200	3.9	1.1	52.8	15.4
2019	0.4	0.0	3.40	52.3	1200	3.8	1.1	52.8	15.4
2020	0.4	0.0	3.40	52.3	1200	3.8	1.1	52.7	15.4
2021	0.3	0.0	3.40	52.3	1200	3.7	1.1	52.7	15.4
2022	0.3	0.0	3.40	52.3	1200	3.7	1.1	52.6	15.3
2023	0.2	0.0	3.40	52.3	1200	3.6	1.0	52.5	15.3

Notes:

1. The water treatment plant is designed for higher capacities to cater for uncertainties in the reservoir modelling and predictions of liquid hold-up in the subsea pipeline.
2. Rainfall flow rates are based on Met Eireann meteorological data for maximum rainfall in a month, 259 mm (peak) and maximum rainfall over a year, 1448 mm (normal). The maximum instantaneous rainwater flow rate relates to a maximum hourly rainfall (25.9 mm), which is 480 m³/hr; this flow is accommodated within the open drains sump for reduced capacity processing.
3. Firewater is retained within the treatment facilities for treatment before discharge.

The total produced (i.e. condensed and formation) water shown in **Table 9.20** does not exceed an average of 500 bbls/d (3.3 m³/h). Recovery of produced water from the subsea pipeline is likely to be intermittent, as liquid hold-up within the pipeline can be several thousand cubic metres with slugs up to 3,200 m³. To maintain flexibility and ensure methanol is recovered for reinjection, the methanol recovery and produced water treatment systems are designed for a nominal 1000 bbls/d (6.6 m³/h) throughput. This is to provide a substantial design margin to cater for a 'worst case' production profile scenario and to allow catch-up operations following the receipt of a large aqueous slug from the subsea pipeline. Water discharged at 1000 bbls/d would increase the duration of normal outfall operations by approximately 1 hr/day.

The outfall facilities are designed as a fixed flow, batch operation to cope with total produced water and peak rainwater flow rates. If continuous pump-out outfall modelling shows a better environmental performance and a lower risk of encrusting marine growth in the pipeline diffuser, the design will be modified. Outfall facilities have been designed for a capacity of 82.3 m^3/hr so that, on average, pump-out operations are only required for 2 hrs in every 24 hours. At peak rainwater, the pump-out operation is required for 16 hrs every 24 hours. It is assumed that a minimum demand is equivalent to no rainwater and low produced water, where pump-out could only occur as little as once a week for a couple of hours. The outfall facilities are not designed for the peak firewater demand, as it is assumed that recovered firewater will be retained for future treatment.

In worst flow conditions, the daily volume of water extracted from the gas in the Terminal is expected to peak at about 80 m^3. This represents about 0.03% of the average water flow from the Glenamoy River.

On the basis of the above the predicted impact of the produced water discharge to the Bay is considered to be minor without mitigation.

9.5.4 Landfall and Estuarine Works

The site preparation works to be performed in advance of landfall construction activities that have the potential to impact the water environment will include:

- stripping and storing of topsoil;
- the provision of temporary construction access routes from the coast roads into the construction area;
- provision of hard standing areas underlain by impermeable membranes;
- full containment of fuel and chemical stores as well as refuelling points to prevent releases to the surrounding land or water bodies; and
- identification and protection of existing utility services.

The potential impacts upon the landfall and estuarine aqueous environment from these activities are considered to be negligible in the long term and minor in the short term during construction.

9.6 Do-Nothing Scenario

If the development did not proceed, the only impacts on the aqueous marine environment would be those already in existence from local rivers, sewage outfalls, fishing vessels and other commercial vessels operating in the areas both inshore and offshore.

9.7 Mitigation Measures

9.7.1 Offshore

9.7.1.1 Seismic Surveys

It is not expected that future wide area seismic surveys will be required over the Corrib Field.

9.7.1.2 Drilling

During rig positioning, running and setting of anchors and disturbance to the marine environment will be minimised by limiting the footprint of the activities.

The following mitigation measures will be employed during drilling:

- impacts associated with the discharge of water-based mud (WBM) and cuttings during drilling will be minimised by using a WBM formulated with environmentally benign chemicals (PLONOR or HOCNF category E) with low environmental toxicity, high biodegradability and low bioaccumulation potential. The barite used will only contain trace levels of heavy metals (in particular Cd < 0.5 mg/kg and Hg < 0.01 mg/kg). The majority of the cadmium and mercury present will be in an inorganic form, associated with the insoluble barite. The ultimate fate following release will therefore be incorporation into the sediments, where the bulk of the metals will not be bioavailable;

- the slimhole well design reduces the volume of drilling fluid required;

- impacts associated with the use of low toxicity oil-based mud (LTOBM), during drilling of the lower hole sections, will be eliminated by returning the cuttings to shore for recycling and disposal;

- impacts associated with cementing of the drill casing will be minimised by using a predetermined casing programme, with cement volume requirements estimated on a section by section basis, to reduce the volume of excess cement discharged;

- impacts resulting from testing of the BOP will be minimised by using a glycol based control fluid which is of low toxicity, and has a relatively high biodegradability and low bioaccumulation potential;

- impacts associated with the routine discharge of rig wash waters will be mitigated through the use of a rig wash chemical that is of low toxicity and biodegradable; and

- discharges of drainage and waste water (including black water, grey water and galley wastes) will be minimised through a number of mitigation measures, as follows:
  - oily water effluent will be treated to achieve a maximum of 15 ppm (mg/litre) oil in water content. Continuous automatic sampling of oily water effluent will be undertaken and linked to a system to automatically divert off-specification effluent back to the oily bilge tank system. High level alarms will be fitted to oily bilge tank units;
  - all spaces on board will be categorised according to the likely contamination status of the drainage and separate closed and open drainage systems will be operated;
  - all storage tanks and machinery spaces will be bunded and routed to the closed drainage system; and
  - the operation of vessels will be carried out in accordance with Annex V of MARPOL 73/78. The biological oxygen demand (BOD) of the sewage and galley waste will be reduced by a treatment process to a concentration of 50 mg/l. The treatment process will involve preliminary maceration of the incoming sewage, followed by biological treatment, and subsequent chlorination of the outlet effluent stream. All putrescible galley waste will be macerated to less than 25 mm before release.

9.7.1.3 Field Facilities

During Installation

The main mitigation methods associated with the installation of field facilities are those associated with physical disturbance of the seabed. During well tie-in and installation of the flowlines, mats will be used, and trenching will be kept to a minimum and where practicable, small, less stable trenches will be used to encourage natural backfilling and reduce any suspension of sediment into the water column.

During Operation

To minimise the impact resulting from discharge of hydraulic fluid at the subsea facilities, a glycol:water mix (50:50) will be used. The mixture is an environmentally benign hydraulic fluid of low toxicity, high biodegradability and low bioaccumulation potential.

During Decommissioning

A study will be undertaken prior to decommissioning to determine the most appropriate methods of decommissioning the different parts of the subsea development. The study will include environmental issues, and will review the impacts from each decommissioning option. The final recommendation for decommissioning will be agreed with the Irish authorities, and will include measures to mitigate any impacts that could be caused during the works.

9.7.2 Pipeline and Umbilical

During Installation

The main mitigation methods associated with pipelaying operations are those associated with physical disturbance of the seabed and consequent suspension of sediment into the water column. In this respect:

- a dynamically positioned laybarge will be used during pipe laying. This will reduce disturbance through anchoring operations;
- during dredging operations, the use of a suction head dredger will minimise effects, as this discharges cleaner water than other types of dredgers. In addition, the appropriate choice of dumping site will minimise effects. The DOMNR will be consulted on site selection and testing protocols for the dredged material. Licence conditions will be adhered to and audits and spot checks will be undertaken throughout the operations;
- during rock placement, a fall-pipe will be used to increase the accuracy of the operation and measures will be taken to ensure that the correct grade of rock is used; and
- the operation of vessels will be carried out in accordance with Annex V of MARPOL 73/78. The biological oxygen demand (BOD) of the sewage and galley waste will be reduced by a treatment process to a concentration of 50 mg/l. The treatment process will involve preliminary maceration of the incoming sewage, followed by biological treatment, and subsequent chlorination of the outlet effluent stream. All putrescible galley waste will be macerated to less than 25 mm before release.

During Operation

The sacrificial anodes used for cathodic protection will be designed to dissolve slowly, such that only low concentrations of metals are released over a long time period.

During Decommissioning

No mitigation measures are proposed, as potential impacts are not anticipated from leaving the pipeline and umbilical in place.

9.7.3 Waste Water Outfall

During Installation

The installation of the waste water outfall will be carried out at the same time as the installation of the gas pipeline. The outfall will be piggy backed on the gas pipeline. The mitigation measures are therefore the same as described in **Section 9.7.4**.

During Operation

This section discusses the mitigation measures proposed, in order to minimise the impact on Broadhaven Bay as a result of the discharge of waste water. During operation the primary mitigation of impacts on the water which arises in the Terminal will be a process of segregation and minimisation.

The produced water treatment system at the Terminal is the subsequent mitigation measure against impact to Broadhaven Bay. It will be designed in accordance with BAT (Best Available Technology) principles and will be operated in accordance with the terms of an IPC (Integrated Pollution Control) licence, which will detail discharge conditions and the monitoring programme. Full details are provided in the Terminal EIS.

The resulting discharge will be to a quality in excess of that normally required by European or Irish legislation.

9.7.3.1 Segregation, Minimisation and Management of Waste Water

The major principles for minimising and treating waste water discharges that have been applied are as follows:

- minimise the production of effluent;
- recycle flows, where practicable;
- segregate different types of effluent; and
- pre-treat to remove specific contaminants at source prior to mixing with other effluents.

For the Terminal site, sources of waste water are variable in terms of the quantities involved. The design of the Terminal and associated drainage will minimise the production of effluent by limiting areas of contamination, i.e., limit and segregate paved areas, maintain clean operations to limit washdown etc. As water is not used within the process, there is limited capability to recycle water. However, to limit contamination of other treated waters, recycling facilities for re-treatment are provided upstream of any mixing of different aqueous effluents.

9.7.3.2 Produced Water Treatment

A block flow diagram for the overall water treatment facilities is presented in **Appendix 9.3**. This shows the proposed produced water treatment scheme which consists of the following stages. primary treatment to remove methanol for recycling;

- secondary treatment, to remove metals; and
- tertiary treatment for final removal of metals and trace organic contaminants.

Primary Treatment

- raw methanol storage tanks (gravity separation);
- methanol coalescer (enhanced gravity separation); and
- methanol still (distillation).

The primary physical separation used for produced water is the regeneration of the system in the methanol distillation column. This significantly reduces the oil and grease content, the methanol content and possibly the speciality chemicals used in corrosion inhibition and scale inhibition such that the main contaminants in the effluent stream to secondary treatment are salts and heavy metals.

A break sump is provided upstream of the secondary treatment such that off-spec effluent can be recycled to the raw methanol storage tank.

Secondary Treatment

- pH adjustment, flocculation and dissolved air floatation (physical and chemical separation)

A combined dissolved air flotation unit (DAF) with pH adjustment, feed flocculation and sedimentation is provided for heavy metals removal and pH adjustment using lime, sulphide and acid dosing. Lime can be used to remove a broad spectrum of heavy metals as required, whilst a sulphiding operation will remove specific metals, e.g. mercury.

Solids removal in the DAF is assumed as 96.5%, with a minimum 50 mg/l in the outlet. The lower limit residual concentration of each heavy metal is assumed conservatively at 0.03 mg/l exiting the sand filter.

Tertiary Treatment

- activated carbon (adsorption).

Granular activated carbon (GAC) beds, preceded by sand filters, are proposed as a final stage to reduce some heavy metals, amine, phenol and BTEX concentrations to below EQS levels.

It is assumed that there will be 2 mg/l residual solids in effluent leaving the sand filter. The granular activated carbon filter package (GAC) will remove to less than 0.005 mg/l if required; this would achieve final levels as demonstrated in **Table 9.19**. Test work with synthesised solutions is to be undertaken to confirm performance.

On recharge of the sand filter and GAC, the resultant spent media will be disposed of in accordance with the special waste regulations. During detailed design, the equipment vendor will assess the suitability of reclamation.

Full details of the waste water treatment process are presented in the Terminal EIS.

9.7.3.3 Rainwater and Firewater Treatment Facilities

Whilst the site will be well-maintained, contamination is possible in the event of fire emergency situations. Rainwater and firewater are collected in the Terminal open drains system. The aim of the system is to minimise contamination of the initially clean water by ensuring areas of spillage are minimised. High levels of oil or hydrocarbon are not expected from the Terminal. Storage tanks have their own separate containment bunds that will be checked on a regular basis as part of the Environmental Management Plan. The water in the open drains system will be subject to two levels of treatment:

Primary Separation

In general, this consists of the simple separation of gross oil and solids content using techniques such as American Petroleum Institute (API) separators with plate interceptors (tilted or corrugated). Rainwater and/or firewater collected in paved areas (the process and utility areas) will run via drain traps into the open drains system.

The oily water will be treated in a Tilted Plate Separator (TPS) to remove free oil and settling solids in the expected drainage flow from the plant. The TPS will be located downstream of the first flush compartment in the open drains sump, with an underflow overflow baffle and weir for excess water beyond a first flush period. The underflow overflow baffle and weir is to ensure that excess water is taken from below any oily surface/ interface.

The first flush compartment will hold approximately one hour's maximum rainfall (480 m^3) from the paved process areas. The first flush compartment and the treated water sump will together hold a minimum of one hour's firewater at max capacity (1200 m^3), or one day's maximum rainfall (1256 m^3). These volumes are retained within the open drains and treated water sump capacities (1340 m^3). Additional emergency hold-up of approx. 1000 m^3 will collect in the sump, assuming that the open drains collection headers become flooded. The oil/ hydrocarbon from the TPS will be collected in a slop oil tank within the open drains sump.

Secondary Separation

Additional connections within the open drains sump and TPS discharge allow installation of a polishing step, so that discharge concentrations can be further reduced. Biomass adsorbents, such as bagged hay, walnut shells, or peat, will be provided in the flow path to remove hydrocarbon and suspended solids, the effectiveness of such materials has been proven on other water treatment sites. Test work would be required with local materials to confirm the degree of effectiveness.

Full details of the treatment options selected are presented in the Terminal EIS.

9.7.3.4 Environmental Quality Standards

In considering the design of the water treatment plant for the Terminal and given the outcome of the assessment of alternatives (treated water would be discharged into the sea in Broadhaven Bay), the Environmental Quality Standards proposed by the EPA were used (EPA, 1997a).

From EU Directive 76/464/EEC, the EQS is to be defined on the basis of the toxicity, persistence and bioaccumulation of a substance released into the environment. In Europe, the Scientific Advisory Committee on Toxicity and Ecotoxicity of Chemicals has proved to be a valuable source of expertise on EQS levels and the EPA have used this body to assist in the setting of proposed aquatic EQS values. Also consulted was the Office of Water in the United States Environmental Protection Agency (USEPA).

The European Commission prepared a list of 129 priority candidate compounds and these appear in List I of Directive 76/464/EEC. This list was altered thereafter to include two further chemicals, making a total of 131 on the current List I.

In the EPA procedure for setting EQS standards "the aim is that the suggested standards should reflect the maximum amount of a substance which may be present in a water body without affecting the biological communities in their functional processes or otherwise giving rise to unacceptable, adverse effects on the ecosystem or accumulation of substances that are harmful to the biota (including man), whether via the food chain or otherwise. The EQSs could thus be lower than the "ecosystem NOEC" [No Observed Effect Concentration] values, which can only be determined experimentally by long term multi-species experiments", (Environmental Quality Objectives and Environmental Quality Standards, The Aquatic Environment, A Discussion Document; pp38; EPA, 1997).

For the purposes of this EIS concerning the impact on the environment from the discharges of water into Broadhaven Bay, the EQS values proposed by the EPA and the philosophy outlined above have been used.

9.7.3.5 Water quality modelling

In order to assess the consequences of both existing and proposed discharges to the water environment, Enterprise commissioned Kirk McClure Morton to implement a dispersion modelling study of Broadhaven Bay. A two dimensional depth integrated hydrodynamic model of Broadhaven Bay has been developed **(Section 9.3.2.4)** and verified by comparing model predictions to recorded data and anecdotal information. The correlation achieved between the model predictions and field observations of tidal currents and heights is considered sufficient to give confidence that the model is predicting the correct tidal exchange between the various inlets and outer Broadhaven Bay. Within the main body of Broadhaven Bay a slack tidal regime is predicted which is commensurate with available records and observations.

A series of dispersion models have been developed and simulations of typical wet and dry weather effluent discharges undertaken for a range of possible outfall positions within Broadhaven Bay. Information on the projected flow rates and concentrations of various constituents in the final effluent have been obtained from the Water Treatment Strategy for the terminal prepared by Kvaerner. Due to the high level of effluent treatment proposed (equal to or better than the EQS before discharge), the investigation has been restricted to investigating elements for which existing background levels are available. The results of the model simulations have, therefore, been presented in terms of the percentage increase in the concentration of each constituent above the existing background level.

For this study the effluent dispersal model, PLUME-RW, was utilised to model the release of treated effluent from the proposed gas reception terminal at Bellanaboy Bridge into the receiving waters of Broadhaven Bay. Two possible discharge scenarios corresponding to the estimated discharges during dry and wet weather were considered in this study.

The pollutant dispersion model, PLUME-RW, simulates the movement of pollutant plumes discharged, for example, from sea outfalls or storm water overflows, using a random walk representation of turbulent diffusion. Pollutant discharges are represented by the release of discrete particles, which move in three dimensions under the influence of mean tidal currents, based on TELEMAC-2D simulations and under the influence of wind.

For the purpose of this study, two extreme conditions were selected for simulation in the dispersion model corresponding to the effluent discharge during periods of dry weather and the peak wet weather discharge. Representative wet and dry weather loading rates were established by assuming that the daily loading was discharged over a total 16 or 2 hours respectively.

The resulting discharge rates were:

- dry weather: 82.3 m^3/hr for 2 hours per day or 165 m^3 in a day; and
- storm conditions: 82.3 m^3/hr for 16 hours per day or 1317 m^3 in a day, assumed to be equivalent to 54.8 m^3/hr over the full day due to pump cycling, i.e., the pump would not be run continuously over a 16 hour period since the peak rate of inflow is only 55.6 m^3/hr.

Since the rainwater component of the discharge does not contribute to the pollutant loadings assessed in this study, these two scenarios are sufficient to assess the environmental impact of all possible alternative dry weather discharges that might be proposed. For example, the impact of using a low pumping rate to give a continuous discharge from the outfall during dry weather will be identical to the impact predicted for the wet weather discharge, since the actual pollutant loading rate is the same. Consequently, the impact of any other discharge time between 2 and 24 hours will produce an impact that lies somewhere between that predicted for the dry and wet weather simulations included in this study.

Twelve plume simulation runs were carried out in order to assess the impact of the proposed effluent discharge and determine the optimum position for the final effluent discharge.

In summary, the simulation runs covered outfall locations at the 10, 20, 30 and 40 m bathymetric contour, where it intersects the gas pipeline. Each run covered both a spring and a neap tidal cycle and also a wet and a dry weather scenario. At the 40 m location four additional runs were carried out to look at wind effects on the discharge. Wind directions modelled were northerly, north-westerly, westerly and south-westerly.

The results of the modelling indicated that by moving the point of discharge into progressively deeper water the maximum concentration of each constituent of the effluent was reduced. However the incremental benefit achieved, reduced with increasing total water depth to the point that there was no significant reduction as a result of moving from a water depth of 30 m to 40 m. Thus it was concluded that extending the outfall into deeper water within the Bay would not yield any significant benefit in terms of water quality. Similarly even if the point of discharge was moved out of the Bay into the offshore waters it is extremely unlikely that the magnitude of the associated impact would be significantly reduced. Hence the provision of an outfall extending to the 40 m contour in Broadhaven Bay was identified as the preferred option for the future disposal of effluent.

The results also clearly indicate that the principal effect of extending the duration of the intermittent effluent discharge was to reduce the magnitude of the resulting impact on effluent concentrations in the receiving waters of Broadhaven Bay. The results indicate that increasing the duration of the discharge from 2 hours to 6 hours will reduce peak concentrations by at least a factor of two.

Thus, consideration will be given during the design of the works to the provision of a pumping regime that would allow the produced water loading during dry weather to be discharged at a lower rate than that required to handle the peak storm flow. It is also noted that it may not be operationally possible or desirable to provide a continuous discharge, due to the relatively large variation in flow rate that would be required. However, the results of the simulations undertaken during the modelling study indicate that the ability to discharge the dry weather loading over 6 hours is sufficient to reduce the magnitude of the peak increase in concentration to less than 1% of the existing background level.

The full report on the dispersion modelling study is presented in **Appendix 9.1**.

9.7.4 Landfall and Estuarine Works

During Installation

Storage areas, including temporary warehousing for pipeline and associated materials and supplies, will be prepared within the working area at the landfall site. These areas will be fenced off from other working areas, in order to prevent loss of or damage to materials prior to their incorporation in the landfall facility. These areas will be designed to contain any releases of fuel, solid and liquid chemicals, or other environmentally hazardous materials.

Designated areas will be constructed for the temporary storage of waste, which will be segregated upon receipt in the storage area, pending disposal to an appropriately licensed facility.

During Operation

There will be no impact from the landfall area during operation and hence, no mitigation is required.

The site will be fully restored following installation. Re-instatement activities will include, but will not necessarily be limited to, the following:

- the foreshore region, including the beach zone and affected areas extending landward to the limits of the landfall site;
- winch or sheave block sites, shore-based anchors and associated works;
- general levelling of areas, both within and outside the tidal areas;
- complete removal of the cofferdam, if used, and all temporary installation works;
- removal of underwater deposits that could cause obstruction to marine activities;
- re-instatement of roads, services and coastal defences affected by the construction work to their initial state, except where facilities have been upgraded for the purpose of the landfall construction activities;
- the original topsoil will be used to re-instate the site areas;
- replanting of flora, where required; and
- general cleansing and tidying of the whole site.

All of the above will be in accordance with an agreed restoration plan supported by ongoing auditing of the progress of the restoration.

During Decommissioning

The site will be fully restored following decommissioning. Re-instatement activities will include, but will not necessarily be limited to, those described above for post installation restoration.

9.8 Predicted Impact of the Proposed Development

9.8.1 Offshore

9.8.1.1 Drilling and Completion

The predicted impact of the proposed development on the offshore aqueous environment is anticipated to be minor or negligible in the long term, as the releases to the environment are both small in quantity and of very low toxicity.

The impact on the aqueous environment from rig positioning, running and setting of anchors and pulling of anchors, is likely to be negligible, due to the small area affected and the fact that bottom currents are quite strong and persistent and will effectively disperse any re-suspended sediment. The likelihood of release of sediment-bound pollutants into the water column near to the seafloor in a bioavailable form is very low.

The discharge of WBM and cuttings also has the potential to increase water column turbidity near the seafloor. However, as mentioned above, due to bottom currents, these effects are expected to be short term and transient.

Although LTOBM will be used during drilling for the lower hole sections, this will not have any impact on the aqueous environment, as the cuttings will be transported to the shore for disposal.

Discharged cement slurry will initially disperse into the water column. The high pH may have a localised effect on water quality. However, this impact will be negligible, as the buffering properties of seawater will neutralise the discharge. Any solids will ultimately settle out onto the seabed.

It is anticipated that discharges of rig wash water, drainage water and waste water (including black water, grey water and galley wastes) will have a negligible, localised impact on water quality in the immediate vicinity of the discharge. Impacts will be limited, as dilution and dispersion of these discharges will be rapid.

Discharge of blow out preventer (BOP) fluid will have negligible effect, as a glycol based low toxicity product will be used, and only small quantities will be released periodically.

9.8.1.2 Field Facilities

Installation

Some sediment will become re-suspended during the installation process. The current regime in the area (current velocity can reach 50 cm/s, see **Section 9.6**) will, effectively, disperse any re-suspended sediment. The likelihood of the release into the water column, near to the seafloor, of high levels of sediment-bound pollutants in a bioavailable form is very low.

Operations

Intermittent discharges of low volumes of hydraulic fluid (glycol:water) at the subsea completion point will have a negligible impact, as the discharged fluid is a PLONOR substance and dilution and dispersion will be rapid.

There is likely to be a requirement for some well maintenance and survey vessel operations during the life of the Field. There will be discharges of service and drainage waters associated with the presence of these vessels in the Corrib Field. These discharges will have a negligible effect on the water quality in the Corrib Field, because dilution and dispersion will be rapid.

During Decommissioning

During decommissioning of the field facilities, the impact on the marine environment from water column turbidity is anticipated to be negligible. This is due to the small area affected and the fact that bottom currents are quite strong and persistent.

In addition, impacts from the disturbance of cuttings are anticipated to be negligible, as decommissioning will take place after approximately 15-20 years of operation. By this stage, any remaining cuttings will be in shallow accumulations and any toxins will have leached from them. Therefore, disturbance of the cuttings will not have a significant effect on water quality.

9.8.2 Pipeline and Umbilical

Installation

Installation of the pipeline on the seabed, and the burying of the umbilical using a remote jetting trencher, will have a minor, short-term, localised impact (offshore pipelaying will take place over a 25 day period) on water column turbidity and subsequent smothering of organisms due to both the rapid re-colonisation, and the low levels of sediment bound pollutants (Gardline Surveys, 2000).

Rock placement along the pipeline will create some sediment disturbance, and result in re-suspension of sediment particles, increasing turbidity in the water column close to the seabed. This will be a short term operation and is expected to have a negligible impact on water quality.

The impacts of this operation on the nearshore environment within Broadhaven Bay are discussed in **Section 9.8.3**.

During hydrotesting and commissioning of the pipeline, water will be abstracted from offshore and then discharged after use back into the marine environment. This discharge is anticipated to have a negligible impact, as the use of corrosion inhibitors, dyes and biocides, will be minimised and discharge via the subsea installation will maximise dilution.

During Operation

Leaching of trace metals from the sacrificial anodes is anticipated to have a negligible impact on the marine environment, as they will dissolve very slowly over the life of the pipeline. This will release small amounts of metal ions into the water column which will be diluted by the natural water movements along the pipeline route. Any metals which leach from anodes which are covered by the sediment may take longer to disperse.

It should be noted that sacrificial anodes are present on most types of ocean-going vessel, and that metal ions will be released from these anodes on an almost continual basis.

During Decommissioning

No impact is anticipated during decommissioning of the pipeline and umbilical.

9.8.3 Waste Water Outfall

During Installation

The will be no additional impact associated with this aspect, as it is piggy backed on to the gas pipeline and they will be installed together.

Initially a short-term increase in suspended sediment is predicted in the Broadhaven Bay water in the vicinity of the seabed, which is trenched to receive the outfall pipeline (gas pipeline and umbilical). The short-term nature of the trenching, together with the fact that the degree of re-suspension of seabed sediments in the Bay is considerable under natural current and wave conditions, leads to the prediction that the impacts on water quality will be negligible, possibly minor in the short term.

During Operation

The sources and flows of waste water to be discharged through the outfall have been discussed in **Section 9.5.3** and are fully described in the Terminal EIS. This section discusses the predicted impact.

Enterprise Energy have made a commitment to providing a sufficient level of treatment to reduce pollutant concentrations in the final effluent to equal to or below the Environmental Quality Standard (EQS) (prior to discharge to sea), appropriate to each pollutant, as defined by the EPA (1997a) (see **Section 9.7.3.5**). The maximum daily loading of each of the metallic elements investigated in this study can, therefore, be calculated as the product of the EQS concentration and the quantity of produced water discharged over the day.

Normally, the significance of the impact associated with an effluent discharge would be assessed by comparison to the EQS. However, since the pollutant concentration in the discharge will be at, or below, the EQS limit, this is not appropriate in this case. Consequently, the dispersion study, carried out by Kirk McClure Morton, investigated the impact of those elements in the effluent stream for which background levels in Broadhaven Bay had been measured, as shown in **Table 9.12**.

Table 9.21 shows the predicted annual load of various constituents of the waste water in the worst year.

Table 9.21: Maximum annual contaminant loading of the waste water in year 2

Contaminant	Annual discharge Kg/year	Contaminant	Annual discharge Tonnes/year
Barium	14.4200	Total Organic Carbon*	2.98
Boron	57.6700	Methanol	0.58
Phosphorus	28.8400	Total Dissolved Solids	2191.00
Chromium	2.8800	Oil and Grease	0.02
Manganese	8.6500		
Nickel	2.8800		
Copper	1.4400		
Zinc	2.8800		
Arsenic	1.4400		
Selenium	0.5800		
Silver	0.2900		
Cadmium	0.1400		
Mercury	0.0029		
Lead	0.1400		
* - the tonnage of TOC includes methanol and oil and grease			

Figure 9.4 shows the comparison in the form of a histogram of the various elements and their concentrations in the seawater at the point of discharge, and their concentrations in the discharge against the EQS levels. The figure shows the worst-case situation of dry weather and neap tides (no rainfall dilution and lowest current velocities), thus providing for lower dispersion and dilution potential in the sea.

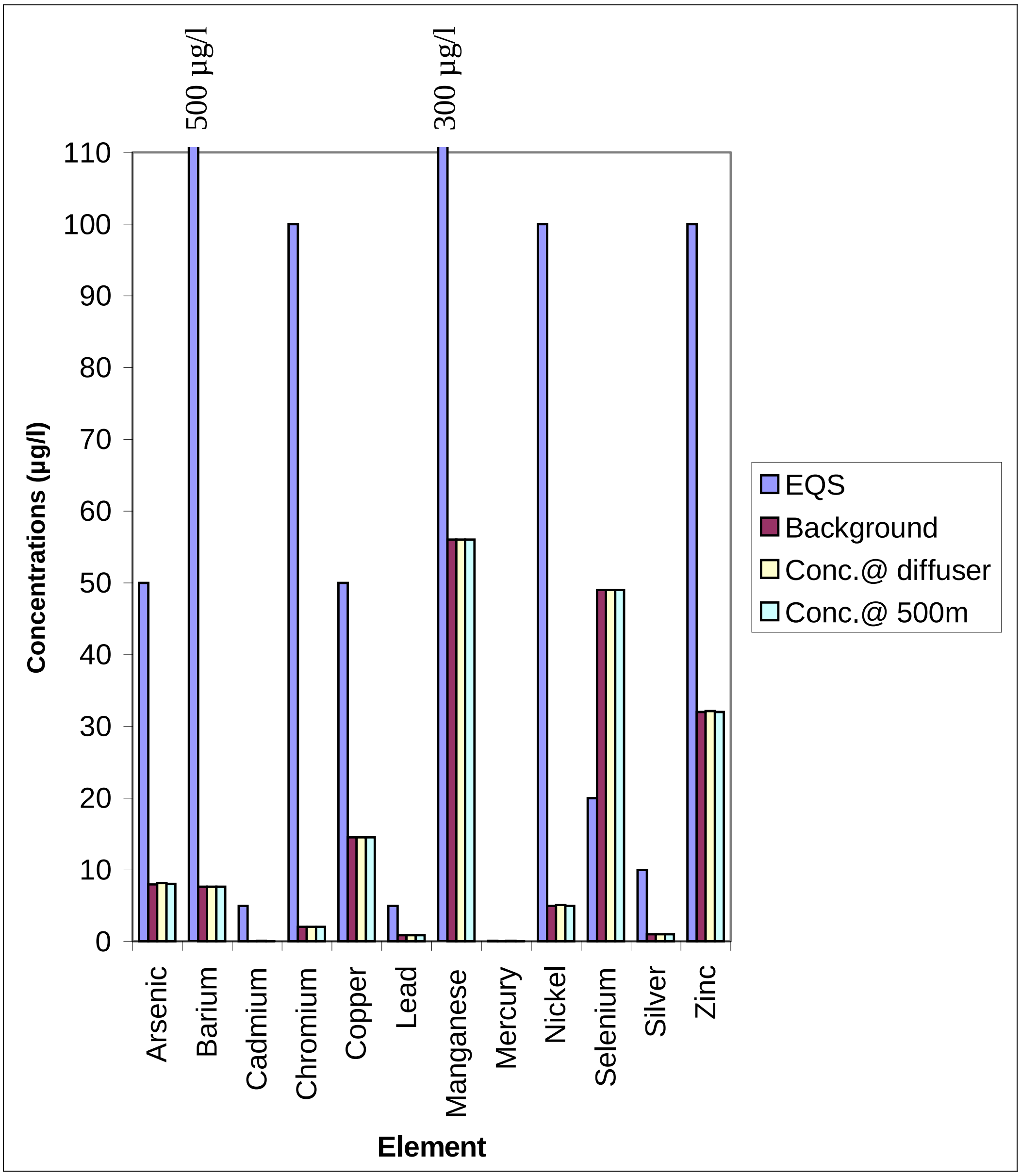


Figure 9.4: Comparison of background metal concentrations in Broadhaven Bay and the proposed discharge, against their respective EQS levels at the point of discharge

Following treatment and mixing with rain water in the outlet sump of the water treatment plant, the concentrations of metals in the water will be at or below EQS. This standard exceeds the current practice in Ireland (or Europe) for discharge to sea. The predicted impact of the discharge to sea outfall is considered to be negligible, in that all of the constituents of the waste water **(Table 9.19)** are discharged at or below EQS.

In the case of selenium, background levels measured in water samples taken from Broadhaven Bay were higher than the EQS level. In this situation when the selenium in the discharge mixes with the seawater, the concentration will rapidly reach background, which is higher than EQS.

As discussed in **Section 9.5.3,** the effluent from the Bellanaboy Bridge Terminal and any rainwater falling within the site boundary will, be discharged together via a common outfall pumping station. Consequently, since the rainwater does not contain a significant quantity of metal elements, the actual loading rate for the outfall will vary greatly, depending on meteorological conditions on any particular day.

In order to assess the predicted impact of these discharges, reference was made to the water quality modelling which used as an input the predicted annual contaminant loading from the water treatment plant given in **Table 9.21** and the waste water flow rates given in **Table 9.20**. The modelling provided an estimate of the likely impacts on the waters of Broadhaven Bay, due to the discharge of wastewater from the water treatment plant in the Terminal.

The dispersion model simulations generally indicate that the impact of the discharge during dry weather conditions is more significant than during wet weather. However, in all cases the actual impact is predicted to be relatively low, with maximum increases of less that 7% for all scenarios investigated. Only the shortest outfall option investigated, extending to the 10 m contour, is predicted to result in effluent entering the inlets on the eastern side of Broadhaven Bay in sufficient quantities to cause a measurable increase in the concentration of metallic elements. None of the outfall positions included in the investigation are predicted to have an impact on water quality within inner Broadhaven Bay, i.e., the area south of a line between Gubacashel and Brandy Point.

The results of the modelling indicated that by moving the point of discharge into progressively deeper water, the maximum concentration of each constituent of the effluent is reduced. However, the incremental benefit achieved reduced with increasing total water depth to the point that there is no significant reduction as a result of moving from a water depth of 30 m to 40 m. Thus, it was concluded that extending the outfall into deeper water within the Bay would not yield any significant benefit in terms of water quality. Similarly, even if the point of discharge was moved out of the Bay into the offshore waters, it is extremely unlikely that the magnitude of the associated impact would be significantly reduced. Hence, the provision of an outfall extending to the 40 m contour in Broadhaven Bay was identified as the preferred option for the future disposal of effluent. The proposed location of the outfall is approximately 7 km from the landfall, and is presented in **Figure 9.5**.

The influence of secondary effects, such as wind induced currents, was also included in the analysis for the preferred outfall position along with an assessment of the effect of varying the duration of the intermittent dry weather discharge was also included. The results of these simulations indicate that typical wind derived currents will not cause effluent to be advected into any of the inlets leading off Broadhaven Bay. The inclusion of wind effects in the dispersion simulations is actually predicted to result in slightly lower maximum concentrations, due to the increased dispersion during periods of low tidal flow. The simulations of discharging the dry weather loading over a longer period indicate that this will reduce the already low magnitude of the resulting impact. Thus, for the final design of the outfall and associated works consideration will be given to providing a capability to discharge the produced water at a lower rate during periods of dry weather.

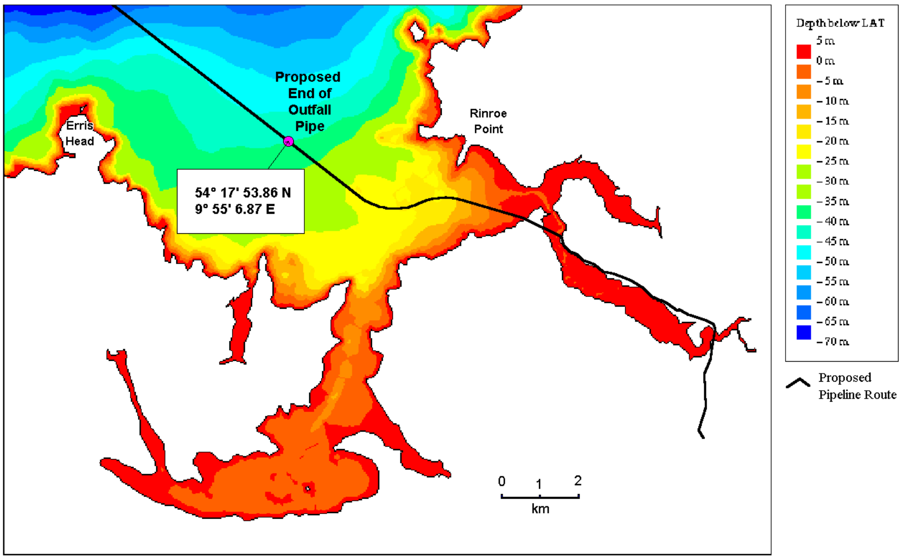


Figure 9.5: Proposed location of end of outfall pipe

In Section 9.5.3.2 the potential impact was assessed as minor due to the low volumes of produced water that would be discharged into a large body of open water that already receives significant inputs of fresh water from adjacent rivers.

Thus, it can be concluded that, provided the effluent is treated to at least the EQS standard before discharge, the use of an outfall extending to the 40 m contour in Broadhaven Bay will have a negligible impact on water quality in the Bay. In the worst case investigated, the effect of the discharge will be to increase chromium levels by about 2% of the existing background at the diffuser, with the increase in other constituents being significantly lower, generally less than 0.5% of background. For all metals there will be no more than a temporary increase of 0.5% above natural background.

9.8.4 Landfall and Estuarine Works

During construction there will be some releases of sediment into the waters of the Sruwaddacon, during the process of trench construction. At its worst, this impact is assessed as moderate, as the construction process is only expected to take about one week. The strong tidal currents are expected to restore the seabed to an equilibrium condition very quickly.

9.9 Monitoring

Discharge limits for liquid effluents are subject to prior agreement, as consent levels with the Environment Protection Agency (EPA), under the terms of an Integrated Pollution Control (IPC) licence, must be in place before operations at the Terminal can commence. Regular flow-proportional sampling will be undertaken along with spot measurements of the discharge of the produced water and oily water treatment facilities to ensure that the relevant concentrations are achieved and maintained. Monitoring of the process effluents will be made for the following:

- flow rate;
- pH;
- temperature; and
- TOC (a surrogate for COD/BOD).

Frequent flow-proportional sampling for total oil will be provided, as currently no reliable on-line technology is available due to interference from the level of salts expected. Samples will also be monitored for other appropriate parameters, including:

- oil in water;
- ammoniacal and total nitrogen;
- suspended solids;
- phenols;
- sulphides; and
- metals (typically Cd, Hg, Cr, Ni, Zn, Cu and As).

In addition to the regular monitoring is carried out by the operator to demonstrate compliance with the discharge limits set, occasional broader analyses will be completed out covering a broad spectrum of substances, to establish that all relevant substances have been taken into account when setting the discharge limits.

The monitoring programme will also be subject to the terms of the IPC agreement.

9.10 Reinstatement and Residual Impacts

Once the Corrib Field facilities have been removed and the wells have been plugged with cement, there are no expected impacts to the water quality. Depending upon the option selected during the decommissioning study for the pipeline, there could be a slow breakdown of the sacrificial anodes if the pipe is left on the seabed, releasing metal ions into the water. This is expected to provide a negligible impact because of the slow rate of release and high dilution available. If left on the seabed, the pipeline will be thoroughly cleaned and filled with water, it will corrode and fracture at some stage in the future, but there are no anticipated impacts to water quality.

On the basis of the hydrodynamic modelling, and the implementation of the mitigation options, no residual impact is expected.