11 NOISE

11.1 Introduction

This section considers the potential impact of noise and vibration generated by the construction and operation of the offshore field facilities, pipeline and landfall. The crossings of the Sruwaddacon are also included.

Underwater noise propagation is also considered in the context of potential impacts on marine species, both in the shallow water of Broadhaven Bay and in deeper water in the vicinity of the Corrib Field.

11.2 Study Methodology and Published Guidance

Noise impact is assessed both in comparison with prevailing environmental conditions and absolute levels of acceptability. In a quiet rural environment, increased noise levels are inevitable from any new activity, and must be assessed in both relative and absolute terms. The impact is then balanced against the duration of activity, its geographical zone of effect and likely resultant interference caused.

The combination of comparative and absolute assessment applies to both airborne and underwater impacts. The most sensitive receptors are considered in each case, these being the resident human population on land and marine mammals in Broadhaven Bay and offshore. Marine mammals are discussed in detail in **Section 7**.

The most relevant published guidance on noise from construction activities is BS 5228 (1997): 'Noise and vibration control on construction and open sites', that provides guidance on controlling noise from construction activities, rather than specifying noise limits, or determining whether or not a site is likely to give rise to complaints.

The Environmental Protection Agency (EPA) administers Ireland's primary noise control mechanism via the integrated pollution control (IPC) licensing scheme. This applies to ongoing noise emissions from fixed installations, rather than temporary noise generated by construction or installation operations, and will not be of great relevance to landfall and offshore construction and installation.

The EPA document *Guidance Note for Noise in Relation to Scheduled Activities 1995* does, however, give guidance on noise and vibration thresholds for quarrying and mining activities. Although there is no standard methodology for assessing underwater noise impact on marine fauna, there is considerable research on this subject in relation to offshore petroleum activity, from which information has been drawn. Further discussion of this can be found in **Section 7** and **Appendix 2.1**.

Throughout this section, noise levels (sound pressure levels) are presented as decibels (dB). For noise levels in air, dB refers to the standard convention of dB re 20 µPa. For underwater noise, dB refers to the standard convention of dB re 1 µPa in water. Impulsive noise sources associated with blasting are referred to in terms of overpressure in kPa. Other terms mentioned in this section are defined in the glossary.

11.3 Receiving Environment

11.3.1 Offshore

Typical sound intensity levels for an offshore marine environment close to the continental shelf, such as off the west coast of Ireland, are presented in **Table 11.1**.

Table 11.1: Characteristics and levels of some key sources of underwater noise (Richardson *et al.*, 1995)

Source	Sound Intensity Levels	Dominant Frequency Range	Other Typical Characteristics
Wind*	At 100 – 200 Hz 65 dB re 1 µPa2/Hz (force 3)/85 – 95 dB re 1 µPa2/Hz (force 12)	1 Hz – 25 kHz	Greatest levels at higher wind speeds. Noise is continuous on a scale of hours to days.
Rain*	0 dB (no rain)/80 dB re 1 µPa²/Hz (heavy rainstorm)	Broad spectrum	Flat frequency spectra
Baleen Whales	150 – 190dB re 1 µPa at 1m	20-400Hz	Varies between species, within species, and dependent on noise/signal type
Toothed Whales	125-180 dB re 1 µPa at 1m	200-130,000 Hz	Varies between species, within species, and dependent on noise/signal type
Shipping	140-170 dB re 1 µPa at 1m (ferry), 140-160 dB re 1 µPa at 1m (supply vessel), 170-180 dB re 1 µPa at 1m (merchant vessel), to 172-190 dB re 1 µPa at 1m (tanker)	20-1000Hz	Dependent on vessel size, design and speed

*Note: Ambient noise from sources such as wind and rain is expressed simply as dB re 1 µPa²/Hz. (Ambient noise does not have a single source point and it is therefore not possible to use reference distances).

In very general terms, ambient underwater noise levels can be assumed to range between about 80-100 dB (re 1 µPa) close to the surface, decreasing with depth. Such ambient conditions are influenced by surface wind and waves (Richardson *et al.*, 1995). Rain, seismic activity and biological sources, along with a limited amount of noise from shipping and fishing activities, would also contribute noise to the ambient levels. These are presented in tabular and graphical form in Appendix 11.

By way of comparison, a large tanker would generate noise levels between 172 and 190 dB (re 1 µPa), at 1 m from the noise source (propulsion system) (Richardson *et al.*, 1995).

The region is understood to be inhabited by a number of species of marine mammal, whose calls can generate noise levels of 190 dB (re 1 µPa) at 1 m and possibly higher (up to 220 dB (re 1 µPa)) typically in the frequency range 20-2000Hz for moans and songs and often 1,500-20,000+Hz for clicks based on estimates from underwater recordings (Richardson *et al.*, 1991; Würsig & Clark, 1993).

Studies of underwater noise associated with offshore oil and gas exploration have indicated that the semi-submersible rig used in the Corrib Field development will typically produce sounds up to 150 decibels (dB re 1 µPa), with the different operations producing sounds over a relatively large frequency range (typically between 10-4000 Hz) (Richardson *et al.*, 1995).

Several features of a fish's anatomy, lifecycle, and habits will determine the potential effects of loud noise sources. Turnpenny & Nedwell (1994) measured the sound pressure level thresholds for the onset of fish injuries. Auditory damage was recorded at 180 dB re 1 µPa, transient stunning at 192 dB re 1 µPa and internal injuries at 220 dB re 1 µPa. The level of sound produced by the semi-submersible is not predicted to cause physical injury to fish. Instead behavioural responses may be exhibited, with fish moving away from the sound source. The reaction threshold for fish has been recorded as 140 dB re 1 µPa (Ona, 1992; cited in Nakken 1992); therefore, fish are likely to avoid the immediate vicinity of high noise sources associated with the drilling rig during operation.

During drilling at noise levels typical for semi-submersible drilling rigs, it is likely that marine mammals could experience some difficulty with communications within approximately 1 km of the drilling rig if they were to move within that radius. The exact extent (determined by maskogram analysis (Erbe & Farmer, 2000)) will be highly species specific. In general terms, the toothed cetaceans will be affected to a lesser extent than other species due to their use of higher frequency ranges for communication. Low frequencies resulting from drilling activities are in some cases similar to those used by baleen whales. Toothed whales poorly detect low frequency sound. They are therefore less likely to be affected by the operations. The degree of disturbance to cetaceans from drilling operations is the subject of ongoing research; studies have indicated that some baleen whales may react to noise, for example by avoiding the noise source when the noise intensity reaches a certain level. It is suggested that the intensity needed to initiate such behaviour typically occurs at ranges of tens of metres for semi-submersible drilling rigs. It is considered unlikely that such responses will result in any long-term displacement of animals from the area.

Several studies have been undertaken regarding the impact of noise on cetaceans. In one set of experiments (Malme *et al.* (1983) *cited in* Richardson *et al.*, 1995) observations were made of more than 3500 migrating gray whales as they swam past a platform, from which playbacks of oil exploration and production noises were made. Avoidance responses began at sound exposures of 110 dB re 1 µPa and increased with increasing "received sound". More than 80% of the whales showed avoidance behaviour at signal levels higher than 130 dB re 1 µPa. Typically, when confronted with the noise, the whales slowed down and deflected their courses around the source. They also moved into the shallow surf zone and into "sound shadows" provided by rocks in an effort to avoid the noise. Their respiration rates were found to increase and mothers and calves appeared to be especially sensitive.

The effect of drilling noise will also be a function of the presence of cetaceans within the zone of effect. The Corrib Field is located in 350 m of water on the coastal side of the continental slope. Species recorded in this vicinity include a number of dolphin species but few large whales. Historically, whalers reported catches from the oceanic side of the shelf edge, although no visual observations in Gordon *et al*. (2000) confirm this. Similarly, sperm whales are typically found in water depths of 200 metres or more in this locality and beaked whales have not been recorded in water depths of less than 1000 metres. It is therefore likely, based on current data, that the zone of acoustic effect will principally affect dolphin species with a lesser effect on other animals due their preferred habitat being more geographically remote from Corrib.

In the offshore noise environment above sea level sea state and wind noise dominate with occasional passage of marine vessels and helicopters and other aircraft. Underwater sounds from helicopters are transient and the strongest sounds are detectable for roughly the period of time the aircraft is within a 26^0 cone above the receiver. The dominant tones are generally below 500 Hz and sounds will be strongest just below the sea surface under the aircraft. Cetaceans are likely to dive or turn away during overflights (Richardson *et al*., 1995).

11.3.2 Nearshore

Within the confines of Broadhaven Bay, and close to the landfall site located on the eastern side, the prevailing noise climate is typical of a pastoral coastline. Sea state and wind noise are significant factors during adverse weather conditions, with contributions from marine and land based sources of traffic and agricultural noise.

The underwater conditions in the shallow waters of Broadhaven Bay differ from those offshore, due to the relative proximity of boundary conditions at the seabed and surface. The acoustic interactions between these layers result in a complex 'reverberant' condition in the immediate area, and less efficient propagation at greater distances.

Underwater conditions within Broadhaven Bay will result in higher ambient noise levels due to the closer proximity and spatial density of noise source, both natural (e.g. waves) and that generated by human activity.

11.3.3 Landfall and Sruwaddacon

The site proposed for the landfall of the pipeline from the Corrib Field is at Dooncarton, between sand dunes and a rocky foreshore to the west. The area is in relatively close proximity to Rossport (on the other side of the bay), and a few residential properties exist in the area around Dooncarton itself. The nearest properties to the landfall have been identified at a distance of approximately 350 m to the south. They are located on the Pollatomish-Brandy Point road which runs east-west.

The downstream crossing of Sruwaddacon Bay occurs approximately 1 km southeast of the landfall, with residential properties within approximately 400 m on either shore.

The upstream crossing of Sruwaddacon Bay occurs in tidal waters below the confluence of the Glenamoy and Muingnabo Rivers. The closest residential properties to this location are found at approximately 400 m to the south.

Background noise levels close to the proposed landfall locations were surveyed between 10th and 14th July 2000. Measurements were made over consecutive 15 minute sample periods and consisted of the following principal descriptors: L_{Aeq}, L_{A90}, L_{Amax}.

Environmental windshields were used at all times throughout the survey. Weather conditions varied throughout the measurement period, with periods of wind and rain, and other times being dry and relatively calm. In general, weather conditions became progressively better throughout the survey. No record was taken of tidal state during the survey, although sea-state noise did rise during periods of less calm weather. Measurements were made at the three locations shown in **Figure 11.1.**

Location 1: At the nearest residential property to the alternative Brandy Point landfall location (now rejected as an option). The location was approximately 35 m from that proposed landfall.

Location 2: On the boundary of the coast road and nearest residential property to the Dooncarton landfall location. This location was approximately 450 m from the landfall.

Location 3: At a location approximately 1400 m to the north of the proposed Terminal site, and approximately 1000 m to the south west of the upstream Sruwaddacon crossing.

Although selected with specific reference to areas of likely sensitivity, the survey measurement positions can be considered representative of the general noise climate of the area at large.

Figure 11.1: Baseline noise monitoring locations

11.3.3.1 Noise Survey Results

For the purposes of this section the background noise survey has been summarised. The 24-hour period has been divided into daytime (07:00-19:00), evening (19:00-23:00) and night-time (23:00-07:00). The results are summarised in **Table 11.2**.

Table 11.2: Typical Background noise levels at the closest properties to the proposed landfall and Sruwaddacon crossing sites

Location	Daytime (dB (re 20 µPa))		Evening (dB (re 20 µPa))		Night-time (dB (re 20 µPa))	
	L_{Aeq}	L_{A90}	L_{Aeq}	L_{A90}	L_{Aeq}	L_{A90}
1	48.5	40.8	49.2	32.8	39.9	25.7
2	50.8	44.1	50.7	39.2	46.8	38.8
3	56.7	38.4	52.8	30.8	42.6	28.9

Daytime

During the daytime period the noise environment at all locations was dominated by individual traffic movements along local roads. Background noise levels were below 45 dB L_{A90} (re 20 µPa), consistent with a typical rural environment.

Sea noise and agricultural equipment (such as tractors) were considered to be significant noise sources in determining the minimum background noise levels. The lowest daytime background levels were recorded at the inland site, position 3, although local activity increased the average levels above those at positions 1 and 2.

Evening

The background noise measurements during the evening fell due to reduced activity and vehicular traffic to below 40 dB L_{A90} (re 20 µPa). Average (L_{Aeq}) levels dropped more sharply at position 3, having been affected to a greater extent by agricultural activity during the day.

Night-time

Measured background L_{A90} noise levels during the survey period fell to below 30 dB(A) (re 20 µPa) at both locations 1 and 3 during the night, but maintained a similar level at the landfall site (position 2) as for the evening. This is due the closer proximity to population centres. The background noise climate was considered to be typical of a rural/agricultural area during the night, which is consistent with an isotropic environment (no continuous dominant noise sources).

The L_{Aeq} measurements at location 2 were noted to have been significantly affected by individual traffic movements along nearby roads.

11.4 Characteristics of the Proposed Development

11.4.1 Offshore

Drilling

In the Corrib Field the appraisal wells which have already been drilled will be re-entered and completed for use as producers. Up to three further wells will be drilled and they will also be used as producers. This will result in two noise sources; one during drilling and one from vertical seismic profiling (VSP). Drilling a well may take up to 60 days, and re-completion is estimated to take 25 days per well.

VSP takes place after the well has been drilled and involves a number of loggers being strung at 10 m depth intervals down the well (in the case of well 18/25-3 the string contained 12 loggers). Typically a VSP survey takes 8 hours.

A seismic source is deployed underwater from the rig and is used to generate an acoustic signal. Logging instruments (geophones) record the signal at the different depths in the well. The string of geophones is then moved up the well, and the seismic source is fired again. For well 18/25-3 a total length of 2400 m was covered, involving 20 movements of the string and 20 firings of the seismic source. The single airgun used as the seismic source for VSP has a volume of 500 cubic inches (approximately 1/6 to 1/8 of that used in 3-D seismic surveys) and a source level of 230 – 245 dB re 1 µPa-m with a dominant frequency of less than 120Hz.

Installation

The offshore facilities will be installed on the seabed by marine vessels including a drilling rig. The duration of this activity is expected to be approximately 30 days in 2002 and 60 days in 2003. The rig will be there for about 6 months, but involved in completions. The offshore pipeline and umbilical will be laid between the landfall and the Field by specialised lay vessels. This is expected to take up to 30 days.

Operation

During the operational life of the Corrib Field there will be visits to the Field by survey vessels, and drilling rigs used in well work-overs, otherwise, there will be no activities associated with normal operations which will generate noise either in air or underwater.

Decommissioning

The seabed facilities within the Field will be retrieved to shore, so that no structures remain proud of the sediment. The decommissioning method for the pipelines and umbilical have not been confirmed as yet, but the options will be the subject of a detailed study, approximately five years before decommissioning is due to commence.

11.4.2 Nearshore

Installation

Construction of the pipeline and umbilical is described in detail in **Section 3.** The gas pipeline and umbilical will be laid from the landfall to the Field by separate vessels. The outfall pipeline will be laid at the same time as the gas pipeline, but only to a short distance from the landfall. A backhoe dredger will be used to construct the inshore trench close to the landfall.

Typical noise signatures for these activities are provided in **Table 11.3**.

Table 11.3 Underwater noise signatures for vessels that could be present in Broadhaven Bay during installation activities.

Vessel	Frequency (Hz)	Source level (dB re 1 µPa-m)
12m fishing vessel @12 knots	250-1000	151
150-200m freighter (similar size to Solitaire)	41-60	172-180
50m supply vessels	20-1000	105-115
50m supply vessel bow thrusters	118	Peaks of 140
Clamshell/Backhoe Dredger	250	150-162
25m tug pulling loaded barge	1000	170
16m Crew boat	90	156
5m RIB 25 hp outboard	6300	152
Data source: Richardson *et al.*, 1995		

From **Table 11.3** it can be seen that the supply vessel with bow thrusters generates an increased noise level of about 25dB when the thrusters are operating. Underwater noise data for clamshell dredgers (Richardson *et al.*, 1995) is used as a worst case guide to what might be expected from a backhoe, the type of dredger proposed for the inshore trench construction.

Operation

During the operational life of the nearshore facilities, there will be occasional visits by survey vessels along the length of the pipeline and umbilical.

Decommissioning

The decommissioning method for the pipelines and umbilical have not been confirmed as yet, but the options will be the subject of a detailed study, approximately five years before decommissioning is due to commence. Decommissioning operations are likely to include a similar range of vessels to those used during installation.

11.4.3 Landfall and Crossings

Installation

Construction of the landfall and Sruwaddacon crossings is described in detail in **Section 3**. In summary, the pipeline will be pulled a distance of approximately 2.5 km from the pipelay vessel to the shore by onshore winches. The crossings will be achieved by constructing trenches across the Sruwaddacon and pulling the pipeline through them. It may be necessary to blast a section of trench approximately 500 m long at the landfall below low water and possibly in the intertidal zone. A small underground chamber to house the connections between the offshore and onshore gas pipeline and umbilical will also be constructed near the landfall.

Operation

During operation of this section of the development, there will be surveys of the landfall area and crossing points, and regular visits to the underground chamber by authorized personnel.

Decommissioning

The underground chamber will be removed and the area re-instated. The options for decommissioning the pipeline and umbilical will be the subject of studies, approximately five years before decommissioning is due to commence.

11.5 Potential Impacts

11.5.1 Offshore

The potential for offshore noise impacts concentrates entirely on underwater acoustic matters. At 65 km offshore, the drilling rig (MODU) and vessel activities are too far from sensitive human receivers to be of concern.

The water depth in the Corrib Field is approximately 350 m. This allows sufficient depth for considerable dispersion of 'normal' noise associated with surface vessel activity, such as engine operation and propeller cavitation.

Drilling

Drilling operations introduce a noise source at the seabed, in addition to the surface noise from vessel engines. Therefore, during the course of the drilling operations, water within the field is subject to increased noise levels at all depths. Richardson *et al.* (1995) estimated that noise levels from a semi-submersible drilling rig were 154 dB (re 1 µPa) in the frequency range 10 – 4000 Hz. Standby vessels will be on station for the duration of the drilling of each well, with supply vessels in attendance on an irregular basis for a few days per well. Drilling and completion operations are likely to create a minor disturbance to cetaceans in the area.

The seismic source used in VSP is 500 cubic inches, approximately 1/6 to 1/8 of that used in a single seismic array in 3-D seismic surveying. The gun pressure is similar to that used in 3-D seismic (source level of 230–245 dB re 1 µPa-m with a dominant frequency of less than 120 Hz).The shot intervals are far less frequent, and the period over which VSP is carried out is limited to approximately 8 hours. The impacts from a VSP operation are minor, if cetaceans are in the vicinity, and negligible, if there are no cetaceans. Cetaceans in the vicinity of a VSP survey are likely to swim away and avoid the noise.

Installation of Field Facilities

Completion of the wells includes installation of a 'christmas tree' valve assembly being installed by ROV at each wellhead from the MODU used for well re-entry. The gathering manifold and pipeline end manifold will be lowered to the seabed by a dive support vessel (DSV).

DSVs will remain on station using dynamic positioning (DP). DP uses a variable number of thrusters to maintain vessel position. This type of thruster could generate a harmonic family of tones with a rather high fundamental frequency corresponding to the high rotation rate of the thrusters (Greene, 1985; 1987; Brueggeman *et al.*, 1990 in Richardson *et al* 1995). The noise is likely to be intermittent due to the nature of the operation, and variable in frequency dependent on the weather conditions. Strong winds and tides will require greater thruster use than low winds and weak tides.

Underwater construction of this nature generates relatively low noise levels for a short period, and the impact is considered to be minor over the short term (see above) of construction.

Infield flowlines and umbilicals will be laid by a pipelay vessel and be buried using a tracked trenching vehicle which sinks the lines into the soft seabed. Concrete covers for stability and protection could be required in some areas where the trenching vehicle cannot reach, and in areas close to the facilities where the lines need to leave the seabed. Noise levels from installation and burial of the flowlines and umbilicals are expected to be much lower than those for drilling, and to extend over a shorter time period (approximately 2 months).

Installation of the Pipeline and Umbilical

The pipelay vessel will generate similar noise levels and signatures to the DSV described above for the field facilities installation.

The main pipeline route has been planned to minimise the requirement for seabed preparation works. However, in some areas a degree of levelling will be required. This will be achieved using a tracked trencher to level off high spots, and filling in the spans by rock placement.

Placing of the pipeline and umbilical on the seabed will generate low levels of underwater noise, but will be transient in nature. The noise will be generated as the pipe is lowered to the seabed. The route has been designed to follow soft sediment as far as possible, and noise levels from pipelaying in soft sediment areas are expected to be very low. There are no data on sound source levels for this activity. However, a similar operation in the Moray Firth, Scotland, involved the laying of an oil export pipeline, the characteristics of which are likely to be similar to the gas export line from Corrib. Pierpoint (pers comm.), who undertook acoustic monitoring for cetaceans for this operation, states that sound levels from the pipeline during installation were very low. The dominant noises were those generated by associated shipping (see above for standby and support vessel noise).

Laying of a rock mattress for the pipeline to lie on, will generate some noise . Data are lacking but this is activity is short term and unlikely to represent a significant impact.

Low levels of noise will also be generated by the trenching of the umbilical throughout its length. Impacts from these operations will be of short duration and can be considered as minor.

Operation

Occasional impulsive noise events due to valve operation at the field facilities may occur. The valve operations will be infrequent, and the impacts are considered to be negligible.

It is occasionally necessary to work-over wells, for maintenance purposes, to remedy faults or improve performance. While it is carried out from a drilling rig, the work has a significantly reduced scope of activity and a lesser duration in comparison with the drilling of the original wells. The operation does have the potential to generate similar noise levels to drilling. The impact is therefore assessed as being minor. Further discussion on drilling noise impacts is provided in **Section 7**.

Decommissioning

Wells will be filled with concrete and conductors cut off below seabed level. Subsea manifolds will be dismantled and removed. The works will involve a similar spread of vessels to that used in the installation phase. Noise levels associated with these operations can be assumed to be similar to those generated during construction, but to last for a shorter period. Infield flowlines and umbilicals will also be removed. Decommissioning the gas pipeline and umbilical will be the subject of a study close to the end of Field life. The option of removing both from the seabed is likely to result in the greatest noise in the underwater environment. The complete decommissioning of the development will be the subject of an options assessment study report closer to the time.

11.5.2 Nearshore

Installation

Normal pipe and umbilical lay methods will be used from approximately 2.5 km from the landfall out to the Corrib Field. However, for the Broadhaven Bay area, the pipelay vessel will be followed by a trenching vessel which will bury the pipeline. Similar low levels of underwater noise are expected from pipe installation in the nearshore area to that offshore, with minor transient impacts. Noise levels from the trenching machine will be higher but of short duration, probably only a few days.

The draught of the pipelay vessel will be too great for it to lay pipe to the shoreline, therefore, it will stop at about 2.5 km from the landfall. From this point a shallow draft laybarge will be used held on station by anchors. The running of anchor wires and subsequent winching is not expected to be any noisier than the thruster noise levels on the pipelay vessel.

For the pipelay operations, a trench will be constructed to approximately 3 m depth in the seabed, and the pipeline will be pulled onshore by linear winches onshore. Noise levels for the duration of the pull operation, at the closest residence to the landfall, will be 54 – 57 dB(A) (re 20 µPa), noise generated from connecting the onshore and offshore pipelines will be approximately 65 dB $L_{Aeq,8hr}$ (re 20 µPa) at the nearest property. The pull operation will need to be continuous, requiring night-time working, which could be assessed as providing a moderate, but short term impact close to the landfall.

The umbilical lay vessel will arrive and pick up a connection to the conduit, and the umbilical will be pulled onshore through the conduit by similar, but smaller winches to those used for the pipe pull. Noise impacts from pulling the umbilical ashore are likely to be minor.

The offshore umbilical will then be connected to the onshore umbilical in the same underground chamber as the pipeline connection was made. The lay vessel will then move out to the Corrib Field laying the umbilical.

Trench Construction

The most significant impacts in Broadhaven Bay are likely to be due to underwater noise events related to any possible underwater blasting and subsequent underwater excavation which could be necessary in approaching the landfall site.

In itself underwater blasting does not usually create any significant audible noise in the air. Vibration ranges tend to be in the 3 – 30 Hz zone. Humans and other biosensors in the local area may detect these.

As far as possible, the pipe trench will be excavated using a backhoe dredger barge (and land-based earth movers above the low water mark). Some rocky areas will require blasting, both above and below sea level. In this case, after controlled blasting, excavation will continue as before, using the trenching plant to remove fractured rock debris.

Typical frequency ranges for underwater blasting are 30 –1500 Hz with peak pressure level expected to be 279 dB re 1 µPa. @ 1m. The excavation plant, both above and below sea-level is expected to create sound pressure levels of 150-162 dB re 1 µPa with a frequency band of 20-1000 Hz (Richardson et al 1995) on a temporary basis. The duration of the trenching operation is expected to be up to 30 days, although blasting will only occur once or twice per day.

When an explosive charge is detonated underwater the water shock wave travels at 1,500 m/sec. In shallow water the wave travels along three paths as shown in **Figure 11.2**.

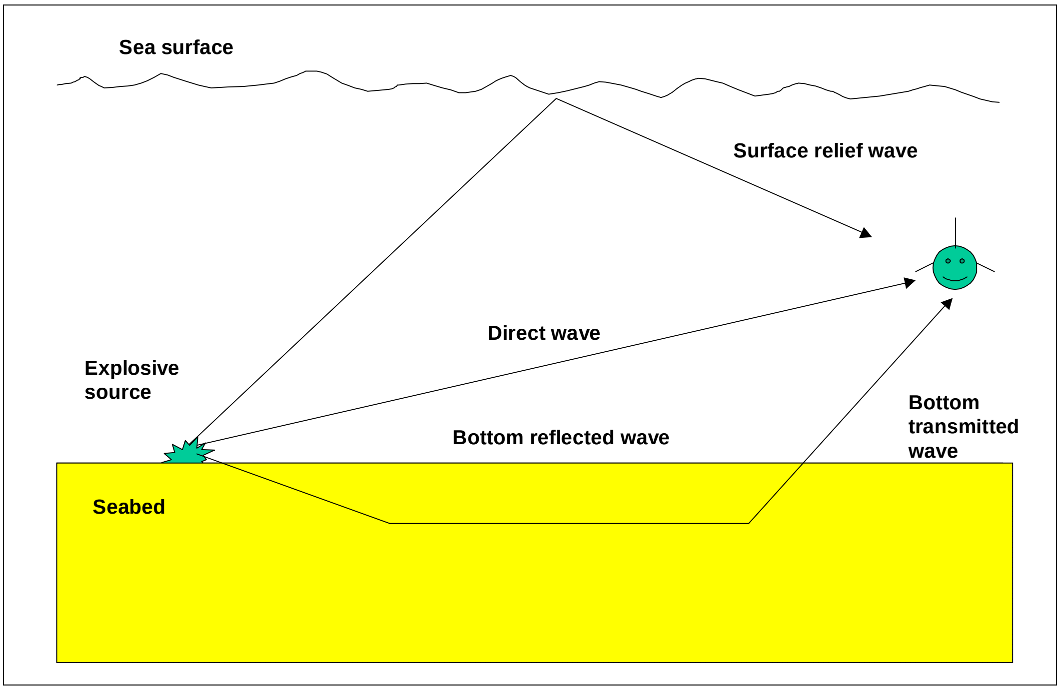

Figure 11.2: Wave paths from underwater explosions

The surface relief wave and the direct wave can, if the direct wave is slowed down, destructively interfere with each other. The surface relief wave, having been reflected at the sea surface has undergone a phase reversal. This acoustic characteristic will reduce the impact on the underwater environment.

Explosives with high detonation velocities generate the shortest rise time, and therefore will have the greater impact.

The factors that affect the degree of impact from explosive sources are:

- topography;
- proximity of ear;
- anatomy and health of ear;
- charge weight and type;
- rise time;
- overpressure;
- pressure and duration of positive pressure phase; and
- proximity of receptor species.

The potential for permanent hearing damage and other physiological impacts from nearby explosions is well known for humans and other terrestrial mammals. There is very little published data concerning such effects on marine mammals and there are no data on noise levels that induce permanent hearing impairment on marine mammals (Richardson *et al.*, 1995). Research is currently in progress on this issue.

In humans it is accepted that chronic exposure to workplace noise ~80 dB (over ~8h/day over ~10years) or more above the absolute hearing threshold can accelerate hearing loss caused by ageing, (Kryter, 1985). If this value for humans in air applies to marine mammals in water, then very prolonged exposure to noise levels (corrected for marine mammals) of ~120dB re 1 µPa (80 dB above threshold at best frequency) might induce a permanent shift in belugas (Richardson *et al*., 1995). This situation will not occur on the Corrib project because there will not be any continuous noise sources.

In terms of impulsive noise, such as might be caused by underwater blasting, there are no data, however Richardson in attempting to try and provide some guidance in this area uses the human as a model and extrapolates (Richardson *et al*., 1995). This results in a damaging noise level some 40-70dB higher than that for humans in air. For a single brief explosive pulse the range for a marine mammal in water would be 214-244 dB re 1 µPa.

As stated above, the peak pressure level for underwater blasting is expected to be about 279 dB re 1 µPa. @ 1m. Since this is higher than the postulated damaging noise level, it would be necessary to ensure that no marine mammals were close to the source of the blast.

Young (1991) has produced equations to predict safe ranges for the worst combination of blast depth and mammal depth. These values are considered to be conservative. Using this predictive equation and on the basis of a 25 kg explosive charge, the safe range for a 6m whale is estimated at 220 m whilst for a porpoise calf it is 480 m and for a diver it is 1000 m.

These estimates are based on free field propagation and therefore, they do not take account of the shallow water or local seabed geology effects which are present at Broadhaven Bay and result in additional attenuation (reduction) of the blast wave. Estimates are also based on fast rise time and complex waveforms related to more modern explosives (eg. TNT clones and water-gel explosives such as HBX and TOVEX).

General

Airborne noise impacts in and around Broadhaven Bay will be generated by the pipelaying and dredging vessels, and ancillary small craft movements.

Other movements in and around Broadhaven Bay, during the course of the project, will comprise small Rigid Inflatable Boat (RIB) type support vessels that will temporarily increase the amount of general traffic in Broadhaven Bay. The movements of small craft in and around the Bay will provide a small general increase in the ambient noise levels, but the level of impact is not considered to be significant.

11.5.3 Landfall and Crossings

Installation

The landfall construction site itself will be 5 hectares, with a range of onshore plant present during construction and installation. Typically, the onshore spread would consist of: excavators (2 x 15 tonne, 4 x 20 tonne, 4 x 25 tonne), JCB dumptrucks (4 x 20 tonne, 6 x 7 tonne), bulldozers (3 x 15 tonne), sidebooms (4 x CAT 572), tracked crane, forklift, crawler loader, Hiab truck, compressor, umbilical cable reel transporter, pipe bending machine, pipe bevelling machine, weld rig, generator, lighting towers, rock borer and pile hammer.

A similar, but reduced spread would be required at the Sruwaddacon crossings. The activities most likely to cause noise impacts at the landfall and crossings are the pulling operations, which will need to be continuous to keep the pipe moving through the trenches. The pull operations will generate noise levels of 54 – 57 dB(A) (re 20 µPa) at the closest residences (to the landfall and crossings). Such levels are not expected to cause an impact during the daytime, but as the pull operations will need to be continuous, they could cause a minor impact at night (the pull operations at the crossings are expected to take no more than 2 days, while the onshore pull may take up between 24 and 48 hours.

The sound power level and continuous sound pressure level equivalent for the expected landfall spread is provided in **Table 11.4**.

Table 11.4: Noise emissions from typical onshore plant for landfall construction

Plant	Number of Plant Items in use	Sound Power Level (dB) (ref 1 pW)*	Activity Equivalent Continuous Sound Pressure Level (LAeq@10m-re 20 µPa)
Mobile			
15 tonne excavator CAT 312BL	2	101	73
25 tonne excavator CAT 322B	2	105	77
Sideboom pipelayer CAT 572	1	110	82
Hiab truck-roller 165	1	97	69
Backhoe JCB 3/CAT 428C	1	105	77
Dumptruck (309 kW)	4	110	82
Tracked dozer / loader CAT 953C	3	108	80
4 tonne wheel loader CAT 902	3	101	73
8 tonne wheel loader CAT 914G	3	106	78
Crawler loader CAT 963C	1	110	82
Site Transport (2 12 seaters, 3 4x4s)	5	110	82

Plant	Number of Plant Items in use	Sound Power Level (dB) (ref 1 pW)*	Activity Equivalent Continuous Sound Pressure Level (LAeq@10m-re 20 µPa)
Diesel Forklift	1	103	75
Static/Portable			
Vibrating or diesel pile hammer	1	128	100
Site generator for power	1	89	61
Site Compressor (750 cfm)	1	102	74
Pipe Bevelling/Grinding	1	112	84
Cold Pipe Bending	1	115	87
Arc welding	10	104	76
Generator for welding	10	108	80
Lighting Towers	4	104	76
Rock drilling equipment & compressor	1	128	100

* 1 pW -= 1 picoWatt (1 x 10^{-12}) sound power level

Assuming all of the above plant runs during a given typical day, with each plant item operational for 50% of the time, noise levels at the nearest property to the landfall would be in the region of 65 dB $L_{Aeq,8hr}$ (re 20 µPa), assuming minimal 'line of sight' screening.

Two individual operations dominate the noise level calculations, these being the pile hammer and rock drilling equipment. However, both operations are less commonplace activities which would not occur on a daily basis.

If these items are removed from the received noise calculation, a reduction of 10 dB (A) is achieved, giving an 'everyday' received noise level of approximately 55 dB $L_{Aeq,8hr}$ (re 20 µPa), rising to approximately 58 dB $L_{Aeq,8hr}$ during periods of concentrated pipe welding and associated activities

Normal operations will not take place at night, but daytime noise levels could provide a minor impact at the closest property.

Road Traffic Noise

The increase in traffic movements on minor roads is likely to cause a noticeable increase in daytime noise levels. However, this effect will be localised and temporary, and will be restricted to the construction phase of the development.

Operation

The permanent landfall installation will comprise a small concrete underground chamber at the transition between land and subsea umbilical. No appreciable noise levels are expected to be emitted from this facility. The installation will not be manned, but visited routinely by authorized personnel for security and maintenance. No noise impacts are expected from operations.

Decommissioning

Decommissioning of the underground chamber will be a relatively small-scale demolition project. The method of dealing with the associated pipeline terminations will be dependent on the pipeline decommissioning strategy at the relevant time.

11.6 Do-Nothing Scenario

No substantial changes are anticipated in either airborne, or underwater, ambient acoustic environments, if the development were not to occur.

11.7 Mitigation Measures

The operations where significant noise mitigation measures are proposed include drilling and the blasting operations associated with construction, if required.

11.7.1 Drilling

In general, semi-submersible drilling rigs (MODUs) produce less subsea noise than drill ships, this is because of the presence of an air gap between the location of the machinery and the sea. Drilling in the Corrib Field will be from a MODU, and the duration of the drilling operation will be kept as short as possible.

11.7.2 Blasting

The routeing of the pipeline to avoid rock outcrops and shallow buried rock is the main mitigation measure that has been employed. In addition, the extent of blasting operations will be minimised by using alternative excavation techniques, such as impact rippers, wherever possible. However, blasting cannot be avoided in all cases. Where blasting is required, operations will be restricted to normal working hours and will avoid, where possible, weekend working. However, in order to reduce the time spent on this aspect of the work, and to take advantage of favourable weather conditions at sea, marine operations including blasting could take place seven days a week. No blasting will be carried out at night.

Once the detailed requirements for inshore blasting operations are established, they will be assessed against absolute limits due to the high levels of sound energy involved, which can be intrusive, startling and, in extreme cases, pose a threat of damage to hearing. Detailed mitigation measures to minimise the potential for damage and nuisance, both underwater and in air will be formulated. These measures will include the limitation of peak particle velocity by expert design of explosive charges and control of propagation where possible and will represent best practice in terms of impact minimisation.

The key elements of the underwater blasting operation that will be taken into account in the design to reduce the environmental impact are:

- placing of charges below the seabed in shot holes and not directly on the seabed or in the water column;
- blast design (type of explosive, depth of charge and size of charge) to minimize shock wave;
- careful shot hole loading to ensure all explosive is below seabed level in the hole;
- use of down hole initiation, i.e. no detonating cord outside of the shot hole;
- small explosive charges will be detonated underwater in order to scare fish away from the blast site in advance of blasting;
- blasting is only carried out in day-light hours and only after audible signals have been given;
- blasting where possible at low tide when fish population tends to be lower;
- use of seal scrammer to scare away seals;
- no blasting when marine mammals are in the vicinity;
- use of delay blasting to reduce the maximum instantaneous charge; and
- use of air curtain to attenuate pressure wave.

As discussed in **Section 11.5.2**, there is very little specific information about the susceptibility of marine mammals to underwater blasts. Marine mammals are presumed to be better adapted to pressure changes (to cope with deep diving) and are also better adapted to hear underwater. Thus it is not clear whether they are more likely or not to be affected by underwater blasts than humans.

It is therefore argued by Richardson (1995) that for the purposes of planning the conservative human safety criteria of Young (1991) should be used rather than the less conservative data for marine mammals.

In view of the paucity of marine mammal distribution data for the Broadhaven Bay area and the potential for impact from the operation, a precautionary approach will be applied. This will work on the assumption that animals could be present.

From the discussion in **Section 11.5.2** the possible mitigation measures which will be considered have been selected following extensive consultation with cetacean experts in Ireland, the U.K. and from published data, and include:

- use of dedicated marine mammal observers, who will be qualified and experienced marine biologists, or zoologists, whose job would be to carry out a visual scan of the potential impact area observing from rigid inflatable boats (RIBs) at locations around the mammal exclusion area. In the event that an animal(s) is detected within a radius of 1 km, detonation would be delayed until the animal(s) have moved beyond the exclusion area of 1000 m (twice the safe distance predicted by Young (1991) from the location of the blast and an additional 20 minutes grace time added;

- use of small pre-shots which will have the effect of scaring fish and mammals from the immediate vicinity of the main blast;
- a commitment to carry out operations only in daylight hours and in good visibility, in the event that this is not possible, sonar buoys and/or
  - passive acoustic hydrophone arrays will be used to detect marine mammals; and
  - airborne blast propagation can be controlled to some extent using solid screening barriers. Some work has been carried out on controlling underwater noise propagation by introducing air pockets and turbulence in the intervening medium. 'Bubble curtains' have been shown to be effective in masking underwater acoustic signals and limiting propagation.

Once started, blasting operations will be completed in as short a period as possible. This will serve to both minimise the period of temporarily unavailable habitat, and discourage fish and cetaceans from returning to the area between blasts.

These mitigation measures will be developed in close liaison, and detailed measures agreed, with Duchas before any operations take place.

For control of onshore noise blasting, the guidance given by the EPA is as follows:

> *'In the case of quarrying and mining operations, the vibration levels from blasting should not exceed a peak particle velocity of 12 mm/sec, measured in any three mutually orthogonal directions at a receiving location when blasting occurs at a frequency of once per week, or less. For more frequent blasting the peak particle velocity should not exceed 8 mm/sec. These levels are for low frequency vibration, i.e. less than 40 Hertz.'*

Although blasting operations associated with the landfall construction might be one or two per day, (for a short period), the EPA guidance is intended for permanent or semi-permanent sites (mines and quarries). In the context of the temporary landfall construction site, it is considered appropriate to use the higher of the two limits given above.

Guidance from the EPA states that *'blasting should not give rise to air overpressure values at sensitive locations which are in excess of 125 (Lin) max peak'*. Compliance with this absolute limit will be the responsibility of the blasting contractor, and will be monitored in sensitive locations.

Environmental impacts associated with rock blasting on land arise from:

- ground vibrations. – see below;
- noise (air over-pressure) – controlled by good practice;
- fly-rock – controlled by good practice and delineated risk zone;
- dust. – probably the biggest source of environmental dust in quarrying controlled by using bigger less frequent blasts.

It is expected that should it be necessary to fracture any rock in the trench at the landfall, no more than one or two blasts per day over a one to two week period would be required.

The limit values proposed for the ground vibration parameters are:

- a peak particle velocity (ppv) not exceeding 8 mm/second at any sensitive receptor;
- no blast or combination of simultaneous blasts should give rise to an air overpressure level at any noise sensitive location which exceeds 125 dB (lin) max. peak.

Alternatively compliance with a code or standard that is sensitive to the dominant frequency of the blast vibration. As an example of a frequency sensitive standard, DIN 4150 (1983) is widely used for the protection of structures.

In general, the shot-firer has an over-riding statutory and moral obligation to ensure that life, welfare and property are not jeopardised. The handling, use, storage and disposal of explosives will be conducted in strict compliance with all relevant regulations and in close liaison with the Gardai and Mayo County Council.

In designing the blast for compliance with vibration limits, the blasting engineer will assume that breakage will be incomplete because this is the condition that gives rise to abnormally high (but nevertheless, entirely predictable) ppvs.

Notwithstanding the occasional occurrence of incomplete breakage, the ppvs that are recorded at receptors tend to be within a range that is also site-specific. In other words under identical conditions, the standard deviation of ppvs will vary between sites, and the blasting engineer must adopt a statistical process for determining the upper limit of predicted ppv at one or several levels of confidence.

While the levels to which the community is likely to be exposed are comfortably below dangerous levels, they will be audible for a some distance from the blast.. Therefore, comprehensive information will be provided to the community regarding timing and likely duration of blasting works. Short programmes of blasting are generally considered less disruptive than a less intensive but more prolonged schedule.

11.7.3 Other Mitigating Measures

Installation of Field facilities and the main gas pipeline and umbilical will be completed in as short a time as possible, along a route which has been selected to have the minimum amount of rock. This routeing procedure will minimise the need for construction methods which have the potential to generate high noise levels.

Detailed information on the noise levels which will be generated by the specific methods, and equipment to be used, once these details are finalised, including actions required to minimise the noise impact will be presented to the relevant authorities prior to operations taking place.

The sites will be laid out to maximise acoustic and visual screening afforded by temporary accommodation and other features. It has been assumed that it is possible to screen all direct lines of sight from plant noise source to the nearest neighbour by a combination of natural and artificial means, as required.

Normal working hours will be defined as 0700-1900 hours Monday to Friday and 0700-1600 hours on Saturdays. Sunday working will be avoided, but not entirely excluded. When extended working hours are required, during the pipeline pulls, they will be discussed with Mayo County Council before operation begins, with adequate notice to the local community.

In noise-sensitive areas, controls may be imposed which are stricter in the early morning, evening and at weekends than they will be during the daytime, in agreement with Mayo County Council.

Where appropriate, residents living near to the landfall and river crossing sites will be kept informed of the contractors' proposed working schedules and will be advised of the times and duration of any abnormally noisy activity likely to cause concern.

The contractors will be made aware of the absolute necessity to avoid unnecessary noise from the sites, particularly at night.

Noise levels which will be generated from each of the options for decommissioning the development will be considered when the assessment of options is made.

11.8 Predicted Impacts

11.8.1 Offshore

Drilling

The only substantial noise levels generated by the process are due to drilling itself. Noise levels from semi-submersible rigs, such as that to be used in the Corrib, Field produce relatively low source levels (Richardson *et al.*, 1995). In one study Greene (1986 *cited in* Richardson *et al.,* 1995) found that broadband levels for the SEDCO 708 drilling rig did not exceed local ambient levels in corresponding bandwidths beyond approximately 1 km with estimated source levels of 154 dB re 1µPa. The impact is therefore seen to be negligible.

During well testing, any increases in noise will be temporary, and related to increased marine vessel activity and movements, rather than significant increases in process noise. Any noise from the burner (flare stack) during well testing will be temporary and will have a negligible impact on the environment.

VSP operations are not likely to create any more than a short-term minor impact to any marine fauna in the close vicinity of the drilling rig.

For the duration of the drilling and completion operations it is likely that there will be minor disturbance to marine fauna in the area. Any effect is likely to be transient and restricted to a behavioural response (avoidance).

Installation

Relatively low noise levels will be generated by the installation vessels, these are likely to result in a negligible impact to cetaceans.

Operations

Valve noise will be restricted to the immediate vicinity of the manifold and wellheads.

Long term noise impact due valve noise from the production manifolds and pipelines is not expected to increase ambient subsea levels.

11.8.2 Nearshore

Installation

The pipelay barge can be expected to anchor at least 1 km offshore and will not generate noise levels which would result in significant impacts to residences at such a distance.

The backhoe dredging vessels are not expected to approach closer than 100 m to the shore, but will be operational at night. Noise levels at the shoreline will be slightly elevated as a result, particularly at night, but at distances of greater than 300 m the noise will have reduced to approximately ambient levels. This will be of short duration (about one month) and temporary in nature.

Support vessels operating in Broadhaven Bay will comprise up to two tenders, which may occasionally work at night. This can be considered as a slight increase in normal activity but and would be very unlikely to cause disturbance to local residences.

Potential blasting impacts (**Section 11.5.2**) and appropriate mitigation (**Section 11.7.2**) measures have been described earlier. The predicted impact from blasting is expected to be minor in nature given the extensive set of mitigation measures involved. Furthermore, any proposed blasting will need to be carried out in compliance with all the relevant regulatory requirements, and in close liaison with the Gardai and Mayo County Council both for above and below sea level operations.

Operation

There will be no impact.

11.8.3 Landfall and Crossings

Installation

Enterprise is committed to ensuring that the impacts on the local environment during construction are kept as low as possible. The key impact parameters, including noise, will be very carefully monitored and controlled.

Enterprise will consult and liase closely with the local community in order to mitigate as far as possible the impacts during construction. Local liaison will ensure that the community are regularly consulted and informed of the elements of construction that will have most impact. These include the arrival of a heavy load or large piece of plant and the activities of rock breaking.

The impact from construction noise is seen to be minor for most of the operation, given the mitigation measures proposed. Occasionally the impact may be moderate, but over a very short period of time whilst a particularly noisy activity takes place. The impacts are temporary in nature.

Sruwaddacon Crossings and Onshore Pipe Pull

The operations required to achieve these crossings are very similar to the landfall, but reduced in size and duration (smaller winches, less excavators etc.). They are described in detail in **Section 3** and noise criteria are presented in **Table 11.4**. With residential neighbours at a similar proximity as for the landfall, the impacts are assumed to be at or below those calculated for the landfall.

Pulling the pipeline from the laybarge to the landfall will need to be a continuous operation, in order to keep the pipeline moving through the trench. It is expected to last for about one week. Noise level calculations for this operation, based on data for winches similar to those likely to be used, predict a noise level of between 54-57 dB(A) (re 20 μPa) at the nearest dwelling. This noise level could represent a very slight increase in normal average daytime levels, but a significant increase during the evening and at night, when the landfall site would normally be quiet.

It should be noted that distance loss and simplistic 'line of sight' screening are the only reducing effect considered. Actual noise levels will be further reduced by topographical and absorption effects.

11.9 Monitoring

A programme of noise and vibration monitoring of equipment will be implemented which will include the following: -

- **Landfall construction** – monitoring of noise and vibration at multiple locations where construction activities are in close proximity to sensitive receivers. For example for potentially intrusive activities such as site traffic routes or rock drilling;
- **Underwater construction**- during underwater blasting, observations will be made from RIBs in order to determine cetacean activity in the area. The use of passive acoustic listening devices (hydrophones) and other measures detailed in **Section 11.7.3** will be employed, in consultation with Duchas and implemented though an EMP in order to detect marine mammals underwater. In addition both underwater and landbased vibration sensors will be used to monitor and measure the following key parameters; peak pressure, frequency and vibration.

11.10 Reinstatement and Residual Impacts

If during decommissioning the pipeline is completely removed, similar short-term impacts could be expected as for the construction programme.

Once the development has been decommissioned, the environmental noise levels should return to those which were present before the construction of the project.