Fisheries and Oceans Canada Comments on the Whites Point Quarry and Marine Terminal Blasting Protocol

Introduction

A Blasting Protocol was submitted by Bilcon of Nova Scotia to Fisheries and Oceans Canada (DFO) - Habitat Management Division (HMD) on February 6, 2005 and updated in May 2005 (attached). This information, along with the original Whites Point Quarry Blasting Plan (2002) and the report titled "Peak Pressure and Ground Vibration Study for White's Cove Quarry Blasting Plan", was provided to DFO for review and comment for the proponent's preparation of the Environmental Impact Statement to be submitted to the Joint Review Panel formed under the *Canadian Environmental Assessment Act* and the *Nova Scotia Environment Act*.

It is understood that the following comments are based on the information submitted by Bilcon of Nova Scotia Corporation (including information submitted under the name Nova Stone Exporters Incoroporated). The review of the Blasting Protocol represents only a preliminary examination of part of the proposed undertaking and does not preclude further examination and commentary by DFO during the joint panel review. DFO's position and opinions are therefore subject to change depending on the information provided during the Joint Panel Review.

The analysis of the Blasting Protocol has been divided into two sections. The first is an analysis of the potential impacts of blasting on fish species, particularly the inner Bay of Fundy Atlantic Salmon population. The second section is an analysis of the potential impact of blasting on marine mammals. In obtaining this advice, DFO's Habitat Management Division (HMD) solicited information from various experts within DFO. However, any questions regarding the information should be addressed directly to DFO-HMD, Maritimes Region.

Fish Species

The Proponent has provided information related to concerns raised by DFO with respect to inner Bay of Fundy (iBoF) Atlantic salmon; a Schedule 1 listed endangered species under the *Species at Risk Act* (SARA). By committing to a horizontal distance from shoreline to the blast location which is at least triple that determined by the application of the equations in the "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters" (three time the guideline horizontal distance is approximately 100 metres), and by minimizing and decking the individual charges, any harm to iBoF Atlantic salmon and other species such as herring is likely to be avoided. As a precaution, the Proponent should supply calculations that predict the overpressures (at the locations salmon are likely to be) that will result from an "initial blast" described in the Proponent's Blasting Protocol. If an initial blast is to proceed, the calculations would be reviewed by DFO and, if required, the "initial blast" will be performed outside of the period when iBoF Atlantic salmon could be present. Monitoring of an "initial blast" using the above criteria (i.e. horizontal setback distances and decking of charges etc.) as outlined in the Proponent's Blasting Protocol, would be done and the results compared to the predicted results. An adaptive management strategy could be developed in consultation with DFO if the project is permitted to proceed.

The proponent has indicated the blasting would not be undertaken on a continuous basis. In the early stages of development, the quarry, blasting would be once a week and during full production, blasting would occur once every two weeks. This could assist in the timing of any blasting to accommodate the passage of fish and marine mammals past the quarry site. The company would limit ground vibration to 12.5 mm/sec to limit damage to any nearby structures. This figure compares to our peak pressure velocity guideline of 13 mm/sec for protection of spawning areas. The monitoring, suggested in the Proponent's Blasting Protocol, with monitoring stations identified on map 001, may be adequate from DFOs perspective to ensure compliance to this guideline.

Marine Mammals

For the provision of advice to Bilcon of Nova Scotia on their Blasting Protocol and in order to be prepared for inquires which may arise during the panel review, HMD requested a DFO Science review of the potential harmful effects of onshore blasting at Whites Point Quarry on marine mammals, and advice on mitigation and monitoring. In particular the following questions were presented for a DFO Science review by HMD:

- What is the potential for harmful effects on marine mammals beyond a 500m distance from the blasting site resulting from the sounds of blasting proposed for Whites Point Quarry?
- What is the potential for physical effects on endangered marine mammals beyond a 2500m distance from the blasting site resulting from the sounds of blasting proposed for Whites Point Quarry?
- What is the potential for behavioural effects on endangered marine mammals beyond a 2500m distance from the blasting site resulting from the sound of blasting proposed for Whites Point Quarry?
- How would mitigation activities currently proposed to be conducted in association with the blasting operations change the potential for impact on marine mammals?
- What monitoring could be conducted to validate the results of this assessment?

Issue

Construction of Whites Point Quarry and Marine Terminal (location map provided in Appendix A) would require in-ground blasting within close proximity to the Bay of Fundy shoreline. Whites Point lies approximately 22 km from the center of the Grand Manan Basin summer/fall congregation area of the endangered North Atlantic right whale. The presence of a protected area for endangered marine mammal species within a few miles of the site requires special consideration. A colony of harbour seals at Crowell's Cove has been known to haul out at a site within 3 km of the proposed blast site. Other marine mammals are also expected to be present within close proximity to the proposed blasting site.

The proponent has proposed use of a 500 m safety radius from the detonation area (Bilcon of Nova Scotia Corporation, 2005), which would be monitored for marine mammals by experienced observers from shore-based sites. Blasting would not knowingly occur if marine mammals were seen to be present within this zone. A trained observer would also be employed to ensure no explosive was detonated within 2,500 m of an endangered marine mammal, such as a North Atlantic right whale (Bilcon of Nova Scotia Corporation, 2005). Advice is being sought on the potential effectiveness of these mitigation measures.

Assessment

Assessment Framework

The questions posed by Habitat Management Division will be answered in the context of an assessment framework developed specifically for this purpose.

Approach

Assessment of the risk of noise to the marine environment can be conducted using a source-pathway-receptor approach. For a risk of impact to exist, there must be a plausible relationship between the source, which in this case is the explosive charges; the pathway, i.e. the mechanism by which the source and receptor come in contact; and the receptor, which in this case would be the marine mammals likely present in the Bay of Fundy. Details on the characteristics of source, pathway, and receptor that will be used to conduct this assessment are provided in Table 1.

Source: Blasting Characteristics
- Source Location
- Source Intensity
- Detonation Timing
- Scheduling
Pathways: Sound Energy Propagation
- Possible Sound Energy Pathways
- Influence of Environmental Conditions
- Propagation Modelling
Receptors: Marine Mammals
- Occurrence
- Acoustic Sensitivity
- Biological Effects
Mitigation and Monitoring
- Mitigation
- Monitoring

Table 1. Assessment Framework for Effects of Onshore Blasting on Marine Mammals.

While existing literature can provide useful information on the state of knowledge related to noise and its impacts in the marine environment, and the proponent will be required to provide details on the project and any proposed mitigation, regional scientific expertise is used to help ensure that site-specific characteristics are taken into account in the application of this impact assessment framework.

Format
Each of the following sections begins with a description of information and/or analysis recommended as the basis for any assessment related to the impacts of onshore blasting noise on marine mammals. This is followed by information and/or analysis specific to the Whites Point Quarry assessment.

Source: Blasting Characteristics

Source Location

For the assessment of blasting on land, the distance of the source from the high tide mark will be used to determine the source levels entering the marine environment. Sound propagation paths will include air-to-water, rock-to-water, the latter including interference effects from reverberation within the water column itself. Where there would be multiple charges, the relative location of these charges will be used to determine the likely overlap of sound/pressure waves – with a particular focus on the potential for constructive interference resulting in higher than anticipated sound levels. To resolve this issue, information on source location will be evaluated in combination with information on blast timing (see below).

According to the original Blasting Plan (2002), the 56 initial charges would be laid in a 2.7 m by 2.7 m configuration with hole depths between 7.3 and 8.8 m (Nova Stone Exporters Inc., 2002, see Figure 1). Subsequent blast configurations have not been described.

Source Levels

Explosive detonations, while carefully controlled, are influenced by a variety of factors that make accurate determination of source levels difficult. For determination of pressure levels propagated through the air, the source is best described by its size, i.e. the size of the charge can be associated with an estimated concussion some distance away. In this framework, we are interested in the sound propagation from an onshore detonation into the marine environment. The role of multipath propagation, discussed in more detail below, makes a simple model of blast sounds based solely on charge size problematic.

For the Whites Point Quarry project, the load per hole is proposed as 45 kg ANFO (ammonium nitrate-fuel oil) explosives at 4.6 lbs/foot. The concussion from the air blast is estimated to be 128 dBA or less within 7 meters of the nearest structure not located on the site (Nova Stone Exporters Inc., 2002).

Detonation Timing

Blast timing would influence both the levels of sound entering the receiving environment and the likelihood that the sound would be received by some receptor. As mentioned previously, timing of individual blasts would influence the cumulative energy produced in terms of the potential for beam forming, i.e. where impulsive sound is emitted from multiple sources timed in such a manner that a receiver at range in certain directions would perceive the combined sounds from more than one source as a single source.

According to the proponent, blasting at Whites Point Quarry could be conducted at any time of the year. Blasting would not be conducted on Sundays or between 1800 and 0800 hours (Blicon of Nova ScotiaCorporation, 2005). The original blasting plan proposed an average delay between blasts of approximately 25 ms, but this was subsequently reduced to 8 ms for safety reasons in the Hannay and Thomson report, 2003.

Assuming acoustic energy to be radiated as short impulsive signals of dominantly high frequency content, beam forming can occur whenever the sound propagation interval between any arbitrary pair of shot holes exceeds the pair-specific inter-hole delay time. Assuming a local propagation velocity of around 3 km/s, sound should propagate across the shot pattern largest dimension in about 10 ms or so. Therefore some degree of "beam forming" is still theoretically possible. However, preliminary examination does not indicate any instances where sound energy would be beamed straight at the nearest part of the coastline. In part, this may be due to the specific layout of the lines and the onset of the detonation sequence at the westernmost corner (see Figure 1).

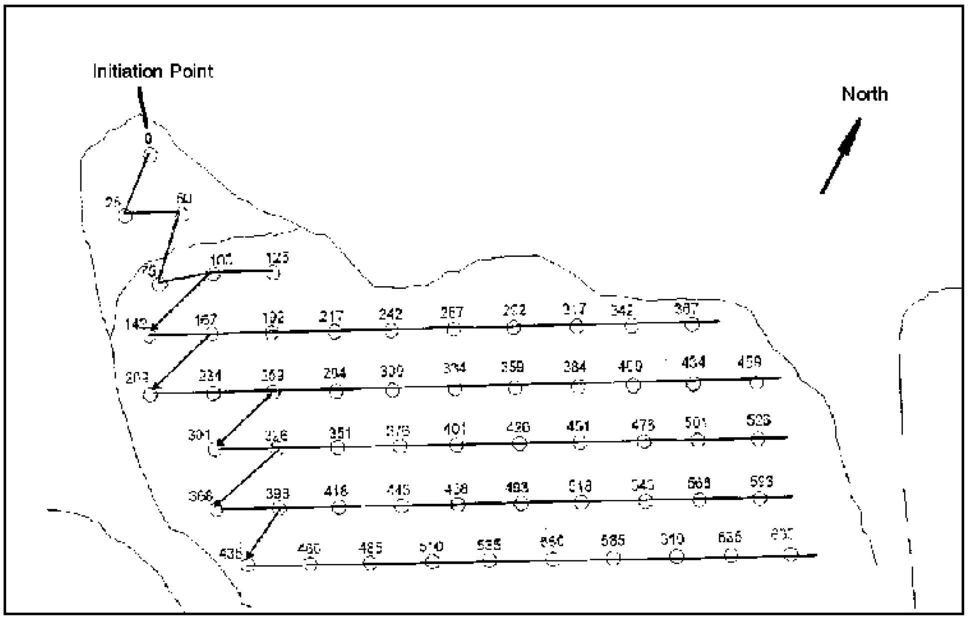

Figure 1. Proposed Initial Blast Sequence (Nova Stone Exporters, 2002).
Note: The proposed timing delays have since been modified, thus this diagram should only be considered to reflect the relative timing of shots.

The modification to produce a minimum of 8 ms delay between any two blasts over the entire pattern is expected to be less effective than a 25 ms delays but far better than no delay, i.e. simultaneous detonation of all shot holes.

Scheduling

Blast schedule would influence the potential for cumulative effects of multiple exposures on receptors present in the vicinity of the blast site.

For Whites Point Quarry, the proposed frequency of blasting during quarry start-up will be once per week and once every two weeks during full production (Blicon of Nova ScotiaCorporation, 2005). Thus, these acoustic events will be temporally isolated, in contrast to the continuous or semi-continuous (over periods of weeks to several months) transmissions that are characteristic of offshore seismic exploration.

Pathways: Sound Energy Propagation

Possible Acoustic Pathways

Acoustic pathways which could result in sound exposures that have the potential to cause effects on marine mammals include:

- Sound waves propagated through the air to be received by marine mammals situated at the ocean surface or at nearby haul out sites.
- Pressure waves propagated through substrate and then through the water column to be received by submerged marine mammals.
- Vibrations propagated through substrate to be received by marine mammals that may be in contact with the sea floor [considered highly unlikely].

Multi-path considerations, i.e., sound propagation through multiple pathways to reach a receptor, will be important. For example, it is possible that energy may propagate through the substrate, into the water column and directly to a receiver *or* pressure waves could also reflect off the ocean surface before reaching the same receiver. Another example of multi-path propagation can occur when underwater sounds are transmitted both directly through the water, and in a parallel direction through the sea bottom; this has been true for seismic sounds transmitted through both water and the subsea permafrost in the Arctic ocean (see review in Lawson and McQuinn 2004).

Within the first kilometer or two, acoustic energy is communicated into a wedge-shaped deepening water column from the underlying substrate. The combined effects of direct path energy and energy reflected off the water surface are probably dominant but more complex multi-path reverberation effects will also be present. The presence of shear elasticity in the substrate would appear to allow the substrate energy to be more efficiently coupled into the water column than in the case in which shear is absent.

Beyond a few kilometers range we are most likely dealing with a propagation problem for energy already communicated into the water column. Wave guide dimensions and sound speed structure existing within the water column could be important for energy propagation to ranges of tens of kilometers. Sound speed structures could tend to refract sound into the comparatively lossy bottom or, conversely, to isolate the water column propagating sound from such interactions. This issue has not been quantitatively explored.

Environmental Conditions

The physical environment in which a blast is situated would play a major role in the likelihood that energy will be propagated towards some receptor in a manner sufficient to cause biologically significant impacts. In this case, the physical environment under consideration includes the bedrock in which the explosives are situated, the substrate through which energy is propagated between the blast site and the marine environment, the characteristics of the water column and underlying seafloor, topography and bathymetry, and possibly the atmospheric conditions which may influence the propagation of airborne sound waves.

For the Whites Point Quarry project, the proposed initial blast location is situated on Jurassic north Mountain basalt bedrock that underlies the entire quarry and extends into the nearshore marine environment. The intertidal zone is rocky with a well established macroalgal community. Approximately 50 m offshore, there is an area with a layer of sand covering the bedrock with some outcrops and boulders. Water depths at distance from the lowest average tide are provided in Table 2. It is important to note that the geometry, i.e. water depths at a given location and distance to water edge, vary over the tidal cycle.

Table 2. Water depth at distance from lowest normal tide.

Water Mark (m)	Depth (m)
60	2
120	5
180	10
240	20
540	30
1020	40
1380	50
1620	60
2580	80
4020	100

Propagation Modelling

In the absence of field measurements, determination of the propagation characteristics of explosive sound energy through bedrock into the marine environment must rely on numeric modelling. Ideally, such modelling would take into account source characteristics, bottom topography, water column properties, and ambient underwater noise levels. Results of propagation modelling typically describe the intensity of sound pressure pulses at various distances from the source (decibels relative to 1µPa in water). The frequency content and rise time of the pulse are two other measures of importance to the determination of potential impacts on marine life.

Sound propagation modelling of a single 45 kg ANFO charge detonated at 6 m was provided by the proponent (Hannay and Thomson, 2003). This modelling predicts that "…the pressures at even the closest location in the water are not expected to exceed 50 kPa [214 dB re 1µPa peak pressure]. If the blasts are performed within 3 hours of low tide then the maximum pressures will likely remain less than approximately 25 kPa [208 dB re 1µPa peak pressure] in the water." At 500 m, this modelling predicts that the peak sound pressure would be approximately 2 kPa in the water column, which equates to approximately 186 dB re 1µPa (peak pressure). The rise time of the pressure wave is described as increasing with increasing distance from the blast. The conclusion is made that "effects of peak pressure would be less than those predicted from a high explosive source" (Hannay and Thomson, 2003). The frequency content of the pressure pulse is not provided. Modelling of long-range sound propagation (beyond 500 m) was not conducted.

In general, sound propagation modelling conducted by the proponent is consistent with analysis that has been conducted by Maritimes DFO Science. Results, i.e. sound levels in the water column at 500 m of 186 dB re 1µPa (peak pressure), are expected to represent the worst case estimate for a **single blast**.

Sound propagation modeling conducted by the proponent makes use of a reference to Oriard (1985). In particular, Figure 1 in the Oriard paper is provided as Figure 3 in Hannay and Thomson (2003). The data in this figure quantitatively agrees with DFO calculations when strictly interpreted as an 'energy ratio' as labelled. However, Oriard interprets 'energy ratio' as "the squares of the amplitudes of reflected and transmitted waves relative to those of the incident waves." This interpretation, which is used by Hannay and Thomson in the caption to Figure 3, is thought to be incorrect. Hannay and Thomson do qualify the equivalence with the word "approximately". DFO calculations show that the amplitude of the water transmitted P wave is lower than that stated by Hannay and Thomson, although higher than that calculated neglecting shear in the substrate altogether.

Modelling of **multiple blasts** (8 ms separation time) has not been provided by the proponent. At 500 m range within the water column, successive pressure pulses at 8 ms separation may be sufficiently closely spaced to partially overlap. However, overlap is expected to extend the length of the resultant superimposed pulse rather than to increase its amplitude.

No ambient noise measures have been made in this area. If there is a relatively high level of natural and pre-existing anthropogenic underwater noise, blast sounds might attenuate to these higher background levels more quickly than in quieter areas. However, without ambient noise measures we cannot assume this to be true.

Receptors: Marine Mammals

Occurrence

Marine mammals must be present in order for there to be any reasonable expectation of impact from the noise of onshore blasting. Ideally, it would be useful to be able to reference seasonal observations within the expected zone of influence of noise for a proposed project. This would establish the seasonal occurrence of potential receptors. In the absence of site-specific observations, regional observations and datasets should be accessed. In addition to determination of the presence and timing of marine mammals in general, the potential presence of protected species, i.e. species for which there may be a higher level of risk aversion, should also be determined.

Table 2 shows the marine mammals listed on Schedules 1-3 of the Species at Risk Act that may be found in the Bay of Fundy during the proposed blasting at Whites Point Quarry. The most likely timing of their expected presence in the Bay of Fundy is provided, along with their current status under SARA and COSEWIC. Other marine mammals that are known to occur within the Bay of Fundy are provided in Appendix B.

Species	***Timing***	***SARA Status***	***COSEWIC Status***
North Atlantic right whale	Jun –Nov	Schedule 1: Endangered	Endangered (2003)
Blue whale	Jun – Nov	Schedule 1: Endangered	Endangered (2002)
Harbour porpoise	All Year	Schedule 2: Threatened[1]	Special Concern (2003)
Fin whale	All Year	Schedule 3: Special Concern	Special Concern (2005)

Table 2. Timing and Status of SARA Marine Mammal Species in the Bay of Fundy.

Whites Point Quarry lies about 22 km from the center of the Grand Manan Basin summer/fall congregation area of the endangered North Atlantic right whale. Observations of right whales in this area are available from the right whale consortium database, which is housed at Rhode Island. In 2002, a map of North Atlantic right whale sightings per unit effort within the Bay of Fundy was compiled as part of the proposal to the International Maritime Organization (IMO) to alter the shipping lanes in this area (Figure 2). This map is useful in that it takes effort into account, i.e. it addresses the fact that the density and distribution of right whale records will be related to the intensity and distribution of observational effort; however, it only includes data from 1987-2000. From this map, it appears as though there have been limited observations (effort and/or sightings) of right whales immediately adjacent to the proposed Whites Point Quarry location; however, sightings per unit effort adjacent to Long Island have been in the order of 1-16 whales per 1000 km of survey track (all months).

[1] DFO has recommended that the assessment of harbour porpoise be returned to COSEWIC for further information or consideration (Canada Gazette, Dec. 10, 2005).

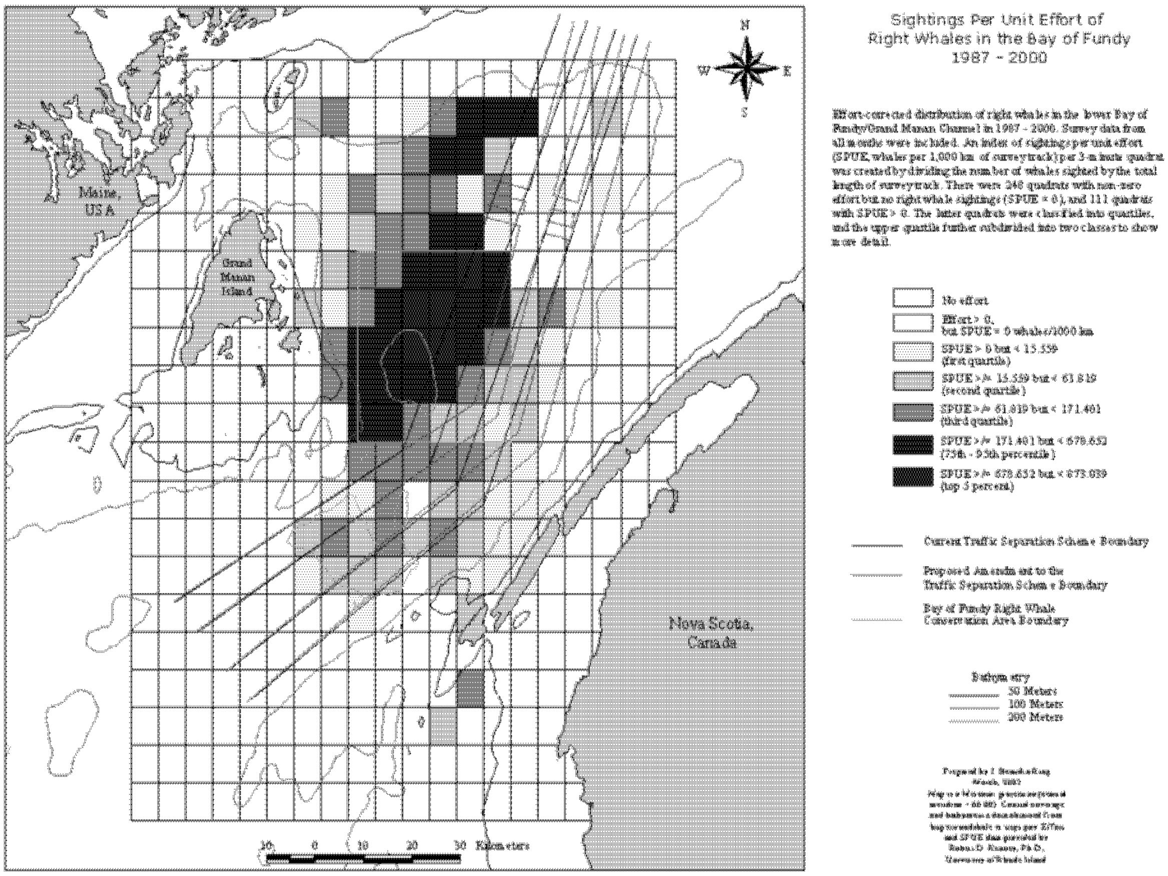

Figure 2. North Atlantic right whale sightings per unit effort in the Bay of Fundy (1987-2000).

A marine mammal survey was conducted by the proponent within 1 nm of the coastline between East Ferry and Sandy Cove in July and August 2002. No North Atlantic right whales were observed; however, minke whales were sighted south of Whites Cove, a seal colony was observed in the vicinity of Crowells Cove, and seals were frequently observed in the waters off Whites Point (Nova Stone Exporters Inc., 2002).

Results from the Maritimes DFO sightings database (Figure 3) show that finback, humpback and minke whales, as well as harbour porpoises have also been sighted along Digby Neck. It should be noted that these results have not been corrected for effort, and the large number of sightings northwest of Digby Neck are due in part to the observation by a whale-watching company operating in that area. These maps should not be considered an accurate reflection of the relative density of whales and porpoises in the region, but they can be considered evidence of the occurrence of these species within the area.

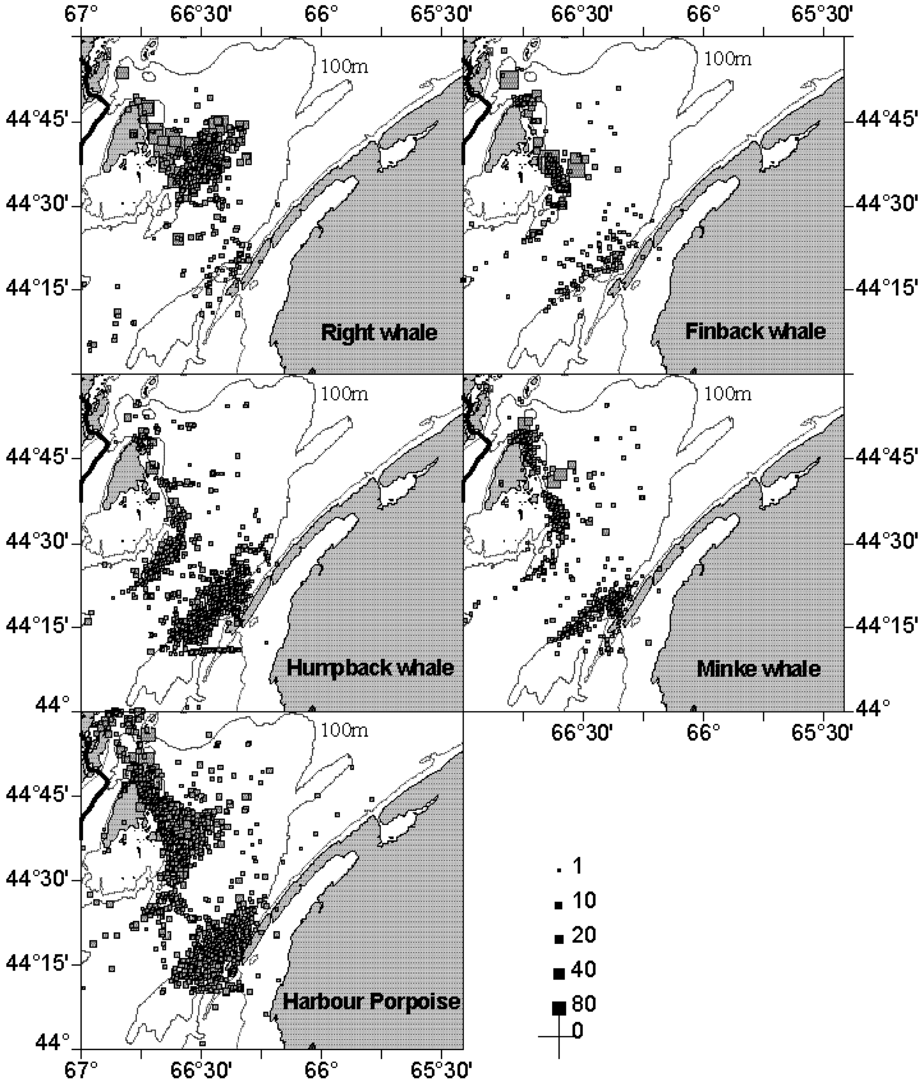

Figure 3. Sightings of North Atlantic right whales, finback whales, humpback whales, minke whales and harbour porpoise contained within the St. Andrews Biological Station sightings database (K. Smedbol, *pers. comm.*, 2005).

Acoustic Sensitivity

Marine mammals are well known to be acoustic animals that react to and are adversely affected by noise (for a recent review see Lawson and McQuinn 2004). While critical injury and temporary hearing sensitivity changes could result from certain impulsive sound exposures, these have not been documented in free-living marine mammals. On the other hand, there have been many documented marine mammal behavioural reactions to anthropogenic sounds. For instance, some large baleen whales have exhibited behavioural reactions, primarily displacement, when exposed to blasting sounds.[2]

[2] The limited available evidence indicates that marine mammals, like humans, show less reaction to discontinuous noise pulses with a given peak level than they do to continuous noise at that same level (see review in Richardson *et al.* 1995). However, some species of baleen whales exhibited some avoidance of areas where there are noise pulses with received peak pressures exceeded 160-170 dB re 1μPa (SEL) which is near 156 dB re 1μPa (SEL).

The acoustic sound pressure levels at which permanent hearing threshold shift or even temporary hearing threshold shift occurs are unknown. Because even slight damage to the hearing mechanism could be of serious impact to marine mammals highly dependent on acoustics to socially communicate and locate prey – not to mention avoidance of ship traffic – the question of auditory damage is an important one.

It is thought that baleen whales may be more sensitive to low frequency noise than toothed whales. However, studies of acoustic sensitivity have not been conducted for all species that may be present within the Bay of Fundy.

Seals are considered to be more behaviourally tolerant to loud sounds and to have less sensitive underwater hearing relative to many cetacean species.

According to the draft Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment (DFO, 2005. Note: this draft is under review and wording may change) , biological and ecological effects on marine mammals may be higher if there were to be behavioural consequences that would:

- displace feeding marine mammals from areas where there are no alternate areas;
- displace marine mammals from breeding or nursery areas; or
- divert migrating marine mammals from routes or corridors for which alternate routes or corridors either do not exist or would incur substantially greater physical costs to traverse.

The same would likely hold true for other types of noise in the marine environment.

Biological Effects

There is a high level of uncertainty in regards to the sound pressure levels that are required to generate biological effects in marine mammals.

The US National Marine Fisheries Service has been using 180 dB re 1 μPa (root-mean-square, rms) as the maximum acceptable exposure level to impulsive sounds for cetaceans, and 190 dB re 1 μPa (rms) for seals. These levels are considered to constitute "Level A" harassment under the US Marine Mammal Protection Act and were adopted to minimize temporary hearing threshold shifts along with more extreme physiological damage. "Level B" harassment is currently considered to occur at 160 dB re 1 μPa (rms) for impulsive sound and 120 dB re 1 μPa (rms) for continuous sound. These thresholds (including the 180 dB threshold) are currently being revisited (NOAA, 2005). It should be noted that these thresholds are given as rms measures and not peak pressure measures. To compare these thresholds to the sound levels predicted for the Whites Point Quarry project, one should add approximately 5 dB to the rms values as a rough conversion to peak pressure values. However, there are many conditions under which this relationship between rms and peak pressure is not valid.

Subtle behavioural effects, especially for baleen whales, have been documented to occur at much lower acoustic levels, particularly with longer exposure duration.

Canada has not proposed thresholds of acceptable or unacceptable sound exposure for marine mammals. In DFO's Guidelines for the Use of Explosives in or near Canadian Fisheries Waters (Wright and Hopky, 1998), it is recommended that explosives not be detonated within 500 m of any marine mammal and it is recommended that explosives producing an instantaneous pressure change greater than 100 kPa in the swimbladder of a fish not be permitted.

Mitigation and Monitoring

Mitigation

Mitigation proposed by the proponent (Bilcon of Nova Scotia Corporation, 2005) included use of a 500 m marine "safety radius" for marine mammals. To establish this zone, an observer, experienced and/or trained in marine mammal identification, would be positioned at an elevated shore position at least 1 hr prior to the start of blasting. The observer's task would be to detect and identify marine mammals within 500 m of the blast site. The observer would wear polarized glasses and be equipped with binoculars to enhance visual acuity. A two-way VHF radio or cellular phone would be used by the observer to communicate with the blast coordinator. In practice, blasting operations would be suspended if the observer sighted a marine mammal within the 500 m buffer zone, and would not resume until 30 min after these animals either were observed or were presumed to have left the buffer zone based on activity and swimming direction. It is unclear whether blasting would occur if weather conditions did not permit observations to 500 m.

A 500 meter safety zone for all marine mammals is a mitigation technique that **might** be effective at reducing the potential for physical effects, and it is consistent with DFO's Guidelines for the Use of Explosives in or near Canadian Fisheries Waters (Wright and Hopky, 1998). However, without measures of the underwater sound pressure levels and frequency characteristics during the earliest worst-cast blast operations to confirm accuracy of modelling, and better understanding of the sound levels that cause physical effects in marine mammals likely to be present within the Bay of Fundy, a more definitive answer to this question can not be provided. A monitoring program to investigate the underwater sound levels and frequency characteristics produced by blasting at various distances from the source would help to reduce uncertainty.

A 2500 meter safety zone for endangered marine mammals in the Bay of Fundy (blue whales and right whales) is **likely** to be effective for a **single** blast; however, concern remains about the potential effects of exposures to multiple blasts – particularly in quick succession (< 1 second). However, even with an elevated position it will be very difficult for an observer to detect a marine mammal at a distance of 2500 meters. Even if conditions are optimal for viewing (e.g., low glare, low sea state, at least 7· 50 binoculars on a fixed pedestal), there can be whales and seals that can remain undetected - especially as they can swim underwater for kilometres without being detectable by surface observers.

Monitoring

Sound propagation modelling and analysis has been conducted for the initial proposed blasting arrangement. It is not clear from the proposal how "subsequent blasts will be designed based on the information gathered from monitoring the initial blast…" For instance, if ground velocities monitored during an initial blast are lower than those predicted from the empirical formulas does this justify modifying the formula for future predictions? One should have more data than might be obtained from one proximate monitoring site during one shot to justify such changes. Depth of shot holes and hence possible coupling would vary for future blasts.

Test or production blasts conducted when right whales are not present in the Bay of Fundy, during which underwater sound measurements are made and effective marine mammal monitoring is conducted, would allow for further assessment of the likely impacts of these blasts. If the sounds levels are undetectable at the nearest margin of the right whale area, and the buffer distances for marine mammal injury or severe disturbance are shown to be small, then perhaps the proponent could conduct such blasts near the waterline when right whales are present. On the other hand, if sound levels are detectable at great distances, or are dangerously high at distances underwater for which marine mammal monitoring is ineffective, then the proponent could be required to modify their blasting protocols (smaller charges, fewer in sequence, shallower depths, further back from the shoreline) or schedule (conducted when right whales are less likely to be present). However, some consideration should be given to the potential for differences in acoustic propagation conditions at different times of the year, e.g. when right whales are present versus when they are not.

Underwater sound measurements should be made at 500, 1000, and 2500 meters from the test blast site. Ideally, the proponent should also measure sounds levels at the "edge" of the right whale aggregation area, although it is suspected that the sounds levels will attenuate below the ambient sound levels at this distance in this relatively shallow marine environment.

In addition to test blasting, pre-, during, and post-blast observations of the harbour seal colony during the breeding season when behavioural disturbances are likely to have the greatest risk of biological effects through separation of mothers and pups is recommended. These observations should be conducted by an experienced biologist.

Longer-term or subtle behavioural effects, if induced in endangered right whales following blast sound exposure, may be very hard to detect and quantify. Such questions can be addressed only with a well-designed, broad-scale (and expensive) research programme.

Conclusions and Advice

While the zone of disturbance of marine organisms by sound may extend beyond the 500 m suggested in the Whites Point Quarry proposal, it is considered unlikely that blasting would result in physical effects on marine mammals, endangered or otherwise, beyond 500 m. However, there is a high level of uncertainty associated with this conclusion. If the project proceeds, a test blast prior to project initiation would help to validate the sound propagation modelling used to reach this conclusion and would significantly increase the level of certainty in short-range impact estimations.

Subtle behavioural effects on marine mammals are expected to extend beyond 2500 m from the blast site. However, these are not expected to result in overall changes to the distribution of the population or other population-scale impacts. There is a moderate level of uncertainty associated with this conclusion. A test blast as described above would also help to increase the level of certainty in long-range impact estimations.

Proposed mitigation, i.e. the 500 m safety zone for marine mammals and the 2500 safety zone for endangered marine mammals, is expected to reduce the potential for harmful impacts of blasting on marine mammals under good visibility conditions.

The following research and monitoring recommendations would help to verify the results of this assessment:

(1) Calibrated blast sound measures in near- and far-field locations prior to operational blasting and arrival of endangered right whales in the Bay of Fundy.
   - Measure the underwater blast sound levels at 500, 1000 and 2500 meters, plus at the margin of the right whale core area, during tests conducted prior to or after right whale presence.
   - Schedule blasting such that tests or production shots are made prior to or after right whales are expected to be present; if measurements reveal low levels at distances that can be monitored effectively, then permit operations.
   - Marine mammal monitoring by trained observers should occur prior to and during any blasting, as proposed, but the observer should use at least 7x50 binocular on a pedestal to ensure the ability to better detect marine mammals at greater distances.

(2) Visual observation of marine mammal behaviour before, during, and after operational blasting – especially of known marine mammal aggregations, i.e. during seal pupping.

(3) Testing of the effectiveness of visual observation methods at 2500 m from the blast site is also recommended, including determination of the average site visibility conditions.

(4) Use of ongoing passive acoustic monitoring should be considered.

(5) Opportunities to link up with other research initiatives, e.g. university research, should also be considered.

Sources of Uncertainty

Uncertainty in the sound propagation modelling.
It is still unclear from the Oriard model (Hannay and Thomson, 2003), whether the pressure levels experienced at 500 m and beyond where water depths, at least as gleaned from the charts above, become significant, resulting in less effective cancellation of the water surface reflection. Shot overlap also becomes a greater problem.

Questions remain as to the validity of Oriard (1985) results presented in Figure 3 of Hannay and Thomson (2003). The problem involves P to S wave conversions and reflections at the interface between the elastic solid and the overlying liquid. The only applicable and accessible literature treatment of this problem is in a 1960 translation of a book by L.M. Brekhovskikh (1980). A computer simulation of the problem based on Brekhovskikh's solution was set up by DFO. Using the parameters of Figure 3, good agreement for "Reflected P" and "P Reflected as S" with the Hannay and Thomson results is obtained over the full range of incidence angles. However, the critical "Transmitted P" values do not agree. This may be a typographical error in Brekhovskikh's "Transmitted P" formula since Oriard's three results, as a group, obey energy conservation while Brekhovskikh's do not. Brekhovskikh's "Transmitted P" result can be brought into accord with Oriard's by changing one exponent in the former's analytical formulation.

Once this error is corrected, a DFO computer simulation gives a pressure (amplitude) transmission coefficient of only 0.057 at an incidence angle of 80^0 compared to the easily derived value of 0.03 on neglecting shear in the substrate. The former value is much smaller than the upper estimate of 0.3 quoted by Hannay and Thomson (2003). It appears they neglected the acoustic impedance differences between the upper and lower media and the change in physical width of the energy beam in crossing the interface when they converted transmitted to incident P wave energy ratios into pressure transmission coefficients. If this is indeed the case, the acoustic pressure levels transmitted into the water are much lower than Hannay and Thomson have estimated.

Incidence Angle ^{0}	Pressure Transmission Coefficient
70	0.080
80	0.057
85	0.014

Uncertainty in the behavioural responses of marine mammals.
Marine mammals are individuals that may behave unexpectedly at times. It is difficult to account for these individual differences, and typically only general behavioural trends are considered in analysis of potential impacts. However, use of a trained observer to monitor the 2500 m and 500 m buffers should help to provide flexibility in response to any unexpected behaviours. However, there is also some uncertainty related to the ability to detect marine mammals at distances of 2500 m, particularly under poor visibility conditions.

Contributors

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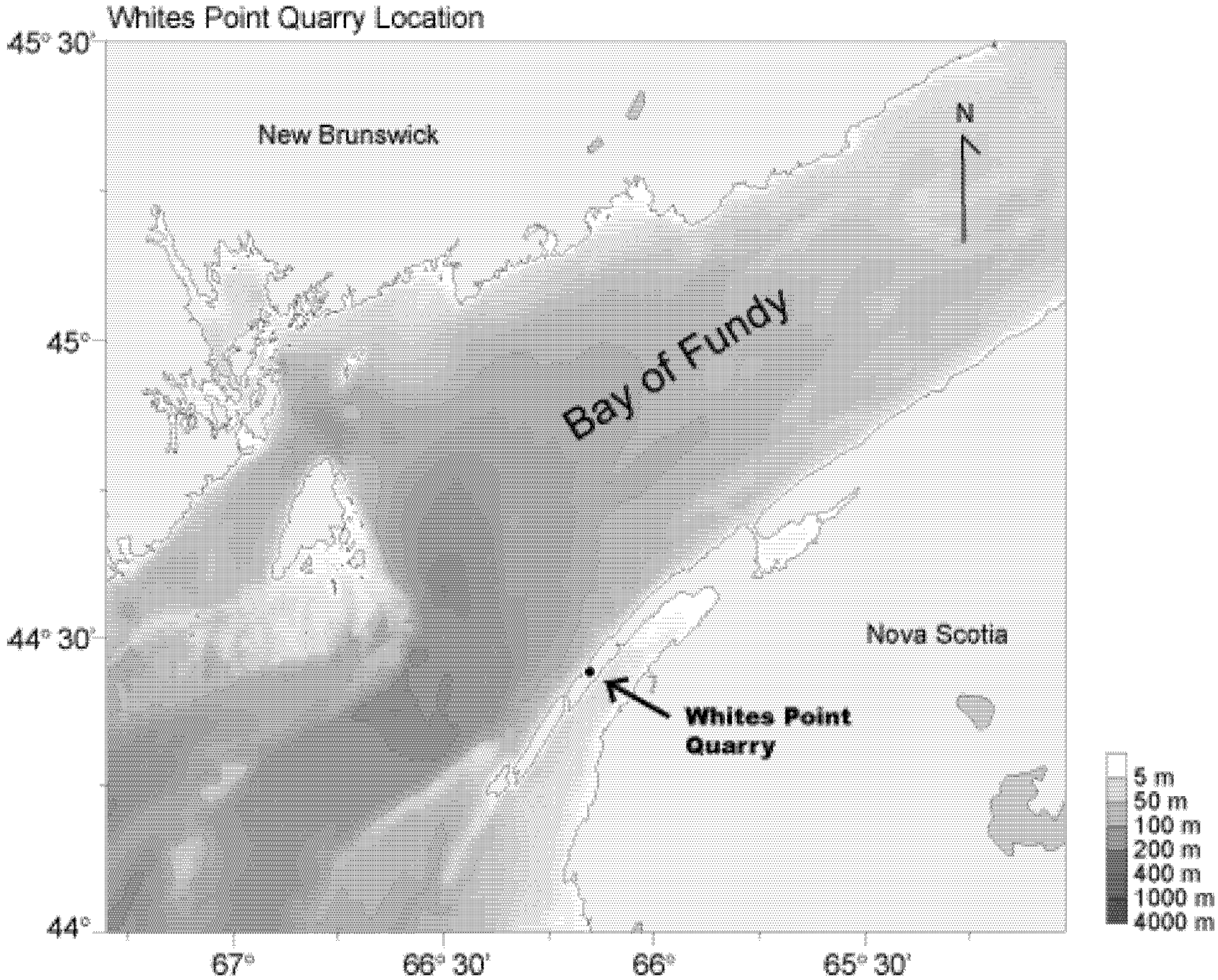
Appendix A. Location of Whites Point Quarry



Appendix B: Marine Mammals in the Bay of Fundy

Cetaceans

Common name	**Occurrence in the Bay of Fundy**[1]
North Atlantic right whale	Common
Minke whale	Common
Fin whale	Common
Northern minke whale	Common
Finback whale	Common
Harbour porpoise	Common
Humpback whale	Occasional to common
Atlantic white-sided dolphin	Occasional to common
Long-finned pilot whale	Occasional
Sei whale	Occasional
Sperm whale	Occasional
Blue whale	Rare
Pygmy sperm whale	Rare, sporadic visitor
White-beaked dolphin	Rare, but previously common
Northern bottlenose whale	Extremely rare

Seals

Harbour seal	Common
Grey seal	Occasional but increasing
Hooded seal	Rare
Harp seal	Rare

[1]Pohle, G., L. Van Guelpen, A. Martin, D. Welshman, and A. McGuire. 2004. Bay of Fundy Species Information. World Wide Web electronic publication. Retrieved December 15, 2005, from http://gmbis.marinebiodiversity.ca/BayOfFundy/background.html (version 1.0/2004)