5 ENVIRONMENTAL IMPACT ASSESSMENT

5.1 INTRODUCTION

This chapter reports the findings of the environmental impact assessment of the proposed Lunskoye seismic survey programme. The assessment has evaluated how the survey could affect the physical, natural, human and cultural environment.

The wider impacts of the Sakhalin II Project have not been addressed in this ES and are the subject of a separate EIA.

5.2 EIA METHODOLOGY

This section describes the methodology adopted for the assessment of impacts beginning with the first stages of key issue identification through the identification of potential impacts and the determination of significance and magnitude.

5.2.1 Identification of Key Issues

The first step in the assessment process is to identify the key environmental issues that require evaluation. This is carried out considering the various activities associated with the survey (see *Chapter 3*) and the impacts they could have on the receiving environment (see *Chapter 4*). The potential interaction of each activity, or series of activities, on each environmental resource (*eg* physico-chemical, biological or human) can be identified. This may be through an understanding of known interactions or, in the absence of information, by professional judgement.

The identification of key issues is carried out prior to any assessment of the relative importance of each issue, the sensitivity of resources or the degree of the potential impact, and does not take account of potential mitigation measures (see below). At this stage of the assessment for the Lunskoye seismic survey programme, it was judged that some issues could be screened out because their impact on the environment would be so small as to be irrelevant. These issues are not considered further in the assessment process. Other issues may be carried forward to the next stage and assessed as being of *no impact, minor or moderate* significance once mitigation measures have been taken into account [(1)].

(1) No residual major impacts should be predicted, as the process of mitigation identification and investigation should have successfully reduced major impacts to a lower significance category (see *Chapters 7 and 8*).

Key environmental issues for this EIA have been identified as:

- disturbance and noise effects from the survey operations on marine mammals;
- disturbance and noise effects from the survey operations on other marine biota;
- interference with other users of the area;
- pollution risks from emissions, effluents and wastes;
- accidental spills, leaks and dropped objects.

5.2.2 *Identification of Potential Impacts*

The next step is to identify potential impacts from the survey activities on the identified resources. These impacts include:

- primary impacts of the proposals on the environment and secondary and higher order impacts resulting from these;
- permanent, long term and temporary, short term impacts (*ie* those caused by irreversible loss or damage to features in the environment or over the long term as a result of the proposals, and those that arise only temporarily during the survey).

5.2.3 *Evaluation of Significance*

Once potential issues and impacts have been identified, a determination of significance is required. For the purposes of this ES, the following definition of significance has been adopted:

> *An impact is significant if, in isolation or in combination with other impacts, it should, in the judgement of the EIA team, be taken into account in the decision-making process, including the identification of mitigation measures and consenting conditions.*

In assessing whether an impact is significant, reference has been made, where appropriate, to criteria on which the evaluation is based. These may include legal standards, policy guidance or accepted practice.

Assessment of the level of significance requires a consideration of the likelihood and magnitude of the environmental effect; it's geographical scale and duration in relation to the sensitivity of the key environmental receptors. For this assessment, four impact significance categories have been applied:

- *No impact* or *negligible* significance;
- *minor* significance;
- *moderate* significance;
- *major* significance.

For ecological impacts, quantitative predictions are widely acknowledged as problematic and there are a number of different methods used to define impact and significance levels. The following definitions were used for the assessment of the Lunskoye seismic survey programme to qualify the likely scale of predicted ecological impacts.

- *Major Impacts*: affect an entire population or species in sufficient magnitude to cause a decline in abundance and /or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it, to its former level within several generations of the species being affected. In the case of fish, an impact over one season/generation would be significant (1).

- *Moderate Impacts*: affect a portion of a population and may bring about a change in abundance and / or distribution over one or more generation of the species affected, but does not threaten the integrity of that population or any population dependent on it. *Moderate Impacts* to the same resource multiplied over a wide area would be regarded as a *Major Impact*.
- *Minor Impacts*: affect a specific group of localised individuals within a population over a short time period (one generation of the species affected or less), but does not affect other trophic levels or the population itself.
- *No Impact (*also referred to as *negligible)*: is a category assigned where there are no significant effects predicted to occur to the environment, species (or dependant trophic levels) or other potential receptors within that environment.

Given the international significance of endangered species, and the presence of species considered to be Critically Endangered (western gray whales) and Endangered (North Pacific right whale) in the vicinity of the proposed Lunskoye seismic survey operations (2), a precautionary approach was adopted when defining impact assessment criteria so that all impacts on these species are considered to be either *moderate* or *major* (*ie* no impacts are defined as *minor*). In some cases the mitigation measures will effectively reduce the

(1) Based on the assumption of average fish life-spans.
(2) IUCN, 2002. For definitions and details of the species characteristics and distributions in the vicinity of the Lunskoye Field, refer to *Chapters 2* and *4*, respectively.

impacts to *minor* or even to *no impact* levels, but the impact will still be defined as *moderate* or *major*. The impact assessment significance criteria for *minor*, *moderate* and *major* ecological impacts are described in more detail in *Table 5.1* below.

Table 5.1 Impact Assessment Significance Criteria for Ecological Impacts

Importance/Sensitivity	Minor Impacts	Moderate Impacts	Major Impacts
Locally important habitat or flora/fauna	*Minor*	*Minor*	*Moderate*
Nationally important habitat or flora/fauna	*Minor*	*Moderate*	*Major*
Internationally important habitat or flora/fauna	*Moderate*	*Major*	*Major*

For marine mammals, significant environmental impacts are those that are considered to be of sufficient magnitude, duration and scale to cause a change in populations that will alter their status or integrity beyond an acceptable level. The impact can be related to the numbers of individuals affected or the degree of the impact on the individuals (*eg* mortality, sub-lethal effects, or exclusion attributable to disturbance). For example, for endangered species the death of one individual from collision, or the exclusion of a group of individuals from their feeding areas for more than one month would be defined as a *major* impact.

For internationally important habitats and species, moderate and major impacts are considered to be of *major* significance and m*inor* impacts are generally considered to be of *moderate* significance. For impacts that are of low probability, magnitude, scale and duration, however, some impacts will be considered as of *minor* significance.

EIA is a process that deals with the future and there is inevitably, always uncertainty about what will actually happen. Impact predictions have been made using available data, but where significant uncertainty remains, this is acknowledged and an indication of its scale is provided. Where the sensitivity of the resource to a particular activity is unknown and the magnitude of impacts cannot be predicted, the EIA team has used its professional experience to judge whether a significant impact is likely to occur or not and this is reported accordingly.

5.2.4 Mitigation

Practical ways of avoiding or reducing potential significant impacts of the proposed survey require to be identified. These are commonly referred to as *mitigation measures* and are incorporated into the proposals, including all project commitments relating to environmental standards and environmental performance. For areas where there is uncertainty relating to the magnitude of predicted impacts, monitoring programmes have been agreed to allow

adjustments to be made, where practicable, on the way the survey is conducted and on the mitigation measures applied.

No Impact is the term applied where activities do not have an impact, or the impact is of such small magnitude that it does not require further consideration in the assessment. No specific mitigation measures are therefore required.

Minor significant impacts are considered to be of low or minor importance due to the scale, duration and degree of impact on environmental resources and no specific mitigation measures other than good practice operating procedures are required.

Moderate significant impacts require mitigation measures to be developed and applied to reduce the impact to as low as reasonably practicable (ALARP) levels.

Major significant impacts require mitigation to be applied/or some other action (eg alternative technologies or scheduling) taken to reduce the impact to *moderate* or *minor*.

Chapter 6 addresses the alternatives considered for the survey programme and outlines the reasons for the choices made.

5.2.5 *Residual Impacts*

The identified potential impacts are reassessed taking in to account the agreed mitigation measures, including the safeguards built into the vessels standard operating procedures.

5.3 *NOISE AND DISTURBANCE EFFECTS ON MARINE MAMMALS*

5.3.1 *Introduction*

Noise and disturbance impacts on marine mammals from the proposed seismic survey programme have been identified as key potential issues. This section of the assessment:

- identifies the sources of these impacts;
- outlines the specific evaluation criteria used for the assessment of noise and disturbance effects to species of marine mammals;
- presents a review of existing information regarding the acoustic and disturbance sensitivities of marine mammals;
- assesses the potential acoustic and disturbance impacts to individual marine mammal species.

5.3.2 *Sources of Impact*

One of the primary potential impacts of the seismic exploration activities is the effect of noise from the airgun arrays on marine mammals in effective range of the survey area.

As described in *Section 3.7* of *Chapter 3*, the seismic survey will be conducted for a period of one month, operating on a 24 hour per day schedule and beginning in July or August, 2003. The planned source level is quoted as 90 bar-m peak to peak (out to 128 Hz filter) when operating at a depth of 6 m. This equates to a source level of 259.1 dB re 1 μPa-m p-p, or about 243 dB re 1 μPa-m rms (1) when the energy is directed downward. The effective source level in the horizontal direction for a typical large airgun array is likely to be about 235 to 240 dB re 1 μPa-m rms. The range of water depths in the planned survey area is 25 to 60 m. Especially in the western (shallower) part of the operating area, water depth is sufficiently shallow such that the lowest frequency components are likely to attenuate more rapidly than the higher frequency components. Even so, strong pulses of underwater sound, predominantly at low frequencies but also extending up to medium frequencies, will occur and propagate to long distances.

The key impacts with respect to underwater noise are:

- potential for injury or fatality of marine mammals from exposure to significant levels of noise or any associated pressure effects;
- disturbance, leading to behavioural changes or displacement;
- interference with communication;
- interference with echolocation pulses used by certain marine mammals for the location of prey and other objects.

Additional potential impacts may result from disturbance and interference effects resulting from the physical presence of the seismic survey and support vessels.

5.3.3 *Significance Criteria for Marine Mammals*

Given the importance of impacts of seismic surveys on marine mammals in general, and the potential impacts on endangered species in the waters off Sakhalin Island in particular, a set of specific definitions for the assessment criteria for marine mammals was developed. It is recognised that ecological impact assessments require a degree of professional judgement and the divisions between the various definitions are inevitably subjective. By setting

(1) These are defined in '*Units of Measurement*' within *Section 5.3.5* below.

out quantified definitions for the assessment criteria in this way, however, the basis of the assessment process is transparent.

The following specific criteria were used for the assessment of potential impacts on marine mammals.

Magnitude

Magnitude describes the nature and extent of the environmental effect for each activity and is defined as follows.

- *Low magnitude* affects ≤1 % of individuals present off northeast Sakhalin Island. Effects can be outright mortality, sub-lethal effects, or exclusion attributable to disturbance.
- *Medium magnitude* affects 1 to 5 % of individuals present off northeast Sakhalin Island. Effects can be outright mortality, sub-lethal effects, or exclusion attributable to disturbance.
- *High magnitude* affects ≥ 5 % of individuals present off northeast Sakhalin Island. Effects can be outright mortality, sub-lethal effects, or exclusion attributable to disturbance.

Scale

Scale refers to the geographical extent of the area affected by the project and has been categorised as:

- *sub-local* (less than 1 km^2);
- *local* (1 to 10 km^2);
- *district* (11 to 100 km^2);
- *regional* (101 to 1,000 km^2);
- *global* (1,001 to 10,000 km^2).

Duration

Duration describes how long the project activity and/or environmental effect will occur, and has been defined as:

- *short* (less than 1 month);
- *medium* (1 month to 1 year);
- *long* (1 to 3 years);
- *very long* (over 3 years).

Short and medium durations are considered to be transient, whereas long and very long durations are considered to be permanent.

The Effects of Magnitude, Duration and Extent on Impact Categories

- A *major* impact would be caused by a combination of the following magnitude, duration, and geographic extent:

  A transient impact of high or medium magnitude for a duration greater than one month and over a geographic extent greater than 100 km^2 (eg excluding a number of whales from a feeding area for more than a month).

  OR

  A permanent impact of low, medium, or high magnitude for a duration greater than one year and over any geographic extent (eg mortality of one or more whales as a result of collision with a vessel).

- A *moderate* impact would be caused by a combination of the following magnitude, duration, and geographic extent:

  A transient impact of low, medium, or high magnitude for a duration greater than one month over a geographic extent between 1-100 km^2 (eg displacement of a migration corridor).

- A *minor* impact would occur if an activity affects a portion of the population but the identified effects are not distinguishable from those that could be attributed to natural variation. Negligible impacts require no mitigation measures.

  A negligible impact would be caused by a combination of the following magnitude, duration, and geographic extent:

  A transient impact of low, medium, or high magnitude for a duration less than one month over a geographic extent less than 1 km^2 (eg a few whales swimming past a sidescan sonar).

- There is *no impact* if no effects can be expected, for example, because of the biology of western gray whales or their distribution in the project area, if a noise is outside of the whales' hearing range or if project activities occur in locations where whales are not known to be present.

5.3.4 *Hearing in Marine Mammals*

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and react to many man-made sounds including sounds made during seismic exploration. The following section begins with a description of the hearing abilities of marine mammals, followed by a review of known and potential impacts of marine seismic exploration on marine mammals, and a discussion of the zone of potential effects around seismic sources.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioural evidence indicates that they hear very well at frequencies below 1 kHz (Richardson *et al.* 1995). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centred at 4 kHz (see Richardson *et al.* 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz. The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000).

The hearing systems of baleen whales are almost certainly more sensitive to low-frequency sounds than small toothed whales. Small toothed whales can apparently hear pulses from airgun arrays tens of kilometres away (see below), so the distance at which baleen whales would be expected to hear pulses is considered to be in excess of this.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (Richardson *et al.* 1995). The hearing sensitivities of several species have been determined as a function of frequency. In most of the tests, hearing sensitivity was determined only for frequencies above 1 kHz. However, for three species: the bottlenose dolphin, beluga whale, and Pacific white-sided dolphin, hearing sensitivity has been extensively studied at low, moderate, and high frequencies (see *Figure 20*). Some limited low frequency data are also available for three additional species: the false killer whale, Risso's dolphin, and harbour porpoise.

Small to moderate-sized toothed whales have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are no specific data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm whale and the various species of beaked whales.

The audiograms shown in *Figure 20* refer to the detection of pure tones of relatively long duration. Hearing thresholds of marine and other mammals are higher (*ie* poorer sensitivity) for pulses whose durations are shorter than 0.1 to 0.2 s, and possibly in some species for pulses as long as 1 s (Richardson *et al.* 1995). Underwater noise from airguns is pulsed, however, pulse duration is long (more than 0.2 s) at the long distances where received pulse level is approaching the threshold level. Thus, the thresholds shown in *Figure 20* are probably applicable to sounds from airgun arrays.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes

remain above the hearing thresholds of odontocetes at distances out to several tens of kilometres. Results from the Beaufort Sea indicate that pulses from airgun arrays are probably audible to odontocetes at distances out to over 100 km at certain times (Richardson and Würsig 1997). However, there is no evidence that odontocetes react to airgun pulses at such long distances (see below).

Pinnipeds

Most pinnipeds have essentially flat audiograms from 1 kHz to 30 to 50 kHz, with thresholds between 60 and 85 dB re 1μPa (see *Figure 21*). At frequencies below 1 kHz, thresholds increase with decreasing frequency (Kastak and Schusterman, 1998). For harbour seals, the 100-Hz threshold was 96 dB re 1 μPa, which is considerably more sensitive than for odontocetes. The Northern elephant seal has slightly better low-frequency hearing than the harbour seal (see *Figure 21*). The functional high frequency limit for the tested species is approximately 60 kHz (Richardson *et al.* 1995). Given what is known about their hearing abilities, it can be concluded that pinnipeds can undoubtedly hear seismic pulses (Richardson *et al.* 1995, p. 211, 357; Kastak and Schusterman, 1998).

5.3.5 *Review of Known and Potential Noise Effects on Marine Mammals*

There have been several reviews of the effects of underwater noise, including seismic exploration, on marine mammals. These include Richardson *et al.* (1989, 1995), McCauley (1994), Turnpenny and Nedwell (1994), Turnpenny *et al.* (1994), Gordon and Moscrop (1996), Evans and Nice (1996), Richardson and Würsig (1997), Gisiner (1999), Würsig and Evans (2001), and Moore and Clarke (2002). Although there have been several extensive reviews, the same limited experimental and observational data underlie each of the publications. The reactions of only three species of baleen whale to seismic sounds have been studied in detail (bowhead whale, gray whale, and humpback whale). Reactions of several pinniped species to airguns have been observed in recent years, although little of the information has been formally published at present. There are even fewer data on the reactions of odontocete whales to seismic sounds, but some descriptive reports have recently been released.

There are several zones or radii around a strong source of sound within which various effects on marine mammals are expected to occur. The zones include the area within which the underwater noise is audible to the marine mammal, the areas with behavioural responses or auditory masking [(1)], and the (theoretical) zones within which there could be hearing loss and physical damage (Richardson *et al.* 1995). The zones are briefly discussed in the following sections. However, first it is necessary to understand the units used to measure noise sources. These units are discussed in the following subsection.

(1) Auditory masking is a basic auditory principle whereby one tone of sufficient intensity can mask or decrease the perception of another tone that is occurring at the same time.

Units of Measurement

The sound output from an airgun or an array of airguns can be expressed using different terms. Different researchers have reported the received levels of airgun sounds in varying ways, making it very difficult to compare the results from some of the studies.

Geophysicists usually use peak-to-peak (p-p) pressure, typically expressed in bars or (for source levels) bar-meters, as their unit of measurement. That represents the pressure difference between the peak positive pulse and the peak negative pulse. The scientific literature usually expresses source or received levels in decibels (dB) relative to 1 micropascal (μPa); 1 bar equals 220 dB re 1 μPa; 100 bars equals 260 dB re 1 μPa. Zero to peak pressure values are about 6 dB lower than the equivalent peak-to-peak values (260 dB p-p approximately equal to 254 dB peak). The root mean square (rms) level of a pulsed airgun sound is the average pulse pressure level over the duration of the pulse. For received airgun sounds, rms levels are typically 10 to 12 dB lower than peak levels (Greene 1997; McCauley *et al.* 1998). However, the rms level is in part a function of pulse duration, which can vary depending on distance from the source and sound propagation conditions. It is probably important to specify not only the rms pressure level but also the pulse duration in order to specify impulse noise adequately.

Alternatively, the total energy in the pulse can be specified in the units dB re 1 μPa^2-s, or can be specified using the 'Sound Exposure Level' (SEL) approach. SEL, a measure of the total acoustic energy in a transient sound, has been found to be a useful predictor of the occurrence and degree of annoyance and also of TTS (Temporary Threshold Shift) resulting from human exposure to transient sounds of different durations and repetition rates. SEL is proportional to 10 log (P^2T), where P is the rms pressure measured over time T, the duration of the transient. SEL is defined as the constant equivalent sound level that supplies the same acoustic energy dose in one second as provided by the actual time-varying transient sound over duration T. For a sound pulse from a distant airgun array, the energy or SEL value, in dB re 1 μPa^2-s, is typically about 15 dB lower than the rms level in dB re 1 μPa.

Zone of Audibility

The zone of audibility is the zone within which a marine mammal can hear the seismic pulses. The size of the zone depends on the hearing threshold of the species at the frequency of the emitted sound, the received level of the sound at that distance, and the level of ambient noise at corresponding frequencies. For baleen whales that hear well at low frequencies, it can be assumed that ambient noise levels will usually be higher than the hearing threshold, so the ambient noise will define the maximum radius of audibility. *Odontocetes* hear relatively poorly at low frequencies, so their maximum detection radius for low-frequency components of seismic sounds will normally be determined by

absolute hearing threshold rather than the ambient noise level (Richardson *et al.* 1995; Richardson and Würsig, 1997). However, seismic pulses also include significant energy at frequencies from a few hundred to a few thousand hertz. Although this mid-frequency energy is weaker than that at lower frequencies, it may be more prominent to odontocetes given their rapid increase in auditory sensitivity with increasing frequency (see *Figure 20*). For pinnipeds, the maximum radius of audibility will be intermediate between that for baleen whales and odontocetes.

The theoretical zone of audibility for seismic pulses can be quite large, reaching distances of over 50 km even for odontocetes (Richardson *et al.* 1995; Richardson and Würsig, 1997). Although the radius of audibility establishes the theoretical maximum possible zone of effect, there is no evidence that merely hearing weak seismic pulses from a distant source has any negative effect on marine mammals given the levels of natural and anthropogenic background noise generally present in the underwater environment (Richardson *et al.* 1995). The maximum radius of influence is normally expected to be less (often much less) than the maximum radius of audibility.

Zone of Masking

Anthropogenic sources of noise can interfere with the detection of acoustic signals such as communication calls, echolocation calls, and environmental sounds important to marine mammals. If the man-made noise is strong enough relative to the received signal, the signal will be 'masked' and undetectable (auditory masking). There is very little information about masking of sounds important to marine mammals, however, it is probably safe to conclude that masking will result primarily from continuous noise rather than the short pulses associated with seismic exploration (Richardson *et al.* 1995). Seismic pulses will generally have a masking effect for less than 1 second out of every 10 seconds (the interval between successive pulses). Thus, for 90% or more of the time, the seismic pulses will not have an appreciable masking effect. Some whales are known to continue to call in the presence of seismic pulses (Richardson *et al.* 1986). Based on the above conclusions, masking is not identified as being a significant issue, and is not considered further in this assessment.

Zone of Behavioural Effects

Studies of marine mammal responses to underwater noise have documented a significant difference in response thresholds for sequences of short impulsive sounds from airguns compared to the response thresholds for continuous or slowly varying sound levels (Malme *et al.* 1983, 1984; Richardson *et al.* 1995). Behavioural effects can range from a visible acknowledgement by an animal that it has heard the sound, such as a brief startle response, to strong and prolonged avoidance. Most commonly, marine mammals react by changing their direction and/or speed of movement or behavioural activity. If a marine mammal does react to an underwater sound by changing its behaviour or moving a small distance, the impacts of the change may be *moderate* or *minor*

to the individual marine mammal, the stock, and the species as a whole. Alternatively, if a sound source displaces marine mammals from an important feeding or breeding area or blocks the migration route to those areas for a prolonged period, impacts on the animals could be *major* at the population level. Different species and even different individuals of the same species react to a given acoustic stimulus in different ways. At times, the reactions also vary by season, reproductive state, and the current activity of the animal. Some marine mammals seem to be very tolerant of underwater noise under some circumstances but more responsive at other times.

Zone of Physical Effects

In humans, prolonged or repeated exposure to high levels of airborne sound accelerates the normal process of gradual hearing deterioration that occurs naturally with increasing age (Kryter, 1985). Such deterioration is a 'permanent threshold shift' (PTS). In addition, temporary increases in threshold occur during and shortly after exposure to high noise levels. This 'temporary threshold shift' (TTS) can last from minutes or hours to days. The magnitude of TTS depends on the level and duration of noise exposure, among other factors. TTS is a naturally occurring phenomenon and occasional mild TTS probably has little long-term effect. However, TTS is of interest because sound levels that are high enough to elicit mild TTS provide information regarding sound levels above which more serious auditory effects are likely to occur.

Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals. Ridgway *et al.* (1997) and Schlundt *et al.* (2000) exposed bottlenose dolphins and beluga whales to single one-second pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 μPa rms at 0.4, 3, 10, 20, and 76 kHz. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt *et al.* 2000). They established that the slight hearing impairment elicited by the sound exposures disappeared after exposure within an interval shorter than or equal to the interval of pulses.

Finneran *et al.* (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound power levels) of 221 dB re 1 μPa produced no more than a slight and temporary reduction in hearing. Similar results were obtained by Finneran *et al.* (2002) despite the use of a water gun (impulses contain more energy at higher frequencies than an airgun), which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study.

Masked TTS (MTTS; defined as a 6-dB or larger increase in post-exposure thresholds) was observed in a beluga whale after exposure to single impulses of peak-to-peak pressures of 226 dB re 1 μPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value approximately 4 minutes after exposure. No MTTS was observed in a bottlenose dolphin exposed to maximum conditions of peak-to-peak pressures of 228 dB re 1 μPa, peak pressure of 207 kPa, and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$. (Finneran *et al.* 2000, 2002).

Additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low frequency pulses of airgun sound. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of 20 ms, the received level of a single seismic pulse might need to be at least 210 dB re 1 μPa rms in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200 to 205 dB might result in slight TTS in a small odontocete. Received levels of less than or equal to 200 to 205 dB are usually restricted to a radius of no more than 100 m around a seismic vessel.

TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. There are some indications that, for corresponding durations of sound, pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes (Kastak *et al.* 1999; *cf.* Au *et al.* 2000). There are no data on levels or properties of sound that are required to induce TTS in any baleen whale.

A marine mammal near the seismic vessel might be exposed to a few pulses with levels of 205 dB, and possibly more pulses if the mammal moved with the seismic vessel. As will be shown, most cetaceans show some degree of avoidance of seismic vessels. It is unlikely that a cetacean would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see below). It is not known whether pinnipeds near seismic vessels incur significant TTS.

There are major differences in the exposures required to cause temporary and permanent threshold shifts (PTS). In humans and other terrestrial animals, sounds that are strong enough to elicit TTS following short-term exposure have been found to be strong enough to cause permanent hearing impairment (PTS) following prolonged exposure. For received levels only slightly above the TTS threshold, very prolonged exposure (*eg* 8 hours per day for at least 10 years) is necessary to cause PTS in excess of that expected from the normal aging processes. Received levels well above the TTS threshold are usually necessary before short-term noise exposure will elicit PTS.

One exception is that exposure to impulses with sharp rise-times can sometimes cause PTS even when the received level is not much stronger than that necessary to elicit mild TTS. It is not known whether the rise-times of airgun pulses, as received at close range, are rapid enough for that to occur in marine mammals.

Sound impulse duration, peak amplitude, and rise-time are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1995) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. However, caution is warranted given the very limited knowledge about noise-induced hearing damage in marine mammals. Recent evidence indicates that some beaked whales exposed to repeated pulses from mid-frequency military sonar incurred auditory damage, and then stranded and died (NOAA and US Navy, 2001). Seismic pulses and mid-frequency sonar pulses are quite different. However, evidence that the sonar pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that a precautionary approach is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

At very high-received levels, low-frequency underwater sounds can have non-auditory physiological effects on human divers and other submerged terrestrial mammals. The effects can include resonance in the lungs and other body cavities, dizziness, nausea, and visual effects. Those phenomena are the subject of considerable recent and ongoing research, mainly in relation to potential effects of powerful low-frequency sonar systems (Cudahy and Sims, 1998). Low-frequency sonar produce transient sounds considerably longer in duration than the brief pulses produced by airgun arrays. Very little is known about the occurrence of noise-induced non-auditory physiological effects in marine mammals. Available data do not allow a meaningful assessment of the circumstances (if any) in which airgun pulses might have effects of this type on marine mammals. If the effects do occur, they would presumably be limited to short ranges. Marine mammals that show behavioural avoidance of seismic vessels (*eg* most baleen whales) presumably would not be affected.

5.3.6 *Potential Impacts of Noise on Baleen Whales other than Gray Whales*

Available Data

Humpback, gray, and bowhead whales reacted to noise pulses from marine seismic exploration by deviating from their normal migration route and/or interrupting their feeding and moving away (*eg* Malme *et al.* 1984, 1985, 1988; Richardson *et al.* 1986, 1995; Ljungblad *et al.* 1988; Richardson and Malme 1993; McCauley *et al.* 1998, 2000; Miller *et al.* 1999). Fin and blue whales also

show some behavioural reactions to airgun sounds (Ljungblad *et al.* 1982; McDonald *et al.* 1993; Stone 1997, 1998, 2000).

Prior to the late 1990s, it was thought that migrating bowhead whales, gray whales and humpback whales all began to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 μPa rms (Malme and Miles, 1985; Richardson *et al.* 1986, 1995; Ljungblad *et al.* 1988; McCauley *et al.* 1998). However, some of those experiments were not designed to detect long-range behavioural effects.

Detailed studies in the Beaufort Sea using intensive aerial surveys have shown that almost all migrating bowhead whales remained at least 20 km away from an active seismic survey boat with small- to moderate-sized arrays of airguns (maximum 16 guns and 1500 in^3or 24.6 L). There was also a statistically significant reduction in numbers present at distances of 20 to 30 km at times when the airguns were operating (Miller *et al.* 1999). Received sound levels at those distances were approximately 116 to 135 dB re 1 μPa rms. Some whales apparently began to deflect their migration path slightly at distances of approximately 35 km from the source at even lower received sound levels. Although the avoidance effect occurred at a greater distance than had been documented in previous systematic studies, avoidance of the area around the seismic operation did not persist beyond approximately 12 hours after airgun operations ceased. Migrating whales that approached after operations had ceased, moved back into the area of previous airgun operations. They did not continue to follow the 'displaced' migration corridor established during the period of airgun operations.

McCauley *et al.* (1998, 2000) have conducted studies of the responses of humpback whales off the coast of Western Australia to a full-scale seismic survey and to a single 20 in^3 (0.33 L) airgun (source level 227 dB re 1 μPa-m, p-p). They found that the overall distribution of migrating humpbacks through their study area was unaffected by the full-scale seismic program. McCauley *et al.* (1998) did, however, document localised avoidance of the array and the single gun. Observations from the source vessel indicated that avoidance reactions began at 5 to 8 km from the array, and the reactions kept most pods approximately 3 to 4 km away from the vessel and the survey activities. Corresponding distances for the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean airgun level at which humpback whales exhibited avoidance was 140 dB re 1μPa mean squared pressure. The startle response and the stand-off range (the minimum distance at which the animals would allow the airgun to approach) occurred at mean received levels of 112 and 143 dB re 1μPa mean squared pressure, respectively. However, many individual whales, especially males, approached within distances (100 to 400 m) where the maximum received level was 179 dB re 1μPa mean squared pressure.

Before exhibiting obvious avoidance behaviour when approached by an operating seismic vessel, bowhead whales typically show subtle behaviour changes such as reduced surfacing and dive durations, fewer blows per

surfacing, and longer intervals between blows. These effects were exhibited most strongly during active avoidance at ranges of under 5 km, but were also clearly evident at 5 to 10 km (Ljungblad *et al.* 1988) and, in a more subtle way, at distances out to approximately 50 km (Richardson *et al.* 1986). Similar changes in surfacing, respiration and diving cycles were evident when feeding gray whales in the Bering Sea were exposed to airgun pulses (Malme *et al.* 1988). Acoustic measurements and propagation modelling during the studies of both bowhead and gray whales showed that the seismic pulses were clearly detectable in the water column out to distances much greater than those where obvious avoidance reactions became evident.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because the responses appear less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic pulses become evident.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises provide no information about long-term effects. It is not known whether impulsive noises affect reproduction rate or distribution and habitat use in subsequent days or years, however:

- eastern gray whales continue to migrate annually along the west coast of North America despite the occurrence for decades of intermittent seismic exploration within the area (Malme *et al.* 1984);

- western gray whales continue to occupy the northeastern Sakhalin shelf in summer despite the occasional seismic programmes that have been conducted in previous years;

- bowhead whales also continue to travel to the eastern Beaufort Sea each summer despite the seismic exploration within their summer and/or autumn range that have occurred most years.

Bowhead whales were often seen in summering areas where seismic exploration had occurred in preceding summers (Richardson *et al.* 1987). They have also been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individuals of bowhead whales were involved in these repeated observations (within and between years). It is also not known whether whales that tolerate exposure to seismic pulses are less efficient in their foraging or are otherwise stressed.

Studies of gray, bowhead, and humpback whales have determined the received levels of seismic noise that induce behavioural responses in whales exposed to operating airguns and airgun arrays. Received levels (rms) of pulses in the 160-170 dB re 1 μPa rms range appear to cause obvious avoidance behaviour in a substantial fraction of the animals exposed. These

rms levels equate to sound exposure levels (SELs) per pulse of 150 to 160 dB re 1 μPa. In some areas, seismic pulses will have diminished to 150-160 dB SEL at distances of 4.5 to 14.5 km from the source. Acoustic measurements recorded in near shore waters near Piltun Bay during the summer of 1997, when seismic exploration was occurring in the Piltun-Astokh license area, indicated mean received levels (over 1 s) of approximately 153 dB re 1 μPa in areas where western gray whales were present and the seismic ship was 30 to 35 km away (Würsig *et al.* 1999).

The above review of the reactions of baleen whales to seismic surveys and acoustic sources indicates that a substantial proportion of individuals within 15 km of the seismic airgun array may show avoidance or other strong disturbance reactions. A small number of whales may show avoidance reactions at somewhat greater distances, and subtle behavioural effects (*eg* alterations in surfacing-respiration-dive cycles) may extend to well beyond 15 km. In the case of migrating bowhead whales, strong effects have been found at longer ranges and lower received sound levels, but whether any other species would show comparable sensitivity is unknown.

The studies to date indicate that disturbance reactions are likely to be transitory, with normal behaviour resuming within 1 to 12 hours after a single passage of the survey vessel.

Predicted Impacts

This section assesses impacts on baleen whales other than western gray whales; however, known reactions of gray whales are mentioned in this section to help indicate which types of reactions are consistent across baleen whale species.

Although a fairly large area (327 km^2) will be directly affected during the Lunskoye seismic programme, individual baleen whales (other than gray whales) will be disturbed only periodically and in small numbers because of the species' distributions. The most significant behavioural reactions are likely to consist of short-range avoidance movements.

Bowhead whales are known to be present off northeastern Sakhalin Island only in February and March, so there will be *no impacts* to this species.

The predicted acoustic impacts on fin whales and minke whales are judged to be of regional scale, with the potential for a substantial proportion of whales showing strong disturbance reactions within a 15 km radius of the airgun arrays (equating to an area approximately 700 km^2). As disturbance will not extend beyond the seismic shooting period, potential impacts can be described as being of medium duration [(1)]. Only a few individuals of the 400 to 600 fin whales and 3,000 to 3,500 minke whales would be affected, resulting in a low

(1) Impacts from the Lunskoye survey, being scheduled for 1 month, can be described as being of 'medium duration' (defined as 1 month to 1 year.)

magnitude (less than or equal to 1% of numbers off northeast Sakhalin Island). Thus, impacts on fin whales and minke whales are likely to be *moderate*.

The North Pacific right whale defined as being Endangered by the IUCN throughout its range. The species is rare in the nearshore waters of northeast Sakhalin Island (150 to 200 individuals). The predicted acoustic impacts on North Pacific right whales are judged to be on a regional scale and for a medium duration. Very few (1 or 2) individuals are likely to be present near the survey area, resulting in a low magnitude (<1 % of numbers off northeast Sakhalin). Thus, potential impacts on North Pacific right whales are likely to be *moderate*.

Assuming that the ramp-up ('soft-start') mitigation method is applied, TTS, PTS, and non-auditory physiological effects on baleen whales are likely to be *minor* because of the known avoidance reactions of the species that have been studied at the close distances that are necessary for damage to occur.

Due to the sensitivity of the western gray whale, potential impacts of noise on the species are considered in a separate section below.

5.3.7 *Potential Impacts of Noise on Western Gray Whales*

Available Data

Studies of the reactions of eastern gray whales to seismic pulses have been conducted on their summer feeding grounds in the Bering Sea and during their migration off the coast of California. Studies of the reactions of western gray whales to seismic pulses have been conducted on their summer feeding grounds off northeast Sakhalin Island in 1997 and 2001.

Malme *et al.* (1986, 1988) studied the responses of feeding gray whales to pulses from a single 100 in^3 (1.64 l) airgun offshore from St. Lawrence Island in the northern Bering Sea. Observers on boats followed the whales, collected behavioural data, and calculated whale movements from triangulated positions. Acousticians computed received sound levels at locations corresponding to behavioural observations. Observers on boats searched for whales, and when a group was found, the boat with the operating airgun source approached the area. Eight observations of the movements and behaviour of focal animals in relation to received sound levels were made. Feeding whales responded to the sound of the airgun at estimated received sound levels of 149 to 176 dB re 1 μPa rms and at distances of up to 4 km. In one case, little response was observed from a whale that was exposed to a received sound level of 165 dB at a distance of 0.66 km, but on five occasions there was cessation of feeding and movement away from the boat that carried the airgun source. In three cases, whales resumed feeding in the same area during the experiment or immediately after it. Two other whales stopped feeding and one of them moved away. Most of the responses involved an abrupt change in direction/or an increase in swim speed with movement away from the source (Malme *et al.* 1986, 1988).

In response to airgun sounds, the whales increased the interval between blows and decreased the length of surfacing, duration of dive, and number of blows per surfacing. That is the same pattern that has been documented in bowhead whales exposed to airgun pulses (Richardson *et al.* 1986; Ljungblad *et al.* 1988). Their surfacing and dive cycles sped up as the eastern gray whales switched from feeding to travelling in response to the airgun noise. Recovery to pre-disturbance surfacing and dive behaviour took place approximately one hour after the end of disturbance (Malme *et al.* 1986). Malme *et al.* (1996) estimated, based on small sample sizes, that 50% of feeding gray whales will cease feeding at an average peak pressure level of 173 dB re 1 μPa on an approximate rms basis, and that 10% of feeding whales will interrupt feeding at received levels of 163 dB. Malme *et al.* (1986) also estimated that an average peak pressure level of 173 dB would occur at a range of 2.6 to 2.8 km from an array with a source level of 250 dB.

Results generally consistent with the summer results summarised above were obtained when eastern gray whales migrating along the California coast were exposed to a single airgun or a full-scale airgun array (Malme *et al.* 1983, 1984). The experiments with migrating whales involved considerably larger sample sizes than the experiments on feeding whales, and tended to corroborate the reaction thresholds estimated for feeding whales. Aside from the sample sizes, the fundamental difference between the experiments on feeding and migrating whales was the fact that, in the migration experiment, the whales were already moving and were moving toward the source.

During the experiment on feeding whales, the source moved toward the whales and the whales changed activity from feeding to travelling. The main objective of the migration study was to measure the distance from the sound source at which deflection of swimming directions occurred, and the associated sound levels. In summarising their data, Malme and Miles (1985) concluded that a few gray whales avoided the area around the airgun(s) where average pulse pressure levels were 160 dB re 1 μPa (approximate rms basis), and about 50% avoided the area where those levels were 170 dB. The latter level (170 dB) was estimated to occur at a distance of 2.5 km from a 4,000 in^3 (65.5 l) array operating off the central California coast, where underwater sound tends to attenuate quickly with increasing distance [(1)]. Some initial behavioural changes were noted at greater distances and lower received sound levels, about 140 to 160 dB. Upon receiving these levels, eastern gray whales approaching the airguns began to show subtle indications of behavioural change, including slight deflection of the migration route (by a few degrees) to avoid swimming directly toward the airgun. However, they continued generally toward the source, passing sufficiently far to the side such that a typical whale avoided exposure to levels of sound above 170 dB (Malme and Miles, 1985).

A study conducted in 1997 to monitor influences of seismic activity on western gray whales near Sakhalin Island (within the Piltun-Astokh license

(1) The corresponding distance would be greater in an area with more efficient propagation of underwater sound.

area) indicated that whales were not displaced from their feeding grounds (Würsig *et al.* 1999). However, there were apparent changes in their behaviour. These behavioural changes included alterations in swimming speed and direction, distance travelled, and surface-respiration-dive characteristics (blow interval) during periods when seismic surveys were being conducted [(1)]. The reduction in average blow interval observed during this survey contradicts the trends shown in some other studies on the effects of seismic pulses on gray and bowhead whales (Richardson *et al.* 1995).

It is uncertain whether the changes in behaviour described above affect the overall well being of individual whales.

In 2001, Exxon Neftegas Limited (ENL) conducted a seismic survey covering their Odoptu field, which is located immediately north of the PA license area. ENL imposed strict buffer zones (4 to 5 km buffer between the seismic vessel and gray whales) to avoid exposing feeding western gray whales to seismic pulses louder than 163 dB re 1 μPa (rms) (Johnson, 2002). The 163 dB level was an experimentally determined noise threshold at which only 10% of eastern gray whales stopped feeding and departed their feeding area (Malme *et al*. 1986, 1988).

Notwithstanding the employment of the buffer zone and a variety of other acoustic mitigation measures (including reduction of the size of the airgun array, reduction in number of seismic lines surveyed, visibility restrictions, ramping-up or soft starts, shut-downs for whales and real time monitoring programs), a small number (3 to 5) of western gray whales responded to the seismic survey by shifting southward away from the seismic area and into the main feeding area off Piltun Bay (Johnson, 2002). Weller *et al*. (2002b) reported a southward shift away from the Odoptu seismic surveys by a larger number of individuals, but their method of calculation did not consider other factors such as weather and disturbance from vessel traffic in the area.

Predicted Impacts on Summering Western Gray Whales

The western gray whale stock summers in the northeastern Sakhalin Island region, tending to concentrate and feed in the shallow (5 to 15 m) nearshore waters in the vicinity of Piltun Bay (see *Chapter 4*). Some of the animals remain in the area for part or most of the open water season, and numerous animals return to the area in subsequent years (Würsig *et al.* 1999).

The best-known feeding area at Piltun Bay is located some 200 km north of the Lunskoye Field, however little specific information is available about the use of the Lunskoye Field area and the population probably migrates through it en route to the north in spring, and the south in autumn. Most western gray whales arrive at the Piltun feeding area between May and June, remaining until about October. In September 2001, a second feeding area was discovered in deeper (40 to 50 m) water off Chaivo Bay, 50 to 80 km north of the

(1) As compared to periods when seismic shooting was not occurring.

Lunskoye field. Numerous whales used the offshore Chaivo feeding area in 2001, and relatively large numbers of individuals were observed within both the nearshore Piltun and offshore Chaivo areas during aerial surveys conducted in late July and late August 2002 (*pers Comm* S. Blokhin, 2002).

The discovery of the deep-water feeding area off Chaivo Bay in 2001 raises the possibility that there are other, as yet undocumented feeding areas, possibly including the Lunskoye Field. To date, there has been no strong evidence of regular feeding in the Lunskoye area, although aerial survey coverage there has not been particularly comprehensive [(1)].

If western gray whales do feed in the Lunskoye area during the proposed survey period, they may be exposed to seismic pulses for a substantial proportion of the time when both they and the survey vessel are present. Feeding is likely to be disrupted if and when the seismic vessel approaches within a few kilometres, and subtle effects on behaviour are probable at some times while the airgun array is operating farther away. The extent of any such disruption of feeding, and its effect on individual animals, is unknown. If the operating airguns approach within a few kilometres, the whales are likely to show localised displacement as a minimum response. Whether they would move entirely out of the Lunskoye Field area is unknown.

There are alternative feeding areas to which they could move (*eg* the Piltun and Chaivo feeding areas). However, it is not known whether they would move entirely out of the Lunskoye area, what the energetic costs of such a move would be, or whether competitive interactions with whales already using the alternative areas might result in detrimental effects on the displaced whales and/or the whales already using the alternative areas.

In the likely event that the numbers of individuals feeding in the Lunskoye Field area are low, then competitive effects are unlikely to be severe even if those animals are displaced to another feeding area. However, if some individuals did incur significant reduction in feeding opportunities for one month or more, detrimental effects to those individuals could result. Given the small population size of western gray whales, effects to individuals have the potential to impact upon the whole population (*eg* through the loss of reproductive potential, reduction in growth, and reduction in the ability to survive winter).

Behavioural studies conducted in association with earlier seismic experiments (see Malme *et al*. 1983, 1984, 1986, 1988; Malme and Miles 1985) provide the best information available on the effects of seismic surveys on the eastern population of gray whales. Experiments on feeding gray whales in the Bering Sea indicated that 10% of the whales showed major modifications to behaviour (ceased feeding and moved rapidly away from the vessel) when the received sound levels generated by a seismic ship were greater than 163 dB re 1 μPa rms as measured in the water column (Malme *et al*. 1983, 1984, 1986, 1988;

(1) *Section 4.9.2* reports the details of the intensive and extensive aerial surveys conducted between 2000 and 2002.

Malme and Miles 1985). However, the effect was transient, with the majority of displaced whales returning to their original locations and resuming feeding within 1 hr of the seismic source being shut down (Malme *et al*. 1986). A calibration study carried out prior to a seismic survey conducted by ENL in 2001, near the north end of the Piltun feeding area, determined that the distance at which seismic pulses attenuated to 163 dB re 1μPa rms was about 7 km from the airgun array, when the array was operating at full volume (3,090 cu in or 50.6 l) and about 4 km from the array when operating at about half volume (1640 cu in or 26.9 l). With the 47.5 l array planned for the Lunskoye seismic survey, the distance would be approximately 6 to 7 km.

If the Lunskoye Field was found to be a western gray whale feeding area, the predicted acoustic impacts on feeding whales would be predicted to be of regional scale (more than 100 km^2, representing a 6 to 7 km radius, the distance to which interruption of feeding in only 10% of western gray whales is predicted) and for a medium duration. Disturbance would not be expected to extend beyond the period of shooting; although any substantial energetic effects of reduced feeding and/or increased swimming that might occur could persist for more than a year. Due to the timing of the survey, when the majority of the population has been observed in the vicinity of the Piltun Bay feeding area 200 km to the north, and the Chaivo feeding area, 50 km to the north, very few, if any of the 100 to 250 western gray whale population would have the potential to be affected. This would result in a medium magnitude (1 to 5% of numbers off northeast Sakhalin Island) or possibly high magnitude (more than 5% of the population). Based on previous survey observations, few whales are expected to be within the field between July and September, however, there is a possibility that new data will show that whales are feeding or are otherwise present during this period. The assessment of potential impacts therefore requires a precautionary approach to be taken, which has resulted in the prediction of *major* potential impacts on any feeding western gray whales that may be present within the field.

Monthly, intensive (100% coverage) baseline surveys of the Lunskoye area were conducted during the summer of 2002. Several western gray whales were seen there in July but there was no evidence of feeding. If those limited observations can be taken as evidence that western gray whales do not feed there, a summer seismic survey is expected to have at most a *moderate* impact on feeding western gray whales.

Predicted Impacts on Migrating Western Gray Whales

Western gray whales begin arriving in northeast Sakhalin Island waters in late May, after the sea ice has left the area, and some remain until late November, when ice returns. Migration routes used by western gray whales are presently unknown, but most specialists believe that the majority of animals migrate through La Perouse Strait (south of Sakhalin Island) and the south Kuril straits before migrating up the east side of Sakhalin Island (*pers comm* V. Vladimirov, 2002). Others believe that some individuals migrate through Tartar Strait (west of Sakhalin Island) and arrive on the northeast Sakhalin Shelf from the

north. If they migrate along the east coast of Sakhalin Island, they would presumably pass the Lunskoye area on their way north to their summer feeding grounds, mostly between May and June, and on their way south to their winter breeding grounds, mostly between October and November. Eastern gray whales usually stay in coastal waters during migration, except when crossing the mouths of bays, so it is likely that western gray whales would migrate inshore from, or perhaps through, the Lunskoye Field.

The seismic survey is planned to begin in July or August, when few if any western gray whales are expected to migrate through the Lunskoye Field. However, if the seismic survey were to occur during a migration period, and if gray whales migrate through mid-shelf waters where the Lunskoye seismic survey is to occur, they could be displaced from their usual migration route, either in the offshore or the inshore direction. Based on the observations of migrating eastern gray whales exposed to airgun pulses (Malme and Miles, 1985), migrating gray whales are probably considerably less responsive than migrating bowhead whales (see above). Any displacement of the migration corridor is likely to be by a few kilometres. Likewise, based on the eastern gray whale data, it is unlikely that the migration of gray whales would be blocked by the presence of an operating seismic vessel; they would divert around it.

In the unlikely event that migrating western gray whales occur in the Lunskoye area during the period of seismic operations, the predicted acoustic impacts on migrating gray whales are judged to be of local or district geographic extent (an assumed maximum displacement of 10 km), for a short to medium duration. For any migrating individual whale, disturbance is not expected to extend beyond the few hours that it would require for that whale to pass through the area, but for the population, displacement could occur for the duration of the survey. A diversion by a few kilometres and any concomitant delay in reaching the feeding grounds is not expected to have more than *minor* effects on energy balance. Because most migration is likely to occur before or after the survey period, probably only a few individuals of the 100 to 250 western gray whales would be affected, resulting in a medium magnitude (1 to 5% of the population) or possibly high magnitude (more than 5% of the population), resulting in the prediction of *moderate* impacts.

Assuming that the ramp-up ('soft-start') mitigation method is applied, TTS, PTS, and non-auditory physiological effects on western gray whales are likely to be *minor* because of the known avoidance reactions of the species that have been studied at the close distances that are necessary for damage to occur.

Potential Impacts of Sidescan Sonar Noise on Baleen Whales

The sounds produced by the side scan sonar survey will occur at frequencies far above the expected hearing range of baleen whales, including the western gray whale. Thus, there would be essentially *no impacts* on the minke whales, fin whales, North Pacific right whales, and western gray whales that may occur near Lunskoye during the side scan sonar survey period.

5.3.8 *Potential Impacts of Noise on Toothed Whales*

Available Data

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the baleen whale seismic pulse work summarised above have been reported for this group of cetaceans. Richardson *et al.* (1995) concluded that the reactions of odontocetes to seismic pulses deserved detailed study. Despite the relatively poor low-frequency hearing thresholds of small and medium sized odontocetes, they should be able to hear pulses from airgun arrays operating many tens of kilometres away (Richardson *et al.* 1995; Richardson and Würsig 1997). There are also no data on the absolute hearing thresholds of larger odontocetes including sperm whales and beaked whales. The low-frequency hearing of some of these species might be more sensitive than that of the smaller odontocetes.

There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) instances of exposure to weak noise pulses from extremely distant (more than 300 km) seismic exploration (Bowles *et al.* 1994). Watkins and Schevill (1975) also reported that sperm whales exposed to high frequency, pulsed man-made sounds ceased their calls. This 'quieting' is considered to represent a disturbance effect. Sperm whales in the Gulf of Mexico may also have exhibited disturbance reactions resulting from the presence of a seismic survey vessel (Mate *et al.* 1994). However, more recent data from vessel-based monitoring programmes in UK waters suggest that sperm whales show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone, 1997, 1998, 2000).

Dolphins are often seen from seismic vessels and exhibit some tolerance of airgun sounds, but when exposed to strong airgun noise from a nearby vessel they sometimes exhibit avoidance or behavioural changes. Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis,* of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the 'guard ship' that towed a hydrophone 180 m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1 km radius from the airguns (Goold, 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, not attributable to seismic surveys (Goold, 1996a,b, c).

Observers stationed on seismic vessels operating off the United Kingdom in recent years have provided data on the occurrence and behaviour of various small to moderate sized toothed whales exposed to seismic pulses (Stone 1997, 1998, 2000). Results were variable among species and years. However, dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small

odontocetes. In contrast, pilot whales and, (as noted above) sperm whales, seemed to show less evidence of behavioural reactions and avoidance than was expected.

Ridgway *et al.* (1997) and Schlundt (2000) conducted tests of behavioural response and temporary threshold shift in five bottlenose dolphins and two white whales in a captive situation. They were exposed to single one-second tones at received levels ranging from 141 to 201 dB re 1 μPa at frequencies of 0.4, 3, 10, 20, and 75 kHz. Dolphins exhibited short-term changes in behaviour above received sound levels of 178 to 193 dB re 1 μPa rms, and white whales did so at received levels of 180 to 196 dB and above. At 400 Hz, short-term changes in behaviour occurred at received levels of 180 to 190 dB. It is not clear how these results relate to dolphins in the wild and how responses would change in the presence of regularly repeated seismic pulses. It is very likely, however, that exposure to seismic pulses with corresponding SEL values would evoke marked avoidance behaviour.

Predicted Impacts

There is very little quantitative information about the behavioural responses of odontocetes to seismic exploration. Goold (1996a) found that common dolphins were tolerant of the noises from an array at distances of over 1 km. The threshold levels for behavioural responses by bottlenose dolphins to single one-second pulses ranged from 178 to 186 dB re 1 μPa for frequencies from 75 to 3 kHz (Ridgway *et al.* 1997). Received levels of seismic pulses on a SEL basis (appropriate for comparison with the one second exposures of Ridgway *et al.*) could decrease to those thresholds at distances of 100 to 500 m depending upon location. Making an allowance for possible differences between wild and captive animals, and accounting for the observations of Goold and Stone, we can speculate that the zone of behavioural effect for odontocetes may be about 1 km in radius, with much variability. Because killer whales apparently hear better at low frequencies than do the smaller toothed whales (Szmanski *et al.* 1999), the zone of influence for killer whales may be larger than that of the smaller species.

Because odontocetes appear to show less avoidance of operating seismic vessels than do baleen whales, and are occasionally seen within a few hundred meters of an operating airgun array, there is some potential for physical effects, for example, damage to hearing to occur. The low auditory sensitivity of many, if not all, odontocetes to low-frequency sounds may somewhat reduce their vulnerability to exposure to intense airgun sounds.

Beaked whales may be more sensitive to underwater noise than other species. There have been several reports of fatal stranding incidents involving beaked whales during naval exercises when mid-frequency sonar was used (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; NOAA and US Navy, 2001). In at least one of these cases (Frantzis, 1998), low-frequency sonar was also in use. Although the cause(s) of most of these incidents are arguable, in one case (NOAA and US Navy, 2001) it is widely agreed that the pulsed

sounds were responsible for both auditory injury and behavioural reactions that led to the deaths of some whales. If beaked whales are present in the shooting area, it is possible that some animals might be injured and/or panic and beach themselves, resulting in fatalities. The potential impacts of any such effect on populations of such an unpredictable and widespread species are unknown, but are predicted to be small. The species is wide-ranging, and tends to occur in deep water. The few beaked whales that might occur near the Lunskoye Field are therefore most likely to be offshore of the airguns, and are unlikely to move onshore in response to a seismic programme. It is implausible that a seismic programme in a nearshore area such as the Lunskoye Field would affect a significant number of beaked whales. Furthermore, the possibility of non-auditory physiological effects would be limited to animals situated close to the operating array, and it is very unlikely that beaked whales would occur in the relatively shallow water that is present in and close to the proposed area of seismic operations.

Although a fairly large area will be affected during the Lunskoye seismic programme, individual odontocetes will be disturbed only periodically and in small numbers due to general species' distributions [(1)]. The most significant behavioural reactions are likely to consist of short-range avoidance movements.

White whales are known to be present off northeastern Sakhalin Island only between May and June, so *no impacts* are predicted to result from a summer (July to September) seismic survey programme.

Many of the species discussed in *Section 4.9* are known to prefer deeper, offshore water (Dall's porpoise, sperm whale, Baird's beaked whale, Cuvier's beaked whale, northern right whale dolphin, short-finned pilot whale, Pacific white-sided dolphin). The survey is predicted to have *minor* to *no impacts* on these species, as the seismic survey will take place 8 to 20 km from shore and mostly in water depths of less than 50 m.

Some of the species discussed in *Section 4.9* have been reported only from Cape Terpeniie and further south (Pacific white-sided dolphin, northern right whale dolphin, short-finned pilot whale, and bottlenose dolphin), so there will be *no impacts* on those species.

The harbour porpoise is a coastal species that tends to stay within a few kilometres of the shore. One km is the distance to which a substantial proportion of odontocetes may show strong disturbance reactions, so there will be *no impacts* on harbour porpoises.

The predicted acoustic impacts on odontocete species that may be found near the seismic survey area *eg* the common dolphin and killer whale, are judged to be of local scale (about 3 km^2 representing a radius of 1 km which is considered to be the distance to which a substantial proportion of the

(1) Although some of the species that may be encountered there occur in large pods.

odontocetes may show strong disturbance reactions) and for a short or medium duration. For any individual whale, disturbance is expected to occur for occasional brief periods when the vessel comes close, but on a brader population scale, disturbance could occur for the duration of the survey. As many as 25 to 30 (the largest pod reported by Sobolevsky, 2000) of the 300 to 400 killer whales off northeast Sakhalin Island could be affected, resulting in an impact of high magnitude (more than 5% of numbers). To our knowledge, there is no estimate for the number of common dolphins off northeast Sakhalin Island. They can occur in very large groups, so predicted impacts could be of high magnitude. Thus, impacts on the common dolphin and the killer whale are predicted to be *moderate*.

Assuming that the ramp-up ('soft-start') mitigation method is applied, TTS, PTS, and non-auditory physiological effects on toothed whales are likely to be *minor* because of the known avoidance reactions of the species that have been studied at the close distances that are necessary for damage to occur.

Potential Impacts of Sidescan Sonar Noise on Toothed Whales

Available data

Navy sonars have been linked to avoidance reactions and strandings of cetaceans. However, those sonars are generally more powerful than the side scan sonar, have a longer pulse duration, and are directed in a larger beam width. The area of possible influence of the side scan sonar is much smaller. Toothed whales that encounter the side scan sonar at close range in the Lunskoye Field are unlikely to be subjected to repeated pulses because of the narrow beam width, and will receive only limited amounts of pulse energy because of the short pulses. Toothed whales would be most sensitive to the high-frequency sound produced by a side scan sonar.

Odontocete behavioural reactions to military and other sonars appear to vary by species and circumstance. Sperm whales reacted to military sonar, apparently from a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent, and becoming difficult to approach (Watkins *et al.* 1985). Other early and generally limited observations were summarised in Richardson et al. (1995). More recently, Rendell and Gordon (1999) recorded vocal behaviour of pilot whales during periods of active naval sonar transmission. The sonar signal was made up of several components each lasting 0.17 s and sweeping up from 4 to 5 kHz. The pilot whales were significantly more vocal while the pulse trios were being emitted than during the intervening quiet periods, but did not leave the area even after several hours of exposure to the sonar. In contrast, some individual beaked whales beached themselves, and others may have abandoned an area following extended exposure to mid-frequency naval sonar pulses from a variety of ships in the Bahamas (Balcomb and Claridge, 2001; NOAA and USN, 2001). Pulse durations from those sonars were much longer than those of the side scan sonar, and a given mammal would probably receive many pulses. All of these observations are of limited relevance to the present

situation because exposures to side scan sonar pulses are expected to be brief (as the vessel passes by), and the individual pulses will be very short.

Captive bottlenose dolphins and a white whale exhibited changes in behaviour when exposed to 1 s pulsed sounds at frequencies (3, 10, 20, and 75 kHz) lower than those emitted from the proposed side scan sonar (Ridgway *et al.* 1997; Schlundt *et al.* 2000), and to shorter broadband pulsed signals (Finneran *et al.* 2000, 2002). Behavioural changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.* 2000; Finneran *et al.* 2002). Dolphins exposed to 1 s intense tones exhibited short-term changes in behaviour above received sound levels of 178 to 193 dB re 1 μPa rms, and beluga whales did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.* 2000, 2002). Test animals sometimes vocalised after exposure to pulsed, mid-frequency sound (0.4, 4, and 30 kHz) from a watergun (Finneran *et al.* 2002. In some instances, animals exhibited aggressive behaviour toward the test apparatus (Ridgway *et al.* 1997; Schlundt *et al.* 2000). The relevance of those data to side scan sonar use and free-ranging odontocetes is uncertain. In the wild, cetaceans sometimes avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt (2000).

Impact Prediction

Individual odontocetes will be disturbed only periodically and in small numbers because of the species' distributions, although some of the species that may be encountered there occur in large pods. The most significant behavioural reactions are likely to consist of short-range avoidance movements.

The only odontocete species that are likely to be found near the seismic survey area are the common dolphin and the killer whale. The predicted acoustic impacts of sidescan sonar are judged to be on a sub-local scale (less than 1 km^2) and for a short (less than 1 month) duration. As many as 25 to 30 (the largest pod reported by Sobolevsky, 2000) of the 300 to 400 killer whales off northeast Sakhalin Island could be affected, resulting in an impact of high magnitude (more than 5% of numbers). To our knowledge, there is no estimate for the number of common dolphins off northeast Sakhalin Island. They can occur in very large groups, so predicted impacts could also be of high magnitude. Thus, no impacts to common dolphins and killer whales are predicted to occur.

5.3.9 *Predicted Impacts of Noise on Pinnipeds*

Available Data

Until recently, few data on the reactions of pinnipeds to open-water seismic exploration have been available (Richardson *et al.* 1995). However,

monitoring studies in the Beaufort Sea and elsewhere since 1995 (*eg* Harris *et al.* 2001) have provided considerable observational information. Preliminary results from a telemetry study in Europe have also provided more detailed information about responses of two species of seals (Thompson *et al.* 1998). Some pinnipeds exposed to seismic pulses exhibit behavioural changes, including interruption of previous behaviour (*eg*, feeding) and avoidance of the immediate area around a seismic vessel. However, individuals tend to show variable reactions to seismic sounds, and many animals show very little evidence of avoidance or other behavioural changes. Given that some animals show little avoidance and are seen close to seismic vessels, there is potential for hearing loss in pinnipeds that do not take avoidance actions.

Pinnipeds (mainly California sea lions, *Zalophus californianus*) observed during a seismic program off Southern California in 1995 reportedly showed variable reactions: Some individuals avoided, some approached, and some did not react overtly (Arnold 1996). More systematic data were obtained during seismic projects in the Beaufort Sea during 1996 to 2001 (Harris *et al.* 2001; Moulton and Lawson 2002). Those projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1,500 in^3 (9.2 to 24.6 litres). There was no significant variation in the behaviour of phocids (1) in the presence or absence of seismic pulses; however, seals usually avoided the immediate area around the vessel during seismic operations (or perhaps changed their behaviour so that they were less likely to be detected when near the seismic operations). Only 12 largha (spotted) seals were identified from the seismic vessels during the 1996 to 2000 surveys. Like ringed seals, the spotted seals showed variable behaviour, with several individuals approaching the active seismic vessel and two seals swimming away. Overall, the effect of seismic sounds on phocids in the Beaufort Sea appears to be localised, as seals were observed throughout the season in the general area where seismic operations were occurring.

In the United Kingdom, short-term behavioural changes in harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) exposed to airgun pulses have been reported based on a radio telemetry study (Thompson *et al.* 1998). In the study, harbour seals were exposed to seismic pulses from a 90 in^3 (1.5 l) array (3 x 30 in^3 airguns). Behavioural responses differed among individuals. One seal avoided the array at distances up to 2.5 km from the source, and only resumed foraging dives after seismic shooting stopped. Another harbour seal exposed to the same array showed no detectable behavioural response, even when the array was within 500 m. All grey seals exposed to a single 10 in^3 (0.16 l) airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short term, as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses.

(1) Phocids is a term used to represent species of the pinniped group Phocidae, which includes ringed seals, largha seals, elephant seals and the Weddell seal. Approximately 95% of seals identified in these projects were ringed seals.

The survey results described above suggest that there are interspecific and individual differences in pinniped responses to seismic sounds.

Little is known about the possibility that exposure to strong noise pulses might result in temporary or permanent effects on the hearing sensitivity of pinnipeds. Richardson *et al.* (1995) summarised the limited available data on the auditory effects of seismic and other pulsed sounds on pinnipeds. Kastak *et al.* (1999) describe TTS in seals exposed to moderate-level steady sounds, but there are no data on TTS caused by exposure of pinnipeds to single or multiple impulses of sound. In dolphins, as in terrestrial mammals, the level of sound necessary to cause shifts is inversely related to the duration of exposure (Finneran *et al.* 2000, 2002). It is considered that this relationship is probably also true in seals (Schusterman *et al.* 2000). The United States National Marine Fisheries Service considers that the maximum levels of impulse sounds to which pinnipeds should be exposed are 190 dB re 1 μPa on an rms basis, *ie* averaged over the duration of a pulse (NMFS, 2000a,b). At higher received levels, there is concern about potential effects on hearing.

Predicted Impacts

The most abundant pinnipeds species in and near to the proposed seismic area during the summer is the largha seal. During the July to September period when the seismic survey will be underway, largha seals will not be involved in breeding or moulting activities, as those events occur during the spring. The largha seal occurs along the entire east coast of Sakhalin Island, but most animals have been observed in Terpeniie, Lunsky and Chaivo Bays. Early in the summer (June to July) seals (primarily largha seals) are scattered all along the northeast coast of Sakhalin Island and are not aggregated (Sobolevsky, 1988). During this early period a small but unknown number of largha seals are likely to be in close proximity to the Lunskoye Field and could be exposed to seismic pulses. Later in the summer, when salmon begin to enter Lunsky Bay, seals (primarily largha seals) haul out in aggregations at the sand spit that forms the southern edge of the bay (Kosygin *et al.* 1986). During aerial surveys in this area during July 2000, about 40 seals were observed swimming at the mouth of the bay. During August, surveys saw this number increase to 100, and by autumn numbers had declined, with no rookeries being observed in September and very few individuals being recorded at the mouth of the bay in October (Sobolevsky, 2001). Hauled out seals would not be expected to suffer exposure to seismic pulses, but may be potentially exposed when they leave haul-out sites to feed outside the bay.

Unfortunately, there are no substantial data available on the reactions of largha seals to seismic activity. However, largha seals that are hauled out on beaches (at least those in Alaska) are much more sensitive to aircraft overflights than the other pinniped species of pinnipeds (see Richardson *et al.* 1995; Rugh *et al.* 1997). Although disturbance by aircraft overflights is not directly comparable to disturbance by seismic activity, it may indicate that largha seals are less tolerant of disturbance. Responses of largha seals to helicopter overflights at several adjacent haulout sites at Chaivo Bay, located

approximately 100 km north of the Lunskoye Field, were variable (Sobolevsky, 2000). The largha seal haulout site at the mouth of Lunsky Bay is the closest major pinniped haulout site to the Lunskoye Field.

Other pinnipeds known to be present in the area during the summer, but in relatively smaller numbers, than largha seals include the ringed, bearded, and northern fur seal.

The predicted acoustic impacts on largha, ringed, bearded, and northern fur seals are judged to be on a local or possibly district geographical extent and for a medium duration (1 month to 1 year) because disturbance will not extend beyond the period of shooting. The survey would affect no more than 100 individuals (the highest number seen by Sobolevsky, 2001) of the 27,000 to 48,000 largha seals, or a few individuals of the 130,000 ringed seals, 60 to 75,000 bearded seals, and 75 to80,000 northern fur seals on the northeast coast, resulting in a low magnitude (less than 1% of populations to the northeast of Sakhalin Island). Thus, impacts on largha, ringed, bearded, and northern fur seals are likely to be *moderate*.

Ribbon seals are not likely to be within the vicinity of the seismic survey area because of their offshore distribution during the summer months. There is a slight possibility that some Steller sea lions, which are listed as 'Status 2: Vulnerable' in the *Red Book of the Russian Federation* (Krasnaya Kniga RFZ, 2001), may occur near the seismic area. However, it is considered to be highly unlikely as the nearest rookery is at Tiulenii Island, over 300 km away from the proposed seismic survey area. It is therefore predicted that there will be *no impacts* to *minor* on ribbon seals and Steller sea lions.

If the strong responsiveness of Alaskan largha seals to aircraft is not relevant to the present situation, then (based on previous studies of pinniped reactions to seismic surveys) it is expected that some pinnipeds will avoid the immediate area around the seismic vessel but that most will remain in the general area and some may even approach the vessel.

Assuming that the ramp-up mitigation method is applied, TTS, PTS, and non-auditory physiological effects on pinnipeds are likely to be *minor* because of the known avoidance reactions of the species that have been studied at the close distances that are necessary for damage to occur.

Potential Impacts of Side Scan Sonar Noise on Pinnipeds

Available data

The sounds emitted from the side scan sonar will be largely or entirely inaudible to pinnipeds. Some harp seals (*Pagophilus groenlandicus*) seemed to alter their swimming patterns (exhibited avoidance) when they were exposed to the beam of an echosounder, nominally operating at 200 kHz (Terhune 1976); that frequency is above the range of effective hearing of seals. However, there was significant energy at lower frequencies that would be

audible to a harp seal (Richardson *et al.* 1995). Seals (primarily ringed seals, *Phoca hispida*) were commonly sighted from a vessel operating a side scan sonar (the same model proposed for use at the Lunskoye Field) plus other shallow hazard detection equipment that produced sounds in the hearing frequency range of phocids (*ie* mini-sparker at 200 to 2500 Hz and sub-bottom profiler at 3.5 kHz); however, those seals did appear to exhibit localised avoidance of the vessel when shallow-hazard detection systems were operating (Coltrane, 2002). The behaviour of ringed and Weddell (*Leptonychotes weddelli*) seals fitted with acoustic pingers, transmitting at 60 to 69 kHz, did not seem to be affected by the sounds from those devices. Mate (1993) described experiments where periodic 12 to 17 kHz sound pulses of varying duration were effective, at source levels of 187 dB, in reducing harbour seal abundance near fish hatcheries (although a few older seals may have habituated and foraged nearby with modified techniques such that they were not seen as frequently). For California sea lions, the same system produced a dramatic initial startle response but was otherwise ineffective. Mate (1993) noted that many marine mammals will react to moving sound sources even if strong stationary sources are tolerated. Mate also noted that, by not using swept frequencies, the experimental acoustic source lost the illusion of motion that would have been simulated by Doppler-like frequency sweeps.

Impact Prediction

The only pinniped likely to occur in any numbers near the sidescan sonar survey is the largha seal. Ringed, bearded, and northern fur seals may also be present in low numbers. Ribbon seals and Steller sea lions are not expected to occur within the survey area (see *Section 5.1.9*), and therefore *no impacts* are predicted to occur to these species. Because of the known hearing abilities of the other seal species, *no impacts* are predicted.

5.3.10 *Summary of Impacts of Noise on Marine Mammals*

Potential impacts of the seismic survey on marine mammals are summarised in *Table 5.2.*

5.3.11 *Impacts on Marine Mammals from Vessel Collisions*

Moore and Clarke (2002) indicate that vessel traffic (including commercial fishing) may have negative impacts on whales through collisions. Migrating eastern gray whales appear more susceptible to collisions compared to other whale species (Laist *et al.* 2000). While migrating, eastern gray whales may change course when within 15 to 300 m of a ship (Schulberg *et al.* 1989). However, many collisions have been reported (Patten *et al.* 1980; Schulberg *et al.* 1989; Laist *et al.* 2001). Right whales are also particularly susceptible to collisions with ships because they are slow, spend much time at the surface, and in some areas use habitats in the vicinity of major shipping lanes (Clapham *et al.* 1999).

Thus, western gray whales and North Pacific right whales may be vulnerable to collisions with the seismic survey vessel or the support vessel when the survey vessel is not firing its airgun arrays (during the survey, whales will avoid the vessel). However, no such collisions have been reported to date.

Impacts from collisions with the vessels may range from low to high magnitude, would occur over the short term (while the vessels are entering and leaving the survey area), at a regional geographic scale. However, serious injury or mortality of a western gray whale would be a long- or very long-term effect. Potential impacts of collisions between vessels and western gray whales or North Pacific right whales will therefore be *major.*

Assuming that the ramp-up ('soft-start') mitigation method is applied, along with regular firing of guns, potential impacts from collision are likely to be reduced to *moderate* because of the known avoidance reactions of the species.

Table 5.2 Predicted Impacts of Noise from the Lunskoye Seismic Survey on Marine Mammals

Marine Mammal	Effect	Magnitude	Geographic extent	Duration	Predicted impact before mitigation
All whales and pinnipeds	TTS, PTS, and non-auditory physiological effects				Moderate
Fin whales and minke whales	Short-range avoidance movements	Low	Regional	Medium	Moderate
North Pacific right whale	Short-range avoidance movements, possible feeding interruption	Low	Regional	Medium	Moderate
Western gray whale *if* migrating past the survey area	Temporary displacement from usual migration route	Medium to High	Local to District	Short to Medium	Moderate
Western gray whale *if* feeding near the survey area (1)	Reduction in feeding opportunities, possible loss of reproductive potential, reduction in growth, and reduction in ability to survive winter	Medium to High	Regional	Medium to Long	Major
Common dolphin, killer whale	Short-range avoidance movements	High	Local	Short to Medium	Moderate
Largha, ringed, bearded, and northern fur seals	Short-range avoidance movements	Low	Local to District	Medium	Moderate

(1) On the basis of present data there are no western gray whales feeding in the Lunskoye area, which would make impacts at most *moderate*. However, if new data would show that whales are feeding, the potential impact would be *major*, to be reduced to *moderate*.

5.3.12 *Impacts of Noise and Disturbance on Fish and Marine Invertebrates*

Impacts on Fish

Available literature regarding the potential for fish injury and fatality as a result of acoustic impacts and associated pressure effects indicates that direct injuries to fish, fish eggs or fish larvae are predicted to occur only when they are within a few metres of the airguns. Significant numbers can only be affected in situations where the survey line passes directly over fisheries in shallow waters *eg* where large numbers of fish eggs or larvae exist.

The importance of the Lunskoye Field area for fish is unknown, however, the survey will mainly be taking place in water depths of 25 m or more. Taking the depth of the airgun array into account (approximately 6 meters) information on the distribution of commercial fish species along the northeast Sakhalin Island coast shows no evidence of any such fisheries within the Lunskoye Field.

The Polar Fisheries and Oceanography Research Institute, reported by the National Environmental Protection Committee of the Russian Federation (2000) concluded a number of 'safe radii' inside which injury and fatality effects may be observed in a number of organisms. They concluded that for the PIK, Pulse and Bolt-1900 airguns young pollack and cod have a safe radius of one metre whilst flounder eggs and larvae have a radius of two metres and adult flounder one metre. Due to these narrow radii, the researchers also concluded that airguns had minimal effect on aquatic life form populations.

Only fish in the immediate vicinity of the airguns on commencement of the firing are expected to suffer injury, as the majority of fish are predicted to be driven away by the approaching sound source, the 'soft start' procedure (see *Chapter 7*) and the movement of the vessel. Levels of injury and fatality are considered to be *minor* in the context of local species populations.

The significance of behavioural change associated with seismic surveying for the fish themselves is also considered to vary between species and their individual feeding and spawning characteristics. For example, species searching for food over large areas of the seabed will move away from survey operations and will not be disadvantaged by the move as all parts of the seabed are of equal value to them. However, for species actively feeding on a small area of seabed, movement could result in a significant loss of feeding opportunity. In this latter case, the species may choose to remain in the area to continue feeding, despite the possible acoustic stresses caused by the survey activities (Gadus Associates, 1999). Any behavioural change is predicted to be transient and *minor*.

Many experiments have been conducted to deduce the effects of seismic surveying on fish catches, and no conclusive result can be determined. Gadus Associates (1999) report that whilst many experiments have shown a

significant reduction in fish catches, a similar number of experiments have shown catch increases Many results have also recorded neutral impacts. Reductions are considered to be associated with behavioural changes but are not necessarily indicative of a displacement of the fish away from the survey areas, with some studies showing the sideways movement of species away from the immediate line of the vessel only, or a change in swimming depth within the water column. Increases in catches may be also relate to the movement of species laterally or vertically within the water column in relation to the placement of nets, with some net configurations catching fish as they move away from the survey line. Given the duration and area of the survey in relation to available fishing groundstial impacts of the Lunskoye seismic programme on fish catches are predicted to be *minor* and transient.

No experiments assessing the acoustic disturbance effects of seismic surveying on fish spawning behaviour have been identified. As mentioned above, the Lunskoye survey area is not considered to be an important spawning ground in relation to the larger offshore spawning grounds and the survey is therefore expected to have *no impact* on fish spawning success or disturbance and damage to eggs.

Impact of Noise on marine invertebrates

Safe radii for plankton, jellyfish, crustaceans and molluscs are shown in *Table 5.3* (conclusions of the Polar Fisheries and Oceanography Research Institute and SakNIRO airgun research study (1998) reported in National Environmental Protection Committee of the Russian Federation, 2000).

From this data, crustaceans and molluscs can be considered to be the least vulnerable, with jellyfish and decapods being the most sensitive to potential acoustic impacts. In all cases the impacts on any organisms within the safe radius are transient, ceasing on completion of the survey. As with fish species, the radii represent a small area of the marine environment, and impacts are therefore estimated to have a *minor* effect on overall population levels.

Limited studies on shrimp have shown no decreases in catch rates during seismic survey operations, and shellfish species in general are considered to show little spatial variation (Gadus Associates, 1999). Impacts on shellfisheries are considered to be transient and *minor*.

Table 5.3 Safe Radii for Plankton, Jellyfish, Crustaceans and Molluscs

Species	Safe Radius (metres)
Zooplankton	3
Copepods	1 to 1.5
Decapods	2 to 3
Jellyfish	3
Crustaceans and molluscs	0.5

5.3.13 *Impacts of Noise and Disturbance on Birds*

Species of birds observed and recorded in the coastal environment to the west of the Lunskoye Field have been described in *Chapter 4*. Potential impacts to these species include:

- disturbance from usual feeding, breeding or migration patterns;
- secondary impact as a result of noise and disturbance impacts on prey fish species.

None of the species reviewed in *Chapter 4* showed tendencies to hunt or habitat areas in the vicinity of the Lunskoye Field and proposed survey operations, preferring instead to stay closer to the shore. The migration routes for all species are also coastal, being confined to land or the nearshore environment. The random flight responses of birds to the hunting of ducks in Lunsky Bay (see *Chapter 4*) are not predicted to result in species flying through the field as birds would not be expected to travel offshore over the distances required (12 km), and hunting activities have generally been observed during September and October (fauna Information and Research Center, 2001). *No impact* is therefore predicted to occur directly to bird species as a result of injury, fatality or disturbance relating to the survey operations.

Noise and disturbance impacts on fish are discussed in the section above. Disturbance of fish shoals and fish catches (commercial) was predicted to be *minor*. However, given that no predatory bird species are known to hunt within the proposed area of the survey, *no impacts* are expected to result.

5.4 *INTERFERENCE WITH OTHER USERS OF THE AREA*

5.4.1 *Potential Impacts*

The proposed seismic survey has the potential to interfere with other users of the area and the local social environment. The following issues have been considered:

- interference with commercial fishing activities and damage to fishing equipment;
- interference to marine mammal hunting;
- interference or disturbance effects on the local social environment and economy;
- interaction or interference with marine traffic;

- interference or damage to submarine infrastructure and offshore oil and gas production facilities;
- Interference and damage to marine archaeology and cultural heritage;
- interference with military uses for the area.

5.4.2 *Evaluation of Impacts*

Commercial Fishing Practices and Equipment

As described in *Chapter 4*, the proposed survey area lies within productive fishing grounds (fish, shrimp and crab). Detailed information on the extent of fishing activity in the area is not available however, it has been reported that the area is not intensively fished and that a small number of local boats at most might occasionally use the area (*pers comm* SEIC, 2002).

The seismic survey has the potential to cause interference with fishing activities and damage to fishing equipment (*eg* nets, lines, fixed gear) in the area.

Damage to fishing equipment is a concern from both a safety perspective (*ie* potential risk to personnel on the fishing vessel and the survey vessel) and in terms of adverse reactions / complaints and subsequent compensation claims from fishermen whose equipment has been damaged (*ie* loss of equipment and temporary loss of earnings / livelihood). Damage to the streamers from fishing gear is also a concern (see *Accidental Spills, Leaks and Dropped Objects*).

There are a number of standard procedures that seismic vessel operators adopt to reduce potential impacts with fishing vessels or equipment. These include consultations/notifications prior to the survey commencing to identify interested parties and to alert fishermen who operate in the vicinity to avoid the survey location during the period of operations. This may be tied to compensation payments for loss of earnings. During the survey, a support vessel will be used to warn fishing vessels in the area of the survey and to remove any fixed fishing gear that may damage the survey equipment. Records will also be kept of all communications with fishermen and damage to fishing gear and all compensation claims will be handled according to agreed protocols between the survey contractor and the local fisheries representatives.

It is considered that potential conflicts between the survey programme and local fishermen / fishing activities can be maintained within acceptable levels providing these mitigation measures are met. The impacts on fishermen are considered to be *minor.*

Hunting of Marine Mammals

As described in *Chapter 4*, there is little hunting of marine mammals in the vicinity of the Lunskoye Field, existing only in the form of coastal sea ice seal hunting by indigenous groups during the winter. *No impacts* are therefore expected to occur, given the timing of the proposed survey and its location in relation to the hunting areas.

The Local Social Environment and Economy

The seismic vessel will arrive in the Lunskoye Field fully supplied to conduct the survey without having to visit port in Sakhalin Island. Contact with local communities is therefore very unlikely, except in the event of an accident or emergency when the vessel may be forced to visit port or personnel are airlifted to the island for hospital treatment.

There are no records of any diving or marine-based tourist or recreational activities in the vicinity of the Lunskoye Field. As a precautionary measure, warnings of the proposed activities will be issued (Notice to Mariners) and a vigilant watch will be maintained throughout survey activities.

No impacts on local communities, the local economy, recreational activities, tourism and amenity are predicted.

Marine Traffic

Due to the meteorological conditions in the region, the majority of ports are located towards the south of Sakhalin Island where they remain free of sea ice for the majority of the year. For this reason, there are no merchant shipping routes in the vicinity of the Lunskoye Field. Levels of marine traffic in the survey area are therefore expected be very low, consisting only of local [(1)] fishing boats.

Potential impacts from interactions between the seismic survey vessels and equipment and other marine traffic include:

- damage to vessels and potential injury/loss of life;
- pollution from fuel, streamer oil or cargo spillage.

The survey vessel will operate 24 hours a day, during periods of low visibility and will be surveying lines in an east to west direction (perpendicular to the shore). Although the weather conditions during the proposed survey period (July to August) are generally stable, fog is not uncommon (20 to 40% recurrence of fogs during this period.

(1) There are no foreign fishing permit allocations in the area at present.

Survey vessel warning and navigation operating procedures will be adopted to reduce the risk of collisions with other vessels. These will include issuing a Notice to Mariners to warn that the survey is taking place and conveying the limited manoeuvrability of the survey vessel. The vessels will be fitted with suitable radar, foghorns and navigational equipment to ensure adequate warnings can be issued to any vessels in the area. The support vessel will be available to warn marine traffic to keep clear of the seismic survey vessel and associated trailing equipment. Collision risks with other vessels during transit to and from the survey area from the survey vessels' homeport also exist. These will be controlled by the adoption of standard navigation procedures. These mitigation measures would be expected to reduce potential impacts to minor.

Submarine Infrastructure and Offshore Oil and Gas Production Facilities

There are currently no offshore oil and gas production facilities, pipelines or submarine infrastructure *eg* utilities cables within the seismic survey (the closest being 120 km to the north). *No impacts* on existing infrastructure due to collision or disturbance are therefore predicted to occur.

Marine Archaeology and Cultural Heritage

Key concerns relating to the interactions between features of marine archaeological and cultural heritage importance and the seismic survey vessel, the support vessels and the survey equipment *ie* the streamer, include:

- direct damage to identified or unidentified wreck or non-wreck sites as a result of collision;
- direct damage to the seismic survey vessel, support vessel and survey equipment and potential injury/loss of life;
- pollution from spilt fuel oil and kerosene due to the snagging of vessels and survey equipment on subsurface features *eg* wrecks.

No features of archaeological or cultural heritage importance have been identified in the vicinity of the Lunskoye Field. There are two shipwrecks to the north of the field, but their exact location is not currently known (Yuzhno-Sakhalinsk State Pedagogical Institute, 1998). As these features are not within the field, it is considered unlikely that any impacts would occur as a result of the survey operations.

A side-scan sonar survey will be carried out prior to the seismic survey to identify any potential obstructions on the seabed. A 500 m exclusion zone will be established around the site of features considered to be of possible importance. The risk of collision with a feature of potential archaeological or cultural heritage importance and the consequential damage to the feature and the seismic survey vessel equipment is therefore considered unlikely.

Some authors have reported that pressure waves may induce a 'ruffling' effect on the seabed sediments resulting in localised increases in turbidity (UK Offshore Operators Association Ltd, 1995). However, the re-suspension of sediments would not be significantly higher than that produced by natural processes (currents, wave action and eddies).

No impacts to features and objects of archaeological or cultural heritage value associated with the proposed seismic survey.

Military Use

There is no known military interest or activity in the Lunskoye Field and therefore *no impacts* are predicted.

5.5 POLLUTION IMPACTS FROM EFFLUENTS, EMISSIONS AND WASTES

5.5.1 Potential Sources of Impact

Effluent discharges, emissions and generation of solid and scheduled wastes from vessels engaged in survey activities have a range of potential environmental consequences. Potential discharges and impacts include:

- oil contaminated drainage and sanitary effluent discharges may effect water quality or have direct or indirect adverse effects on marine organisms;
- chlorine in discharges from sewage treatment or water generator systems may cause harm to marine organisms;
- cooling water discharges may result in localised thermal stress and reduced dissolved oxygen levels;
- physical damage to pelagic organisms that may be drawn up in cooling and service water uptake;
- toxic effects on marine organisms in the event of an accidental release of solid or scheduled wastes into the marine environment;
- physical damage to marine organisms and impacts on water quality and the coastal environment as a result of inappropriate or insufficient waste management and disposal methods;
- short-term localised increases in down wind pollutant concentrations and reductions in local air quality;
- reduced visibility due to smoke emissions from vessel exhausts or solid waste incineration;

- contributions to regional and global atmospheric pollution phenomena *eg* acidic deposition (1) ozone layer depletion (2) and the greenhouse effect (3).

5.5.2 *Evaluation of Impacts*

Drainage System Discharges

Drainage effluents such as rainwater and sea spray runoff from uncontaminated deck areas will have no effect on the water quality and ecology of the receiving waters. *No impact* will therefore result.

Drainage from cable handling areas, machinery spaces, bilges *etc* may be contaminated with oil (*eg* diesel, cable oil, lubrication oil). These drainage fluids will be treated in an oil/water separator prior to discharge in compliance with MARPOL *Annex I* requirements (maximum discharge concentration of 15 parts per million (ppm)). After treatment, the residual hydrocarbons in the effluent discharge will have a localised and temporary impact on water quality around the area of discharge. These impacts are considered to be *minor*.

An International Oil Pollution Prevention (IOPP) Certificate, a slop oil tank and an Oil Record Book will be on board the vessels.

Sanitary Effluent

Sewage generated onboard the survey vessels is expected to be treated (by aerobic methods, settlement and the neutralisation of pathogens) prior to discharge. Discharged sanitary effluents are predicted to exert a minor biological oxygen demand on the receiving waters. Micronutrient elements will promote enhanced biological productivity in the marine environment local to the discharge outlet, with organic materials providing a food source for pelagic organisms. Natural dispersion by wave action, current flow and the assimilative capacity of the water column should ensure that these localised and temporary increases in organic material will have a *minor* impact, providing that all the material discharged is biodegradable.

Chlorinated Water Discharges

Discharges from service water systems and sewage treatments may contain residual concentrations of chlorine. Typical concentrations are estimated to be

(1) Otherwise known as 'acid rain'. Rain, snow, or fog that has been acidified by air pollutants such as sulphur dioxide or nitrogen dioxide.
(2) The depletion of a layer of ozone (O_3) (by ozone depleting substances *eg* CFCs and HCFCs) which surrounds the earth, shielding the planet from ultraviolet radiation.
(3) The greenhouse effect is a natural warming process whereby energy from the sun enters the atmosphere. This energy is partially absorbed and partially reflected. The absorbed energy warms the earth, which consequently emits heat energy back towards space in the form of long wave radiation. This radiation is trapped by gases such as water vapour, methane and carbon dioxide, which are named the 'greenhouse gases' (ghg). These gases re-radiate the energy, which results in an additional warming of the atmosphere and earth's surface. Anthropogenic activities such as the burning of fossil fuels release greenhouse gases thereby raising the concentrations and absorption capabilities of gases in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) have agreed that anthropogenic greenhouse gas emissions are influencing global climate.

approximately 1.0 ppm. Chlorine is harmful to aquatic life even at low concentrations, with toxic thresholds for fish species being in the range of 0.1 to 0.4 ppm (International Hydrological Programme, 1979). Following discharge to the marine environment of the Lunskoye Field, a combination of dilution and dispersion effects will rapidly reduce chlorine concentrations to below potentially harmful levels. Impacts on marine organisms as a result of residual chlorine in effluent discharges are considered to be *minor*.

Cooling Water Discharge and Water Uptake

Heated engine cooling water from the survey vessels will be discharged to the marine environment, usually after a once-through pass. The heated water will rapidly lose thermal energy to the surrounding water column, reducing the plume temperature, and insuring that a significant thermal plume cannot form. *No impacts* are predicted to occur as a result of this discharge.

The intake of seawater for cooling purposes and service water use (*eg* potable water production and deck washdown) has the potential to damage and entrain marine biota in the uplift stream. Weakly swimming or free floating planktonic populations are predicted to be affected by the intake, experiencing mortality and injury as a result of mechanical and thermal effects. Due to the high level of natural mortality in planktonic populations, the temporary and localised loss relating to seawater uptake by seismic vessels is predicted to be *minor*.

A coarse filtration system is expected to be fitted to the seismic survey vessels, which will prevent the entrainment of fish species into the seawater intakes. As a result of this measure, the seawater uptake will have a *minor* impact on fish populations.

Scheduled Wastes

Scheduled wastes such as lubrication oil and oily slops generated on the survey programme vessels will be returned onshore and disposed of at an appropriate facility when the vessels return to port [(1)]. The handling, management and disposal of these wastes will be conducted in accordance with appropriate legislative requirements and guidance. Hazardous materials (*eg* lithium batteries) will be stored onboard and returned to the supplier at a suitable time.

There have been numerous reports of marine life ingesting disposed wastes. It is believed that floating debris is mistaken for food or accidentally ingested as the animals feed on their prey. Pinnipeds, toothed whales, and baleen whales are all known to have ingested plastic products (Martin and Clarke, 1986; Barros *et al*. 1990; Walker and Coe 1990). Foreign objects can obstruct the gastrointestinal tract and cause gastric inflammation, nausea, and loss of appetite, which may result in starvation and death (Dierauf, 1990).

(1) Global port location not known at present.

Eastern gray whales found dead in California have been found with plastic bags and plastic sheeting in their stomachs (California Coastal Commission, 2002). Walker and Coe (1990) have commented that bottom-feeding cetaceans are at risk from ingesting non-buoyant debris. Uncontrolled disposal of solid and schedules wastes could damage sea mammals and other marine organisms and potential impacts are therefore considered to be *moderate*.

The proposed seismic survey vessel has onboard facilities for the compaction and incineration of solid wastes (including food wastes). Non-combustible wastes and incineration residues will be stored onboard and returned to port for disposal. The waste management procedures in place onboard the survey vessels (see *Chapters 7* and *8*) will be designed to ensure that there will be no fouling or contamination of the marine environment as a result of solid and scheduled wastes generated during survey operations. *No impacts* from the generation of wastes are therefore expected.

Air Quality

The principal emission sources from the survey operations will be exhaust gases from vessel propulsion systems, power generation equipment and the incineration of solid wastes. The primary emissions from these sources will include carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons, sulphur dioxide (SO_2) and particulates.

Emissions from the vessel propulsion and power generation systems together with intermittent releases from the onboard solid waste incinerator will result in slight increases in downwind pollutant concentrations. Exceedance of ambient air quality criteria is not expected to occur, and given the transient nature of the survey operations, the volatility of the air emissions and the generally high winds, emissions would be expected to undergo rapid dispersion resulting in *minor impacts* upon air quality.

Particulate Emissions

Particulate emissions from vessel exhausts and the incineration of solid wastes may result in a discernable plume downwind of the operations. However, significant reductions in visibility are not predicted to occur. Impacts from the survey on local air quality are predicted to be *minor* and will be transient in nature, lasting for the duration of the survey [(1)].

Acidic, Ozone Depleting and Greenhouse Gases

Nitrogen dioxide and sulphur dioxide are predicted to be released during the operations. The principal greenhouse gas to be released will be carbon dioxide.

Ozone depleting substances will not be used onboard the vessels, and will only be used as refrigerants in older vessels. In the latter case closed recovery

(1) Inversion weather conditions are not generally associated with the marine environment and are therefore not predicted to influence the duration of local air quality impacts.

systems will be in place to prevent any release. No release of ozone depleting substances is therefore associated with the survey operations.

Total quantities of acidic gases and greenhouse gases emitted will be low, and the contribution of the survey emissions towards total Russian emissions are considered to be *minor*.

5.6 ACCIDENTAL SPILLS, LEAKS AND DROPPED OBJECTS

5.6.1 Potential Sources of Impact

Potentially 'acute hazards' are discharges that result from emergency situations *eg* from uncontrolled events or incidents (HSE Advisers Panel, 1999). There are a large number of acute hazards that may result in the release of hydrocarbons, contaminants or materials to the marine environment. General causes of incidents can be referred to as 'threats'. The following threat classes have been identified by the Shell HSE Advisers Panel (1999):

- thermal (*eg* high temperature);
- chemical (*eg* corrosion);
- biological (*eg* marine growth);
- kinetic (*eg* fatigue);
- electrical (*eg* short-circuiting);
- natural environment (*eg* seismicity, volcanism, poor visibility, earthquakes, cyclones and storms);
- uncertainty (*eg* design unknowns);
- human factor (*eg* incompetence and mal-operation).

Key scenarios can also be identified, which may occur as a result of a single, or a combination, of threats:

- small release of harmful substances (*eg* wastes, fuel oil, streamer oil, survey equipment) due to minor accidents (*eg* collision with fishing equipment) and poor operation management (*eg* discharge of untreated bilge water);

- large release of harmful substances and large item of equipment (*eg* streamers) due to major accidents (*eg* collisions with other vessels or vessel grounding).

5.6.2 Evaluation of Impact of Small Releases of Harmful Substances

Streamer Kerosene Release

During seismic survey, if kerosene filled streamers are used, damage to one of more sections of the streamers while deployed can release kerosene into the marine environment. The risk of damage to streamers depends on the hazards in the area (*eg* fishing equipment, submerged wrecks), the weather

conditions and the operational procedures. Data for damage to streamers during seismic surveys indicate that on average damage to one segment of each streamer occurs every three to six months (*pers comm* SEIC, 2002). This damage can result in the release of 100 to 200 litres of kerosene per streamer section into the marine environment. For the Lunskoye survey the survey vessel will deploy 4 to 8 streamers for a period of one month. Based on the above, it can be predicted that two streamer sections may be damaged, releasing between 100 and 500 litres of kerosene.

In the event of major streamer damage (*ie* the streamer is entangled in propellers of a large vessel), considerably more kerosene is likely to be released as more than one segment per streamer would be ruptured. In practice, it is reported that the full volume of oil within a segment is rarely lost.

Kerosene is a volatile, colourless liquid composed of a large number of different chemicals. It is a slight to moderate eye and skin irritant, a neurotoxin and is considered to have carcinogenic properties [(1)]. On release into the marine environment it would be expected to have a short residence time owing to its light and volatile nature. Although the liquid may evaporate within a few hours under moderately warm conditions, residence times would be increased in the colder conditions experienced in the Sakhalin Oblast region. The main body of the liquid would be expected to evaporate, but some of the chemicals in kerosene have been known to persist in water and sediments for long periods of time (UNEP, 2002).

Significant smothering, spreading and fouling effects would not be predicted to occur from kerosene release due to its volatility. The Sakhalin coastline would therefore not be predicted to be impacted by a spill of this nature.

Minor impacts are predicted in the event of a small spill of kerosene from damaged streamers.

Bunker fuel, Diesel, Lube Oil and Oily Sludge Release

Discharge of oily wastes into the marine environment due to minor accidents (*eg* failure of spill containment systems, separation of fuel hoses during bunkering operations) or discharge of bilge water prior to treatment will have an impact on water quality and marine ecology. The impact will depend on the type of oil released, the volume of oil, the location of the spill and the prevailing weather and tidal conditions.

Bunker fuels, diesel and lubricating oils would be expected to form a visible sheen on the surface of the sea, and would persist for longer periods of time than the more volatile hydrocarbons such as kerosene.

(1) At present little is known about the carcinogenic properties of kerosene, although it often contains traces of benzene which is a known carcinogen.

Heavier oils such as oily sludges, accidentally released during maintenance activities are predicted to be more persistent and may eventually wash-up on coastlines as weathered tar balls which ca have localised impacts on coastal habitats and species.

Impacts to water quality potentially could affect marine mammals either directly through skin contact, absorption, or ingestion, or indirectly by contaminating prey on which they feed. Most marine mammals are not very susceptible to the effects of oil and hydrocarbon-based fuels. Whales rely on a layer of blubber for insulation, and oil fouling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman *et al*. 1977; Geraci 1990). Whales could ingest spilled fuel or oil with food, or the baleen of baleen whales could become contaminated. Effects from small spills that dilute and disperse rapidly are unlikely to cause serious internal damage to marine mammals.

Although dependent on the extent and location of the release, a small hydrocarbon spill would generally be predicted to have *minor* impacts.

Loss of Equipment

Any survey equipment lost overboard may foul or create obstructions on the seabed and may act as a future source of pollution. Streamer sections are unlikely to be lost during the course of the survey operations due to automatic devices that inflate when the streamer falls below a certain depth. It is predicted that three plastic 'birds' (depth control units) of approximately one metre in length will be lost over the thirty-day survey period. If solid-filled streamers are used, a small number of lead weight strips used to control buoyancy are predicted to be lost during the course of the survey. These objects are not considered to be a risk regarding the potential for obstruction or release of contaminants into the Lunskoye Field and losses of this nature are predicted to have a *minor* impact.

5.6.3 *Evaluation of Impact of Large Releases of Harmful Substances*

Major Hydrocarbon / Contaminant Releases

The effects of large release of bunker fuel, diesel or kerosene as a result of vessel grounding, collision or other major accident will depend on the quantity of hydrocarbons released, the location of the release and the prevailing weather/oceanographic conditions.

Major releases could effect protected species, such as the western gray whale, and sensitive coastal areas such as the Lunsky Bay Natural Monument, the Chayachi Island Natural Monument and Water Habitat of Rare and Law-Protected Mammal and Bird Species at Nabilsky Bay and the protection of the littoral zone by the Ramsar Convention (see *Chapter 2*).

Most marine mammals are not very susceptible to deleterious effects of oil. However, weak or highly stressed individuals may be vulnerable to oiling.

Whales exposed to oil are generally not at risk because they rely on a layer of blubber for insulation, and oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman *et al*. 1976, 1977; Geraci 1990; St. Aubin 1990). Preliminary laboratory tests show that gray whale baleen, and possibly skin, may be somewhat resistant to damage from short-term exposure to oil (Geraci and St. Aubin 1985; Geraci 1990). However, Hansen (1985) points out that oil or clean up dispersants could have indirect negative effects on gray whales by killing or contaminating their benthic food supply.

Whales could ingest oil with contaminated water or food, or it could be absorbed through the respiratory tract. If oil is ingested, it can be voided in vomit or faeces, but some is absorbed and could cause toxic effects (Geraci, 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978, 1982). However, whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980, 1982). Crude oil could coat the baleen and reduce filtration efficiency; however, effects may be reversible within a few days (see Geraci, 1990 for a review). Effects of oiling of the baleen on feeding efficiency appear to be only minor (Geraci, 1990).

The potential impacts on marine ecology and coastal environment would depend on the location of the major release of hydrocarbons. In sensitive areas the impact could be *moderate* with injury to marine mammals and injury and mortality to marine invertebrates and fish predicted to result.

The seismic survey vessels will have oil and fuel spill response/ contingency plans and spill kits on board in accordance with MARPOL regulations. Oil, chemicals, and hazardous materials are required to be properly stored to prevent spills from occurring (see *Chapter 7* for further details). In the event of an oil or chemical spill from one of those vessels, a response effort will be initiated immediately to contain and clean up the spill and prevents its spread. Residual impacts are considered to be *minor*.

Loss of Equipment

Loss of large objects may cause an obstruction on the seabed and could lead to intermittent pollution over the long term and associated damage to marine organisms (*eg* loss of streamers due to vessel collision and release of kerosene). Impacts would depend on the amount of pollutant and the rate of release from the lost object. Any materials or equipment lost overboard will be recovered wherever practicable (see *Chapter 7*). Environmental impacts from loss of equipment are predicted to be *minor*.