Whites Point Quarry Joint Panel Review
Public Hearings June 16 to June 30, 2007
Undertaking #29
Fisheries and Oceans Canada

Undertaking # 29: *To provide, following collaboration with Environment Canada, an assessment of the ecological risks associated the ammonia residuals resulting from blasting and episodic and controlled releases from the project's settling ponds.*

Response:

Background

Much of the following background information was taken from Environment Canada and Health Canada's Priority Substances List Assessment Report for ammonia in the aquatic environment (Environment Canada and Health Canada 1999). This document is available on-line at www.ec.gc.ca/substances/ese/eng/psap/final/ammonia.cfm.

Ammonia exists in two forms, NH_3 (un-ionized ammonia) and NH_{4+} (ionized ammonia or ammonium) and together they are called total ammonia. It is the NH_3 form that is particularly harmful to aquatic organisms. The formation of NH_3 is favoured at higher pHs but is also affected by temperature. This means that while the concentration of total ammonia may remain constant in a water body, the proportion of un-ionized ammonia fluctuates with temperature and pH (Environment Canada and Health Canada 1999).

The majority of information relating to the effects of ammonia in the marine environment stems from research and analysis related to nutrient enrichment from municipal waste water, agricultural inputs and finfish aquaculture. However, these studies may help characterize the potential impacts of ammonia releases from other sources including blast residues.

The effects from ammonia inputs in the marine environment can include direct toxicity for fish and invertebrates, as well as coastal eutrophication.

Nitrogen is generally the nutrient limiting primary production in the open ocean. Increased ammonia input can lead to anoxic conditions; however, in highly mixed environments this is unlikely. Eutrophication of Canada's east and west coasts is not occurring at present. There are some indications that coastal areas around Vancouver and Halifax are impacted as a result of sewage effluents, but these are not eutrophication issues.

Evidence from the northern hemisphere indicates that over-enrichment of coastal waters can cause an increase in algae which produce toxic chemicals (Burkholder et al., 1992). Marine algae have been found responsible for at least four different illnesses in human consumers of molluscs as well as massive mortality of fish, birds and marine mammals (Paerl, 1997). The occurrence of these "harmful algal blooms" has resulted in the closure of shellfisheries, resulting in large economic impacts on coastal communities. The exact cause of these blooms is not clear, although they tend to follow periods of intense rainfall, runoff and intense periods of sunlight (Smayda, 1997).

Direct toxicity to fish and invertebrates

Ammonia dissolved in water is listed as a toxic substance on Schedule 1 of the *Canadian Environmental Protection Act*. Although no water quality guideline exists in Canada for NH_3 in marine water, it is documented to cause acute lethality to freshwater fish at levels as low as 0.1-0.2 mg/L. The guideline level of NH_3 considered protective for freshwater aquatic life in Canada is 0.019 mg/L.

Ammonia can be chemically toxic. Available acute and chronic ammonia toxicity data for saltwater organisms are more limited than those for freshwater organisms. The U.S. EPA (1989) published a review on the saltwater toxicity of ammonia. Of the fish and invertebrates assessed, winter flounder (*Pseudopleuronectes americanus)* was found to be the most sensitive to ammonia with an LC_{50} level of 0.49 mg NH_3/L. In comparison, lobster had an LC_{50} level of 2.21 mg NH_3/L. Chronic toxicity to fish and benthic invertebrate populations may result in reduced reproductive capacity and reduced growth of young (Environment Canada and Health Canada 1999).

Eutrophication

Eutrophication is a concern in coastal systems worldwide due to changing land use practices, population growth, and increases in fertilizer use and fossil fuels. However, to date there has not been widespread eutrophication of Canada's east coast waters. On smaller scales, eutrophication does occur naturally in numerous harbours with poor flushing characteristics. The contribution of anthropogenic activities to this natural process is harder to assess. Nutrient inputs from sewage effluents into Halifax Harbour have affected nutrient concentrations and biological productivity in Bedford Basin, and recent hypoxic episodes in the Annapolis River estuary have been attributed to reduced circulation when the tidal power plant was off-line. The relationship between nutrient inputs from finfish aquaculture and the development of algal mats on beaches is also being investigated. All of these are instances when anthropogenic changes exacerbate a natural tendency to eutrophication because of poor water circulation.

Ammonia is a preferred nitrogen source for aquatic plants (macrophytes and algae). Additions of ammonia may increase plant growth and biomass depending on natural inorganic nitrogen levels in the immediate environment and the time of year of release. If nitrogen levels are naturally high (mostly likely in the form of nitrate), then adding ammonia would not be likely to have much of an affect on plant growth. Similarly, if ammonia were released in winter when plant biomass is at minimum and growth is limited by low light conditions, the impact on plants would be minimal. If, however, ammonia was to be added in spring-fall, and natural nitrogen concentrations are low in the environment, then the ammonia could stimulate plant growth. This would be similar to the coastal 'eutrophication' situation where nitrogen (nitrate, urea, ammonia) comes from sewage, agriculture, etc. When the excess biomass that is generated decomposes, reduced oxygen levels can be generated (i.e., oxygen is consumed in the decomposition process). This can become a problem in poorly mixed environments.

Potential for Impacts from Whites Point Quarry and Marine Terminal

Although no water quality guideline exists in Canada for NH_3 in marine water, it is documented to cause acute lethality to fish at levels as low as 0.1-0.2 mg/L. Also, ammonia dissolved in water is listed as a toxic substance on Schedule 1 of the *Canadian Environmental Protection Act*.

Some explosives such as ANFO are readily soluble in water. Losses associated with the use of explosives at mine and quarry sites could result in elevated levels of total ammonia in the final effluent. Depending on the proportion of NH_3 and NH_4^+, this could result in an acutely lethal effluent and non-compliance with Section 36 of the *Fisheries Act*, which prohibits the deposit of deleterious substances into waters frequented by fish unless that deposit is authorized by a Regulation. Failing a 96-hour acute-lethality test has been accepted by courts as evidence of depositing a deleterious substance. Environment Canada routinely uses such tests when conducting inspections at unregulated sites.

Without predictions of the amount of blasting residue (which can be highly variable due to environment conditions and practices of the blasting contractor), determining the potential environmental effects of ammonium-nitrate releases and fuel oil in the marine environment is difficult. Even if these quantities were known, further detailed analysis would be required for dispersion predictions to estimate the concentrations at the outfall of the settling ponds or other point sources.

Other factors may also influence these predictions such as the effectiveness of the settling ponds to remove ammonia prior to the release of settling pond water into the coastal environment. Fractured bedrock may also provide a role if fractures provided a direct pathway between unexploded ANFO and the marine environment.

In its review of the environmental assessment documentation for the Whites Point Quarry and Marine Terminal project, Environment Canada highlighted the importance of reducing blasting residues in achieving compliance and reducing the potential for adverse environmental effects. In this regard, the following information requests to the proponent remain outstanding, as highlighted in Environment Canada's June 15 letter to the Panel:

- Identify the amount of residue expected from blasting, the anticipated nitrate levels in surface water runoff, and the potential to affect the pH of water or trophic status in the sediment retention ponds.
- Identify potential blasting residues that could be present in any discharges and how they will be managed taking into account opportunities to reduce residues at source (i.e., pollution prevention).

Without further information, it is difficult to predict the ecological risk associated with ammonia residues from blasting. However, if the proponent is able to reduce the levels of blast residue to their lowest practical levels, from DFO's perspective, any residual material would be unlikely to have any ecological impact, given the mitigation measures proposed and the high rates of flushing in the Bay of Fundy. As DFO noted earlier to the proponent, if the application of the recommendations outlined in the paper by Gordon Revey were incorporated into the blasting plan, there will be little in the way of residual impacts accruing from this aspect of the proposal.

References:

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Paerl, H. 1997. Coastal eutrophication and harmful algal blooms: Importance of atmospheric deposition and groundwater as "new" nitrogen and other nutrient sources. Limnol. Oceanogr. 42: 1154–1165.

Smayda, T. 1997. Harmful algal blooms: their ecophysiology and general relevance to phytoplankton blooms in the sea. Limnol. Oceanogr. 42: 1137–1153.

U.S. EPA (Environmental Protection Agency). 1989. Ambient water quality criteria for ammonia saltwater). Washington, D.C. (EPA 440/5-88-004).

Additional Resources:

The seriousness of proper ammonia management has been recognized by the mining sector in Canada. The Canada Centre for Mineral and Energy Technology (CANMET) and a number of mining companies formed an Ammonia Control Consortium to look at this issue and concluded that better management of ammonia would enable companies to achieve compliance. The Mining Association of Canada (MAC) has also committed to produce a guide on best management practices for ammonia control.

In terms of amounts of blasting residues, the amount of nitrogen-based nutrient loss (total nitrogen, ammonia, nitrate and nitrite) to the receiving environment from blasting at mines can be estimated, as described in Ferguson and Leask, 1988. This may be a useful reference in characterizing the amount of residue that may be associated with the Whites Point Quarry and Marine Terminal project.

Reference

Ferguson, K.S. and S.M. Leask. 1988. The export of nutrients from surface coal mines. Environment Canada, Conservation and Protection. Environmental Protection Pacific and Yukon Region.

Natural Resources Canada

Natural Resources Canada (NRCan) may also be able to provide assistance on methods of reducing ammonia. NRCan's Mining and Mineral Sciences Laboratories (MMSL) have provided mining companies advice in better managing ammonia. Through the Ammonia Control Consortium, it was found that better management of ammonia would enable companies to meet regulations without implementing any new technologies.

The MMSL are federal government research laboratories within the Mineral Technology Branch of Natural Resources Canada. MMSL provides quality research and sound scientific advice to the mining and minerals industries, and to provincial/territorial and federal government departments involved in promoting or regulating these industries.

PRACTICAL METHODS TO REDUCE AMMONIA AND NITRATE LEVELS IN MINE WATER

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ABSTRACT

Most commercial explosives contain 70 to 94% ammonium nitrate, by weight. When portions of these explosives end up in shot rock and ore, through spillage or incomplete detonation, ammonia and nitrates leach out of them and into ground water. In recent years, State and Federal regulators have been applying more stringent water quality standards, particularly at new mines and development projects. Bulk ANFO, a mixture of ammonium nitrate and fuel oil, is the explosive of choice at most mines, when mining conditions allow it. ANFO use is desired because it less costly than other explosives, but when spilled it dissolves readily in water. Several case histories in the United States and Canada show a clear connection between uncontrolled losses of bulk explosives and high nitrate levels in mine effluents.

Mining companies have tried several approaches to reduce ammonia and nitrate levels in groundwater. They either control explosive losses, or they treat mine effluents at the end-of-pipe. This paper addresses the former solution -- controlling explosive losses. For both packaged and bulk explosives, guidelines designed to limit losses during storage, handling and use, are described in detail.

AMMONIA AND NITRATE TOXICITY

Relatively small concentrations of ammonia in water are very detrimental to fish, and particularly to most trout species. The toxicity of ammonia varies with pH and temperature. Researchers have found that, at lower temperature and pH, the toxicity of free ammonia increases (Wiber, M., et al, 1991). In aqueous solutions, ammonia exists in two forms: free ammonia which carries no ionic charge (NH_3) and ammonium which carries a positive charge (NH_4^+). The free ammonia is the more toxic of the two. The U.S. EPA ambient water quality criterion is 0.02 mg/l free ammonia. For U.S. mines NPDES permits commonly include a limit of 10 mg/L total ammonia as N in end-of-pipe effluents. The U.S. EPA drinking water criterion for nitrate as nitrogen (NO_3^--N) is 10 mg/l. In warm blooded animals, nitrate can be reduced to nitrites in the gastrointestinal tract. The nitrite reaches the bloodstream where it reacts directly with hemoglobin to produce methaemoglobin that impairs oxygen transport.

AMMONIA AND NITRATE SOURCES

Many mines have learned that there is a direct relationship between ammonia and nitrate levels in water and the amount of undetonated explosives in the rock through which the water flows. Most commercial blasting agents contain from 70 to 94% ammonium nitrate. ANFO, the most commonly used blasting agent, is usually a mixture of 6 percent #2 diesel fuel oil (DFO) and 94 percent ammonium nitrate. ANFO readily dissolves in water, releasing both ammonia and nitrate. Emulsion and watergel based explosives also contain a large amount of ammonium nitrate and other oxidizing salts that can leach nitrates to ground water. The rate at which nitrates leach from different explosives varies dramatically, based on the explosive's composition.

In tests conducted at the ICI Explosives Technical Center in McMasterville, Quebec, nitrate leaching rates were established for:

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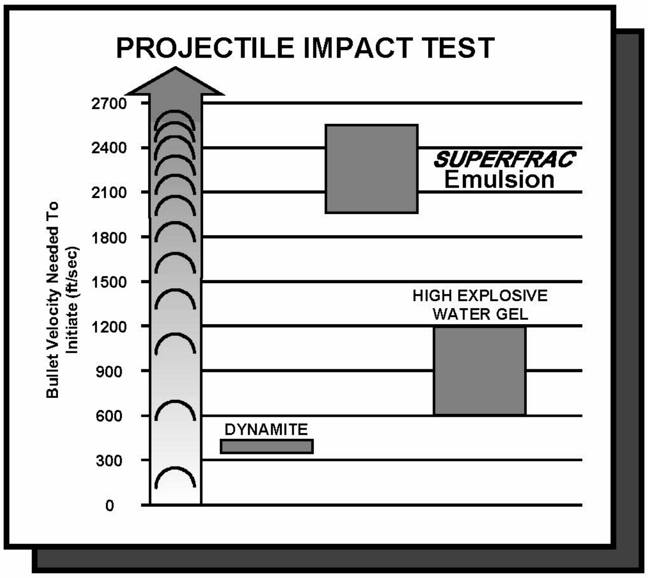
1) Standard ANFO
2) WR "Water Resistant" ANFO
(ANFO with additives to inhibit the ingress of water)
3) Detonator sensitive watergel
4) Detonator sensitive emulsion

PERCENTAGE OF NITRATES LEACHED FROM EXPLOSIVE*				
Time (hrs)	ANFO	WR ANFO	WATERGEL	EMULSION
0.1	~ 25	-	-	-
1	> 50	~ 25	-	-
6	-	-	24.6	0.6
144	-	-	> 75	1.2

* When 25% of the nitrates are dissolved, the explosive is probably no longer detonable.

As expected, the emulsion did not release nitrates as readily as the ANFO or watergel explosive. The leaching rate for emulsion explosives is much lower because the ammonium nitrate is contained in an aqueous phase that is surrounded by an oil, or oil and wax, fuel phase. Hence, when water contacts undetonated emulsions, the ammonium nitrate is protected by the relatively impervious oil and wax matrix. Despite their very slow leaching rates, emulsions--when given enough water exposure time--can produce significant levels of nitrates and ammonia. In comparison, spilled ANFO will quickly dissolve in water and release all its ammonia and nitrates. If continuously spilled, the daily level of nitrates and ammonia released by any type of explosive--exposed to water--will eventually become significant. The ammonium nitrate leaching rate for packaged explosives will vary based on the integrity of the package. However, this is usually a moot point because packages of undetonated explosives are almost always ruptured by the violent rock movement within the blast. Despite being ruptured, the packaged explosive can often be recovered from shot rock. Nitroglycerin (NG) based dynamites will also leach ammonia and nitrates at varying rates based on their composition. In addition, NG sensitized products are much more sensitive to shock impact; for this reason, as well as environmental concerns, the occurrence of unfired dynamite in shot rock should be prevented.



In underground metal mines, noxious levels of ammonia gas often occur when undetonated explosives mix with alkaline water draining from cemented fill or grouting operations (Joyce, D.K., 1992). This parallel ammonia problem is another reason to control explosive spills.

The conclusion from this analysis is that losses of all types of explosives must be controlled, regardless of their composition or packaging.

MANAGING EXPLOSIVE LOSSES

There are several ways that undetonated explosives end up on the ground or in shot rock. First, sloppy handling, storage, and loading practices may cause a significant amount of explosive spillage, particularly when bulk explosives are used. Poor drilling and loading practices can also create significant amounts of undetonated explosives. Charges are often disrupted or torn away by premature rock movement caused by earlier detonations. Drill patterns, stemming or collar length, explosive selection, priming methods, and delay timing are the elements of blast design that can be adjusted to control charge cut-offs or failures.

In a paper presented at the 1991 Northwest Mining Convention in Spokane, Washington, the authors present water monitoring case histories from three separate underground mines in Canada (Wiber, M., et al, 1991). In all three cases, the levels of ammonia in mine water were lowered by at least 50 percent after rigorous explosive management programs were started.

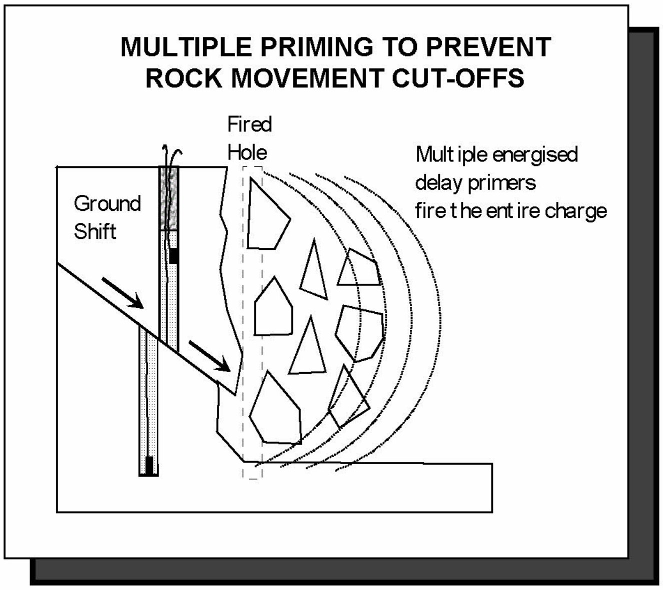
Storage And Handling Controls

In both surface and underground mining, ANFO and bulk emulsion blasting agents are often spilled during storage, transfer or loading. Bulk ANFO commonly spills out of poorly designed or damaged bins, rail cars, and transfer augers. Bulk emulsion spills are often seen at storage tank outlets and at pump transfer areas. Maintenance employees are an important part of a complete explosives management program. They should understand that all bins, tanks, storage trailers, and loading equipment should be regularly maintained to prevent explosives spills. Employees who understand the importance of preventing explosive spills can greatly reduce their occurrence. However, no level of training will completely prevent all spills; so it is important to develop spill containment and clean-up procedures. To contain spills, some surface mines have placed their bulk explosive bins in concrete containment tanks or they have built rock berms around tanks and bins. Explosive manufacturers can usually provide spill clean up recommendations for their products, and in many areas they can provide special mobile clean-up crew and equipment services.

Blast Design Considerations

For safety, environmental, and economic reasons, blast designs should include measures that ensure complete detonation of all explosives. For this analysis, any charge or portion of a charge that fails for any reason is considered a misfire. Some common causes of misfires, along with design practices that will prevent them are:

<u>Cut-offs</u>: We can not control ground conditions, but we can control drill patterns, explosive loads, and initiation methods. In ground with weak seams or joints, the gasses and shock from early firing charges can cause premature movement of the rock containing adjacent, unfired holes. When the rock moves it separates or cuts off the explosive columns within it. The portions of the columns that do not contain energized primers will misfire and contribute ammonia and nitrate to ground water. Many of these misfires can be prevented by using multiple in-hole delay primers.

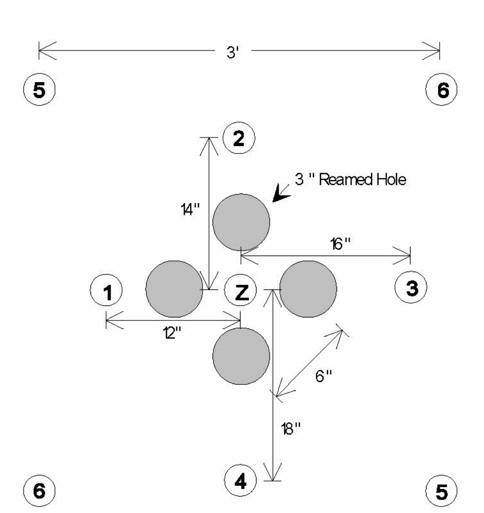


Some failures occur because there is too much delay time between adjacent holes, or rows of holes. In these situations, reducing the delay time between holes can reduce cut-offs. Cut-offs and explosive losses often occur when detonating cord downlines and surface delays are used in bench blasting. When detonating cord is used without a delay detonator in the hole, the ground swell that occurs when the first row of holes fires, can tear cord and delay connections before they fire, hence causing multiple hole failures. This type of cut-off can be prevented by using Fully Activated Sequential Timing (FAST) systems that use relatively long in-hole delays in combination with short surface delays.

The goal with these systems is to have all of the in-hole initiators sequentially energized before the first charges fire and rock starts moving. In very large shots that can not be fully energized, try to have at least two rows energized behind the row that is firing. FAST sequential timing can be achieved with either nonelectric or electric initiation systems.

Precompression Failures: Several blasting problems can occur when hole-to-hole shock pressures are too high. High blast induced pressure in rock can cause sympathetic detonation (propagation) of dynamite charges, and pre-compression failure in emulsion and watergel explosives. Many blasting incidents, often with severe damage to nearby structures, have been caused by propagating dynamite. In critical blasting areas, the propagation hazard is virtually eliminated by substituting less sensitive explosives for dynamite. However, under certain conditions, packaged emulsion and watergel explosives can fail when rock or gas pressure from an adjacent charge squeezes them to a density above their critical limit. This pre-compression or "dead-pressing" phenomenon is caused by several conditions or combinations of conditions. When ground is very seamy and wet, the magnitude of hole-to-hole shock is greatly increased. Shock also increases when holes are very close together which is always the case in underground tunnel and surface ditch blasting, where the application demands tightly spaced holes. If precompression failures occur, try spacing blastholes farther apart, or switch to an explosive that can withstand higher pressures. In tunnel rounds, the holes in the burn cut are usually spaced very closely together. The hole-to-hole pressure transmitted to the charges in these holes can be reduced by placing unloaded relief holes between the loaded holes.

Poor explosive choice: The type of explosive used can have a dramatic effect on overall losses. For instance, if bulk instead of packaged explosives are used, spillage losses will be relatively high. If bulk ANFO is used in wet holes, losses caused by complete failures or partial detonation will be high. At one underground metal mine in the northwest U.S., their total daily limit of nitrates in ground water is 100 pounds. To meet this limit they can not tolerate any spillage, so they use only packaged explosives. Moreover, they use a special emulsion product with a distinctive orange color that can be seen and removed from shot rock.



SHIELDED BLASTHOLE BURN CUT
FOR 1 3/4 to 2 inch JUMBO ROUNDS

When conditions that cause very high hole-to-hole shock pressures exist, only explosives that can resist pre-compression should be used.

Loading Controls

Without specific controls, mines using bulk ANFO typically lose 2 to 5 percent to spillage, or blow back -- during pneumatic loading underground. Surface auger-loading trucks with poorly designed -- or aimed -- discharge hoses spill ANFO prills onto the ground around hole collars during loading. Blowing wind can also add to losses by carrying some prill away from the hole if the discharge hose is too high in the air. Blasters that are conscientious and aware can prevent most spills by simply adjusting their loading practices.

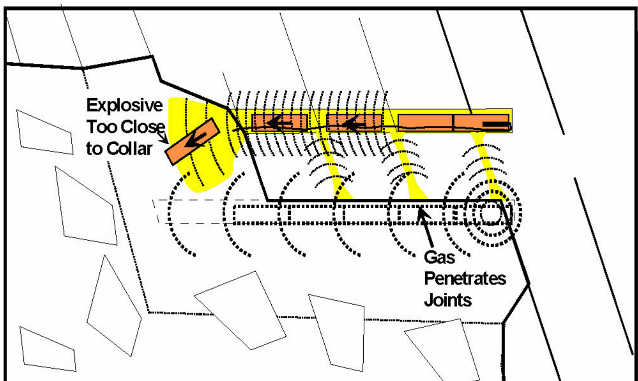
Moreover, when spills do occur, they must know how to clean them up and also understand the importance of doing it.

For some loading applications, explosive makers are developing specialized equipment and products designed to reduce explosive losses. For instance, pneumatic ANFO metering devices can reduce blow loading losses by metering a preset amount of explosives into a blasthole, thus preventing overloading.

Explosive manufacturers have also developed specially formulated tacky ammonium nitrate and fuel mixtures that reduce blow back losses.

In many underground blasting applications, overloading is the greatest cause of explosive losses. When long period delay detonators are used to delay tunnel and other development rounds, the charges in the later firing holes are subjected to tremendous shock and gas pressure generated by the earlier firing charges. This shock and pressure often tear away the rock around the collars of adjacent and yet unfired holes. Any explosive, whether in stick or bulk form, that is in this collar region is cut off and ends up -- undetonated -- in the shot rock. To control these losses, minimum open collar lengths should be established for all underground blast loads, based on geological conditions and application. Cartridge ejection from hole collars will also cause explosive losses. Ejection losses can be reduced by firmly tamping the cartridges near the hole collar. However, remember to never the tamp the primer stick; this practice is dangerous and it is prohibited by MSHA. When charge tamping will cause overloading, the explosive column can be secured by some type of hole plug. To accurately implement good blast designs, operations must have proper loading equipment and trained employees. Loading equipment should be well maintained and in some cases, mines should consider using computerized bulk loading equipment that meters preset weights of explosives into blastholes.

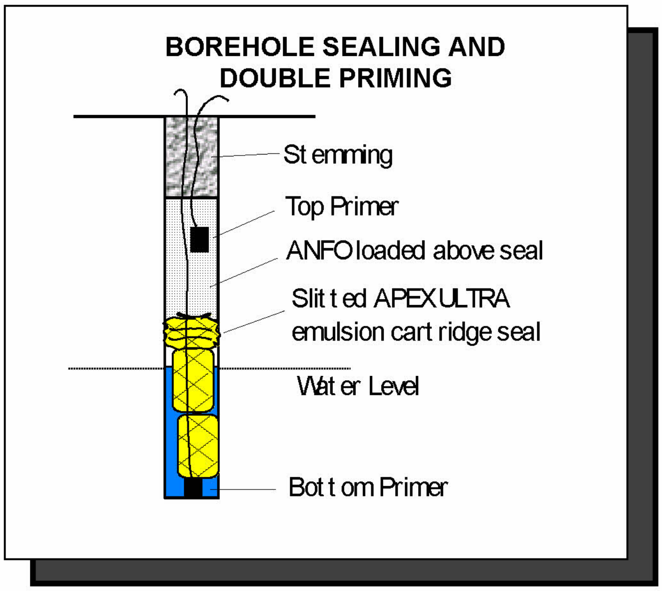
Sometimes during loading, packaged explosives columns are separated when rock chunks fall in the hole or a cartridge becomes stuck. When this occurs, the separated portion should be separately primed with the same delay detonator used in the initial primer. Use of the same delay will prevent one part of the separated charge from disrupting the other, and the desired firing sequence will be maintained.



Column Separation or Ejection in Poorly Tamped or Overloaded Holes

Loading bulk ANFO into wet holes, or letting ANFO sleep too long in wet or damp holes, is another common cause of explosive loss. When water comes into contact with ANFO, it either dissolves it or wicks into it and desensitizes it. In either case the ANFO charge partially or completely fails to detonate. In underground development rounds, static drill water should be blown out of holes with compressed air before pneumatically loading ANFO. In top loaded vertical holes, water resistant cartridged or bulk explosives should be substituted for ANFO.

In wet holes, packaged explosives are often loaded until out of water and the load is finished with ANFO. If the hole is not sealed, the ANFO will sift past the packaged ANFO and dissolve in the water. The water will cause further ANFO loss when it wicks up the sifting ANFO and into the main column. This problem is a common cause of misfires in bench blasting applications. Holes should be sealed with a fully coupled and waterproof explosive before loading ANFO. A good seal can be made by dropping a cut stick of an emulsion explosive into the hole, before pour loading ANFO.



CONCLUSION

At all mines, significant reductions of ammonia and nitrate in mine water can be achieved by developing an aggressive and ongoing explosive management program. At three different mines in Canada, the implementation of rigorous explosive management programs reduced ammonia levels by at least 50% in all cases.

As responsible stewards of our environment, mining companies and explosive suppliers should work together to establish products, loading equipment, and training programs aimed at lowering toxins in mine effluents. Explosive manufacturers, aware of these environmental concerns, are developing new explosive products and loading equipment specifically designed to reduce explosive losses. Excellent slide and video training programs for explosive handlers are also available. Please accept this call to action and work with your explosive suppliers to prevent ammonia and nitrate compliance problems. Mines that wait to act until ammonia and nitrate limits have been exceeded, will pay huge remedial control costs.

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Canadian Environmental Protection Act, 1999

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Canada

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Additional information can be obtained at Environment Canada's Web site at www.ec.gc.ca or at the Inquiry Centre at 1-800-668-6767.

Canadian Environmental Protection Act, 1999

PRIORITY SUBSTANCES LIST ASSESSMENT REPORT

Ammonia in the Aquatic Environment

Environment Canada
Health Canada

February 2001

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ACRM	Aquatic Community Risk Model
CAS	Chemical Abstracts Service
CDF	cumulative density function
CEPA	*Canadian Environmental Protection Act*
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CTV	Critical Toxicity Value
DO	dissolved oxygen
EC_{20}	20% effective concentration
EC_{50}	median effective concentration
EEV	Estimated Exposure Value
ENEV	Estimated No-Effects Value
ET_{50}	time to 50% effect
IC_{20}	concentration causing 20% inhibition in exposed organisms
ISCST3	Industrial Source Complex Short Term model
ISOPART	Inorganic and Secondary Organic Particle model
LC_{10}	10% lethal concentration
LC_{50}	median lethal concentration
LT_{50}	time to 50% mortality
$PM_{2.5}$	particulate matter less than or equal to 2.5 µm in diameter
PM_{10}	particulate matter less than or equal to 10 µm in diameter
N	nitrogen
NH_3	un-ionized ammonia
NH_4^+	ionized ammonia
NPRI	National Pollutant Release Inventory
PSL	Priority Substances List
REVEAL	Regional Visibility Experimental Assessment in the Lower Fraser Valley
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic chemical
WWTP	municipal wastewater treatment plant

SYNOPSIS

Ammonia exists in two forms simultaneously, with the equilibrium between the two forms governed in large part by pH and temperature. The forms are NH_3 (un-ionized ammonia) and NH_4^+ (ionized ammonia or ammonium). Together they are called total ammonia. It is the NH_3 form that is particularly harmful to aquatic organisms. The formation of NH_3 is favoured at higher pHs but is also affected by temperature. This means that while the concentration of total ammonia may remain constant in a water body, the proportion of un-ionized ammonia fluctuates with temperature and pH. Significant formation of NH_3 can occur within a single day as water temperatures fluctuate.

Ammonia evaporates at temperatures above –33°C and will travel short distances (several kilometres) as a gas. It readily forms ammonium sulphate particles in air when in the presence of sulphur compounds; in this form, it can travel hundreds of kilometres.

In 1996, ammonia was ranked first by the National Pollutant Release Inventory in terms of amounts released by industry to the Canadian environment. Just over 32 000 tonnes were reported as released by industries across Canada to all media (air, water and land). Ammonia is also a naturally occurring compound required by most organisms for protein synthesis and a waste product of animal, fish and microbial metabolism. The primary human use of ammonia is as a nitrogen source in fertilizers, especially anhydrous ammonia and urea.

Ammonia is released into the environment by many industries and other human activities. The major quantifiable sources of ammonia released to aquatic ecosystems across Canada are municipal wastewater treatment plants (WWTPs). The amount of ammonia released to water via municipal WWTPs is estimated at 62 000 tonnes/year. Negative environmental impacts on some aquatic ecosystems are occurring from this source.

Agricultural releases of ammonia to water cannot be quantified because of the diffuse nature of agriculture in Canada and the difficulty in quantifying such releases. In general, only those intensive animal-rearing facilities (feedlots and dairies) with direct runoff to watercourses have the potential to significantly contaminate the water.

Industrial releases to water amount to 5972 tonnes/year. The major industries are pulp and paper mills, mines, food processing and fertilizer production.

The major industrial source of ammonia released to the atmosphere is the fertilizer industry, releasing some 12 000 tonnes/year. In contrast, the amount of ammonia released to air from agricultural operations is estimated at 474 000 tonnes/year. Through modelling and measuring ammonia deposition in areas influenced by agricultural emissions and studying the situation in Europe, it was determined that some areas of Canada, like the Lower Fraser Valley, are potential impact regions.

It was determined from reviewing toxicity and exposure data that freshwater organisms are most at risk from releases of ammonia in the aquatic environment. Rainbow trout, freshwater scud, walleye, mountain whitefish and fingernail clams are some of the most sensitive species. Aquatic insects and micro-crustaceans are more resistant to ammonia, although there is a large variation in sensitivity within aquatic insects.

The ecological impact of ammonia in aquatic ecosystems is likely to occur through chronic toxicity to fish and benthic invertebrate populations as a result of reduced reproductive capacity and reduced growth of young. These are subtle impacts that will likely not be noticed for some distance below an outfall. The zone of impact varies greatly with discharge conditions, river flow rate, temperature and pH. Under estimated average conditions, some municipal wastewater discharges could be harmful for

10–20 km. Severe disruption of the benthic flora and fauna has been noted below municipal wastewater discharges. Recovery may not occur for many (20–100) kilometres. It is not clear whether these impacts are solely from ammonia or from a combination of factors, but ammonia is a major, potentially harmful constituent of municipal wastewater effluents.

Owing to the interaction between receiving water pH and temperature, those waters most at risk from municipal wastewater-related ammonia are those that are routinely basic in pH with a relatively warm summer temperature combined with low flows. In Canada, winter temperatures, regardless of pH, are low enough to keep the formation of un-ionized ammonia below the toxic threshold. Potentially toxic conditions typically start in May and can continue through to early October, depending on the water system and the yearly variation in pH, dissolved oxygen and temperature. In general, waters potentially sensitive to ammonia from municipal WWTPs are found in southern areas of Alberta, Saskatchewan and Manitoba; southern Ontario; and the south shore of Quebec.

Ammonia is generally not problematic with respect to the eutrophication of fresh waters in Canada, as this is typically limited by phosphorus. There are a few exceptions to this, in particular the Qu'Appelle Lakes in Saskatchewan. Ammonia released by the Regina WWTP, coupled with phosphorus mobilization from sediments, seems to be contributing to the continued eutrophication of this lake system.

Conifer trees are sensitive to ammonia exposure from air, particularly in winter. They develop a reduction in winter hardiness due to an impaired ability to retain water. The beneficial mycorrhizal fungi that colonize many types of plant roots are particularly sensitive to ammonia. Reductions in mycorrhizal fungi on tree roots may be the reason for reduced water retention in conifers. Conifer forests and sphagnum bogs are particularly at risk if sufficient ammonia is added over time. Conifers may experience a form of eutrophication, and sphagnum cannot compete with grasses under increased ammonia conditions.

Ammonia is not involved in the formation of ground-level ozone, the depletion of stratospheric ozone or climate change.

Based on probabilistic risk assessments of three water bodies receiving ammonia from typical municipal wastewater discharges, it is concluded that ammonia is entering the aquatic environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Based on available data, it is concluded that ammonia is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger to the environment on which life depends. Therefore, ammonia is considered to be "toxic" as defined in Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

As the conclusion of this assessment is based on analyses of risks posed by releases of ammonia from municipal WWTPs, priority should be given to consideration of options to reduce exposure to ammonia from municipal wastewater systems taking into account site-specific conditions. Results of conservative screening-level assessments suggest that releases of ammonia from several other sources (e.g., runoff from manure-fertilized fields and intensive livestock operations) may also be causing environmental harm; however, available data were insufficient to establish the extent and magnitude of such harm. It is recommended that additional data be obtained to determine whether options to reduce exposure to ammonia from such sources should be undertaken.

1.0 INTRODUCTION

The *Canadian Environmental Protection Act, 1999* (CEPA 1999) requires the federal Ministers of the Environment and of Health to prepare and publish a Priority Substances List (PSL) that identifies substances, including chemicals, groups of chemicals, effluents and wastes, that may be harmful to the environment or constitute a danger to human health. The Act also requires both Ministers to assess these substances and determine whether they are "toxic" or capable of becoming "toxic" as defined in Section 64 of the Act, which states:

> … a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that
> (a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity;
> (b) constitute or may constitute a danger to the environment on which life depends; or
> (c) constitute or may constitute a danger in Canada to human life or health.

Substances that are assessed as "toxic" as defined in Section 64 may be placed on Schedule I of the Act and considered for possible risk management measures, such as regulations, guidelines, pollution prevention plans or codes of practice to control any aspect of their life cycle, from the research and development stage through manufacture, use, storage, transport and ultimate disposal.

Based on initial screening of readily accessible information, the rationale for assessing ammonia in the aquatic environment provided by the Ministers' Expert Advisory Panel on the Second Priority Substances List (Ministers' Expert Advisory Panel, 1995) was as follows:

> Anthropogenic sources of ammonia in Canada include effluent from sewage treatment plants, steel mills, fertilizer plants, the petroleum industry and intensive farming. Releases from these sources can result in locally elevated concentrations. At several point sources in Canada, concentrations exceed the threshold levels of sensitive species such as rainbow trout. An assessment of ammonia in the aquatic environment is needed to evaluate the extent of the problem.

Following an initial scoping exercise, it was decided that the scope of the assessment was too narrow and that it should be expanded to include the atmospheric and terrestrial environments in Canada. This decision was based on the findings of European researchers that ammonia transmitted by air to sensitive terrestrial ecosystems was having negative impacts on those ecosystems. Several of the impacted European ecosystems, conifer forests in particular, exist in large areas of Canada. Also, the atmospheric chemistry of ammonia is such that its interactions with sulphates form fine respirable particulate matter ($PM_{2.5}$ and PM_{10}). Since "Respirable particulate matter less than or equal to 10 microns" (i.e., PM_{10}) has been determined to be "toxic" to humans under CEPA 1999, an evaluation of the role of ammonia in the formation (but not the environmental effects) of respirable particulate matter was warranted.

A description of the approaches to assessment of the effects of Priority Substances on the environment is available in a published companion document. The document, entitled "Environmental Assessments of Priority Substances under the *Canadian Environmental Protection Act*. Guidance Manual Version 1.0 — March 1997" (Environment Canada, 1997a), provides guidance for conducting environmental assessments of Priority Substances in Canada. This document may be purchased from:

Environmental Protection Publications
Environmental Technology Advancement Directorate
Environment Canada
Ottawa, Ontario
K1A 0H3

It is also available on the Internet at www.ec.gc.ca/cceb1/ese/eng/esehome.htm under the heading "Guidance Manual." It should be noted that the approach outlined therein has evolved to incorporate recent developments in risk assessment methodology and which will be addressed in future releases of the guidance manual for environmental assessments of Priority Substances.

The search strategies for identification of data relevant to assessment of potential effects on the environment (prior to January 1999) are presented in Appendix F. Review articles were consulted where appropriate. However, all original studies that form the basis for determining whether ammonia is "toxic" under CEPA 1999 have been critically evaluated by staff of Environment Canada (entry and environmental exposure and effects).

The Assessment Report was written by M. Constable, F. Jensen, K. McDonald, K. Taylor and M. Charlton (Canada Centre for Inland Waters) of Environment Canada. The Assessment Report was reviewed by and portions of the supporting documentation (Environment Canada, 2000) related to the assessment of ammonia were prepared by the following members of the Environmental Resource Group, established by Environment Canada to support the environmental assessment:

P. Chambers, National Water Research Institute, Environment Canada
G. Craig, GR Craig and Associates
P. Doyle, Environment Canada
J. Farrell, Canadian Fertilizer Institute
L. Gammie, Canadian Water and Wastewater Association
J. Haskill, Environment Canada
S. McGinn, Agriculture and Agri-Food Canada
J. McLernon, Environment Canada
D. Moore, The Cadmus Group, Inc.
B. Munson, Environment Canada
D. Penney, Alberta Agriculture
K. Reid, Ontario Ministry of Agriculture, Food and Regional Affairs
S. Sheppard, EcoMatters
W. Windle, Environment Canada

Environmental sections of the Assessment Report and supporting documentation (Environment Canada, 2000) were also reviewed by external reviewers:

J. Diamond, TetraTech Inc.
B. Parkhurst, The Cadmus Group, Inc.

The basis for recommending inclusion of ammonia in the aquatic environment by the Ministers' Expert Advisory Panel on the Second Priority Substances List was limited to environmental effects (namely, effects on sensitive aquatic species). As a result, the principal focus of this assessment is a determination of whether ammonia is "toxic" under Paragraph 64(a) of CEPA 1999. However, in view of the expansion of the scope of the assessment of environmental effects to address the terrestrial environment (through exposure via air) as well, effects of ammonia in air and water on human health were also considered, at least in a preliminary fashion, primarily to ensure that conclusions drawn on the basis of a more robust data set on environmental effects would also be protective of human health.

The database on the effects of ammonia relevant to assessment of the effects on human health is limited principally to early short-term studies in animals, older reports of accidental exposures of humans, limited clinical studies and one cross-sectional study of an occupationally exposed population (Health Canada, 1999).

The paucity of information on effects in experimental animals and humans is likely attributable to the considerably greater amounts of ammonia produced endogenously in humans through metabolism in the synthesis of amino acids, nucleosides and other nitrogen-containing compounds compared with environmental exposure, as well as to its relatively low toxicity.

Because of the focus on environmental effects and in view of the limitations of the data relevant to assessment of the effects on human health, a screening assessment was conducted, in which the limited number of identified effect levels for ammonia in the more relevant studies were compared with worst-case or bounding estimates of exposure in air (including indoor air) and drinking water and the adequacy of these rather crude margins of exposure was considered. On the basis of the magnitude of these margins, which are considered sufficient to account for various elements of uncertainty and variability, ammonia is not considered a priority for investigation of options to reduce public exposure through control of sources that are addressed under CEPA 1999 (Health Canada, 1999), and the remainder of this assessment addresses effects on the environment. Unpublished supporting documentation on the health-related effects of ammonia in the aquatic environment, which presents additional information, is available upon request from:

Environmental Health Centre
Room 104
Health Canada
Tunney's Pasture
Ottawa, Ontario
K1A 0L2

A draft of the Assessment Report was made available for a 60-day public comment period (May 13 to July 12, 2000) (Environment Canada and Health Canada, 2000). Following consideration of comments received, the Assessment Report was revised as appropriate. A summary of the comments and responses is available on the Internet at:

www.ec.gc.ca/cceb1/eng/final/index_e.html

Copies of this Assessment Report are available upon request from:

Inquiry Centre
Environment Canada
Main Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 0H3

or on the Internet at:

www.ec.gc.ca/cceb1/eng/final/index_e.html

Unpublished supporting documentation, which presents additional information, is available upon request from:

Commercial Chemicals Evaluation Branch
Environment Canada
14th Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 0H3

2.0 Summary of Information Critical to Assessment of "Toxic" under CEPA 1999

2.1 Identity and physical/chemical properties

Ammonia terminology has been a source of confusion within the technical literature for years. Terms such as free ammonia, total ammonia, non-dissociated ammonia and un-ionized ammonia nitrogen are commonly encountered and tend not only to confuse the reader, but also to make comparison of the data difficult. To solve this problem, the definitions given below will be adhered to throughout this document.

In aqueous solutions, a chemical equilibrium is established between un-ionized ammonia (NH_3), ionized ammonia (NH_4^+) and hydroxide ions (OH^-). The equilibrium for these chemical species can be expressed in simplified form by the equation:

$NH_3 + H_2O \leftrightarrow NH_3{\cdot}H_2O \leftrightarrow NH_4^+ + OH^-$ or NH_4OH

The term "***un-ionized ammonia***" refers to all forms of ammonia in water other than the ammonium ion (NH_4^+). In the literature, this has been designated as NH_3, NH_4OH and $NH_3{\cdot}H_2O$. The expression NH_3 is used throughout this report to represent un-ionized ammonia, except in instances where one or the other expression is more appropriate to the context (e.g., see the chemical equilibrium discussion later in this section).

The term "***ionized ammonia***" refers to the ammonium ion, NH_4^+.

The terms "***total ammonia***" and "***ammonia***" refer to the sum of un-ionized ammonia and ionized ammonia ($NH_3 + NH_4^+$).

Ammonia is a colourless alkaline gas, lighter than air and possessing a unique penetrating odour. The name "***ammonia***" is a general term and refers to anhydrous ammonia, ammonia gas and ammoniac anhydre. Ammonia has the Chemical Abstracts Service (CAS) registry number 7664-41-7. The substance has the molecular formula NH_3 and a molecular weight of 17.03 (Grayson and Eckroth, 1978).

Considerable information about the properties of ammonia is given in WHO (1986) and Environment Canada (1984). The physical and chemical properties relevant to the environmental fate of ammonia are summarized in Table 1.

Using their pK_a calculations, Emerson *et al.* (1975) developed a table (Table 2) describing the percentage of NH_3 in fresh or soft water for temperatures between 0 and 30°C and for pHs in the range 6.0–10.0.

The relationship illustrated in Table 2 holds in most fresh waters. However, the concentration of un-ionized ammonia will be lower at the higher ionic strengths (total dissolved solids) of very hard fresh waters or saline waters. For a given total ammonia concentration, the concentration of un-ionized ammonia decreases slightly with increasing salt content, and this effect can be significant in estuarine and marine waters. Using the appropriate activity coefficients, this relationship can be restated for seawater with an ionic strength of 0.7 as follows (API, 1981):

$$f = 1/[10^{(pK_a - pH) + 0.221} + 1]$$

At 25°C, the pKa is 9.24 (Emerson *et al.*, 1975), so at pH 8, the above equation shows that 3.3% of the total ammonia in seawater would exist in the

TABLE 1 Physical and chemical properties of ammonia

Property	Value
Boiling point at 100 kPa	–33.42°C
Melting point at 100 kPa	–77.74°C
Density (liquid) at –33.7°C and 100 kPa	682.8 kg/m³
Density (gas) at 25°C	0.7067 kg/m³
Vapour pressure	
at 15.5°C	640 kPa[1]
at 21°C	880 kPa[1]
at 25°C	1000 kPa
pK_a (25°C, pH 8)	9.24
Solubility in water, 101 kPa	
at 0°C	895 g/L
at 20°C	529 g/L
at 40°C	316 g/L
at 60°C	168 g/L

[1] Figure from literature review by Environment Canada (1984).

un-ionized form. The corresponding value in fresh water is 5.4%. At this pH and temperature, seawater with an ionic strength of 0.7 contains 38% less un-ionized ammonia than does fresh water.

2.2 Entry characterization

2.2.1 Production and use

According to a marketing research report by Lauriente in 1995, Canada produced 3.0 million tonnes of ammonia in 1990 and 3.4 million tonnes in 1993. Exports of ammonia from Canada were significant compared with imports. In 1989 and 1993, respectively, 1.1 million tonnes and 0.84 million tonnes of ammonia were exported, while 2000 tonnes and <500 tonnes were imported (Lauriente, 1995).

The primary industrial use of ammonia is as the nitrogen source in fertilizers, with direct application of anhydrous ammonia being the largest single method of consumption. The Prairie provinces are the largest users of these products, consuming 81% of the nitrogen content sold (Korol and Rattray, 1998). Ammonium sulphate, ammonium nitrate, urea and ammonium phosphate are fertilizers produced from ammonia. To a lesser extent, ammonia is used in many industrial applications. Ammonia can be regarded as reduced nitric acid and is used in the production of many other substances. At petroleum refineries, ammonia is formed from catalyst regenerators in the fluid catalytic cracking process. Other uses of ammonia include the following:

- Manufacture of synthetic fibres (caprolactam for nylon), plastics and glues; pharmaceuticals, vitamins, amino acids, dentifrices, lotions and cosmetics; household ammonia, detergents and cleansers; numerous organic and inorganic chemicals, such as nitric acid, cyanides, amides, amines, nitrates, nitriles, hexamethylene diamine, ethanolamines, ammonium thiosulphate and dye intermediates.
- Production of explosives, rocket fuel, beer and nitrogen oxides required for manufacturing sulphuric acid, sugar purification and treatment and refinement of metals.

TABLE 2 Percentage of total ammonia present as NH_3 in aqueous ammonia solutions

Temp. (°C)	pH								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0	0.008	0.026	0.082	0.261	0.820	8.55	7.64	20.7	45.3
5	0.012	0.039	0.125	0.394	1.23	3.80	11.1	28.3	55.6
10	0.018	0.058	0.186	0.586	1.83	5.56	15.7	37.1	65.1
15	0.027	0.086	0.273	0.859	2.67	7.97	21.5	46.4	73.3
20	0.039	0.125	0.396	1.24	3.82	11.2	28.4	55.7	79.9
25	0.056	0.180	0.566	1.77	5.38	15.3	36.3	64.3	85.1
30	0.080	0.254	0.799	2.48	7.46	20.3	44.6	71.8	89.0

- Use as a refrigerant in both compression and absorption systems; a neutralizing agent for acids in oil protecting refinery equipment from corrosion; a flux for soldering; a treatment for wheat and barley straw as a supplement to sheep and cattle feed; a food additive; for growth and control of pH in yeast cultures; a latex preservative; a flame-proofing agent; a curing agent in leather making; a mothproofing agent; and as a reducing agent for nitrogen oxides in flue gas during steel production.
- Use as a dyeing agent, and preventing afterglow in matches.

2.2.2 Sources and releases

2.2.2.1 Natural sources

Much of the ammonia in the atmospheric environment is from natural sources. Since ammonia is continually released throughout the biosphere by the breakdown or decomposition of organic waste matter, any natural or industrial process that concentrates and makes nitrogen-containing organic matter available for decomposition represents a potential source of high local concentrations of ammonia.

Releases from natural processes that can be accounted for are approximately double the releases from the animal husbandry industry. Natural releases are estimated at over 500 000 tonnes while animal husbandry industry accounts for 294 000 tonnes to the atmosphere (Appendix A). The estimates of natural production and release to air are very approximate (Geadah, 1980; Environment Canada, 2000b).

2.2.2.2 Anthropogenic sources

2.2.2.2.1 Industrial

Environment Canada conducts an annual survey of Canadian industries (National Pollutant Release Inventory [NPRI]) likely to be using or releasing pollutants, including ammonia (NPRI, 1996). Total reported industrial releases of ammonia in 1996 were 32 037 tonnes. This makes ammonia the top-ranked NPRI substance in terms of amounts released in Canada. The NPRI has strict reporting criteria, such that most municipal sewage treatment plants, very few animal husbandry systems and no transportation systems had to report. These are known to be some of the major anthropogenic sources of ammonia released to the Canadian environment.

Industries in Alberta released more ammonia than industries in any other provinces in 1996, accounting for a third of the releases (9891 tonnes not including deep well disposal). This is due to the large number of fertilizer manufacturing facilities, pulp and paper mills and petroleum refineries in the province. Ontario released 7552 tonnes, and Quebec released 1914 tonnes (see Appendix B for details).

Industrial releases directly to watercourses totalled 5972 tonnes in 1996 and are typically from companies that are resource-based, such as pulp and paper, mining and coal-fired power generation, although a few significant releases come from heavy industries located in cities and from food processing. Fourteen companies were involved in pulp and paper manufacture in 1996, and these released a total of 1371 tonnes of ammonia that year. Three steel mills released 775 tonnes of ammonia, a single food processor released 504 tonnes, two fertilizer manufacturers released 180 tonnes, five mines released 537 tonnes and a coal-fired power generation plant released 62 tonnes. The rest (2543 tonnes) was released by many other industries.

Large releases in a city are usually due to one or two facilities. Hamilton, Ontario, is a major release site due to three steel-producing facilities. Other cities with significant industrial releases of ammonia are:

- Maitland, Ontario (fertilizer and chemical manufacture) — air and water releases,
- Toronto, Ontario (chemical and paper manufacture) — air and waste treatment releases,
- Medicine Hat, Alberta (fertilizer and chemical manufacture) — air and waste treatment releases,
- Brandon, Manitoba (fertilizer and chemical/pharmaceutical manufacture) — air and waste treatment releases, and
- Fort Saskatchewan, Alberta (fertilizer and chemical manufacture) — air and water releases.

The fertilizer industry is the largest industrial releaser of ammonia in Canada. Of the 10 largest industrial sources of ammonia listed in the 1996 NPRI report, six are fertilizer manufacturers. Three are located in Alberta, at Redwater, Medicine Hat and Calgary, one in Manitoba, at Brandon, and two in Ontario, at Courtright and Maitland. Together they released 12 302 tonnes out of 32 037 tonnes reported, which is 38% of the total released. Most of these releases are to air.

The metal foundry industry is located primarily in Ontario. Of the largest ammonia sources in this sector, the top releasers are Algoma Steel in Sault Ste. Marie, Ontario (676 tonnes); the Cobalt Refinery Company, Fort Saskatchewan, Alberta (528 tonnes); the Inco Nickel Refinery, Copper Cliff, Ontario (297 tonnes); the Stelco refinery, Hamilton, Ontario (182 tonnes); and the Dofasco refinery, Hamilton, Ontario (180 tonnes). There are significant differences in the releases, however. The Inco and Cobalt facilities release nearly all of their ammonia to the air, Algoma Steel releases most of its ammonia to water, and the Stelco and Dofasco facilities split their releases between air and water. Other metal-working facilities, such as Stelwire of Hamilton, Ontario, produce large quantities of ammonia (245.5 tonnes), but they send all of it to the local municipal wastewater treatment plant (WWTP), so their releases will show under the municipal wastes for Hamilton.

The petroleum extraction and refining industry is a relatively large source of ammonia. The largest releasers within this sector in 1996, all in Alberta, were the Shell Scotford refinery, Fort Saskatchewan (2488 tonnes), Petro Canada refinery, Edmonton (1718 tonnes), and Imperial Oil Limited Strathcona refinery, Edmonton (1130 tonnes). However, their releases of ammonia are primarily to deep-well disposal, very little being released to surface waters. Following these are the Syncrude Canada Mildred Lake Site near Fort McMurray, Alberta (454 tonnes), and the Ultramar Ltée Raffinerie de St-Romuald, in St-Romuald, Quebec (229 tonnes). Syncrude does not have a reported release, as it uses massive retention ponds.

2.2.2.2.2 Municipal

Four sources of information were used to determine releases of ammonia from municipal sewage treatment plants. Environment Canada issued a voluntary survey to municipalities in all provinces (Environment Canada, 1997b) except Quebec (at their request) to collect information on effluent flow rates and releases of ammonia to local watercourses. Also requested was information on the quantities and ammonia content of sewage sludge and sludge disposal methods. The Ontario Ministry of Environment and Energy (OMEE, 1997) provided a copy of its municipal discharge database, which includes data on ammonia concentrations from all municipalities in Ontario. This was combined with Environment Canada's Municipal Water Use Database (Environment Canada, 1997c), which contains information on flow rates with which to calculate loading rates of ammonia from Ontario municipalities. A survey of 15 communities in Quebec provided ammonia release data and flow rates for a 3-day period in 1996 and 1997 (MEFQ, 1998). The average ammonia concentration in sewage effluents reported to Environment Canada (1997b) was 13.89 mg/L.

A survey of water usage by Canadian municipalities indicates that sewage treatment plants are a large source of ammonia to the aquatic environment. Average daily flow rates from all municipalities in Canada for 1994 were 12.3×10^6 m^3/day (Environment Canada, 1997c). This equates to 4.49×10^{12} L/year. With an estimated average total ammonia concentration of 13.89 mg/L in domestic sewage (Environment Canada, 1997b), the estimated load to aquatic systems is 62 000 tonnes/year.

As the Environment Canada survey of municipalities was not exhaustive, being voluntary, the tonnage of ammonia released is a conservative estimate. Also, many treatment facility operators did not know the concentration of ammonia in their effluent and so did not provide those data. A figure of 13.89 mg/L (the national average) was used to estimate releases from these facilities.

The current knowledge of the quantities of ammonia disposed of in sewage sludge is not very good. The municipal survey did include questions on quantities of sludge produced and ultimate disposal methods; however, the answers received were of low quality. Many facilities record quantities of sludge in volumes, while others record weights. Many do not know the concentrations of ammonia in the sludge. An estimate of 5722 tonnes of ammonia disposed of in sludge was generated, based on 1222 tonnes of ammonia reported and 4500 tonnes extrapolated from the reports. The average ammonia concentration reported in sludge was 2200 mg/kg, with a range of 0.29–38 600 mg/kg.

Appendix C summarizes the ammonia loading rates in municipal wastewater for the top 12 urban centres in 1995–1996. Montréal has the highest ammonia loading rate of any city in Canada. This is due to an effluent flow rate twice that of Toronto, although its effluent is surprisingly dilute for a primary treatment system. Montréal's loading rate of 6128 tonnes/year to the St. Lawrence River is nearly the same as Toronto's, at 5938 tonnes/year released to Lake Ontario. The Greater Vancouver Sewerage and Drainage District (GVS&DD) is the next largest releaser of ammonia (5741 tonnes/year to the Fraser River and Strait of Georgia), as its effluents are moderately high in ammonia and have a high flow rate. The four Vancouver facilities have either primary or secondary treatment. Winnipeg is fourth because of its very high ammonia concentration, averaging 26 mg/L in 1995, giving it a loading rate of 2152 tonnes/year to the Red River. Edmonton is fifth, but by 2005 Edmonton's loading rate should be at least half of what it is currently, as the city is installing a nitrification/ denitrification process. Many urban centres have several sewage treatment facilities; for these calculations, their effluent flows and ammonia concentrations have been flow weighted and aggregated.

A comparison was made of industrial releases directly to water and municipal releases to water. The ammonia from municipal effluents in any province far outweighs the industrial discharges of ammonia to water.

2.2.2.2.3 Combined sewer overflows

Combined sewer overflows occur when stormwater drains are routed into the sewage system, so that the sewage treatment system is overloaded during a large rain event. When overloading occurs, raw sewage is diverted directly into the receiving water along with the stormwater. Mean concentrations of ammonia in stormwater estimated for three Ontario cities — Sarnia, Sault Ste. Marie and Windsor — were 0.5, 0.7 and 0.3 mg NH_3/L, respectively (Marsalek and Ng, 1989). Annual average ammonia concentrations in municipal wastewater effluents were 75.4, 181.5 and 27.7 mg/L, respectively. Concentrations were calculated from point source loadings that were divided by the annual volume of stormwater runoff (UGLCC, 1988a,b,c). When comparing loadings in the stormwater with those in combined sewer overflows, overflows exceeded stormwater in loadings of ammonia in both Sarnia and Windsor, despite the fact that stormwater discharges in Sarnia and Windsor were 6.7×10^6 and 22.3×10^6 m^3/year, respectively, and the volumes of combined sewer overflow in Sarnia and Windsor were 1.0×10^6 and 5.2×10^6 m^3/year, respectively (Marsalek and Ng, 1989).

2.2.2.2.4 Agricultural

Manure application

Few, if any, agricultural operations track ammonia emissions. Livestock manure is considered to be the major source of NH_3 emission to the atmosphere (Ryden *et al.*, 1987); however, quantification of this source is difficult and comes down to estimates of loss rates, ammonia concentrations in manure and numbers of animals (refer to Appendix A). Canada has a large population of farm animals (about 114 million, mostly cattle, swine and poultry). Emission factors range from 0.32 kg NH_3 per animal per year for poultry to 40 kg NH_3 per animal per year for beef cattle (U.S. EPA, 1994). This source generated an estimated 294 000 tonnes of ammonia in 1995 (Environment Canada, 2000b).

Manure is spread on land mainly as a way of disposing of farm animal waste. Land application of manure is higher in regions where farm animal production is high and the manure can be collected and distributed easily. In the Prairies, cattle are concentrated only in certain areas, and fields are large and require large amounts of manure for complete coverage. Although Alberta's large cattle population produces over 25% of all the animal manure in Canada (Patni, 1991), only a small proportion is confined at any time, when manure collection and land application are practical. Mixed farms and ranches are not well suited for collection and application of manure, except from cow-calf operations and feedlots. Manure in British Columbia and central and eastern Canada comes mostly from dairy and poultry farms, which are numerous and scattered throughout crop production regions. This makes it easier to get the manure to the fields where it is needed. Many dairy farms grow silage corn as cattle feed, and the manure from the cattle is applied to the cornfields, creating an on-farm nutrient cycling system.

Agricultural research shows that 10–75% of the ammonia in cattle manure can volatilize if the manure is not incorporated into the soil within a week. During hog production, 40–95% of the excreted nitrogen may be lost before the manure reaches the field. This nitrogen is lost primarily as ammonia volatilized from barns, from manure storage facilities and following field application. Many of the new hog production facilities in Canada, which include lagoon storage and slurry irrigation, will probably result in NH_3 emission losses up to 75% of the excreted nitrogen (Paul, 1997). Lockyer and Pain (1989) showed losses of up to 83% from poultry slurry, 21% from air-dried poultry manure, 36–75% from pig manure and 41% from cattle manure when applied to turf and not incorporated. In most cases, 80% or more of the ammonia loss occurred within 48 hours of application. Air-drying of poultry manure reduced ammonia losses to 12% from the poultry house and from application. Lockyer and Whitehead (1990) conducted ammonia loss experiments with cattle urine applied to soil. They found that 3.7–26.9% of the ammonia in the urine was lost within 15 days of application. Most of the loss occurred within the first 4 days. The temperature of the soil was the most important factor in determining the amount of ammonia lost to the atmosphere. They estimated average ammonia losses to air for grazing systems to be 37 kg N/ha or 12% of the ingested nitrogen content in the forage.

The quantities of ammonia lost from the soil decline considerably if the manure is liquefied and injected under the surface. Hoff *et al.* (1981) showed that liquid swine manure lost 11–14% of the ammonia when applied to the surface and only 2.5% when injected. Ryden *et al.* (1987) showed that cattle manure lost 16–32% of the ammonia when applied to the surface and only 0.9% of the ammonia when injected under the surface.

Storage systems for manure are a source of ammonia loss as well. Under acid conditions, NH_4^+, which is relatively non-volatile, predominates, while under basic conditions, NH_3, which will evaporate readily, predominates. In anaerobic decomposition of poultry manure, low-pH conditions (pH 5–6) led to a low (1%) loss of ammonia. Under aerobic decomposition, the basic pH that developed (pH 8.4–8.9) promoted loss of ammonia (9–44%). Losses of ammonia from storage tanks were reduced by up to 85% simply by covering the tanks; even a tarp sufficed (de Bode, 1990). There are many ways of handling, storing and applying manure from various animals that will reduce the loss of ammonia. The most obvious are quick storage of manure, covering manure pits to prevent volatilization, promoting anaerobic storage conditions, acidifying manure to prevent formation of NH_3 from NH_4^+, tillage of soil prior to surface application, injection of manure slurries into soil rather than surface application, and application during wet or cool weather (McGinn and Pradhan, 1997).

Mineral fertilizer application

Ammonia loss by volatilization from mineral fertilizers depends in large part on the soil pH, due to the overriding dependence of ammonia ionization on pH. NH_3 will evaporate readily, whereas NH_4^+ will not.

Some inorganic nitrogen fertilizers are acidic, so that NH_3 loss from these materials depends on soil chemical reactions or on the inherent alkalinity of the soil. Representative inorganic nitrogen fertilizers in this category are ammonium nitrate, diammonium sulphate and ammonium chloride. If the soil is sufficiently alkaline (with calcium carbonate usually), the reactions will form diammonium carbonate, which is unstable and decomposes, producing NH_3 and carbon dioxide gases (Fenn and Hossner, 1985).

The concern over nitrogen loss from industrial fertilizers has resulted in massive amounts of scientific literature on many relevant aspects. Top-applied ammonium sulphate has been measured, in both field and laboratory, to lose up to 55% of the NH_3-N. Losses from unincorporated urea can be very high, up to 60% over a period of 4 days in surface-applied pastures (Fenn and Hossner, 1985). One study by Touchton and Hargrove (1982) found that a 270 kg N/ha application of urea-ammonium nitrate to the surface resulted in less nitrogen uptake by corn than from an application of 90 kg N/ha with incorporated urea-ammonium nitrate. This equated to a loss of 67% of the NH_3-N when urea-ammonium nitrate was not incorporated.

The Environment Canada Ammonia Air Emissions Inventory for 1995 (Appendix A) estimates ammonia lost from the application of individual types of fertilizer, using appropriate emission factors and sales data. The amounts lost to the atmosphere are greatest from urea, accounting for an estimated 72% of the losses (130 217 tonnes) from applied fertilizers (Environment Canada, 2000b). The Canadian Fertilizer Institute reported 3 million tonnes of urea produced that year (CFI, 1997), so a loss of 130 217 tonnes would be 4.3% of the total applied. This would be consistent with reported losses for incorporated urea, which is the recommended method of application.

Plant tissues

There is some evidence that plants play an important role in the concentrations of ammonia in the atmosphere. The maintenance of low ambient concentrations depends in part on the existence of an NH_3 compensation point, i.e., an atmospheric NH_3 concentration above which plants will absorb NH_3 from the air and below which they will release it. Denmead *et al.* (1977) found that, even though there was considerable release of NH_3 from the ground in a grass-clover pasture, almost none of it escaped to the atmosphere above the canopy. The effect of plant absorption was to reduce the NH_3 concentration in the air from >16 µg/m³ near the soil surface to 1 µg/m³ at the top of the canopy. Other researchers report a similar phenomenon in a field of quack grass (*Agropyron repens*), reducing the NH_3 concentration from 40 µg/m³ above the grass canopy to 3 µg/m³ within it (Lemon and van Houtte, 1980). Accurately estimating losses from this source would be extremely difficult.

Runoff of ammonia from soil

Runoff of nutrients, including ammonia, from various land use types, including intensive livestock operations and crops, has been studied to the extent that we know the vast majority of nutrients in runoff are associated with either soluble phosphorus or nitrate. Both of these are water-soluble and easily transported in solution. Ammonia in ionized form, on the other hand, is typically tightly bound to soil colloids and is not easily transported in solution once it contacts soil. Once ammonia binds with soil, it will travel with soil particles during erosive events. Minor amounts of ammonia will travel in solution if there is freely available ammonia on the soil surface. In spring, however, considerable quantities of ammonia can be liberated as runoff from melting snow. This is due to the accumulation of ammonia trapped in snow or from deposited manure. The soil is still frozen, so that little ammonia will be absorbed and bound; what does not evaporate over winter travels with runoff and enters waterways in the freshet. Data on levels of ammonia in runoff are reported in Section 2.3.2.4.

2.3 Exposure characterization

2.3.1 Environmental fate

The nitrogen cycle is an attempt to describe the natural cycling of nitrogen from the atmosphere through incorporation into living organisms and from them back into the abiotic environment through degradative processes. Figure 1 illustrates the nitrogen cycle (after Manahan, 1994).

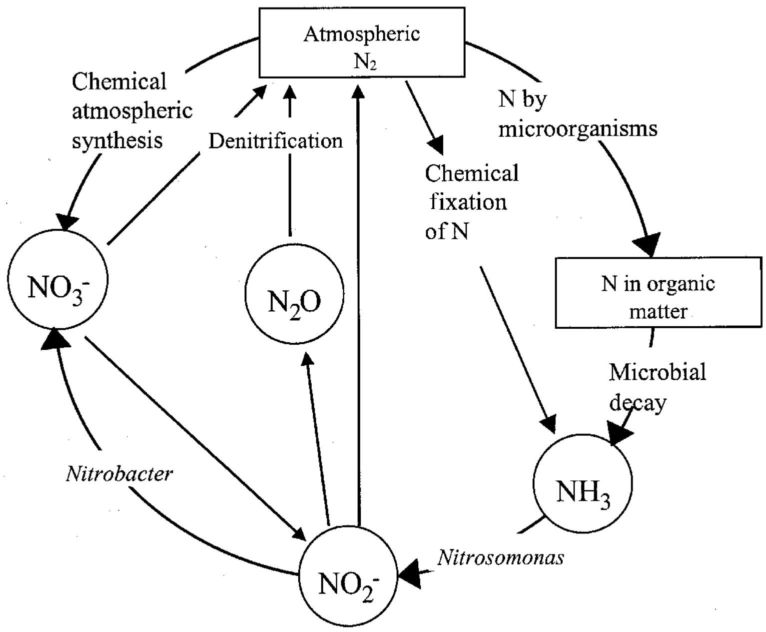
Several processes can create nitrogenous compounds usable by organisms from nitrogen gas (N_2). Lightning and cosmic radiation combine atmospheric nitrogen and oxygen into nitrates, which are carried to the earth's surface in precipitation. A few nitrogen-fixing bacteria, symbiotic mycorrhizal fungi living on the roots of plants, cyanobacteria, and certain lichens and epiphytes in tropical forests can split N_2 and make the nitrogen molecule available for amino acid synthesis. Ammonia is formed either as a waste product or when plants and animals die. Another set of microorganisms is capable of using NH_3 and eventually forming nitrate (NO_3^-) and nitrous oxide (N_2O).

2.3.1.1 Air

Ammonia is released into the atmosphere by agricultural, waste disposal and industrial activities. There is no known photochemical reaction by which ammonia could be produced in the atmosphere (WHO, 1986). Atmospheric ammonia undergoes four primary types of reactions: gas-phase, liquid-phase, thermal and photochemical. The first two are the most important types of reactions. From various studies consulted, the main reactions of interest appear to be those associated with the following combinations of reactants, since there is a high availability of nitric acid (HNO_3), hydrochloric acid (HCl), sulphur dioxide (SO_2) and sulphuric acid (H_2SO_4) in the atmosphere as a result of industrial and urban emissions:

- ammonia/nitric acid/ammonium nitrate ($NH_3/HNO_3/NH_4NO_3$),

FIGURE 1 The nitrogen cycle



- ammonia/hydrochloric acid/ammonium chloride ($NH_3/HCl/NH_4Cl$),
- ammonia/nitric acid/sulphuric acid ($NH_3/HNO_3/H_2SO_4$), and
- ammonia/sulphur dioxide (NH_3/SO_2).

In a polluted atmosphere, ammonia reacts with nitric acid and/or hydrochloric acid, which results in the formation of ammonium nitrate and/or ammonium chloride. These ammonium salts account for 10–30% of the fine aerosol (solid or liquid particles suspended in a gas with a particle diameter <0.5 µm) in a polluted atmosphere. These aerosols are very sensitive to temperature and relative humidity. In a polluted atmosphere, ammonia can also react with more than just one pollutant (Bassett and Seinfeld, 1983):

$$3NH_3\,(g) + 2HNO_3\,(g) + H_2SO_4\,(g) \Leftrightarrow (NH_4)_2SO_4 \cdot 2NH_4NO_3\,(s) \qquad (1)$$

and

$$5NH_3\,(g) + 3HNO_3\,(g) + H_2SO_4\,(g) \Leftrightarrow (NH_4)_2SO_4 \cdot 3NH_4NO_3\,(s) \qquad (2)$$

An intensive study (Esmen and Fergus, 1977) of the NH_3/SO_2 reaction system in a dry atmosphere led to the confirmation of at least eight reactions, the most important of which are:

$$NH_3 + SO_2 + H_2O \Leftrightarrow NH_4HSO_3 \qquad (3)$$

and

$$NH_2HSO_3 + NH_3 \Leftrightarrow NH_2 \cdot SO_3NH_4 \qquad (4)$$

The above reactions were found to be very rapid, on the order of milliseconds. In the atmosphere, gas-phase reactions are expected to occur in the presence of water droplets. Aerosol formed through gas-phase reactions is therefore expected to act as condensation nuclei or to be captured by available drops to contribute high local concentrations of bisulphite ion (HSO_3^-). This is significant in the eventual formation of the ammonium sulphate [$(NH_4)_2SO_4$] aerosol in liquid-phase reactions. For this reason as well, reaction (3) is very important in the presence of water.

With respect to the liquid-phase reactions of the NH_3/SO_2 system, various studies (Moller and Schieferdecker, 1985; Behra *et al.*, 1989; Plass *et al.*, 1993) concluded that the function of NH_3 in this system is to neutralize the hydrogen ions formed in the absorption of sulphur dioxide and its subsequent oxidation to sulphate. Thus, NH_3 maintains sulphur dioxide solubility and the rate of sulphate production by buffering the pH to between 4 and 5.

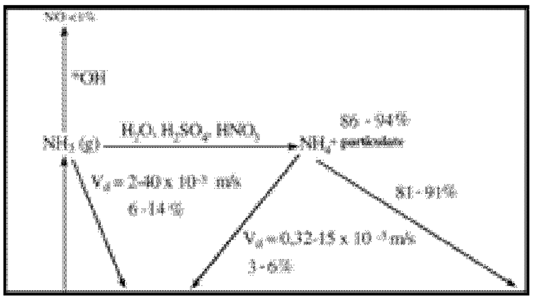
Of all known atmospheric ammonia reactions, one of the most important seems to be that involving conversion of ammonia to ammonium (NH_4^+) particulate (see reaction 4 above). This conversion occurs in the lowest 100 m of the atmosphere at rates in the range 1×10^{-3}/s to 5×10^{-5}/s (/s is indicative of a first-order reaction, which means the reaction rate is dependent on the concentration of one reactant, namely NH_3), and daytime conversion is much faster than that at night. The reaction is dependent on temperature, relative humidity and pH (Fangmeier *et al.*, 1994).

All studies consulted conveyed the opinion that the main factors that hindered long-range transport of ammonia in the atmosphere, both vertically and horizontally, were rapid conversion to ammonium aerosol and the relatively high dry deposition velocity of ammonia.

Because of the rapid reaction rates of ammonia in air, anywhere from 56% (ECETOC, 1994) to 94% (Moller and Schieferdecker, 1985; Quinn *et al.*, 1988; ECETOC, 1994) of atmospheric ammonia is converted to ammonium particulate/ammonium aerosol. Over oceans, ammonium particulate/ammonium aerosol has an estimated atmospheric residence time of 22 hours (Quinn *et al.*, 1988); over land, the estimated residence time is in the range 7–19 days (Moller and Schieferdecker, 1985; Fangmeier *et al.*, 1994). In comparison, the estimated residence time of atmospheric NH_3 is 3.6 hours over oceans (Quinn *et al.*, 1988) and in the range of 2.8 hours to 4 days over land (Fangmeier *et al.*, 1994). These short residence times are primarily due to the rapid conversion to ammonium particulate/ammonium aerosol and the high dry deposition velocities of ammonia (Asman and Janssen, 1987; Asman *et al.*, 1989).

Figure 2 summarizes the chemistry, distribution, transport and deposition of atmospheric ammonia. Depending on the atmospheric conditions, anywhere from 56% to 94% of atmospheric ammonia is converted to ammonium particulate/ammonium aerosol, and less than 1% is converted to nitric oxide (NO). The balance remaining, 6–44%, is gaseous ammonia.

FIGURE 2 Fate analysis of ammonia in the atmosphere



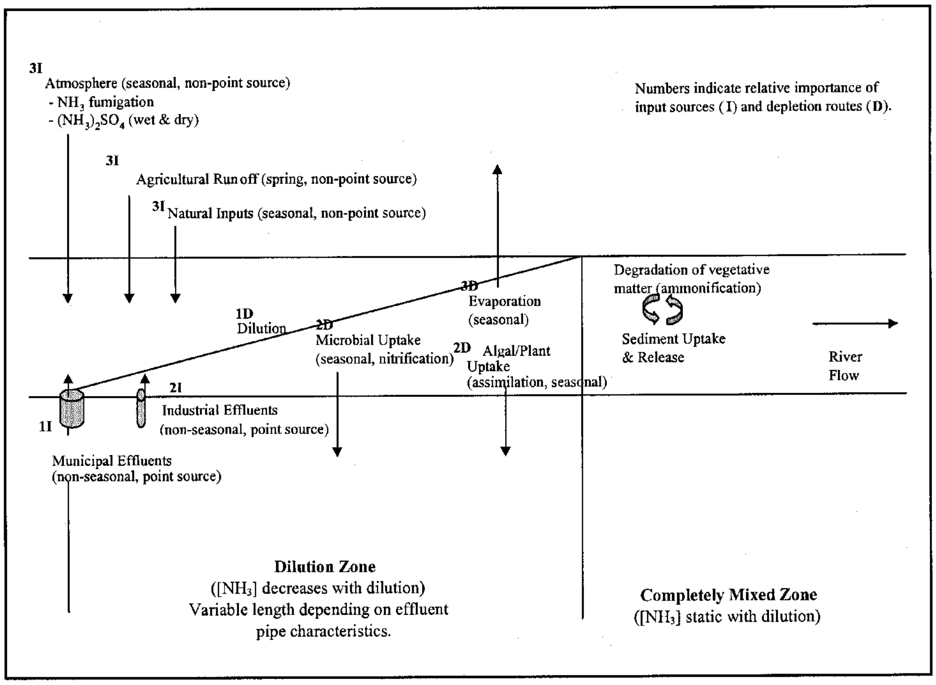
V_d = net dry deposition velocity

Emission	< 5 km	10's – 1000s km
100%	Dry deposition	Wet deposition

It is known from measurements that gaseous ammonia concentration rapidly decreases with height and distance from ground-level emission sources. Results of four studies on the decrease in ammonia concentration with an increase in distance from a ground-level emission source showed that 50–75% of the gaseous ammonia detected was deposited between 500 and 4000 m from the source (Denmead *et al.*, 1982; Asman *et al.*, 1989; Fangmeier *et al.*, 1994; Janzen *et al.*, 1997).

Gaseous ammonia is removed from the atmosphere via dry deposition, whereas

FIGURE 3 Fate analysis of ammonia in aquatic environments



ammonium aerosol is removed via both dry and wet deposition. Dry deposition is most significant in regions with high ammonia emissions and is indicative of short-range transport of less than about 5 km. In contrast, wet deposition is most significant in regions with low ammonia emissions and is indicative of long-range transport, ranging from tens to thousands of kilometres distant (ECETOC, 1994; Fangmeier *et al.*, 1994).

Ammonia may be a significant local pollutant and, as a precursor of nitric oxide and ammonium aerosols, can have long-range impacts.

2.3.1.2 Surface water

A fate analysis for ammonia in the aquatic environment is displayed schematically in Figure 3 and is a composite from several reviews (NRC, 1979; API, 1981; WHO, 1986). Ammonia has a critical role in the nitrogen cycle, so that when it is introduced into aquatic systems, it is usually rapidly transformed into other nitrogenous forms (e.g., nitrates and organically bound nitrogen). The major processes include fixation, assimilation, ammonification, nitrification and denitrification. In the sections below, these major processes are discussed along with reference to decreases in ammonia concentration due to dilution.

Figure 3 also presents the relative importance of input sources and depletion routes for ammonia in the aquatic environment. Nitrification and volatilization are the important and competitive fate processes in surface waters that are not ice covered. Under ice cover, both processes are greatly reduced. Volatilization is the predominant removal process for industrial effluents until the effluents are diluted to a concentration that is not harmful to nitrifying bacteria. These bacteria require a substrate on which to grow, typically suspended solids in the water. Nitrification processes are more likely to be significant in lakes, slow-moving rivers, estuaries and sewage effluents. Nitrification is important in preventing the persistence or accumulation of high ammonia levels in water receiving sewage effluent or runoff. However, winter conditions will inhibit bacterial growth so that under restricted water flow conditions, ammonia can build up in receiving waters. Conditions of high nitrification may contribute to low levels of dissolved oxygen, as nitrification is an oxygen-consuming process (WHO, 1986).

Nitrification of ammonia can also have significant impacts on water systems by promoting acidification. In a greenhouse, seven identical mini-ecosystems, simulating soft-water ponds, were exposed to different types of artificial rainwater. Although ammonium sulphate deposition was only slightly acidic, due to nitrification it acted as an important acid source, causing acidification to pH 3.8. Under acidified conditions, ammonium sulphate deposition led to a luxuriant growth of *Juncus bulbosus* and *Agrostis canina*. In the mini-ecosystems, sulphuric acid deposition with a pH of 3.5 decreased the pH of the water to only 5.1 within 1 year (Schuurkes *et al.*, 1986).

Loss of ammonia to the atmosphere at elevated pH is another mechanism for ammonia removal. It has been estimated (API, 1981) that volatilization could account for 67.5% of the observed loss of ammonia below an industrial discharge to the Wabash River in the United States. It was also estimated that 20% of the ammonia discharged by a fertilizer plant was lost to the atmosphere, and a 55% loss for 10-year, 7-day low-flow conditions was predicted.

2.3.1.3 Soil and groundwater

A schematic of the terrestrial nitrogen cycle is represented in Figure 1. Ammonium is an important intermediate in the assimilation of nitrogen from the soil by plants. Nitrogen is present in the soil largely in the organic form and is unavailable to plants. Microbial processes must mineralize it. As nitrification is an energy-yielding process, the rates of conversion are rapid, so that ammonium rarely accumulates in soil while bacteria are active. Organic nitrogen compounds are reduced to ammonium, which is converted to nitrite (NO_2^-) by *Nitrosomonas* and then to nitrate by *Nitrobacter* (API, 1981; WHO, 1986). Most plants can assimilate the ammonium ion, but it is usually oxidized to the nitrate ion, the most common form of mineralized nitrogen in soil, which may be assimilated by plants as well (NRC, 1979; WHO, 1986).

Another source of mineralized nitrogen is nitrogen fixation, where gaseous nitrogen is transformed to ammonium ion, usually by metabolic processes. Nitrogen fixation occurs in blue-green algae and a few genera of microorganisms, which include aerobic bacteria, such as *Azotobacter* species, anaerobic bacteria, such as *Clostridium* species, and organisms in symbiotic association with higher plants, such as *Rhizobium* species found in legumes. Volatilization, adsorption and chemical transformation will also affect the fate of ammonia in soil (NRC, 1979; WHO, 1986).

Ammonia is bound in soil by the attraction of the positive charge on the ammonium ion to the negatively charged soil micelles. In soil, ammonium is adsorbed primarily by four mechanisms: chemical (exchangeable), fixation (non-exchangeable), reaction with organic matter and physical attractive forces.

Since ammonia is so poorly mobile in soil, it is unlikely to leach to groundwater except under unusual circumstances, such as when the cation exchange capacity of the soil is exceeded. The worst situation for ammonium leaching would probably occur when the soil is at field capacity with respect to water. In this case, ammonium ions can penetrate the soil and continue downward, with only small amounts remaining as part of the interstitial fluid. Moisture that is present in the soil or added as precipitation will dilute ammonia on the surface and reduce its rate of evaporation.

If ammonium ions reach the groundwater table, they will continue to move in the direction of groundwater flow and will be diluted slowly through diffusion or will be adsorbed by soil and mineral particles. It is possible that deep-soil bacteria utilize ammonia for amino acid synthesis in the presence of oxygen.

2.3.2 *Environmental concentrations*

2.3.2.1 Air

Atmospheric levels of gaseous ammonia in urban areas around the world are on average about 20 µg/m^3. Japanese researchers found ammonia concentrations up to 210 µg/m^3 downwind of a heavily industrialized area of Tokyo. Non-urban sites can have a wide range of levels (0.2–2000 µg/m^3), depending on their proximity to point sources (WHO, 1986). One such area in California was studied as a comparison with urban areas. Air near a large 600-animal dairy farm had an ammonia concentration of 560 µg/m^3 (Luebs *et al.*, 1973), and air in the region contained 190 µg/m^3 on a routine basis. Concentrations of ammonia in the troposphere are heavily influenced by ground temperature and so exhibit strong seasonal variations. German researchers found winter concentrations of 1–2 µg/m^3 at 1500 m in winter and 5 µg/m^3 at 4000 m in summer (WHO, 1986). Levels of particulate NH_4^+ ions in the atmosphere above the oceans have been studied; concentrations were found to be between 0.01 and 0.12 µg/m^3 (Servant and Delapart, 1983; Quinn *et al.*, 1988). The authors concluded that the oceans are a source of ammonia for the atmosphere. The general background concentration of ammonium in particulates is around 1 µg/m^3, with a measured average for an American urban area of 7.6 µg/m^3. In general, atmospheric ammonia levels show a seasonal variation, with the lowest levels occurring during the summer and the highest during the winter in Europe, and a reversed pattern in Japan (WHO, 1986; Yamamoto *et al.*, 1995). For the 1970s, rainfall in the continental United States had concentrations of ammonia ranging from 0.01 to 0.15 mg/L (NRC, 1979). In a mixed coniferous stand at Whitaker Forest in the western Sierra Nevada Mountains, California (1988–1990), seasonal ammonia 12-hour daytime averages of 1.11–1.56 µg/m^3 were recorded, with the highest 12-hour daily averages reaching 3.75 µg/m^3. When expressed on a molar basis, NH_3 was the most abundant nitrogen air pollutant and represented almost 50% of the total nitrogen (Bytnerowicz and Riechers, 1995). In Edmonton, Alberta, the average concentration in rainfall was 0.41 mg NH_4^+/L during the summers of 1977 and 1978. In July 1978, an intensive sampling effort detected a distinct gradient of total ammonia, with low values (<0.06 mg/L) found in the foothills of the Rocky Mountains and high values (>0.4 mg/L) eastwards into the agricultural areas of the province (Klemm and Gray, 1982).

Table 3 provides some atmospheric concentrations of ammonia and ammonium from regions with different sources. There is considerable variation in atmospheric concentrations of total ammonia, even in unpolluted regions; however, agriculturally polluted regions, particularly in Europe and California, can have very high concentrations (up to 4000 µg/m^3).

At the Hubbard Brook Experimental Watershed in New Hampshire, Fisher *et al.* (1968) detected 0.18–0.22 mg NH_4^+/L for the years 1965–1968.

Janzen *et al.* (1997) collected precipitation around Lethbridge, Alberta, and analysed it for ammonia and nitrate in an attempt to determine the nitrogen cycling in local soils. Analysis of precipitation collected over a 2-year period suggested that the annual nitrogen input, as nitrate and ammonium, amounted to 5.6 kg N/ha. The authors cited Peake and Wong (1992) to provide an average ratio of 19 µeq NH_4^+ to 14 µeq NO_3^- for rainfall around Lethbridge. Using this ratio with a mean total nitrogen input of 5.6 kg N/ha gives a mean annual input of 3.2 kg NH_3/ha.

TABLE 3 Atmospheric ammonia and ammonium aerosol concentrations at various locations

Location	NH_3 (μg/m³)	NH_4^+ (μg/m³)	Reference
Urban regions			
Uniontown, Pennsylvania	5		Suh *et al.*, 1992
University of Essex, England	33	51	Li and Harrison, 1990
Industrially impacted regions			
Windsor, Ontario	1.6–7.6		Brook *et al.*, 1997
Hamilton, Ontario	3–43.6		Brook *et al.*, 1997
Site near Nanticoke coal-fired power plant on Lake Erie, Ontario	75	50	Anlauf *et al.*, 1985
Yokohama, Japan	41–202		Yamamoto *et al.*, 1995
Agriculturally impacted regions			
Riverside, California	68–1734	486–2000	Doyle *et al.*, 1979
Semi-rural area in the Netherlands	12–661	0–295	Hoek *et al.*, 1996
Rural area in the Netherlands	12–980	5–373	Hoek *et al.*, 1996
Agricultural area in the Netherlands	272–544		Asman *et al.*, 1989
Egbert, Ontario	1.3–9.3		Brook *et al.*, 1997
Southeastern Saskatchewan	85		Cheng and Angle, 1996
Non-impacted regions			
Emission-free moorland in the Netherlands		37	Asman *et al.*, 1989
West coast of Canada	17		Cheng and Angle, 1996
Sutton, Ontario	0.8–4.2		Brook *et al.*, 1997
Kejimkujik National Park, Nova Scotia	0.3–9.4		Brook *et al.*, 1997
Hungary	12	23	Fekete and Gyenes, 1993
Antarctica	0.2–0.5	0.2–0.9	Gras, 1983
Southwest coast of Europe	2–8	1.7–28	Pio *et al.*, 1996

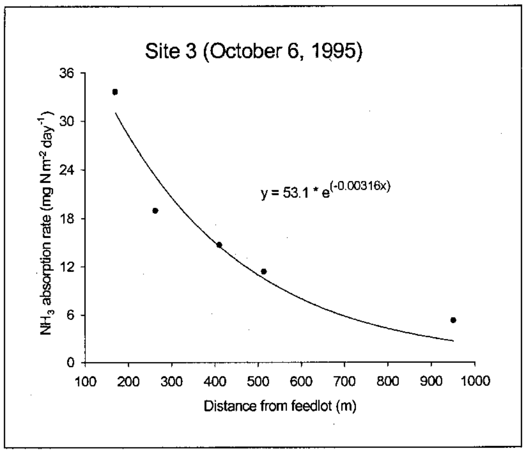
The Canadian Acid Aerosol Measurement Program was established to gain an understanding of the atmospheric behaviour of particulate acidity, which involved the measurement of gaseous ammonia (Brook *et al.*, 1997). The mean concentrations are assumed to be representative of typical ammonia levels in the early to mid-1990s. Mean concentrations of 1.72 and 4.28 mg/m³ were observed at sites with industrialization and human populations (Windsor and Hamilton, Ontario, respectively). Intense agricultural activity also produced elevated mean concentrations of 1.63 mg/m³ (Egbert, Ontario). In non-industrialized rural settings, mean concentrations were lower, at 0.83 mg/m³ (Sutton, Quebec); over water, concentrations were 0.41 mg/m³ (Kejimkujik National Park, Nova Scotia).

2.3.2.2 Atmospheric deposition

Researchers at the Lethbridge Agricultural Research Station (Janzen *et al.*, 1997) measured the rate of NH_3 deposition to soil at nine sites throughout southern Alberta for up to 2 years.

Lowest average rates, typically about 4–6 kg N/ha per year, were observed at the two control sites at the Research Station, while the highest average rates (about 66 kg N/ha per year) were observed near a beef feedlot. The high rates are enough to significantly affect soil nitrogen fertility. The researchers also studied the relationship between distance from NH_3 source and the rate of NH_3 deposition. Soil collectors were set up at various distances downwind of the feedlot; deposition rates were highest close to the feedlot and then diminished with distance. Average background deposition rates (4.4 mg N/m² per day) were not reached within 1 km (Figure 4).

FIGURE 4 Dispersion of NH_3 downwind of a feedlot



This is similar to atmospheric dispersion of ammonia from other areas of the world where intensive livestock facilities exist. The air above a large dairy area in Chino, California, and from an area not close to known ammonia sources was sampled for ammonia. The livestock area was 150 km² containing 143 000 dairy cows on 380 dairies (Luebs *et al.*, 1973). Continuous simultaneous sampling of the air at the dairy area site and at the control site showed the nitrogen concentration to be 23 times greater within the dairy area, with concentrations of 80 μg/m³ at the dairy area site compared with 3–5 μg/m³ at the control site. Rainfall measurements showed that the rain over the dairy area contained roughly 3 times more distillable nitrogen than the control area. The ammonia concentrations ranged from 0.4 to 1.7 mg/L in the dairy area compared with a range from 0.2 to 0.6 mg/L in the control area. The rainfall in the dairy area added 1.59 kg N/ha to soils compared with 0.53 kg N/ha in the control area. At the fence line of the dairy area, concentrations of distillable nitrogen were 540 μg/m³; at 200 m, NH_3 concentrations were roughly 50 μg/m³; and at 800 m downwind, the concentrations were 18 μg/m³ (Luebs *et al.*, 1973).

In one U.S. study, a lake 2 km from a large cattle feedlot (90 000 head of cattle) was found to receive considerable quantities of ammonia from the air, sufficient to raise its total nitrogen concentration by 0.6 mg/L over a year. On average, the differences in atmospheric concentrations of NH_3 between background sites and those closest to the feedlot (400 m) were 20-fold. The average deposition of ammonia closest to the feedlot was 145.6 kg NH_3/ha per year, while at the background site it was 7.8 kg/ha per year (Hutchinson and Viets, 1969).

Ammonia flux density was determined above a large feedlot to be on average 1.4 ± 0.7 kg N/ha per hour in spring and summer in northeast Colorado. A feedlot surface had lower average values than this when wet, but higher values than this during drying. Total NH_3 emissions equalled about half the rate of urinary nitrogen deposition, or about one-quarter of the rate of total nitrogen deposition (Hutchinson *et al.*, 1982). Actual ammonia concentrations were fairly stable, being 361 ± 46 μg NH_3-N/m³. Drying events and periods of warm, calm weather generated much higher NH_3 concentrations (970–1200 μg NH_3-N/m³).

Deposition of up to 66.4 kg NH_3/ha per year was determined within 50 m of a poultry house containing 8000–12 000 chickens near Athens, Georgia. At 1.2 km from the poultry house, the ammonia trapped was at background deposition rates (15 kg/ha per year). Near a beef cattle feedlot, 26.5 kg/ha per year was trapped.

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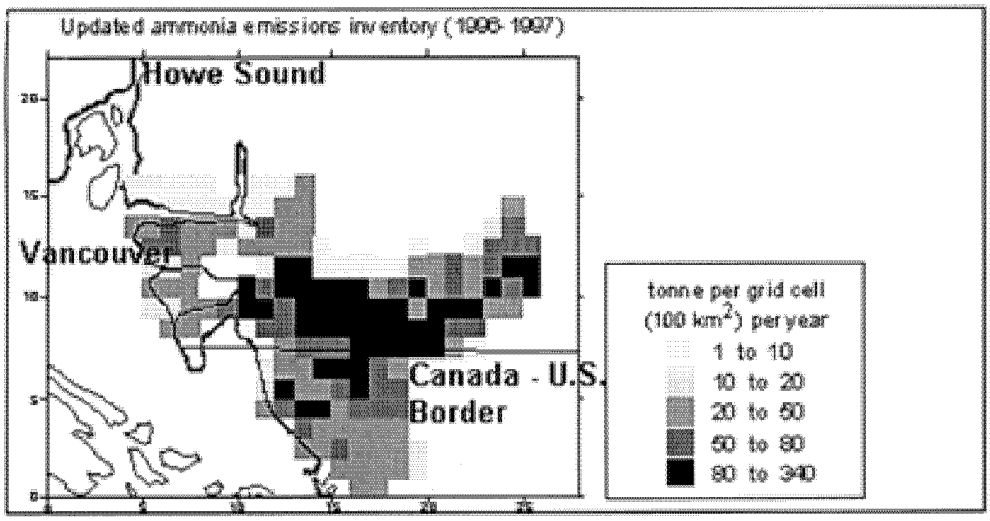
Figure 5 Ammonia air emissions inventory for the Lower Fraser Valley, 1996–1997



At distances greater than 500–800 m, the concentrations dropped to background for the Athens area (Giddens, 1975).

Nitrogenous air pollutants were monitored during three summer seasons (1988–1990) in a mixed coniferous stand at Whitaker Forest in the western Sierra Nevada Mountains, California. NH_4^+ deposition fluxes to ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) branches during the three summer seasons ranged from 17 to 67 kg/m^2 per year. During the 1990 summer season, NH_4^+ washed from branch surfaces provided 0.2 kg/ha per year. The estimated internal uptake of NH_3 was 0.6 kg N/ha per year. The elevated levels of air pollutants and nitrogen deposition could adversely affect the natural ecosystems of the western Sierra Nevadas (Bytnerowicz and Riechers, 1995).

Total inorganic nitrogen deposition in the most highly exposed forests in the Los Angeles Air Basin may be as high as 25–45 kg/ha per year. Nitrogen deposition in these highly exposed areas has led to nitrogen saturation of chaparral and mixed conifer stands. In nitrogen-saturated forests, high concentrations of nitrate are found in stream water, soil solution and foliage (Bytnerowicz and Fenn, 1996).

2.3.2.2.1 Case study: The Lower Fraser Valley

In the Lower Fraser Valley, deterioration of surface water, groundwater and air quality is a major environmental issue. There is particular concern about the potential for nitrate pollution of the Abbotsford/Sumas aquifer, which supplies both Canadian and U.S. drinking water in the area (Zebarth *et al.*, 1997), as well as a decline in the visible air quality around Vancouver (Hoff *et al.*, 1997; Pryor *et al.*, 1997a,b,c). The source of the nitrates is manure applied to fields in winter, and the cause of the reduced air quality is ammonium sulphate particulates. The valley has many farms and livestock facilities that contribute to both direct volatilization of NH_3 and local redeposition (Paul, 1997).

In order to conduct an ammonia modelling project, an NH_3 air emissions inventory was constructed using the latest census data available (1996) from both Canadian and U.S. sources (Jennejohn *et al.*, 1996; Barthelmie and Pryor, 1998). The ammonia emissions inventory for the Lower Fraser Valley in 1996–1997 is shown in Figure 5. Agriculture dominates NH_3 emissions in the Lower Fraser Valley, with an estimated generation of 5260 tonnes/year, while within the

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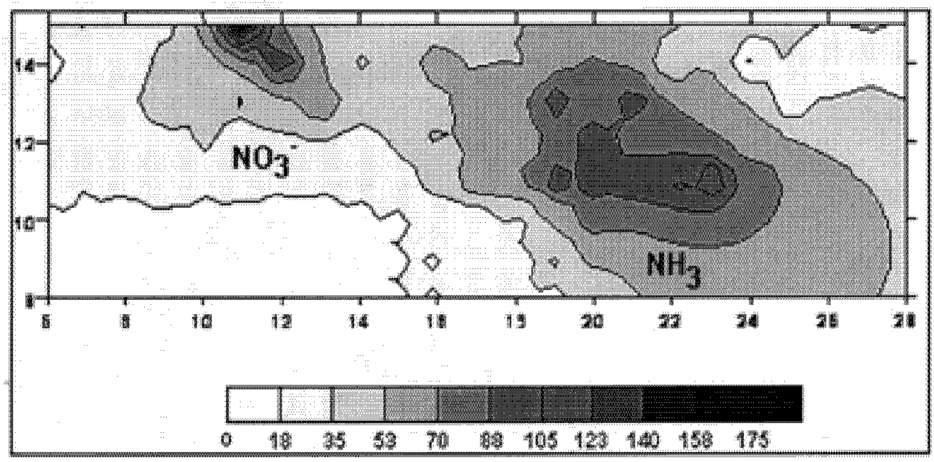
FIGURE 6 Modelled total nitrogen deposition (kg/ha per year) for the Lower Fraser Valley



Greater Vancouver Regional District 3511 tonnes/year are generated. Cattle contribute approximately half of the agricultural NH_3 emissions, poultry are the next major source and mineral fertilizer use contributes significantly (Barthelmie and Pryor, 1998). Approximately 8800 tonnes of ammonia come from the Canadian part of the valley and 2400 tonnes from the U.S. portion.

Since ammonia is chemically important to the production of atmospheric aerosols, understanding the concentrations and deposition of ammonia requires modelling the atmospheric chemistry of aerosols. The Inorganic and Secondary Organic Particle (ISOPART) model was used because it is a Lagrangian model with extensive chemistry and aerosol dynamics.

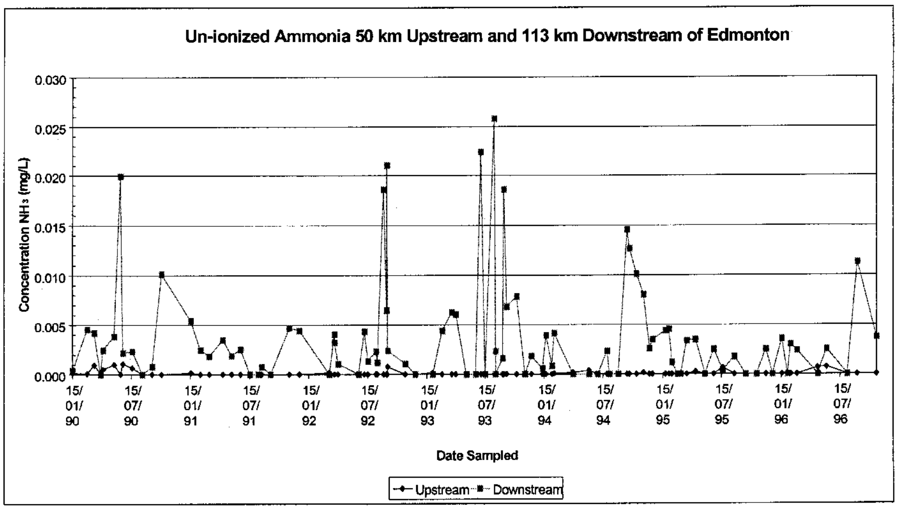
Atmospheric sampling relevant to the current application was undertaken (Hoff *et al.*, 1997). In addition to airborne monitoring, intensive ground-based sampling took place in the summer of 1993 during the Regional Visibility Experimental Assessment in the Lower Fraser Valley (REVEAL) campaign. Aerosol samplers were deployed at seven locations in the Fraser Valley to collect 24-hour averaged fine particulate and gas concentrations (Pryor *et al.*, 1997a,c).

A comparison of modelled near-surface and surface observed aerosol concentrations was performed for the afternoon of August 5, 1993. The areas of highest aerosol concentrations were observed east of Vancouver in the north-central valley in a band running from northwest to southeast. This pattern of aerosol concentrations was also predicted by ISOPART for this period (Pryor *et al.*, 1997b), giving confidence to the aerosol components of the model such that gaseous ammonia concentrations can be derived.

As expected, for NH_3, the highest concentrations were in the central and eastern portions of the valley, in mainly agricultural areas (the source region); the urban area of Vancouver is a source of NO_y (total nitrogen oxide compounds, including nitrate). Ammonium aerosol concentrations were high in a band from Greater Vancouver southeast towards the central valley, while nitrate concentrations were highest around Vancouver and in the central valley. It should be noted that the peak in NH_4^+ concentrations was associated with high sulphate concentrations.

Figure 6 shows total modelled nitrogen deposition in kg N/ha per year. For NH_3, the highest deposition is over the central and eastern portions of the valley, shown as the concentration area on

FIGURE 7 Un-ionized ammonia concentrations upstream and downstream of Edmonton



the right side of the figure (labelled NH_3); this is the source region for ammonia. NO_y deposition is primarily in Greater Vancouver and the highly urban portions of the domain, shown as the concentration area on the left side (labelled NO_3^-). Ammonium aerosol deposition is highest in a band from Greater Vancouver southeast towards the central valley, while nitrate deposition is highest east of Vancouver and over the downtown region. This pattern of nitrogen deposition is to be expected, as it represents two major and separate source regions. Ammonia is rapidly redeposited as a gas, but it is also relatively rapidly converted to the aerosol phase and both transported and deposited as NH_4^+. Estimated maximal ammonia deposition was 105 kg NH_3/ha per year in the rural portions of the Lower Fraser Valley. Most of the agricultural portion of the valley is subjected to a level of nitrogen deposition (primarily as ammonia) considerably greater than the critical load of 10 kg/ha per year (Figure 6). The grid numbers in Figure 6 correspond to the grid numbers in Figure 5.

2.3.2.3 Surface water

Natural waters typically contain little total ammonia, usually in concentrations below 0.1 mg/L. Assuming temperatures of 20°C (typical of times when risk is highest and which are the focus of the risk scenarios) and pHs in the 7–8 range, natural NH_3 levels are in the 0.0004–0.004 mg/L range. Higher concentrations may be an indication of anthropogenic input and organic pollution (CCREM, 1987). This tendency is shown in Figure 7 for waters above and below Edmonton. Above Edmonton, un-ionized ammonia was almost non-detectable (based on the detection limit for total ammonia); at 113 km downstream, un-ionized ammonia ranged as high as 0.026 mg/L and was consistently detected (Tchir, 1998). The highest concentration of un-ionized ammonia in Canadian municipal effluents was 0.68 mg/L, detected in effluents from the Annacis Island facility, Vancouver (Servizi *et al.*, 1978).

Data on ammonia concentrations in fresh waters were collected from federal and provincial monitoring agencies and were examined in order to identify hot spots. Detection limits for un-ionized ammonia must be calculated from the detection limit for total ammonia at a specific pH and temperature. As these two parameters change, the detection limit for un-ionized ammonia will fluctuate; therefore, non-detectable limits for un-ionized ammonia are simply noted as "<detectable." A general analysis of water quality

was received from the Ontario Ministry of Environment and Energy (OMEE, 1997). The average un-ionized ammonia concentration was 0.007 mg/L, with a median value of 0.0004 mg/L and range of <detectable–5.6 mg/L.

Only total ammonia concentrations were reported from across British Columbia (Ryan, 1998; Swain, 1998). They were generally very low, indicating perhaps the large dilution capacity of the rivers and lakes in the province. For the federal government monitoring sites, the average total ammonia concentration was 0.009 mg/L, with a median of 0.005 mg/L and a range of <0.002–0.48 mg/L. From the provincial monitoring sites, the average total ammonia concentration was 0.02 mg/L, with a median of 0.001 mg/L and a range of <0.002–8.4 mg/L.

The Northwest Territories and Nunavut also had extremely low ammonia concentrations in rivers, as would be expected for those territories. The average total ammonia concentration was 0.03 mg/L, with a median of 0.01 mg/L and a range of <0.002–0.68 mg/L (Halliwell, 1998).

There were 1225 samples from 66 sites for the three Prairie provinces from Environment Canada, primarily from interprovincial river sites in 1994 and 1995. Ammonia, temperature and pH measurements were taken so that un-ionized ammonia concentrations could be calculated (Chu, 1997). The average un-ionized ammonia concentration was 0.002 mg/L, with a median of 0.0006 mg/L and a range of <detectable–0.16 mg/L.

Alberta Environmental Protection provided detailed sampling data, but no temperature or pH values (Tchir, 1998). Many of the Alberta data indicated that cities and major industrial centres are elevating ammonia concentrations in the province's streams. The average total ammonia concentration was 0.23 mg/L, with a median of 0.03 mg/L and a range of <0.002–126 mg/L.

Manitoba Department of the Environment has taken water samples from 44 sites. The average un-ionized ammonia concentration was 0.002 mg/L, with a median of 0.0004 mg/L and a range of <detectable–0.21 mg/L (Williamson, 1998).

The City of Winnipeg supplied water quality monitoring data that it collects below each of its sewage treatment plants and downstream of Winnipeg at Lockport Dam (Ross, 1998). At the Fort Garry Bridge below the South End facility, the average un-ionized ammonia concentration was 0.012 mg/L; the median was 0.006 mg/L, with a range of <detectable–0.13 mg/L. At the Main Street Bridge, where the Assiniboine River joins the Red River, the average un-ionized ammonia concentration was 0.006 mg/L, the median was 0.003 mg/L and the range was <detectable–0.04 mg/L. At the North Perimeter Bridge on the Red River, the average un-ionized ammonia concentration was 0.017 mg/L; the median was 0.007 mg/L, with a range of <detectable–0.17 mg/L. At the Lockport Dam on the Red River, the average un-ionized ammonia concentration was 0.017 mg/L, the median was 0.01 mg/L and the range was <detectable–0.14 mg/L.

Two concentrations are available from the Lake Ontario sampling surveys done in 1992 and 1993. One is 0.96 mg/L, measured in Hamilton Harbour in 1992, and the other is 0.39 mg/L, measured in an area of east Toronto known as The Beaches, also taken in 1992 (Charlton, 1997).

Water from the centre of Hamilton Harbour has been analysed for ammonia since at least 1986; the results show routinely high concentrations of total ammonia, which builds up in the winter and degrades throughout the summer. This ammonia concentration process is the result of three municipal WWTPs depositing their effluents in the harbour, reduced water exchange in the harbour and the reduction in nitrifying bacteria in the winter. Environment Canada undertook a weekly survey in 1998 (January 6 – September 9) to determine the extent of ammonia concentrations throughout the harbour (Charlton and Milne, 1999).

At 1 m depth, the average un-ionized ammonia concentration was 0.023 mg/L; the median was 0.016 mg/L, with a range of

0.001–0.114 mg/L. These values all declined through the water column, so that at 19 m depth the average was 0.004 mg/L, with a median of 0.003 mg/L and a range of <detectable–0.012 mg/L.

The province of Quebec provided water quality data, including total ammonia, temperature and pH, for the years 1988–1998 (Dupont, 1998). Based on data for 16 372 samples, the average un-ionized ammonia concentration was 0.001 mg/L, the median was less than a detectable concentration (based on a total ammonia detectable limit of 0.002 mg/L) and the range was <detectable–0.69 mg/L. Many streams and rivers on the south shore of the St. Lawrence River have very high pH values in summer; this, combined with high summer temperatures, generates high un-ionized ammonia concentrations, even when there are relatively low concentrations of total ammonia. It appears that many of the streams with high average total ammonia concentrations are just north or south of Montréal or east of the Québec area on the south shore.

2.3.2.4 Soil runoff

Timmons and Holt (1977) determined the quantities and chemical composition of runoff from native (undisturbed by humans) prairie soils in Minnesota. Over 5 years, they determined that runoff from snowmelt accounted for 80% of the average annual ammonia in runoff. Rainfall caused appreciable runoff only in 1 year (37%). Dissolved ammonia losses ranged from 0.02 to 0.28 kg NH_3-N/ha in snowmelt, with rainfall-derived runoff containing 0.03 kg/ha in that year. The average loss of ammonia from native land was 0.13 kg/ha.

In a controlled deforestation study, Likens *et al.* (1970) showed that complete deforestation of a watershed in the eastern forests of New Hampshire had no effect on the runoff of ammonium. In watersheds that were not cut, the concentration of ammonium over 3 years in runoff ranged from 0.02 to 0.12 mg/L; in the cut watershed, the concentration of ammonium in the runoff ranged from 0.05 to 0.14 mg/L.

Data from 32 forested stream catchments in the Muskoka-Haliburton area of central Ontario, collected over 8 years, were used to develop regression models of long-term NH_4^+ export. There was a weak correlation between stream chemistry (including NH_4^+) and discharge for any site. Retention (defined as the fraction of annual deposition retained by the catchment) was very high (>0.87) for ammonium in all catchments. Deposition of NH_4^+ for the area was 4.794 kg NH_4^+/ha per year (Dillon *et al.*, 1991).

Animal husbandry can significantly elevate the runoff of ammonia from land. Cooke (1996) studied the variations in nitrogen runoff from various land types in Alberta. Under forested land, neither nitrate nor NH_4^+ concentration was high in surface runoff. Under cropland, nitrate dominated, its concentration approaching 50 times the NH_4^+ concentration. Under agricultural land with cattle grazing (25–100 head), runoff delivered 95% of NH_4^+ to streams. Only 2% of the nitrogen in cropland streams was ammonia, 43% of nitrogen in forest streams was ammonia and 89% of nitrogen in streams draining cattle operations was ammonia.

Peak NH_4^+ concentrations were 27 mg/L below cow-calf operations, while spring concentrations in the forested streams were below 1 mg/L. Flow-weighted mean concentrations of 1–2.3 mg/L for NH_4^+ and 0.15–0.2 mg/L for nitrate were detected below cow-calf operations in the spring.

A provincial stream survey in Alberta found that nutrient concentrations tend to be higher in streams that drain intensively farmed land than in streams that drain less intensively farmed land. Typical seasonal patterns were apparent: 1) highest concentrations were generally measured during spring runoff, 2) concentrations declined as flows subsided, and 3) later in spring and in summer, increases in nutrient levels (especially particulates) usually coincided with sudden increases in rainfall. These sudden concentration increases were more apparent in streams that drain land farmed with medium and low intensity, because rain-induced runoff occurred in these drainage basins, whereas none occurred in basins with high agricultural intensity (Anderson *et al.*, 1998b).

Application of manure to fields can be a cost-effective means of disposal of animal wastes and a cost-effective fertilizer; however, at some times of the year, application can be problematic for nearby watercourses. In Quebec, Gangbazo *et al.* (1995) determined that fall application of manure, as a fertilizer, created significant quantities of ammonia in runoff. The fall application of 360 kg manure-N/ha to corn increased ammonia in runoff from 1.9 to 3.4 kg N/ha. The runoff concentrations were elevated for at least 3 years. For surface application to forage, only the fall application of 110 kg manure-N/ha caused excessive ammonia in field runoff. Ammonia was elevated for 2 years over controls.

In Manitoba, Green (1996) studied the spring runoff of ammonia from hog manure surface-applied in the winter. Mean ammonia concentrations were considerably higher in runoff than in field pools. Meltwater from control fields contained 0.19–0.26 mg ammonia/L, while that from manured fields contained 8.5 mg/L. Concentrations of total ammonia in local rivers were relatively high, both upstream (0.32 mg/L) and downstream (0.34–0.52 mg/L) of the study site. There was no apparent impact on local watercourses from the application, despite the fact that substantial quantities of ammonia were leaving the site in runoff.

As part of a eutrophication study in Iowa, Jones *et al.* (1976) made detailed measurements of the concentrations of nutrients in runoff from 48 small and large watersheds. They also conducted an inventory of the animal densities in the watersheds, the types of animal holding facilities in each and the land use in each watershed. In watersheds of over 100 ha, ammonia in stream water was significantly correlated only with the animal units/ha in the watershed. The researchers determined that NH_3-N was increased by 0.77 ± 0.23 mg/L for each animal unit/ha within the watershed. They also determined whether animal placement within the watersheds influenced NH_3-N losses. The number of feedlot animal units/ha with drainage to streams or tile intakes was the only significant variable in the analyses. Jones *et al.* (1976) estimated that 0.96 ± 0.18 kg NH_3-N/ha were associated with each feedlot animal unit/ha with drainage to streams or tile intakes. Concentrations of ammonia in feedlot runoff averaged 6.5 mg/L, while runoff from soybean fields, cornfields and pastures was in the 0.75–1.0 mg/L range. There was no ammonia detected in tile runoff from fields.

Intensive dairy operations conducted in close proximity to streams have the potential to contaminate local watercourses with high levels of ammonia, especially if they have steep slopes to drainage. Daniel *et al.* (1982) showed this with a survey of three dairies in Wisconsin and an urban construction site. The runoff from an intensive dairy operation on a steep slope and in close proximity to a stream contained 5 mg ammonia/L, while runoff from dairies either far removed from streams or on flat land contained around 1 mg ammonia/L. Runoff from the construction site contained around 0.2 mg/L.

2.3.2.5 Soil

There are few data on naturally occurring concentrations of ammonia in Canadian soils. In general, natural ammonia levels in soil are very low (<1 mg/kg) due to the rapid conversion of ammonium to nitrite by *Nitrosomonas* species and then to nitrate by *Nitrobacter* species in the temperature range 0–35°C (Henry, 1995). In some areas of Canada, such as the Lower Fraser Valley, conditions may exist in winter where ammonia can build up in soil due to the application of manure to fields that are not frozen but are too cold for *Nitrosomonas* species to grow.

2.3.2.6 Groundwater

There are few data on concentrations of ammonia in Canadian groundwater. Ammonia contamination of groundwater is not usually an issue, as it is readily converted to positively charged ammonium ions that bind tightly to negatively charged cation exchange sites in soil. Ammonium is not sufficiently mobile in soil to create widespread groundwater contamination problems (Feth, 1966; Liebhardt *et al.*, 1979; Olson, 1997). In rare instances, nitrogen fertilizers, livestock wastes and septic tanks may contribute significant amounts of ammonia to shallow groundwater, especially those underlying poorly drained soils (Gilliam *et al.*, 1974; Rajagopal, 1978), those underlying feedlots and those in areas of groundwater recharge.

2.4 Effects characterization

Two types of biotic effects, direct and indirect, will be discussed in this section. Direct toxic effects from ammonia are those that directly impact on an individual — typically, death, reduced growth rate or reduced reproductive success. Indirect effects are those that typically affect ecosystems by altering the nutritional regime, in the case of eutrophication, or by altering some other physical parameter, like pH in the case of acidification. Negative effects on ecosystems usually take the form of shifts in dominant organisms, usually to ones more capable of exploiting the nutritional regime or withstanding altered physical parameters. In these cases, toxicity to organisms comes about indirectly but is still ultimately traceable to deposition of ammonia in some form. Abiotic effects mediated through the atmosphere — i.e., destruction of stratospheric ozone, formation of ground-level ozone and enhancing the greenhouse effect — are also discussed.

2.4.1 Effects on terrestrial plants

The toxicity of atmospheric ammonia to plants is a very active research area, with the wide-scale importance of the problem being recognized only in the late 1980s and early 1990s. Ammonia was found to be a contributor to forest decline and soil acidification in Europe only after the effects of sulphur and nitrogen oxides were fairly well known. The effects of ammonia stood apart from those of the other atmospheric pollutants because they were seen in lowlands and near livestock production. It is now well documented that visible effects and dieback within metres to kilometres of large livestock operations can be the result of NH_3 emissions.

Ecological effects of NH_3 deposition are most likely to be associated with nitrogen-poor settings, where plants adapted to low nitrogen supply are dominant (Heil and Diemont, 1983; Schjoerring *et al.*, 1998). Alpine and boreal regions may be most susceptible (Boxman *et al.*, 1988; Aber *et al.*, 1989; Bobbink *et al.*, 1992). Soils with low pH buffer capacity and a tendency to be acidic may be susceptible because of the acidifying effects of nitrification of NH_4^+ to nitrate (Schuurkes *et al.*, 1986). Also, the addition of ionic NH_4^+ may disrupt cation balances.

Short-term (<1 day) acute toxicity values for plants are not readily available; however, Van der Eerden (1982) published a graph of mass concentrations versus exposure time for the effects of ammonia on terrestrial plants from published literature values. Some terrestrial plants (deciduous and coniferous trees and crops like buckwheat, cauliflower, tomato and sunflower) were adversely affected (leaf necrosis, increased sensitivity to cold) after an hour-long exposure to air concentrations ranging from 25 to 50 mg/m^3 (25 000 – 50 000 µg/m^3).

2.4.2 Acute effects on freshwater organisms

Concentrations of ammonia that are toxic to aquatic organisms are generally expressed as un-ionized ammonia (NH_3), because NH_3 and not NH_4^+ has been demonstrated to be the principal toxic form of ammonia in the environment, with few exceptions.

Although a sizeable body of knowledge exists on acute, chronic and sublethal effects of ammonia on fish, there is less literature available on its effects on invertebrate species and benthic organisms. Data on concentrations of NH_3 that are toxic to freshwater phytoplankton and vascular plants, although limited, indicate that freshwater plant species are appreciably more tolerant of NH_3 than invertebrates or fish.

2.4.2.1 Algae

Experimental data on the toxicity of ammonia to freshwater phytoplankton and vascular plant communities are limited and contradictory, although that may be the result of variation in response from different species. Most studies reported total ammonia concentrations and did not report pH and temperature, so that it was not possible to calculate un-ionized ammonia concentrations. At relatively high concentrations (compared with exposure levels for fish), some algae and most aquatic macrophytes can use ammonia as a nutrient. At concentrations between 2 and 5 mg total ammonia/L, growth inhibition occurred in *Chlorella vulgaris*, whereas complete growth inhibition occurred at 5.5 mg/L and 50% lethality occurred around 9 mg/L for a 120-hour exposure (Przytocka-Jusiak, 1976). Bretthauer (1978) reported that a concentration (assuming pH 6.5 and 30°C) of 0.6 mg NH_3/L killed *Ochromonas sociabilis* and that development of the population was reduced at 0.3 mg/L (duration of tests not reported). Concentrations of 0.06–0.15 mg NH_3/L had an insignificant effect on growth, and concentrations of 0.015–0.03 mg NH_3/L enhanced growth. Studies have shown that ammonia at concentrations exceeding 2.5 mg NH_3/L inhibited photosynthesis and growth in the algal species *Scenedesmus obliquus* and inhibited photosynthesis in the algae *Chlorella pyrenoidosa*, *Anacystis nidulans* and *Plectonema boryanum* (Abeliovich and Azov, 1976).

2.4.2.2 Fish

Symptoms of acute toxicity of ammonia in fish are loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake, and, eventually, convulsions, coma and death.

Fish can tolerate high concentrations of un-ionized ammonia over a period of hours. As the exposure period extends, tolerance diminishes. Early studies with rainbow trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) (Grindley, 1946; Downing and Merkins, 1955; Lloyd and Herbert, 1960; Ball, 1967; Department of Scientific and Industrial Research, 1967; Brown *et al.*, 1969; Buckley, 1978; Thurston *et al.*, 1981a,b) reported the hours to 50% mortality for various exposure conditions. The relationship developed using the data from these studies describes the time to 50% mortality (LT_{50}) for a given exposure concentration (x, in mg NH_3/L) as:

$$LT_{50} = 4.7942 * x^{-1.7681} \text{ hours}$$

Conversely, for a given exposure period (x, in hours), the LC_{50} (concentration of un-ionized ammonia producing 50% mortality) can be determined:

$$LC_{50} = 1.7928 * x^{-0.3573} \text{ mg } NH_3/L$$

These relationships are valid for exposure periods between 30 minutes and 24 hours, since they are developed from a narrow range of high concentrations in water and a limited number of studies.

A few of the above studies have also reported the slope of the response relationships such that the LC_{10} could be estimated (Craig, 1999). Studies by Ball (1967), Brown *et al.* (1969) and Buckley (1978) demonstrate that between 3 and 48 hours, the LC_{10} is about 10% of the LC_{50}, as calculated by the above equation. As the duration of exposure increases, the percentage increases to about 70%, as illustrated by Broderius and Smith (1979) and reported by Lloyd (1961).

The species mean LC_{50} values for fish found in Canadian waters were calculated from data taken from Table 1 of the U.S. EPA (1985) water quality criteria document. Most of the acute tests were conducted in laboratories where concentrations were maintained at a constant

Table 4 Mean LC_{50}s for un-ionized ammonia in Canadian fish species

Common name	Species name	LC_{50}[1] (mg NH_3/L)	No. of studies	Minimum LC_{50} (mg NH_3/L)	Maximum LC_{50} (mg NH_3/L)
White perch	*Morone americana*	0.279	2	0.150	0.520
Mountain whitefish	*Prosopium williamsoni*	0.289	3	0.143	0.473
Chinook salmon	*Oncorhynchus tshawytscha*	0.442	3	0.399	0.476
Rainbow trout	*Oncorhynchus mykiss*	0.481	112	0.158	1.090
Pumpkinseed	*Lepomis gibbosus*	0.489	4	0.140	0.860
Coho salmon	*Oncorhynchus kisutch*	0.520	8	0.272	0.880
Cutthroat trout	*Oncorhynchus clarki*	0.642	4	0.520	0.800
Brown trout	*Salmo trutta*	0.657	3	0.597	0.701
Mountain sucker	*Catostomus platyrhynchus*	0.685	3	0.668	0.819
Walleye	*Stizostedion vitreum*	0.706	4	0.510	1.100
Golden shiner	*Notemigonus crysoleucas*	0.720	1		
Golden trout	*Oncorhynchus aguabonita*	0.755	1		
Brook trout	*Salvelinus fontinalis*	1.005	2	0.962	1.050
Smallmouth bass	*Micropterus dolomieu*	1.105	4	0.690	1.780
Largemouth bass	*Micropterus salmoides*	1.304	2	1.000	1.700
Fathead minnow	*Pimephales promelas*	1.344	45	0.240	3.440
White sucker	*Catostomus commersoni*	1.349	7	0.760	2.220
Mottled sculpin	*Cottus bairdi*	1.390	1		
Bluegill	*Lepomis macrochirus*	1.406	15	0.260	2.970
Spotfin shiner	*Cyprinella spiloptera*	1.479	3	1.200	1.620
Channel catfish	*Ictalurus punctatus*	1.707	14	0.500	4.200
Stoneroller	*Comostoma anonalum*	1.720	1		
Green sunfish	*Lepomis cyanellus*	1.860	6	0.590	2.110

[1] LC_{50} is the geometric mean when more than one study result is reported.

level, and after 48–96 hours mortality would not change. The species acute mean un-ionized ammonia concentrations are the geometric mean of LC_{50}s reported for respective species in the U.S. EPA (1985) document. The resulting values are presented in Table 4 along with the number of studies used to calculate the species mean LC_{50} and the minimum and maximum LC_{50} reported among the studies for that species. Species that are reported in Table 4 of U.S. EPA (1985) but are not indigenous to Canada have been excluded from Table 4.

Species mean LC_{50} values range from 0.28 mg NH_3/L for white perch (*Morone americana*) to 1.86 mg NH_3/L for green sunfish (*Lepomis cyanellus*). Certain sensitive species are localized, such as white perch, which are usually found in brackish waters on the Atlantic coast but have also been reported in Lake Ontario and the Bay of Quinte (Scott and Crossman, 1973). Mountain whitefish (*Prosopium williamsoni*) are also restricted to western Alberta and are widespread in British Columbia (Scott and Crossman, 1973). Salmonids are widespread and represent the next most sensitive group of species.

TABLE 5 Mean LC_{50}s for un-ionized ammonia in invertebrate species

Common name	Species name	LC_{50} [1] (mg NH_3/L)	No. of studies	Minimum LC_{50} (mg NH_3/L)	Maximum LC_{50} (mg NH_3/L)
Daphnid	*Daphnia pulicaria*	1.160	1		
Cladoceran	*Simocephalus vetulus*	1.185	2	0.613	2.29
Fingernail clam	*Musculium transversum*	1.191	3	0.93	1.29
Flatworm	*Dendrocoelum lacteum*	1.400	1		
Daphnid	*Daphnia magna*	1.613	12	0.53	4.94
Mayfly	*Callibaetis* sp.	1.800	1		
Snail	*Physa gyrina*	1.961	5	1.59	2.49
Stonefly	*Arcynopteryx parallela*	2.030	2	2.00	2.06
Scud	*Crangonyx pseudogracilis*	2.316	5	1.63	5.63
Worm	*Tubifex tubifex*	2.700	1		
Snail	*Helisoma trivolvis*	2.760	1		
Crayfish	*Orconectes nais*	3.150	1		
Mayfly	*Callibaetis skokianus*	4.829	3	3.86	5.88
Isopod	*Asellus racovitzai*	4.950	1		
Beetle	*Stenelmis sexilneata*	8.000	1		
Caddisfly	*Philarctus quaeris*	10.200	1		

[1] LC_{50} is the geometric mean when more than one study result is reported.

2.4.2.3 Invertebrates

A number of invertebrate acute lethality studies are also referenced in the U.S. EPA (1985) water criteria document and presented in Table 5; concentrations are similar to those found for fish.

The species mean LC_{50} values for invertebrates range from 1.2 mg NH_3/L for the cladoceran species and fingernail claim (*Musculium transversum*) to as high as 10.2 mg NH_3/L reported for caddisfly larvae. The more sensitive invertebrates appear to be the pelagic cladocerans, while the epibenthic and benthic organisms appear more tolerant. The sensitivity of invertebrates to ammonia as a group overlaps with the median of most tolerant fish species.

2.4.3 Sublethal effects on freshwater organisms

Sublethal effects occur at concentrations and over extended periods that do not result in acute lethality to the organism, but can affect the population of species and community characteristics. The most evident responses are integrative and are exhibited by reductions in growth (length or weight) or are related to reproductive success (egg production, hatching, larval survival). Other effects, such as behavioural responses, tissue damage (e.g., pathological changes in the tissue of the gills, liver and kidney of fish) or biochemical or physiological changes, can affect the individual but in most cases are reversible and will not necessarily change the character of the community. The concentrations at which these sublethal responses occur are presented in Table 6.

2.4.4 Acute and sublethal effects on saltwater organisms

Available acute and chronic ammonia toxicity data for saltwater organisms are more limited than those for freshwater organisms. The U.S. EPA (1989) published a review on the saltwater toxicity of ammonia, much of which is reported in Table 7.

TABLE 6 Summary of mean sublethal endpoints in freshwater species

Common name	Species name	EC_{20} [1] (mg NH_3/L)	No. of studies	Min. EC_{20} (mg NH_3/L)	Max. EC_{20} (mg NH_3/L)	Reference
Scud	*Hyalella azteca*	0.051	1			Borgmann, 1994
Sockeye salmon	*Oncorhynchus nerka*	0.057	1			Rankin, 1979
Rainbow trout	*Oncorhynchus mykiss*	0.090	4	0.018	0.181	Burkhalter and Kaya, 1977; Broderius and Smith, 1979; Calamari *et al.*, 1981; Solbé and Shurben, 1989
Fathead minnow	*Pimephales promelas*	0.173	3	0.105	0.247	Swigert and Spacie, 1983; Mayes *et al.*, 1986; Thurston *et al.*, 1986
Walleye	*Stizostedion vitreum*	0.189	2	0.179	0.199	Hermanutz *et al.*, 1987
Bluegill and Pumpkin Seed	*Lepomis macrochirus* and *L. gibbons*	0.239	3	0.060	0.553	Reinbold and Pescitelli, 1982; McCormick *et al.*, 1984; Smith *et al.*, 1984
Leopard frog	*Rana pipiens*	0.270	1			Diamond *et al.*, 1993
Catfish	*Ictalurus punctatus*	0.290	6	0.162	0.487	Colt and Tchobanoglous, 1978; Reinbold and Pescitelli, 1982; Swigert and Spacie, 1983; Hermanutz *et al.* , 1987; Bader and Grizzle, 1992
Smallmouth bass	*Micropterus dolomieu*	0.321	2	0.301	0.343	Broderius *et al.*, 1985
Green sunfish	*Lepomis cyanellus*	0.553	1			Reinbold and Pescitelli, 1982
Amphipod	*Crangonyx*	0.370	1			Diamond *et al.*, 1993
	Ceriodaphnia dubia	0.520	1			Nimmo *et al.*, 1989
	Daphnia magna	0.759	2	0.607	0.950	Reinbold and Pescitelli, 1982; Gersich *et al.*, 1985

[1] EC_{20} is the geometric mean when more than one study result is reported.

2.4.4.1 Acute toxicity

Cheung and Wong (1993) found that relatively unpolluted and heavily polluted sediments dredged from around Hong Kong were both highly toxic to the marine clam, *Tapes philippinarium*. A correlation coefficient of 0.99 at $p < 0.001$ was determined between mortality and ammonia concentrations in the seawater in tests with the relatively unpolluted sediments, and from 0.92 to 0.96 at $p < 0.001$ for the heavily polluted sediments. The total ammonia

TABLE 7 Ranked mean acute toxicity values for un-ionized ammonia

Species	Mean LC_{50} or EC_{50} (mg NH_3/L)	Temperature (°C)	Salinity (‰)	pH
Winter flounder, *Pseudopleuronectes americanus*	0.49	7.5	31	8.0 (7.9–8.1)[1]
Red drum, *Sciaenops ocellatus*	0.55	25 (25–26)[1]	29 (28–30)[1]	8.1 (8.0–8.2)[1]
Sargassum shrimp, *Latreutes fucorum*	0.77	23.4	28	8.07
Prawn, *Macrobachium rosenbergii*	0.78	28	12	7.6 (6.8–8.3)[1]
Planehead filefish, *Monocanthus hispidus*	0.83	23.4	28	8.07
Copepods:				
Eucalanus elongatus	0.87	20.3	34	8.0
Eucalanus pileatus	0.79	20.5	34	8.2
Morone spp.:				
Striped bass, *M. saxatilis*	0.48	19.3 (15–23)[1]	12.9 (5–34)[1]	(7.2–8.2)[1]
White perch, *M. americana*	2.13	16	14	8.0
Mysid, *Mysidopsis bahia*	1.02	23.2 (19.3–26.5)[1]	21.4 (10–31)[1]	(6.8–9.2)[1]
Spot, *Leiostomus xanthurus*	1.04	20.4	9.3	79.2
Silversides:				
Inland, *Menidia beryllina*	1.32	25.3 (18–32.5)[1]	26.1 (11–31.5)[1]	(6.9–9.1)[1]
Atlantic, *Menidia menidia*	1.05	20.3 (10.8–24.8)[1]	11.6 (8.5–29.8)[1]	8.0 (7.0–9.0)[1]
Striped mullet, *Mugil cephalus*	1.54	21.8 (21.0–23.3)[1]	10	8.1 (8.0–8.1)[1]
Grass shrimp, *Palaemonetes pugio*	1.65	19.9 (19.3–20.4)[1]	19.2 (10–28.4)[1]	8.1 (7.9–8.1)[1]
Sea bream, *Sparus auratae*	1.88	22.5 (17.9–27)	37.5 (34.5–40.5)	8.1
At dissolved oxygen levels:				
93% saturation	1.93	27	40.5	8.1
61% saturation	1.28			
33% saturation	0.97			
26% saturation	0.41			
Lobster, *Homarus americanus*	2.21	21.9	33.4	8.1
Sheepshead minnow, *Cyprinodon variegatus*	2.74	21.0 (10.3–32.5)[1]	19.4 (9.8–32.5)[1]	(7.6–8.1)[1]
Three-spined stickleback, *Gasterosteus aculeatus*	2.93	19 (15–23)[1]	26.3 (11–34)[1]	(7.6–8.2)[1]
Turbot, *Scophthalmus maximus*	2.96	17.9 (17–18.8)	34.3 (34.0–34.5)	8.15
Brackish water clam, *Rangia cuneata*	3.08	20.2	9.2	7.95

TABLE 7 (continued)

Species	Mean LC_{50} or EC_{50} (mg NH_3/L)	Temperature (°C)	Salinity	pH
Mudskippers:				
Periophthalmodon schlosseri	9.13	25	15	N/A
Boleophthalmus boddaertid	1.02	25	15	N/A
Quahog clam, *Mercenaria mercenaria*	5.36	20	27	(7.7–8.2)[1]
Lake Magadi tilapia, *Oreochromis alcalicus grahamic*	11.47[2]	34	N/A	9.9
Eastern oyster, *Crassostrea virginica*	19.10	20	27	(7.7–8.0)[1]

[1] Mean (range) values for temperature, salinity or pH calculated when values from original text were given individually. When only ranges were given in original text, mean was not calculated.

[2] Average of LC_{50} values at 24 and 48 hours.

concentration in seawater at the ET_{50} (time to 50% effect; 14–15 days) was 10–11 mg/L in both sediment systems.

In published literature, mean LC_{50} values for marine invertebrate species found in North American waters range from 0.77 to 19.1 mg NH_3/L; for marine fish species, they range from 0.49 to 2.9 mg NH_3/L (see Table 7). The winter flounder (*Pseudopleuronectes americanus*) had the most sensitive acute toxicity value of 0.49 mg/L. The remaining genera tested have mean acute values within an order of magnitude of that for the winter flounder. The three most tolerant North American species reported by the U.S. EPA (1989) are molluscs. Species mean acute values of 3.08, 5.36 and 19.1 mg/L were reported for the brackish water clam (*Rangia cuneata*), the quahog clam (*Mercenaria mercenaria*) and the eastern oyster (*Crassostrea virginica*), respectively. Except for these molluscs, there is no phyletic pattern in acute sensitivity to ammonia. Fishes and crustaceans are well represented among both the more sensitive and the more tolerant species tested.

Few consistent trends or patterns were evident in the acute toxicity values with respect to biological or environmental variables. Contributing to this, in part, is test variability. Variability in acute toxicity values may reflect differences in condition of the test organisms, changes in the exposure conditions, particularly pH, during testing, and variance incurred through calculation of un-ionized ammonia concentrations. Few differences are evident in acute toxicity at different salinities in tests with similar life stages and similar pH and temperature conditions. Temperature also has little influence on acute ammonia toxicity to most saltwater animals. There are few differences in acute toxicity with respect to differences in life stage or size of the test organism (U.S. EPA, 1989). Several data sets on the effect of pH on the toxicity of un-ionized ammonia suggest that, unlike the data on freshwater species, the pH–toxicity relationship is not consistent between species.

The U.S. EPA (1989) concluded that there was insufficient information to conclude that any of these factors, when acting alone, has a consistent major influence on the acute toxicity of NH_3 to saltwater organisms.

2.4.4.2 Sublethal toxicity

The U.S. EPA (1989) also reported on unpublished chronic toxicity tests, but with only two saltwater species, neither of which is native to Canada. A life cycle toxicity test has been conducted with the mysid, *Mysidopsis bahia*, and an early life stage test has been completed with the inland silverside (*Menidia beryllina*).

The *M. bahia* test lasted 32 days and was reported in Cardin (1986). Survival was reduced to 35% of controls, and length of test organisms was significantly reduced at 0.33 mg NH_3/L.

The effect of ammonia on survival and growth of the inland silverside *M. beryllina* was assessed in an earlylife stage test lasting 28 days (Poucher, 1986). Fry survival was reduced to 40% at 0.38 mg/L. Average weights of surviving fish at concentrations above 0.074 mg/L were significantly less than that of controls.

2.4.5 Ecosystem effects

This section focuses on effects of ammonia on whole ecosystems, where the impact is not direct toxicity of ammonia. The two major processes found are acidification of soft waters and eutrophication of aquatic and terrestrial ecosystems.

A well-documented effect of human impact upon aquatic ecosystems is eutrophication, a multifaceted term generally associated with increased productivity, structural simplification of biotic components, and a reduction in the ability of the metabolism of the organisms to adapt to imposed changes (reduced stability). In this condition of eutrophication, excessive inputs commonly seem to exceed the capacity of the ecosystem to be balanced. In reality, however, the systems are out of equilibrium only with respect to the freshwater chemical and biotic characteristics desired by humans for specific purposes (Wetzel, 1983).

Acidification of water by ammonium sulphate deposition is a strong reaction, stronger than the addition of sulphuric acid. This is due to the nitrification of the ammonium molecule, releasing hydrogen ions, in addition to the release of the acidic sulphate molecule.

2.4.5.1 Freshwater eutrophication

The material presented on aquatic and marine coastal eutrophication is from a review of the literature on the causes and conditions of aquatic eutrophication in Canada, prepared for Environment Canada (Chambers *et al.*, 2000).

Nutrients are essential to lakes because they provide the raw material for the growth of algae, which are the food sources of zooplankton, which, in turn, are eaten by fish. The concentration of nutrients in a lake is determined by the interplay of the magnitude, timing and bioavailability of the nutrient load, the rate of water supply compared with the volume of the lake (flushing time) and the depth of the lake.

In lakes and rivers not affected by nutrient inputs, the nutrient cycling processes are typically in balance. However, with the excessive input of nutrients, like ammonia and dissolved phosphorus, these processes become unbalanced, usually resulting in large standing crops of algae and plants. The phytoplankton have a high total respiration demand, reducing oxygen concentrations and generating toxins (depending on the algal species present) that can suppress herbivorous plankton. The inevitable die-off of algae in late summer increases the bacterial populations tremendously, which can also increase toxins in the water and will severely decrease the dissolved oxygen content to the point where fish can be killed. Over the long term, elevated eutrophic rates can alter the biological community towards organisms more tolerant of shaded, oxygen-deficient waters.

In most Canadian lakes, phosphorus is the nutrient that is most in demand, and algal growth in the majority of lakes is therefore said to be phosphorus limited. Discovering this relationship led to the significant reduction in releases of phosphorus from municipal water treatment plants, largely through the regulation of phosphorus in detergents and the chemical precipitation of phosphorus in the plants prior to discharge. Major improvements in water quality resulted from these actions.

The role of ammonia in aquatic eutrophication is as a source of nitrogen for the generation of nitrates that are directly usable by algae and aquatic plants. In lakes that receive continuous inputs of ammonia and phosphorus (secondary sewage treatment facilities typically release both), the nitrification process can be operating at a maximum in summer, so that the lakes are enriched in nitrates and phosphorus, leading to lush growths of algae and rooted plants. In the fall, the die-off of algae and plants depletes oxygen and creates a harsh environment for fish. In water systems that receive ammonia but not phosphorus, the nitrification process will still be at a maximum, but, due to the deficiency in phosphorus, they have limited algal and macrophytic growth. In these cases, eutrophication does not proceed, but the concentrations of ammonia and nitrates can rise to toxic levels and can still lead to severely depleted oxygen conditions from the nitrification process. Still other lakes are truly limited by nitrogen; one such system in Canada is the Qu'Appelle Lakes in southern Saskatchewan (see Section 3.1.2.2.3).

2.4.5.2 Coastal marine eutrophication

In the last 20 years, the causes and extent of coastal eutrophication have been increasingly recognized as a global problem (Howarth, 1988; Vollenweider, 1992; NRC, 1993; UNEP, 1995; Paerl, 1997). Coastal areas, including fjords, estuaries, lagoons, continental shelves and inland seas, comprise 1–2% of the total area of the ocean, yet are responsible for 20% of global primary production (Duarte, 1995). These regions receive the bulk of their nutrient inputs from freshwater sources (i.e., terrestrial runoff, rivers and groundwater). The natural background levels of nutrient concentrations of these inputs are normally much higher than those of even the most eutrophic seawater (Dederen, 1992).

Nitrogen is generally the nutrient limiting primary production in the open ocean, in contrast with fresh waters, where phosphorus is typically the limiting nutrient (Howarth, 1988; Vollenweider, 1992). It is in the coastal zone where nutrient-rich freshwater inputs are diluted into the nutrient-poor saline environment of the open ocean. In these highly dynamic transitional waters, either phosphorus or nitrogen limitation can occur, depending on a set of complex interactions.

In recent decades, nitrogen and phosphorus transport to coastal waters has increased (Howarth *et al.*, 1996) and is correlated with various indices of human activity in the watershed (Cole *et al.*, 1993; Caraco, 1995; Howell *et al.*, 1996; Vitousek *et al.*, 1997). If nitrogen is measured, then most of the inputs to coastal waters are derived from non-point sources, typically as nitrate (NRC, 1993).

Evidence from the northern hemisphere indicates that over-enrichment of coastal waters has created a niche occupied by a diverse group of dinoflagellates and diatoms that, like their counterparts in eutrophic lakes (the blue-green algae), produce toxic chemicals (Burkholder *et al.*, 1992). Marine algae have been found responsible for at least four different illnesses in human consumers of molluscs as well as massive mortality of fish, birds and marine mammals (Paerl, 1997). The occurrence of these "harmful algal blooms" has resulted in the closure of shellfisheries, resulting in large economic impacts on coastal communities. The exact cause of these blooms is not clear, although they tend to follow periods of intense rainfall, runoff and intense irradiation from sunlight (Smayda, 1997).

Eutrophication of Canada's east and west coasts is not occurring at present. There are some indications that coastal areas around Vancouver and Halifax are impacted as a result of sewage effluents, but these are not eutrophication issues. This situation will likely remain as long as anthropogenic nutrient loading does not increase substantially (Chambers *et al.*, 2000).

2.4.5.3 Terrestrial eutrophication

Among the mineral elements, nitrogen is required in the largest amount by plants; very often growth is limited by its supply. When more nitrogen is added, plants grow more rapidly, and the nitrogen in the increased plant biomass is effectively retained by the ecosystem. In addition, plants can accumulate nitrogen, as nitrate, in tissues in excess of the specific nutritional requirements. Ecologically, this may be an adaptation to deal with a chronically low nitrogen supply. In effect, plant growth responds to increased nitrogen supply until nitrogen is no longer the limiting factor for growth. Nitrogen-deficient ecosystems can tolerate, even benefit from, periodic excessive doses of nitrogen; however, metabolic imbalances can occur if the excessive nitrogen levels occur for too long.

Nitrogen addition has the potential to affect many attributes of the terrestrial environment, not all of which are well understood. Among the indirect effects, increased leaching of nitrate from soils is one of the more obvious. The concept of "nitrogen saturation" has been used to describe the level of nitrogen in an ecosystem that maximizes the retention within the ecosystem (Aber *et al.*, 1989). Additions above this limit result in nitrate leaving the ecosystem in amounts that could be detrimental downstream. This concept is based on the observation that ecosystems cycle nitrogen very efficiently.

Critical loads of ammonia were established in Europe to avoid two general types of effects. One was the leaching of nitrogen, typically as nitrate, from ecosystems that normally are very conservative in nitrogen cycling. The other general effect to be avoided is the shift in dominance among species, especially in nitrogen-poor environments (Schulze *et al.*, 1989; Bobbink *et al.*, 1992; De Vries, 1992). Some other indirect effects are subtle, such as the loss of mycorrhizal fungi associated with conifer tree roots (Pérez-Soba *et al.*, 1995). The critical loads for nitrogen promulgated by the Dutch Priority Programme on Acidification ranged from 9.8 to 42 kg/ha per year, with the lowest values of this range associated with avoiding changes in species composition in coniferous forests (Lekkerkerk *et al.*, 1995).

2.4.5.4 Acidification

Deposition of ammonium sulphate, the most common form of ammonia particulate, will generate considerable quantities of acid, as eight hydrogen ions may be released during nitrification. The Dutch, Belgians, Norwegians and Germans have found that excessive quantities of ammonium sulphate are having adverse impacts on poorly buffered soils and waters in close proximity to large sources (Schuurkes, 1986; Schuurkes *et al.*, 1986; Gjessing, 1994).

In long-term, indoor, soft-water ecosystem studies, Brouwer *et al.* (1997) showed that acidification of an ecosystem was greater when ammonium sulphate was deposited in rainfall than when sulphuric acid was deposited. This is due to the nitrification of the ammonium, releasing extra hydrogen ions into the ecosystem. Increased levels of dissolved metals were detected, as well as shifts in the plant community. Plants typical of soft waters declined and were overgrown by *Sphagnum* species and *Juncus bulbosus*. The recovery of the impacted ecosystems was also different; the sulphuric acid system recovered quickly, but the ammonium sulphate ecosystems did not fully recover after 10 years of clean water. The ecosystems most sensitive to such acidic inputs are found on the Canadian Shield throughout much of eastern Canada. There has been little in the way of ammonium particulate monitoring within the Canadian acid monitoring program, so the contributions of ammonia to acidification in Canada are not known.

2.4.6 Abiotic effects mediated through the atmosphere

Ammonia is the most prevalent alkaline gas in the atmosphere, as well as the third most common form of nitrogen in the troposphere. Because of its high reactivity, ammonia readily combines with acidic chemical species, such as hydrochloric acid, nitric acid or sulphuric acid, forming ammonia aerosols. Klemm and Gray (1982) determined that the acidity of rainfall in Alberta was determined as much by the presence of alkaline species (calcium and ammonium ions) as by the absence of acidic species (sulphur and nitrogen oxides). Even so, un-ionized ammonia as an atmospheric gas itself is rather passive: it either deposits quickly near sources or is converted to particulate form. As a result, particulates can be transported long distances, affecting tropospheric aerosol loading and thus issues of visibility, smog and climate.

An important connection for air quality issues, therefore, is the conversion of ammonia gas into the aerosol form, increasing tropospheric loading of respirable particulate matter, PM_{10} and $PM_{2.5}$. Ammonia in the atmosphere can determine the type and quantity of fine particulate matter. The chemically preferred form for sulphate is ammonium sulphate, solid or aqueous. However, competition between sulphate and nitrate for the available ammonia produces complicated aerosol behaviour. In areas with low concentrations of atmospheric ammonia, most particulate matter will be acidic, as there is insufficient ammonia to neutralize the available sulphate. In areas with high ammonia concentrations, however, any ammonia that does not react with sulphate will be able to react with available nitrate, forming ammonium nitrate aerosols. PM_{10} and $PM_{2.5}$ have been determined to be "toxic" to humans under CEPA 1999, so effects of ammonia-containing particulate matter are not considered in this report. Table 8 lists other air issues that are connected to atmospheric ammonia.

2.5 Toxicokinetics, mode of action and metabolism

2.5.1 Freshwater fish

This information is derived from an unpublished review (Randall, unpublished), used with the author's permission.

Most biological membranes are permeable to NH_3, but not NH_4^+. Ammonia is excreted by diffusion across the body surface of most aquatic animals, usually the gills, although there may be some carrier-mediated excretion of NH_4^+ in some species. The rate of NH_3 excretion is determined by the magnitude of the NH_3 gradient between blood and water (Wilson *et al.*, 1994). Ammonia excretion is augmented by acidic conditions in the water, because any NH_3 excreted into the water is rapidly converted to and trapped as NH_4^+, maintaining the NH_3 gradient across the gills and augmenting ammonia excretion. Many freshwater fish actively excrete protons, forming an acid boundary layer next to the gill surface (Lin and Randall, 1991), and this augments ammonia excretion (Wright *et al.*, 1989). Above water pH 9.0, ammonia excretion is reduced because of the absence of ammonium ion trapping (Wright *et al.*, 1989), resulting in elevated plasma ammonia levels (Yesaki and Iwama, 1992). Thus, many animals have difficulty excreting ammonia when exposed to alkaline conditions.

2.5.2 Marine fish

Ammonium ion diffusion across the gills may be significant in seawater teleost fish, where ionic permeability is high (Evans, 1984).

The body surface of marine animals is generally more permeable to ions than that of freshwater animals (Evans, 1984). Thus, the passive flux of ammonium ions is likely to be greater in marine animals. There is also evidence for the active excretion of ammonium ions in the mudskipper, *Periophthalmodon schlosseri* (Randall *et al.*, 2000).

TABLE 8 Ammonia connections to other air issues

Air issue	Major atmospheric gases	Ammonia role	Sensitivity
Stratospheric ozone depletion	Chlorofluorocarbons, hydrochlorofluorocarbons	Too reactive a species for stratospheric chemistry	Minimal
Climate change	Carbon dioxide, nitrous oxide, methane, water	May influence global aerosol concentrations	Minimal
Ground-level ozone (smog)	Oxides of nitrogen, volatile organic compounds	Participates in nitrogen chemistry	Minimal
Acid deposition	Sulphates, nitrates, ammonia	Soil/water acidifier through nitrogen cycle; participates in sulphur dioxide oxidation by ozone	Moderate
Hazardous air pollutants (toxics)	Organic compounds and heavy metals	May enhance particulate matter pathway for dispersion of hazardous air pollutants	Moderate
Particulate matter ($PM_{2.5}$ and PM_{10})	Sulphates, nitrates, ammonia, volatile organic compounds	Reacts with acid gases to form hygroscopic salts	High

There is no clear evidence that water pH is modulating toxicity in marine species. It is possible that, because of the increased ammonium ion permeability, the relationship between water pH and ammonia toxicity is minimal. That is, there is no a priori reason to assume that pH will modulate ammonia toxicity in the marine environment. There is a paucity of data on the effects of water pH on ammonia toxicity in the marine environment.

2.5.3 *Accumulation in aquatic organisms*

Accumulation of ammonia in the body can be due to either the inability to excrete or convert nitrogenous wastes or a net influx of NH_3 from the environment. Externally, the concentration of NH_3, rather than NH_4^+, is of concern, as biological membranes are permeable to NH_3 but much less so to NH_4^+. Consequently, NH_3, but not NH_4^+, diffuses readily across the external surface into the body. As a result, if NH_3 levels are high in the environment, ammonia levels in exposed animals increase as well. In acid water, nearly all ammonia is as NH_4^+, and the rate of ammonia entry into the fish is low. As pH increases to more alkaline conditions and water pH approaches the pK (9.2–9.5) of the ammonia/ammonium ion reaction, toxicity increases significantly for many species due to the shift in equilibrium to the more diffusable NH_3 form. Water of pH above 9.5 can be toxic, even though it contains little or no ammonia, because ammonia levels rise to toxic levels in the fish as a result of impaired excretion.

2.5.4 *Factors affecting the aquatic toxicity of ammonia*

Several factors have been shown to modify the acute toxicity of ammonia to freshwater organisms. Some factors alter the concentration of NH_3 in the water by affecting the aqueous ammonia equilibrium, while other factors affect the toxicity of NH_3 itself, either ameliorating or exacerbating its effects. Factors that have been shown to affect ammonia toxicity include temperature, pH, dissolved oxygen concentration, ionic concentration, previous acclimatization to ammonia, fluctuating or intermittent exposure, carbon dioxide concentration, salinity and the presence of other toxic substances. The best studied of these is pH; the acute toxicity of NH_3 has been shown to decrease as pH decreases (becomes more acidic). Data on temperature effects on acute toxicity are limited and variable; the U.S. EPA (1998) recently released revised water quality guidelines for ammonia for which they reviewed the data on temperature. The effects of dissolved oxygen are probably more important than the effects of temperature, with increased toxicity at lower dissolved oxygen concentrations (Thurston *et al.*, 1981a). All of these factors may come into play in any water body. The pH of most rivers fluctuates with season, as does temperature. Dissolved oxygen will inversely follow the temperature variations, with less oxygen dissolved at high temperatures, exacerbating the toxicity effect from temperature. In Canadian waters, pH values usually rise in summer as the temperature increases and the dissolved oxygen content decreases. Downstream of municipal outfalls, there is often an oxygen sag as nitrification of ammonia and other biological processes use up the available oxygen, making the in-plume region more hazardous for organisms.

2.5.4.1 pH

The toxicity of aqueous solutions of ammonia and ammonium compounds to fish has been attributed to NH_3 present in the solution. The pH correlation with toxicity of ammonia was assumed to be based on the aqueous ammonia equilibrium. Thurston *et al.* (1981b) tested the toxicity of ammonia to rainbow trout (*O. mykiss*) and fathead minnows (*Pimephales promelas*) in 96-hour flow-through bioassays at different pH levels within the range 6.5–9. Results showed that the toxicity of ammonia, in terms of NH_3, increased at lower pH values and could also increase at higher pH values. It was concluded either that NH_4^+ exerts some measure of toxicity or that increased hydrogen ion concentration increases the toxicity of NH_3. The U.S. EPA (1998) reviewed the extant toxicity data and came to the conclusion that "all of the datasets show a strong trend of total ammonia LC_{50}s decreasing with increasing pH." This confirms the concept that ammonia is more toxic at basic pHs.

2.5.4.2 Temperature

Information on the correlation between temperature and toxicity of ammonia is varied, but the two appear to have an inverse relationship. The toxicity of ammonia is greater at colder temperatures, the reverse of what would be expected based solely on the aqueous ammonia equilibrium. After the U.S. EPA (1998) reviewed the data for their recent water quality criterion document on ammonia, they concluded that temperature had a minor effect on toxicity and decided that they would not use it in their calculation of a water quality criterion. Thurston and Russo (1983) reported an inverse relationship between temperature and toxicity for rainbow trout (*O. mykiss*) over the temperature range 12–19ºC. Thurston *et al.* (1983) reported a similar decrease in toxicity with increasing temperature in fathead minnow (*P. promelas*) over the temperature range 12–22ºC. A similar relationship was found by Reinbold and Pescitelli (1982) in rainbow trout, bluegill (*Lepomis macrochirus*) and fathead minnow, while Colt and Tchobanoglous (1978) found a similar relationship in channel catfish (*Ictalurus punctatus*).

At a temperature of 19°C and a pH of 8.5, it takes less than 0.4 mg total ammonia/L to generate a potentially toxic condition, while at 19°C and pH 7, it takes over 11 mg/L. At a temperature of 4°C and pH 8.5, it takes just over 1 mg total ammonia/L to generate this condition, while at 4°C and pH 7, it takes over 35 mg/L (Emerson *et al.*, 1975).

2.5.4.3 Dissolved oxygen concentration

The dissolved oxygen concentration of water has long been known to affect the toxicity of ammonia to fish (Merkens and Downing, 1957; Vamos and Tasnadi, 1967; Alabaster *et al.*, 1979). Thurston *et al.* (1981a) conducted a detailed study of this phenomenon and showed the potential impacts of reduced dissolved oxygen levels on the acute toxicity of ammonia. The 96-hour LC_{50} of un-ionized ammonia to rainbow trout (*O. mykiss*) was tested in various concentrations of dissolved oxygen, from 2.6 to 8.6 mg/L. The former concentration was the lowest at which 90% or more of the control fish survived. There was a positive linear correlation between LC_{50} and dissolved oxygen over the entire dissolved oxygen range tested: ammonia toxicity increased as dissolved oxygen decreased. Un-ionized ammonia LC_{50} values were also computed for 12, 24, 48 and 72 hours: the correlation with dissolved oxygen (DO) was greater the shorter the time period. The 96-hour LC_{50} values varied from 0.7 mg/L at 8.6 mg DO/L to 0.3 mg/L at 2.6 mg DO/L. The estimated correlation coefficient was 0.93, with an estimated regression line of $LC_{50} = 0.1903 - 0.06712(DO)$ (Thurston *et al.*, 1981a).

The analysis of dissolved oxygen versus LC_{50} over the entire 96-hour test period showed a clear trend: the shorter the time period, the more pronounced the positive relationship between acute toxicity and dissolved oxgyen. This suggests either that individual fish that were sensitive to ammonia succumbed early or that those fish that do survive become increasingly acclimated to ammonia and oxygen conditions. These tests show that any reduction in dissolved oxygen reduces the tolerance of rainbow trout fingerlings to acutely toxic concentrations of ammonia: the estimated tolerance at 5.0 mg DO/L is 30% less than at 8.5 mg DO/L.

3.0 Assessment of "Toxic" under CEPA 1999

3.1 CEPA 1999 64(a): Environment

The environmental risk assessment of a PSL substance is based on the procedures outlined in Environment Canada (1997a). Environmental assessment endpoints (e.g., adverse reproductive effects on sensitive fish species in a community) are selected based on analysis of exposure information and subsequent identification of sensitive receptors. For each endpoint, a conservative Estimated Exposure Value (EEV) is selected and an Estimated No-Effects Value (ENEV) is determined by dividing a Critical Toxicity Value (CTV) by an application factor. A conservative (or hyperconservative) quotient (EEV/ENEV) is calculated for each of the assessment endpoints in order to determine whether there is potential ecological risk in Canada. If these quotients are less than one, it can be concluded that the substance poses no significant risk to the environment, and the risk assessment is completed. If, however, the quotient is greater than one for a particular assessment endpoint, then the risk assessment for that endpoint proceeds to an analysis where more realistic assumptions are used and the probability and magnitude of effects are considered. This latter approach involves a more thorough consideration of sources of variability and uncertainty in the risk analysis.

3.1.1 Assessment endpoints

The bulk of the ammonia emitted in Canada is released to air, with the remainder being released to water. However, because of the rapid and large dilution of ammonia and the high deposition rate, the impacts through the air are not considered to be the main ones. Impacts on water ecosystems are more important from point sources due to the concentrations of ammonia in municipal WWTP effluents and the nature of the toxicity of ammonia to aquatic organisms.

Assessment endpoints include the reduction of growth and reproductive success in a mixed community of aquatic organisms for chronic exposures. The community included eight species of fish, one amphibian and four species of invertebrates. These are the species listed in Table 6, excluding pumpkinseed. The species were selected on the basis of being widespread in large areas of Canada and having at least one good toxicity study done on them. The most sensitive organisms in this community were the scud, *Hyalella azteca*, sockeye salmon (*Oncorhynchus nerka*) and the rainbow trout (*O. mykiss*). Scud are important in an aquatic ecosystem, as they are bottom browsers and act as an important source of fish food. Sockeye salmon and rainbow trout are top-order carnivores highly prized by humans for sport and food. Other assessment endpoints included 10% lethality of the most sensitive aquatic organisms in a community, again rainbow trout, in multiday exposures and 10% lethality of rainbow trout over 12 hours.

Terrestrial plants are the major organisms exposed via atmospheric transport of ammonia. Assessment endpoints for plants are the destruction of leaf material, specifically necrosis, browning and early leaf drop. A review of terrestrial plant toxicity data determined that acute toxicity is generally not a problem with respect to terrestrial plants, as levels of ammonia required to generate an acute toxic response were far higher than the levels documented from Europe to cause adverse effects on terrestrial ecosystems. Most plants require inputs of nitrogen for continued growth and will respond with increased growth rates under very high nitrogen deposition rates. Under conditions of chronic exposure to gaseous and particulate ammonia, reduced drought tolerance was noted as an assessment endpoint that is quite sensitive.

Several sensitive Canadian ecosystems have been identified, in particular sphagnum bogs and conifer forests. Sphagnum bogs are adapted to low nitrogen conditions and do not respond quickly to inputs of nitrogen as ammonia. They can be endangered from other nitrogen-adapted plants, in particular grasses. Conifer forests can be susceptible to reduced frost hardiness and eutrophication when exposed to high levels of ammonia over long periods of time.

A concept also used in the terrestrial toxicity assessment was developed in Europe in response to heavy inputs of nutrients to many ecosystems. This is the concept of the "critical load," a loading of a chemical on an ecosystem that will not cause a deleterious impact (Boxman *et al.*, 1988; Bobbink *et al.*, 1992). Inputs are calculated as yearly loads of the chemical in question. The measurement endpoint is a specific ecosystem, i.e., conifer forests or sphagnum bogs. The assessment endpoints are effects (a shift towards nitrogen-adapted species like grasses) on similar terrestrial ecosystems in Canada.

3.1.2 Environmental risk characterization

3.1.2.1 Hyperconservative assessments

Hyperconservative assessments are presented in Table 9 for four exposure pathways: exposure of freshwater and saltwater fish, exposure of marine benthic organisms from dredging and dumping sediments, and exposure of conifer trees through atmospheric deposition of ammonia.

The EEVs are as follows: for fresh and salt water, a maximum value of 0.68 mg un-ionized NH_3/L was detected at one location (sewage from Annacis Island, Vancouver) (Servizi *et al.*, 1978), and for air, 0.56 mg NH_3/m^3 was detected downwind of a dairy farm in California (Luebs *et al.*, 1973). Application factors of 10 were used for fish due to the large and fairly complete databases; an application factor of 100 was used with dredging operations due to the moderate database on effects and exposure information; and an application factor of 1000 was used for conifer trees because of the relatively poor database on effects.

For the hyperconservative assessment of saltwater dredging operations, an ENEV of 0.008 mg/L was used for *Ampelisca abdita* (Kohn *et al.*, 1994). The EEV value of 0.177 mg/L is from Sims and Moore (1995) based on average reported pore water concentrations from U.S. Army Corps of Engineers dredging operations in salt water.

3.1.2.2 Conservative assessments

A conservative environmental assessment involves a further analysis of exposure and/or effects to calculate a quotient that is still conservative, but is more "realistic" than the hyperconservative quotient (Environment Canada, 1997a). The EEV is based on typical concentrations or deposition values in the vicinity of sources. The selection of CTVs is more rigorous, taking into account toxicity in organisms that would typically be exposed and matching the length of test exposure to that found in the field. The application factors used may be smaller if an adequate acute toxicity base data set is available (factor of 100) or if threshold sublethal toxicity values are available (factor of 10). However, the ENEV obtained should not be within the range of typical natural concentrations or deposition rates. If the quotient is still greater than one, then a probabilistic risk assessment is warranted, if there are sufficient data. The assumptions inherent in the data and application factor used are examined and minimized where possible, thereby refining the assessment process to generate a more accurate or "real-world" assessment than would be done in a hyperconservative assessment.

3.1.2.2.1 Releases to air

Based on an analysis of the literature (Sheppard, 1999), a critical load of 10 kg N/ha per year may be generally protective for nitrogen-poor sites, such as stands of native vegetation on soils of granitic origin. However, this value is not far above nitrogen deposition rates for remote areas.

Table 9 Summary of hyperconservative assessments

Species	EEV	CTV (EC_{50}/LC_{50})	Application factor	ENEV (mg NH_3/L)	Quotient	CTV reference
Open-water exposure of freshwater fish (rainbow trout, *Oncorhynchus mykiss*)	0.68 mg/L	0.158 mg/L	10	0.016	43	U.S. EPA, 1985
Open-water exposure of saltwater fish (winter flounder, *Pseudopleuronectes americanus*)	0.68 mg/L	0.49 mg/L	10	0.049	14	U.S. EPA, 1989
Saltwater dredging, *Ampelisca abdita*	0.177 mg/L	0.8 mg/L	100	0.008	22.1	Kohn *et al.*, 1994
Air exposure, conifer trees	0.56 mg/m³	0.06 mg/m³	1000	0.000 06	9333	Van der Eerden *et al.*, 1998

For example, Shaw *et al.* (1989) reported deposition of 4.2 kg N/ha per year in a boreal area in central Alberta. Janzen *et al.* (1997) reported a similar value. In contrast, Barthelmie and Pryor (1999) estimated that agricultural areas in the Lower Fraser Valley annually received from 44 to 105 kg N/ha.

The acute CTV for plants (leaf necrosis, increased sensitivity to cold) after an hour-long exposure to ammonia in air is 25 000 µg/m³ (Van der Eerden, 1982).

Information on responses of plants to gaseous ammonia is sparse. There is a slight possibility of localized impacts on sensitive agricultural crops (in particular vegetables) close to point and area sources of ammonia, and the contribution of airborne ammonia to local water bodies is unknown. Ground-level concentrations of ammonia near agricultural and industrial sources are generally low or sporadic in occurrence and intensity. Because of the absence of Canadian data near point sources, a monitoring and modelling study was conducted by Environment Canada to develop exposure data (McDonald, 1999) using the ISCST3 (Industrial Source Complex Short Term) model at the Agrium Inc. fertilizer facility in Fort Saskatchewan, Alberta. The Agrium Inc. fertilizer plant is one of the major point sources of atmospheric ammonia in Canada. Another modelling run was made to estimate the release and potential impacts of ammonia from a manure fertilizer application to a 1-ha field in summer.

An area around the Fort Saskatchewan site, roughly 7.5 km², is exposed to a maximum hourly winter concentration of 100 µg/m³. The acute CTV is 25 000 µg/m³ for "general terrestrial" plants. An application factor of 100 is used due to the limited database on effects, but it is reduced from 1000 in the hyperconservative assessment due to the improved exposure estimates.

$$\text{Quotient} = \frac{100}{250}$$

$$= 0.4$$

This quotient (<1) indicates that even for a large point source of ammonia, there is little likelihood of "instantaneous" injury to nearby terrestrial plants with high hourly concentrations of ammonia.

In order to facilitate a direct comparison between the potential influence of a point and an area source on nearby vegetation, the identical conditions were run again replacing the industrial complex with a 1-ha field treated with manure. Typical emission data for a surface application in Ontario were taken from information presented in Section 2.3.2.1. Prior to application, ammonia flux was measured to be less than 0.015 kg NH_3-N/ha per hour (Period A); immediately after application, fluxes of up to 1.2 kg NH_3-N/ha per hour were measured (Period B). These flux values dropped off quickly to around 0.1–0.3 kg NH_3-N/ha per hour (Period C) and stayed that way over a period of days, with considerable diurnal fluctuation (Beauchamp *et al.*, 1982). A 2-week period in June 1990 was selected with stable weather that was warm and dry.

The ISCST3 model allows us to determine the concentration of ammonia released during manure fertilization of a field. The 1-hour maximum concentration of ammonia released over a significant area (800 m^2 from a fertilized plot of 100 m^2) is 100 µg/m^3. This concentration could be expected outside the perimeter of a fertilized field as well. The acute CTV of 25 000 µg/m^3 is used. An application factor of 100 is used due to the limited database on effects, but it is reduced from 1000 in the hyperconservative assessment due to the improved exposure estimates.

$$\text{Quotient} = \frac{100}{250}$$

$$= 0.4$$

This quotient indicates that for an area source of ammonia (a recently fertilized field using manure), there is little likelihood of an injury to nearby terrestrial plants with high hourly concentrations of ammonia.

In order to improve understanding of the atmospheric fate of nitrogen in the Lower Fraser Valley, two initiatives were undertaken. The first involved updating and improving the ammonia emissions inventory for the region, based on the most recent census data available and improved emission factors. The second initiative was directed towards providing spatial maps of concentration and deposition of nitrogen compounds based on model runs.

The maximum point of deposition during the model exercise was 105 kg/ha per year as NH_3 to the surface in the modelled area. A worst-case scenario was used with this deposition rate applied for a full year. Because this deposition is so driven by sources, this amount could vary substantially with season and may be subject to periodically high levels. This could have important terrestrial impacts, as the Dutch have found terrestrial eutrophication impacts on coniferous forests at such deposition rates.

Because the modelling exercise estimated ammonia inputs to the Lower Fraser Valley as a deposition rate, the critical loading rate will be used to estimate potential toxicity. The critical loading rate for sensitive terrestrial ecosystems in Canada is 10 kg N/ha per year based on long-term effects on conifer ecosystems. The modelling in the Lower Fraser Valley provides an EEV of 105 kg N/ha per year from ammonia. No application factor was used for this assessment, as the natural deposition rate is around 4–5 kg/ha per year and the critical load is estimated at only 10 kg/ha per year.

$$\text{Quotient} = \frac{105}{10}$$

$$= 10.5$$

Based on this quotient, there is a definite possibility that conifer forests in the Lower Fraser Valley may be detrimentally affected by ammonia deposition. Unfortunately, there is little information either on the widespread deposition of ammonia or on the effects of ammonia on Canadian terrestrial ecosystems to allow a probabilistic risk analysis to be performed.

3.1.2.2.2 Releases to water

Due to limitations of either exposure or toxicity data, the risk assessment of ammonia proceeded to a probabilistic risk assessment only for releases of ammonia from municipal WWTPs.

The LC_{10} was chosen as a short-term acute CTV because it is the maximum allowable mortality permitted in the control treatment and therefore defines the accuracy of toxicity testing. For un-ionized ammonia, the LC_{50} to rainbow trout (*O. mykiss*) for a 12-hour exposure was 0.74 mg/L, and the LC_{10} was 0.074 mg/L. The rise of ammonia in fish blood at these water concentrations is rapid. The concentration–lethality relationships are useful for estimating potential effects under these acute conditions when ammonia concentrations are very high. The conservative nature of the LC_{10} value is demonstrated by the fact that this concentration is bracketed by mortality and non-lethality in longer exposures of 21–120 days and is in the range of sublethal growth effects.

The acute lethality data for invertebrates and fish were evaluated collectively as a community of organisms by plotting the cumulative species response as a proportion of the entire community against concentrations of un-ionized ammonia (WERF, 1996). An ecological risk criterion for lethality can be derived from this distribution of data. Figure 8 is the Aquatic Community Risk Model (ACRM) graph for acute toxicity and is a logistic regression of the concentration–response. It allows prediction limits to be determined for any point on the curve. It must be remembered that each point on this graph is the average response of the species that it represents; in some cases, this is a single toxicity test, and in the case of rainbow trout (*O. mykiss*), it is an average of 112 toxicity tests. The ecological risk criterion developed is not specific to any particular water body in Canada. To conduct site-specific assessments, a review of each species' presence–absence would be required for each water body under study. This approach was beyond the scope of this assessment.

Figure 8, which uses all the LC_{50} data from Tables 4 and 5 (fish and invertebrates), indicates that 0.29 mg NH_3/L (95% prediction limits are 0.21–0.37 mg/L) would produce 50% mortality in the most sensitive organisms representing 5% of the community. It should be noted that nearly all of the measured LC_{50} values reported in the literature exceed 0.29 mg/L.

The conservative nature of these estimates is evident when considering that these values are based on constant exposure conditions over a 48- to 96-hour period, conditions that rarely occur in the field. Concentration plumes change in geographical coverage due to variable dilution and currents, and organisms can move in and out of exposure areas over that period of time as part of their natural behaviour. Few aquatic organisms are repelled by ammonia or by municipal wastewater effluents; many, in fact, will be attracted to such effluents due to their supply of organic matter and warmth.

The scientific literature on sublethal ammonia toxicity to invertebrates, amphibians and fish was reviewed in detail and in many cases reanalysed to calculate the EC_{20} (concentration causing an effect in 20% of the organisms exposed) or IC_{20} (concentration causing 20% inhibition in exposed organisms compared with the control response) (Craig, 1999). Not uncommon with growth tests is that fry mortality can be as sensitive as, if not more sensitive than, growth *per se*. The use of the EC_{20} effect concentration allows comparison of organism sensitivity using the same endpoint and avoids comparison of many different endpoints that often use different statistical methods. The use of the 20% effect level is derived from the use in sublethal bioassay tests of an allowable 20% effect in control organisms due to the difficulty in maintaining a population of organisms over a long period. As with the lethal data, the same community ecological risk criteria were developed using the acceptable sublethal data from the literature reviewed (Table 6).

FIGURE 8 Acute ACRM for Canadian freshwater species

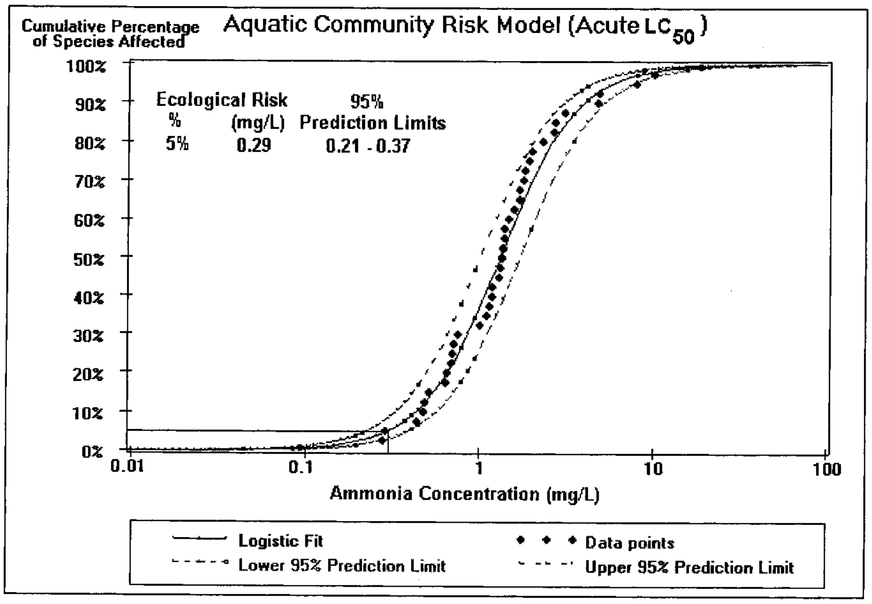


Figure 9 represents the chronic ACRM graph developed for Canadian species listed in Table 6. The points on the graph are the geometric means (where they can be calculated) of the EC_{20} values for that species. The logistic regression of the community response analysis indicates that, at un-ionized ammonia concentrations above 41 µg/L (0.041 mg/L), the most sensitive 5% of the species in an exposed community would be expected to exhibit a 20% reduction in growth or reproduction. The prediction limits on this chronic CTV are 19–63 µg/L due to the relative lack of response data at the lower end of the graph. As with the acute toxicity ACRM, Figure 9 shows the average responses for each species where it was possible to calculate an average. It should also be noted (as shown in Figure 9) that all of the chronic effects values reported in the literature exceed the 0.041 mg/L value.

The acute CTV of ammonia for saltwater fish was determined to be 0.49 mg/L for the winter flounder (*P. americanus*). This is the most sensitive mean acute toxicity value reported for marine organisms (U.S. EPA, 1989).

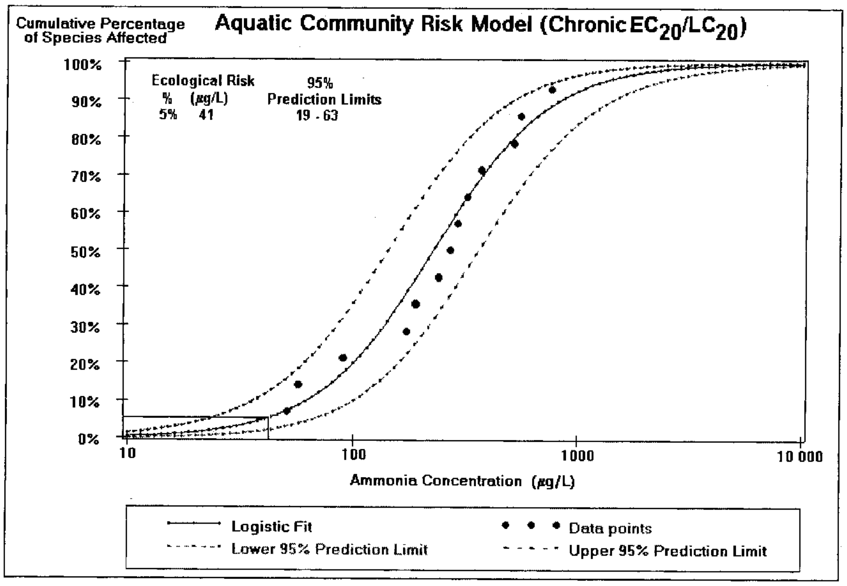
Municipal wastewater effluents

For the conservative assessment of ammonia in freshwater lakes and ocean discharges, it was decided to use un-ionized ammonia concentrations measured (a) in Hamilton Harbour, Lake Ontario, from Hamilton and Burlington municipal effluents, (b) in Lake Ontario from Toronto and (c) at the Iona Island deep-sea outfall from the Greater Vancouver Regional District. These are examples of potentially impacted lake and ocean systems (Barica, 1991; IRC Inc., 1997; Gartner Lee Ltd., 1998).

(a) *Hamilton Harbour*

The maximum concentration of un-ionized ammonia recorded in Hamilton Harbour in 1994 was approximately 0.35 mg/L (Charlton, 1997). This value will be used as the EEV in our lake calculations. The acute CTV of 0.29 mg NH_3/L was used. This value is close to the lowest reported acute effects levels for freshwater

FIGURE 9 Chronic ACRM for Canadian species listed in Table 6



organisms (0.28 and 0.29 for white perch, *M. americana*, and mountain whitefish, *P. williamsoni*, respectively). An application factor of 10 was used due to the large and relatively complete database on fish toxicity.

The conservative assessment of the acute toxicity of un-ionized ammonia to fish in fresh water generated the quotient:

$$\text{Quotient} = \frac{0.35}{0.029}$$

$$= 12$$

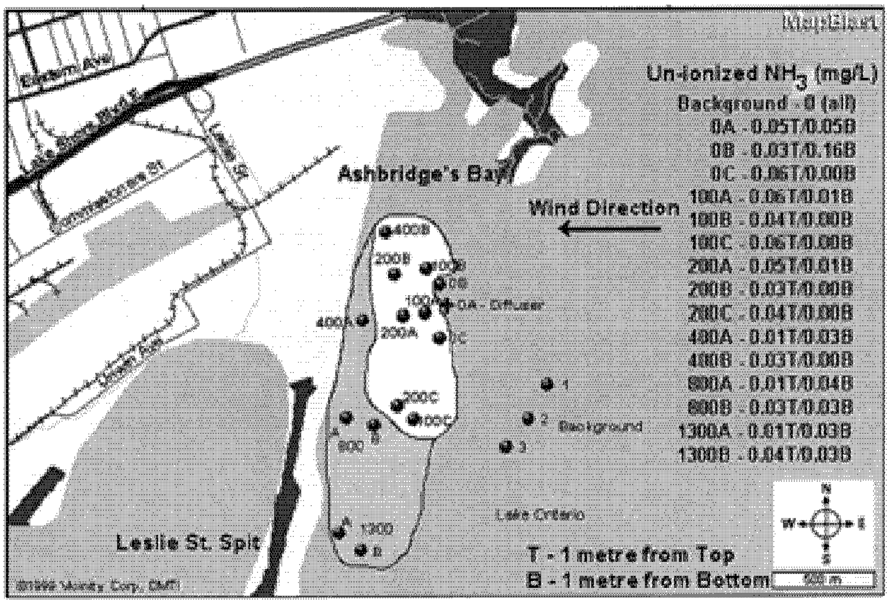
As this quotient is over one, these concentrations could be acutely toxic to sensitive fish. The toxicity assessment of ammonia released to freshwater aquatic environments should proceed to a probabilistic risk assessment. As Environment Canada conducted a detailed water quality project in 1998, there are sufficient data to allow this assessment to be conducted (Charlton and Milne, 1999).

(b) *City of Toronto*

The City of Toronto discharges much of its municipal sewage effluent via a pipeline and diffuser array into Lake Ontario at Ashbridge's Bay (see Figure 10). The water is roughly 6 m deep at the diffuser array. In 1998, Environment Canada contracted Gartner Lee Ltd. to conduct an effluent sampling project around the diffuser array to determine the spread of effluent constituents, specifically chloramines and ammonia (Gartner Lee Ltd., 1998). The diffuser array was located and sampled, as well as three samples from farther out in the lake, to establish the background and range of concentrations expected. The longitudinal length of the effluent plume was determined based on maps produced in a modelling exercise, wind direction and conductivity measurements. The down-gradient extent of the effluent was defined by conductivity concentrations within 10% of the background levels.

A conservative assessment can be done for this discharge into Lake Ontario. At sites OC,

Figure 10 Discharge of Toronto municipal effluent into Lake Ontario, September 1998



100A and 100C (top samples), the un-ionized ammonia concentrations were 0.06 mg/L or greater. The acute CTV of 0.29 mg/L was used because the organisms in this area are expected to be exposed over short periods of time, as the plume moves considerably with the wind. An application factor of 10 was used due to the relatively complete database on freshwater fish toxicity.

$$\text{Quotient} = \frac{0.06}{0.029}$$

$$= 2$$

There appears to be a slight potential for adverse effects from the Toronto Main WWTP effluents. With the uncertainty involved in this calculation and the lack of detailed information on the spatial and temporal extent of these effluents, there is not enough information to continue to a probabilistic risk assessment.

(c) *Greater Vancouver Regional District deep-sea outfall*

Opened in 1963, the Iona Island WWTP provides primary treatment of wastewater and serves the Vancouver Sewerage Area. As wastewater flows to the plant increased, environmental studies showed that the discharge of effluent across Sturgeon Bank in a shallow channel was degrading portions of the bank. Recommendations for upgrading were made and, in 1988, the Greater Vancouver Regional District commenced operation of the Iona deep-sea outfall, which replaced the previous surface discharge. The new outfall discharges treated effluent at depths ranging from about 72 to 106 m to the Strait of Georgia off Sturgeon Bank.

The plant produces a primary effluent moderately high in ammonia (10 mg/L) with a flow of 567 000 m^3/day (Environment Canada, 1997b). This facility deposits roughly 2000 tonnes ammonia/year into the Strait of Georgia. Estimates for initial dilution of the wastewater discharge indicate minimum levels in excess of

100:1 and typical levels of 150:1 at all flows and all discharge depths throughout the year.

Two years of pre-discharge data and 9 years of post-discharge data have been collected. A plume discharge study, including ammonia analyses, was conducted in 1996 following the peak Fraser River flows during a period of high-density stratification at the site. Sampling was done in July and August.

In a 1996 survey, the treated wastewater plume was detected in a north–south corridor up to 1 km north and 4 km south of the outfall diffusers either at a water depth of 55 m or at the bottom. Twenty-nine multidepth water samples were obtained at 10 sampling stations located in the area on 3 days in July 1996. There were no statistically significant differences between in-plume and outside-plume mean concentrations for ammonia in either the 55-m-depth or bottom-water samples. The maximum total ammonia concentration was 0.08 mg NH_3-N/L at 55 m depth at the diffusers, equivalent to 0.0003 mg un-ionized ammonia/L at a pH of 7.4 and a temperature of 9ºC (Bertold, 1999).

A benthic survey in the vicinity of the deep-sea outfall did not detect any anomalies in the benthic or infaunal communities (Stewart *et al.*, 1991).

A concentration of 0.0003 mg un-ionized ammonia/L was detected at the Iona Island outfall, so it was used as the EEV for ocean disposal in this situation. An application factor of 10 was used due to the relative abundance of toxicity data on saltwater organisms. The acute CTV for saltwater fish (winter flounder, 0.49 mg/L) was used due to the likelihood that a benthic fish would not be exposed to the plume over long periods. Based on a maximum detected concentration of 0.08 mg NH_3-N/L (total ammonia), the conservative assessment would be:

$$\text{Quotient} = \frac{0.0003}{0.049}$$

$$= 0.006$$

Based on this high and rapid level of dilution, there does not appear to be an ecological toxicity hazard from the Iona Island deep-sea outfall.

(d) *River discharges: screening*

A significant point source of ammonia release to Canadian rivers is municipal WWTPs. This section examines the characteristics of effluent dilution and mixing in rivers at 10 selected municipal WWTPs across Canada. The characteristics of the effluent plumes that develop downstream of these WWTP outfalls provide insight into the spatial extent of potentially toxic zones within the river under different ambient conditions.

The model CORMIX 3.2 was selected for this application since it was suited to the variety of outfall configurations that exist and could be applied with information that was readily available (Doneker and Jirka, 1990; Jirka *et al.*, 1996; Jones *et al.*, 1996). These predictions have not been validated with field data and represent a conservative view of dilution in rivers.

Study sites were selected from across Canada that would typify the types of treatment systems and receiving environments available. The cities chosen were Edmonton, Alberta; Saskatoon, Saskatchewan; Calgary, Alberta; Winnipeg, Manitoba; Guelph, Ontario; Stratford, Ontario; Ottawa, Ontario; Montréal, Quebec; and Edmundston, New Brunswick. The cities chosen represent a mix of treatment types, discharge types and dilution rates. In each situation, average and low-flow assessments were conducted to provide reasonable estimates of the impacts from sewage treatment processes.

Table 10 summarizes the results of the modelling. In this summary, key characteristics of the plume have been identified for ease of comparison and evaluation. The CORMIX 3.2 predictions presented here are based upon average conditions in the river and assume steady flow. This is rarely the case, and therefore the actual plume locations and centre lines are expected to vary considerably with the variations inherent in rivers.

Table 10 Summary of conservative assessment of modelled sewage treatment systems [1]

Location	Total NH_3 mg/L (at 10:1 dilution)	Flow	Temperature (°C)	EEV as un-ionized NH_3 (mg/L)	Distance to 10:1 dilution (m)	Season	Toxicity quotient
Edmonton	2.142	Low	4	0.024	10 000	winter	0.6
		Avg.	24	0.106	1 935	summer	2.7
Calgary	0.5	Low	4	0.006	>55 000	winter	0.2
		Avg.	17	0.015	13 000	summer	0.4
Saskatoon	1.178	Low	4	0.013	111	winter	0.3
		Avg.	23	0.055	7	summer	1.4
Winnipeg N	1.865	Low	4	0.021	3 400	winter	0.5
		Avg.	23	0.087	150	summer	2.2
Winnipeg W	0.878	Low	25	0.047	>20 000	summer	1.2
		Avg.	15	0.023	94	spring–fall	0.6
Ottawa	0.608	Low	25	0.032	<1	summer	0.8
		Avg.	15	0.016	<1	fall	0.4
Stratford	1.257	Low	28	0.081	>1 500	summer	2.0
		Avg.	10	0.023	>1 500	fall	0.6
Guelph	0.239	Low	28	0.015	Not achieved	summer	0.4
		Avg.	10	0.004	2 120	fall	0.1
Montréal	0.659	Low	22	0.029	660	summer	0.7
		Avg.	10	0.012	830	fall	0.3
Edmundston	1.667	Low	22	0.072	22	summer	1.8
		Avg.	10	0.030	3 000	fall	0.8

[1] Discharges highlighted are not significant.

Many of the data used came from engineering drawings for each facility as presented in Walker (1998). Municipalities provided the ammonia concentrations in the effluents; the water temperatures at average and low flows were estimated for most locations. By assuming a constant pH of 8 for all of the rivers and flow conditions, the un-ionized ammonia concentration was estimated. The point at which the toxicity estimate was made is the 10:1 dilution point, as modelled by CORMIX. The chronic CTV of 0.041 mg/L was used without an application factor. From this, a conservative estimate can be made of the potential for a chronic impact from ammonia for each outfall.

This exercise indicates that ammonia in sewage effluents from some cities is likely toxic under some conditions, but not under others. The cities of Edmonton, Winnipeg (North and West End plants), Edmundston and Stratford all have potentially toxic plumes of a significant size, under some conditions. Edmonton and Winnipeg generate potentially toxic plumes of a significant size under average conditions simulated. There are sufficient data on the effluents from both of these cities and their rivers to conduct probabilistic risk assessments. Because of the very long distance to the 10:1 dilution point below Calgary (>56 km), there is the possibility of "toxic" conditions prior to this point.

The cities of Saskatoon, Guelph, Ottawa-Carleton and Montréal do not have potentially toxic effluents under the situations simulated here. This is due to ammonia removal processes on the part of Guelph and to ammonia reduction techniques and a wide diffuser in the Ottawa River on the part of Ottawa-Carleton and in the South Saskatchewan River on the part of

TABLE 11 Summary of conservative assessments for agricultural runoff situations

Situation	Conditions of entry to water	EEV (mg un-ionized ammonia/L	CTV (mg/L)	Application factor	ENEV (mg/L)	Quotient
Cattle crossing a stream	Temp. 19°C, pH 7.7, slow water	0.008	0.29 (acute)	10	0.029	0.3
Cow-calf operations – long term	Temp. 11.5°C, pH 7.5, spring to fall	0.022	0.04 (chronic)	10	0.004	6
Cow-calf operations – short term	Temp. 1°C, pH 7.05, spring	0.04	0.29 (acute)	10	0.029	1.4
Feedlot/dairy runoff	Temp. 1°C, pH 7.05, spring	0.13	0.29 (acute)	10	0.029	4.5
Manure fertilization runoff	Temp. 2°C, pH 7.8, manure applied to snow; local river sampled	0.003	0.29 (acute)	10	0.029	0.1
Manure fertilization runoff	Temp. 2°C, pH 7.8, manure applied to snow; max. NH_3 in ditch	0.116	0.29 (acute)	10	0.029	4

Saskatoon. Montréal has a weak effluent for a primary treatment system (6 mg/L) and a large dilution capacity in the St. Lawrence River.

Since this work was completed, the cities of Saskatoon and Stratford have installed nitrification systems to remove or alter the form of ammonia they are putting into their local rivers, and they no longer release ammonia concentrations that are toxic under any conditions.

Agricultural runoff

There is no single assessment possible that would cover the many ways in which ammonia could be emitted from an agricultural operation due to the wide variety of such operations across Canada. Therefore, a series of conservative assessments have been conducted for those typical operations where there are data. The results are presented in Table 11.

Application factors of 10 have been used due to the relatively complete database on freshwater fish. In these cases, EEVs have been used from a variety of agricultural situations (see Table 11). Impacts from allowing cattle free access to a small river can be estimated based on Demal (1983) and his study of cattle in the Avon River, Ontario. This is one of the few studies found that estimates ammonia from this source. The short- and long-term impacts from cattle overwintering along a stream can be estimated from the studies by Cooke (1996) and Anderson *et al*. (1998a), respectively. Both of these studies were conducted in Alberta, where beef cattle are common; no other studies could be found pertaining to eastern Canadian situations. The impacts of ammonia in runoff from winter-applied manure can be estimated from Green (1996). The concentrations used in all of these assessments were the maximum detected.

Conservative analyses of agricultural operations with minimal data that involve cattle and manure handling have shown that some practices (overwintering cow-calf operations near streams, long-term cow-calf operations near streams, feedlot/dairy runoff near streams in springtime, manure fertilization of snow-covered fields near streams) have the potential to cause acute toxicity to aquatic organisms. Unfortunately, there is insufficient information on these types of agricultural systems across Canada to allow this analysis to be continued to a level that would include an assessment of the probability of adverse effects.

Dredged saltwater sediments

Concentrations of ammonia in sediment pore water in dredged material from estuarine and marine sites have been reported by the U.S. Army Corps of Engineers (Gibson *et al.*, 1995) and in the open literature (Sims and Moore, 1995). U.S. data were used since Canadian data were limited. Approximately 21 of the sites were estuarine (salinity = 1–30‰), 5 were marine (salinity >30‰) and 13 were fresh water (salinity <1‰). Where concentrations were represented as total ammonia, un-ionized ammonia was calculated from reported pH, salinity and temperature. When the necessary parameters were not available, the following values were assumed: pH = 7.5, temperature = 20°C and salinity = 20‰ for estuarine systems and 30‰ for marine systems. Conversions were based on the results of a study conducted by Hampson (1977).

In general, the median pore water ammonia concentration reported in the dredged material survey was 0.2 mg NH_3/L. Pore water ammonia concentrations for estuarine sites ranged from 0.06 to 1.9 mg NH_3/L. Due to the suspension of sediments in the water column through which the sediment falls, a dilution factor of 10 was applied to the reported EEVs.

The receptor organism is winter flounder (*P. americanus*), which exhibits an average LC_{50} of 0.49 mg/L. An acute CTV is used, as exposure to ammonia from dumping sediments is expected to be of short duration. An application factor of 10 was used due to the relatively complete database on saltwater toxicity to convert this CTV to an ENEV of 0.049 mg/L.

Data available in the published literature for estuarine and marine conditions presented a range of exposure values for ammonia concentration in sediment pore water. Due to the variation in exposure values among sampling sites, risk quotients were calculated using the median and maximum concentrations from the dredged material survey, 0.2 and 1.9 mg NH_3/L, respectively. The assumed pH of 7.5 is too low and the temperature of 20°C is too high for Canadian marine waters (Bertold, 1999), so the average ammonia concentration was recalculated using a pH of 7.8 and a temperature of 9°C. Using the methodology of Spotte and Adams (1983) to calculate a ratio between NH_4^+ and NH_3 in saline water, the median ammonia concentration would be 0.12 mg/L and the maximum would be 1.18 mg/L. Because of the dilution effect that will occur as the dredged sediments fall through the water column, an estimated dilution factor of 10 was applied.

Median

$$\text{Quotient} = \frac{0.012}{0.049}$$

$$= 0.24$$

Maximum

$$\text{Quotient} = \frac{0.118}{0.049}$$

$$= 2.4$$

Using this method, the acute risk quotients for dredging and dumping ammonia-laden material in a saltwater environment would be <1 using a median concentration of 0.12 mg NH_3/L and >1 using the maximum concentration of 1.18 mg/L from dredging surveys done in the United States. The results suggest that the risk of pore water ammonia toxicity in dredged material bioassays is highly variable and depends on the scenario and assumptions considered. The exposure period used to generate the CTV does not adequately match the exposure in the environment, as winter flounder was exposed for 96 hours. It is highly unlikely that benthic fish would be exposed for this time period from dredging operations. Also, the dilution factor of 10 has not been validated, and the physical parameters of saline water (temperature, pH and salinity) can have a major effect on un-ionized ammonia concentrations.

Ammonia is also a natural constituent of sediment. In published literature, a concentration range of 0.17–17 mg un-ionized ammonia/L in sediment pore water was reported to be quite common, and concentrations as high as 430 mg/L have also been reported (Gibson *et al.*, 1995). Calculation of risk quotients using some naturally occurring ammonia concentrations would result in a quotient greater than one.

The conservative assessment of dredged sediments suggests that sensitive pelagic organisms might be harmed by exposure to ammonia liberated from sediments during dredging and dumping, but considerably more work would have to be done to prove that this source of ammonia is harmful in marine environments.

3.1.2.2.3 Other lines of evidence

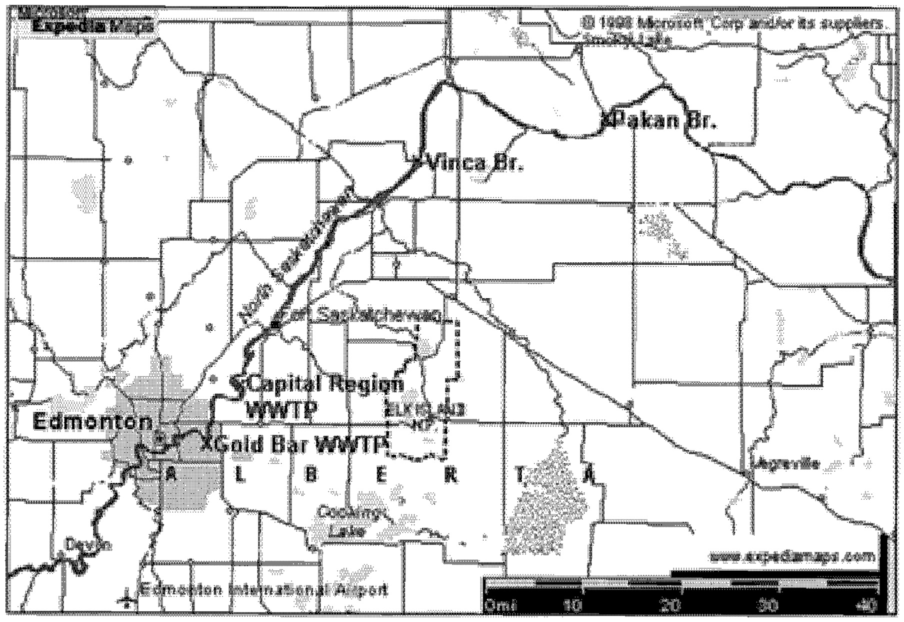
Ammonia concentrations in interstitial pore waters of sediments are frequently of concern when dredging is to be carried out on the sediments (Schubauer-Berigan and Ankley, 1991). Dredging sediment high in ammonia can liberate considerable concentrations of ammonia to the surrounding water, and redepositing the sediment can also create a hazard. Dredged sediment disposal has been shown to cause toxicity in surrounding waters to *Daphnia* sp., *Polydora* sp. and *Paleomonetes* sp. by DeCoursey and Vernberg (1975). Although these researchers did not take water samples for analysis of ammonia, samples were taken from similar operations in the area. These samples contained up to 5 mg NH_3/L at a sediment disposal site and 0.123 mg/L in non-disposal areas.

A major effluent sampling, characterization and effects project was carried out in 1993–1994, called the Joint Industrial–Municipal North Saskatchewan River Study (Golder Associates, 1995). A map of the North Saskatchewan River is illustrated in Figure 11. The project characterized the extent of the effluent plume from the Edmonton WWTP and from a smaller WWTP 20 km downstream. This project formed the basis for most of the plume-specific information used to model the effluent plume for the probabilistic risk analysis on this source. This project also characterized the nature of the benthic invertebrate community above and below the Edmonton WWTP outfall.

Total numbers of invertebrates and taxonomic richness are well-established indicators of environmental quality in rivers. Coupled with the coarse-level taxonomic breakdown of the data, these variables are sufficient to identify the major factor influencing the benthic community of a river. The longitudinal pattern in invertebrate abundance and community composition in the study reach is largely indicative of nutrient enrichment contributed by WWTPs (Golder Associates, 1995). Sewage effluents from Edmonton have altered the zoobenthic community below the discharge from an assembly of clean-water taxa (dominated by species of stoneflies, mayflies and caddisflies) to a less diverse and more abundant fauna characterized by pollution-tolerant taxa (such as oligochaetes and chironomids) (Anderson *et al.*, 1986). Direct effects from nutrients were evident in increased plant growth (measured as chlorophyll *a*), whereas secondary and synergistic effects contributed to some decrease in dissolved oxygen levels, some increase in biochemical oxygen demand, and cyclic and compositional changes in the zoobenthic community (Anderson *et al.*, 1986).

Dissolved oxygen in the river is always high, with only a slight oxygen sag below the Edmonton discharge. This usually amounts to a 5% decrease in the percent saturation from 75% to 70% in July (equivalent to 5.5 mg/L at the time). Farther downstream from Gold Bar, the dissolved

Figure 11 North Saskatchewan River in the vicinity of Edmonton



oxygen, as percent saturation, increases from 70% to >80%. A value of 60% saturation would protect natural populations of all organisms in the North Saskatchewan River (Anderson *et al.*, 1986).

Benthic invertebrate monitoring of the North Saskatchewan River downstream from municipal and industrial outfalls downstream of Edmonton documented severe benthic community alteration. The large increase in oligochaetes (Tubificidae and Naididae) below the Gold Bar WWTP followed by chironomid (*Chironomini, Orthocladiniinae, Tanytarsini and Tanypodinae*) dominance are typical effects of strong nutrient enrichment. A substantial increase in the abundance of pollution-tolerant oligochaete worms generally occurs in this zone at the expense of sensitive taxa. Farther downstream, the large increase in benthic algal biomass resulting from increased nutrient level results in chironomid dominance, followed by a gradual return of more sensitive invertebrates. Moderately enriched far-field areas may support dense populations of chironomids, net-spinning caddisfly larvae and certain mayfly nymphs. Stonefly nymphs (*Chloroperlidae* and *Perlodidae*) generally recover the farthest from WWTP outfalls. The abundance of these invertebrates did not return to upstream levels within 65 km of the study area. Water boatmen (*Callicorixa*) became abundant in areas with extensive growths of attached macrophytes below the outfall that provided good habitat (Golder Associates, 1995).

Lakes in the Central Plains of southern Alberta, Saskatchewan and Manitoba lie in fertile soils that supply high concentrations of nutrients. Eutrophication is generally the single most important water quality issue (Government of Canada, 1996; Hall *et al.*, 1999).

The Qu'Appelle Valley extends over 400 km from its headwaters near Lake Diefenbaker in western Saskatchewan to its confluence with the Assiniboine River in western Manitoba. The Qu'Appelle River and its tributaries provide water to approximately one-third of Saskatchewan's population, including the cities of Regina and Moose Jaw. Agricultural fields and pastures comprise more than 95% of land use in the drainage basin (Hall *et al.*, 1999). A chain of eight lakes, including two headwater reservoirs and six natural lakes, forms a gradient of trophic status in the valley. These lakes represent a major recreational and economically valuable resource for southern Saskatchewan. They are used for commercial and game fishing, recreation, irrigation, livestock watering, drinking water supply and sewage discharge, in addition to serving as flood control and waterfowl habitat (Munroe, 1986; Chambers, 1989).

Typical of the prairies, the lakes are shallow and hypereutrophic (total phosphorus >300 µg/L) and produce immense blooms of blue-green algae throughout the summer (Munroe, 1986; Kenney, 1990; Hall *et al.*, 1999). Although the lakes are naturally eutrophic, present water quality is considerably worse than before European settlement and intensive agricultural development of the region (Allan *et al.*, 1980; Hall *et al.*, 1999). Growing concern over the continued deterioration of water quality in the Qu'Appelle Lakes in the last 30 years resulted in several federal–provincial studies, which attributed excessive algal and plant growth to high nutrient concentrations in agricultural runoff and municipal sewage discharge. It was estimated that 70% of the phosphorus and nitrogen entering the river basin was from sewage discharged by Regina and Moose Jaw (Munroe, 1986). Regina upgraded its sewage treatment facility to remove phosphorus in 1976, and Moose Jaw diverted all of its sewage to agricultural land through the use of spray irrigation by 1987 (Chambers, 1989).

It is unclear whether the upgrades to the sewage treatment plants have had the desired effect on water quality in the Qu'Appelle Lakes. Although open-water total phosphorus concentrations in the lakes have decreased despite increased annual discharge (Chambers, 1989), recent paleolimnological analysis indicates that nitrogen loading to the Qu'Appelle Lakes is at an all-time maximum (Hall *et al.*, 1999). Similarly, the outflow of the Fishing Lakes exhibits an extremely low ratio of total nitrogen to total phosphorus (2.6:1), which suggests that phosphorus is being retained in the lakes, probably in the sediments. This situation maximizes primary production (Munroe, 1986). This evidence suggests that primary production in the Qu'Appelle Lakes would be nitrogen, not phosphorus, limited. Water quality is, thus, not likely to improve until nitrogen removal technology is instituted at Regina's WWTP or until the phosphorus pool in the sediments is depleted.

3.1.2.3 Probabilistic risk assessment

Ecological risk assessment for ammonia using the conservative quotient method indicated that sewage effluents are a major source of toxicity to aquatic habitats. The results identified three case studies where a probabilistic risk assessment could be conducted due to the relative completeness of the data and the likelihood of negative impacts. These are:

1. Hamilton Harbour,
2. the North Saskatchewan River downstream of the Gold Bar municipal WWTP, and
3. the Red River downstream of Winnipeg's three municipal WWTPs.

These case studies are fairly typical of municipal wastewater discharges in Canada. Two are located on fairly large, yet slow rivers supporting large urban populations, while the other is a lake discharge situation with minimal water exchange and intensive urban development in the surrounding watershed. Considering that no two municipal wastewater discharge situations are the same, these case studies should provide a good, generic probabilistic risk assessment for this source of ammonia to fresh water.

3.1.2.3.1 Hamilton Harbour

Extensive sampling was done in 1998 (Charlton and Milne, 1999) to complement measurements taken routinely at a station in the centre of the harbour. The crosses on Figure 12 show the sewage outfall locations in Hamilton Harbour.

FIGURE 12 Hamilton Harbour

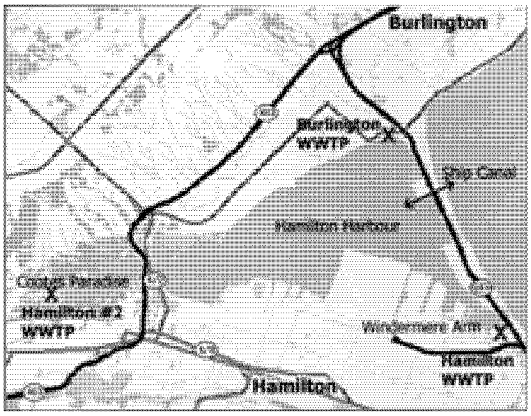


Figure 13 illustrates seasonal fluctuations in ammonia concentrations at the central station in Hamilton Harbour for the years 1986–1999. Weekly grab samples were collected for these years. For the last 6 years, the peak ammonia concentration found in early spring has been increasing. The rapid decrease of ammonia in late spring and summer is caused by nitrifying bacteria that produce nitrate from total ammonia. The nitrifying process is greatly reduced in the winter due to the sensitivity of the bacterial community to low temperatures. As a result, ammonia accumulates in the water during the winter.

As the nitrification process begins to consume ammonia in the spring due to warming temperatures, the proportion of un-ionized ammonia increases for the same reason. At the same time, increasing algal growth withdraws carbon dioxide from the water, and this causes the pH to rise, which also causes the proportion of un-ionized ammonia to increase. The net result is that the timing of the temperature and pH cycle produces increasing concentrations of un-ionized ammonia, even though the total concentration is decreasing in spring (Charlton and Milne, 1999).

The peak ammonia concentration therefore occurs in the spring and depends on the loading rate of ammonia (Rodgers *et al.*, 1992). However, in 1997–1998, several unusual occurrences generated lower than usual ammonia concentrations in the harbour (the concentration was lower by about 0.4 mg/L). The winter of 1998 was unusually mild and the spring was relatively warm, resulting in slightly higher bacterial nitrification, which degraded some of the ammonia. The load from the Woodward sewage treatment plant, which is the main source of ammonia to the harbour, was lower in the fall and winter of 1997–1998. In addition, the ammonia load from the Burlington Skyway sewage plant was lower than normal the previous winter during interruption of operations at a local food processing plant. Thus, both higher temperature and lower ammonia load explain the lower than usual ammonia concentrations in 1998 (Charlton and Milne, 1999) (Figure 13).

Un-ionized ammonia concentrations were usually much higher in the Windermere Arm than elsewhere in the harbour (see Figure 12 for location). The Windermere Arm receives water discharging from the Windermere Basin at the southeast end of the harbour. The Woodward Avenue sewage treatment plant discharges into Redhill Creek near the upstream opening into Windermere Basin. The outflow from the basin comprises mostly treated sewage, along with creek water and combined sewer overflows. The sewage treatment plant is the major source of ammonia in the basin outflow (Charlton and Milne, 1999).

FIGURE 13 Seasonal fluctuations in ammonia at the central station in Hamilton Harbour

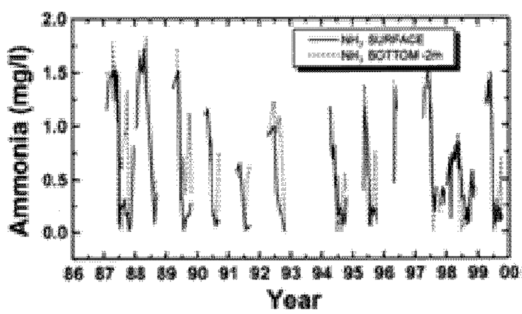
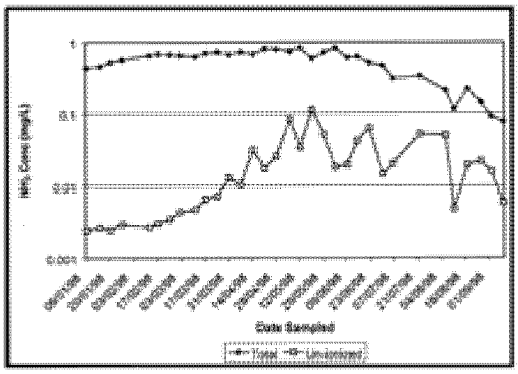


FIGURE 14 Total and un-ionized ammonia concentrations at the central station in Hamilton Harbour, 1-m depth



The data at the central station represented the overall condition of the harbour reasonably well. Even though the central station data were not always the same as the harbour mean, they lay partway between the extremes of the data. The main ammonia loads occur in shallow water near shore, so that those waters will generally have more severe ammonia conditions than will the centre of the harbour. In the centre, the harbour is about 25 m deep at the deepest point. During the spring and summer, the surface water warms, but the rate of warming is less in the lower water, causing a bilayer system to form, because the cool, lower layer is denser. Analyses of water samples collected at 1, 3, 5, 7 and 19 m at the central station show that, until mid-May, ammonia concentrations at all the depths were similar. With the warming in May, concentrations began to decline, but the lower, cooler depths declined the fastest. This seems paradoxical, because the nitrification rate is dependent on temperature. The cause of the rapidly declining ammonia concentrations in the bottom layer is a deep-water flow that brings lake water into the bottom of the harbour via the shipping canal. This dilutes and displaces some of the ammonia accumulated during winter. The bottom water at this time is a potential refuge for fish from high un-ionized ammonia concentrations. The relatively low temperature in the bottom water also favours the ionized form of ammonia. By the end of June, however, the dissolved oxygen in the bottom water is near zero, and this excludes fish and most other higher organisms. Thus, there is no real escape from high un-ionized ammonia in the surface water (Charlton and Milne, 1999).

Exposure concentrations for ammonia were developed from the collection and analysis of water samples from Hamilton Harbour. Two sampling locations were selected: (1) Windermere Arm, where ammonia concentrations are typically the highest in the harbour, and (2) a central station where ammonia concentrations are representative of the overall conditions in the harbour (Figure 12).

Sixty-eight samples were collected from Windermere Arm between March 31 and August 31, 1998 (Charlton and Milne, 1999). Concentrations of un-ionized ammonia ranged from 0.003 to 0.63 mg/L. At the central station, 21 samples were collected at a depth of 1 m between January and September 17, 1998. Concentrations of un-ionized ammonia are represented in Figure 14; concentrations ranged from ≤0.01 to 0.11 mg/L.

Due to the relatively high ammonia concentrations and length of exposures to ammonia in Hamilton Harbour, ecological risks were determined in three ways. The short-term acute CTV was used for a risk assessment of rainbow trout (*O. mykiss*) passing through Windermere Arm over a short period of time; the acute CTV was used to assess lethality risk to organisms in the harbour exposed to intermittent elevated concentrations. The chronic CTV was used to assess the risk in the harbour from exposure to long-term average concentrations. Craig (1999) analysed published trout toxicity data for short-term exposure to high ammonia concentrations. For un-ionized ammonia, the LC_{50} for a 12-hour exposure was 0.74 mg/L, and the LC_{10} was 0.074 mg/L.

Craig (1999) also analysed ammonia LC_{50} data using the Water Environment Research Foundation (WERF, 1996) methodology for logistic regression analysis of community toxicity data. A concentration of 0.29 mg NH_3/L would, on average, theoretically produce 50% mortality in the most sensitive organisms representing the 5th percentile of the aquatic community. This value is approximately equal to the lowest acute effect level for freshwater species that was found in the published literature.

Ammonia sublethal toxicity data were analysed using the WERF regression analysis approach. At un-ionized ammonia concentrations above 0.041 mg/L, 5% of the species in an exposed community would exhibit a 20% reduction in growth or reproduction. This value is also just below the lowest reported chronic effect level for freshwater species (Table 6).

Figure 15 presents the risk analysis for ammonia in Windermere Arm, Hamilton Harbour. Of the weekly ammonia samples taken from Windermere Arm in 1998, there was a slight chance (<4%) that un-ionized ammonia concentrations could exceed the acute CTV of 0.29 mg/L (96-hour LC_{50}). The ammonia concentrations never reached that high a level in the rest of the harbour. Eighteen percent of samples contained un-ionized ammonia concentrations exceeding the short-term acute CTV for trout (12-hour LC_{10}) of 0.074 mg/L. Forty-five percent exceeded the chronic CTV (EC_{20} growth/reproduction) of 0.041 mg/L (Figure 15).

This analysis assumes that weekly samples approximate 96-hour average ammonia concentrations and that the logarithmic trend line in Figure 15 approximates the actual percentile of time that fish are exposed up to a concentration ($R^2 = 0.89$). It indicates that in Windermere Arm, there is little probability that ammonia concentrations would be lethal to 50% of sensitive fish species that remained in the Arm for 96 hours. However, 30% of the time, ammonia concentrations would be expected to cause 10% mortality in a population of rainbow trout passing through the Arm over a 12-hour period. Forty-five percent of the time, the concentrations of un-ionized ammonia in the Arm would be expected to cause a 20% reduction in growth or reproduction in the most sensitive organisms present in the Arm for an extended period of time.

Because the conditions at the central sampling site in Hamilton Harbour were sufficiently similar to those of other stations around the harbour (Charlton and Milne, 1999), this site was used to estimate effects from ammonia in the rest of the harbour. Again, the analysis assumes that sampling times approximate the test exposures and that the logarithmic trend line in Figure 16 approximates the actual percentile of time that fish are exposed up to a concentration ($R^2 = 0.95$). The conditions in the rest of Hamilton Harbour were not as severe as in Windermere Arm. None of the samples reached the 96-hour acute CTV of 0.29 mg/L. However, Figure 16 illustrates that 8% of samples contained un-ionized ammonia concentrations exceeding the short-term acute CTV for trout (LC_{10}, 0.074 mg/L) and 36% exceeded the chronic CTV (EC_{20}, 0.041 mg/L).

This means that in Hamilton Harbour, 8% of the time un-ionized ammonia concentrations would be expected to cause 10% mortality in a population of rainbow trout resident for at least 12 hours and 36% of the time un-ionized ammonia in the harbour would cause a 20% reduction in growth or reproduction of the most sensitive group of species in the harbour.

In summary, in 1998, many sites in Hamilton Harbour had concentrations of un-ionized ammonia that were up to 0.11 mg/L. Un-ionized ammonia concentrations in other areas were above concentrations that are generally safe for aquatic organisms. The ammonia concentrations in 1998 were unusually low. The central harbour site is reasonably similar to the rest of the harbour and, if anything, underestimates ammonia concentrations in shallow-water areas (Charlton and Milne, 1999).

It is concluded that un-ionized ammonia concentrations in the central station of Hamilton Harbour and in Windermere Arm are sufficiently high to cause significant adverse sublethal effects on sensitive organisms that could normally be expected to inhabit these areas. For short periods, the concentrations of un-ionized ammonia can be expected to be acutely lethal to a portion of the rainbow trout population in the harbour.

Figure 15 Un-ionized ammonia concentrations in Windermere Arm, Hamilton Harbour

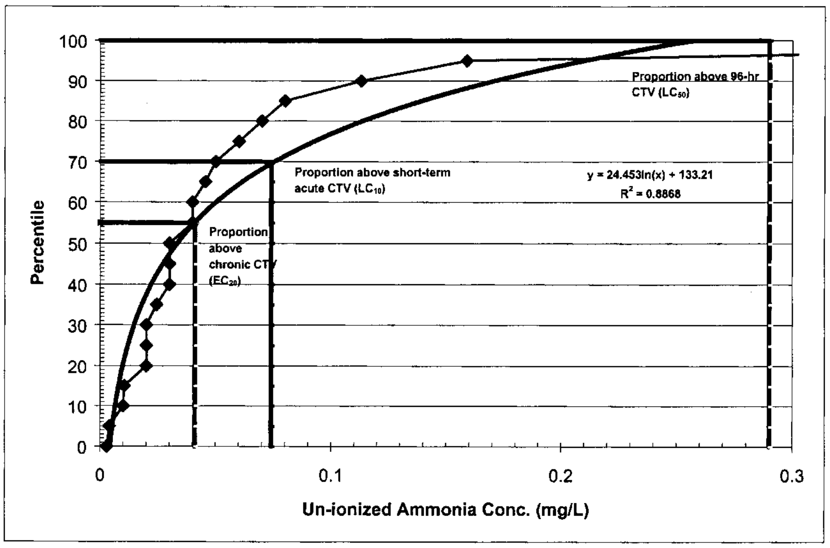
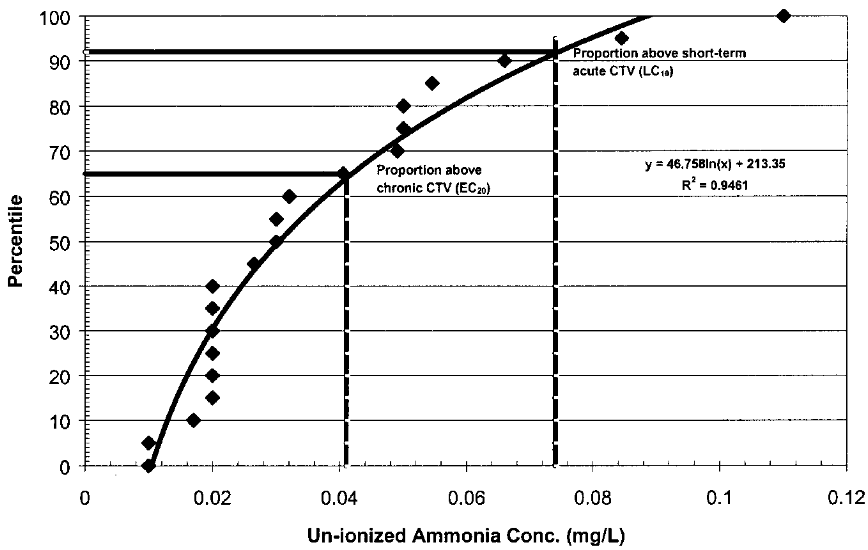


Figure 16 Risk curve for un-ionized ammonia at the central station in Hamilton Harbour

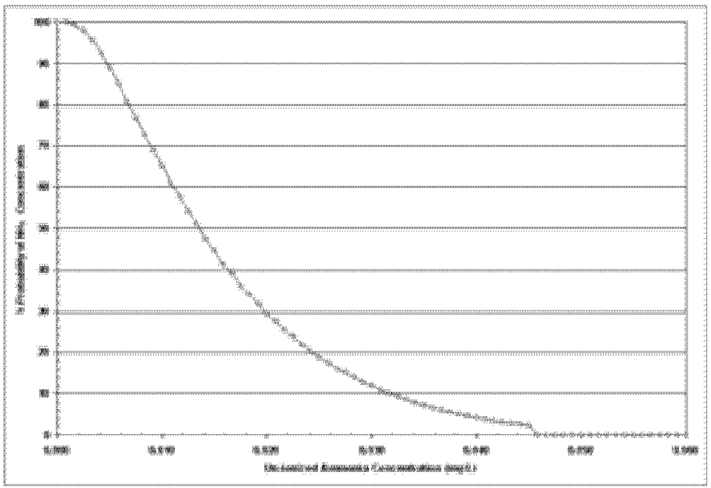


3.1.2.3.2 North Saskatchewan River

Direct measurements of ammonia in the North Saskatchewan River showed that there is a zone of potential toxicity generated in the river downstream from the City of Edmonton's sewage effluents.

The data for this study were collected at only one period of time (September 1993), although they were collected over a large reach of the river. While useful for a validation for the CORMIX plume dispersion modelling program, this study could not be used to adequately determine the risk to aquatic organisms.

FIGURE 17 Cumulative density function of NH_3 concentrations for August at 1 km along the centre of the plume in the North Saskatchewan River



An evaluation of the field monitoring data for the North Saskatchewan River revealed that the data were insufficient to enable development of an exposure cumulative density function (CDF). As an alternative, the CORMIX model was used to estimate levels of un-ionized ammonia at various distances downstream of the WWTP. Initial analyses with CORMIX indicated that ammonia levels in the North Saskatchewan River are typically highest in August. Therefore, the assessment was focused on this month to estimate exposure and risks. Because CORMIX is not a distributional model, exposure CDFs were developed. The steps are described in Appendix D. Figure 17 is an example of an exposure CDF for the North Saskatchewan River 1 km downstream of the Gold Bar WWTP. It represents the probability that a specific ammonia concentration will be exceeded. Reading the ammonia concentration from the bottom of the graph, for example, we can see that there is a 28% chance that ammonia concentrations will be greater than 0.02 mg/L 1 km from the outfall.

For each distance downstream of the North Saskatchewan River treatment plant, a risk curve was derived by combining the exposure CDF and the concentration–response relationship for percentage of biota adversely affected (as derived in the effects characterization). This was done by calculating the un-ionized ammonia concentration that caused effects ranging from 1 to 99% of species affected in 1% increments. Each effect concentration was then compared with the appropriate CDF for exposure to determine the proportion of the exposure values that exceeded the effects concentration. For 0% effect, 100% of the exposure values were greater; hence, each risk curve starts at 100% on the left-hand axis. Risk curves were generated for the centre-line plume 1, 2, 5, 10, 15 and 20 km downstream of the WWTP.

The risk curves are illustrated in Figures 18 to 23 and indicate that impact to aquatic organisms in the North Saskatchewan River decreases downstream of the outfall, as would be expected. For example, Figure 18 shows that at 1 km downstream, there is a 92.2% probability of at least 5% of the species exhibiting a 20% inhibition in growth or reproduction. However, at 20 km downstream, Figure 23 shows that there is a 9.8% probability of the same impact.

Table 12 is a listing of probabilities of an effect (20% or greater reduction in growth/reproduction) to varying proportions

FIGURES 18–23 Risk curves for 1–20 km downstream of the wastewater treatment plant on the North Saskatchewan River

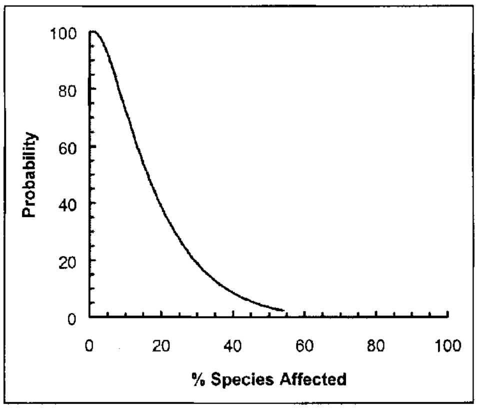


Figure 18: 1 km

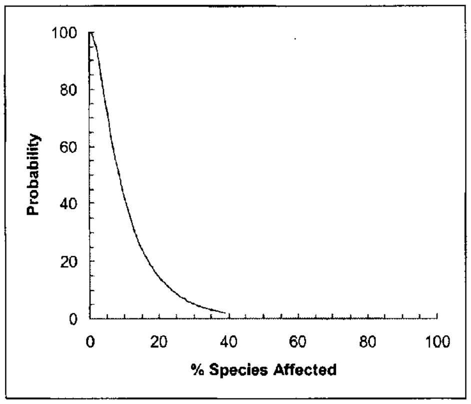


Figure 19: 2 km

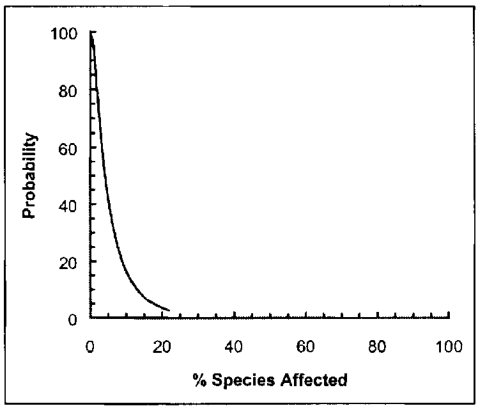


Figure 20: 5 km

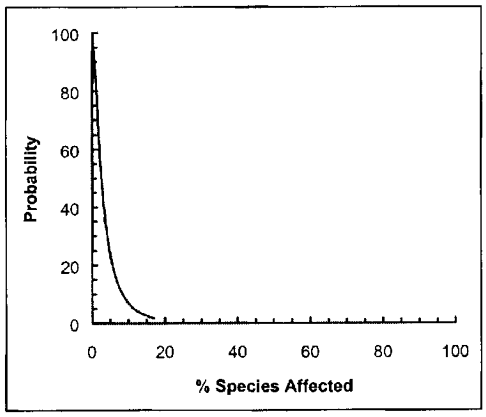


Figure 21: 10 km

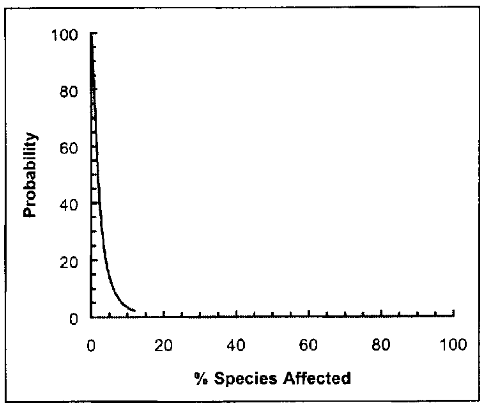


Figure 22: 15 km

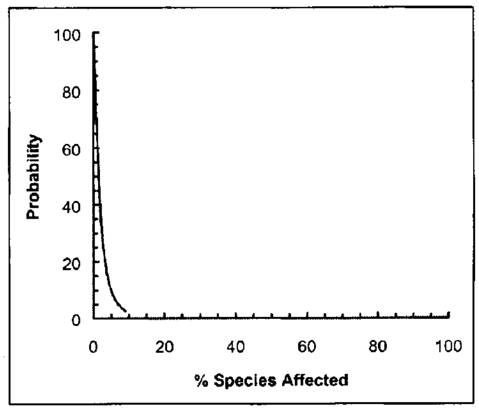


Figure 23: 20 km

TABLE 12 Probability of species affected 1–20 km downstream of the wastewater treatment plant on the North Saskatchewan River in August

Distance from WWTP (km)	Prob. of 5% of species affected	Prob. of 10% of species affected	Prob. of 15% of species affected	Prob. of 20% of species affected	Prob. of 25% of species affected	Prob. of 50% of species affected
1	92	73	54	34	29	4
2	73	42	24	15	9	0
5	42	17	7	4	0	0
10	24	7	3	0	0	0
15	14	3	0	0	0	0
20	10	0	0	0	0	0

of the aquatic community for each distance downstream of the WWTP for the month of August. This table shows that there is a decreasing probability of the defined toxic impact as more species are considered. For example, at 5 km, there is a 42% probability of an impact on 5% of the species, and there is a 0% probability of an impact on 25% of the species.

Figure 24 is a graphical representation of the impact gradient in the plume for 5% of species.

This analysis is, however, a conservative estimate of risk to aquatic biota in the North Saskatchewan River for the month of greatest impact. The uncertainty in quantifying the risk from ammonia is discussed in Section 3.1.2.4.

The accuracy of CORMIX predictions when compared with field measurements is discussed in the supporting document (Environment Canada, 2000). Validation results showed that the greatest difference between the model and measured values lies within the first kilometre of the plume. From the discharge to 1000 m, the accuracy of predictions varies from 95% to 40% of measured, with no particular trend. The prediction improves with distance downstream; it is 98% accurate at 5300 m. Although the near-field zone is of less interest than the far-field zone for the risk assessment on the North Saskatchewan River, it is important to know that CORMIX significantly underestimates ammonia concentration in the first 1000 m.

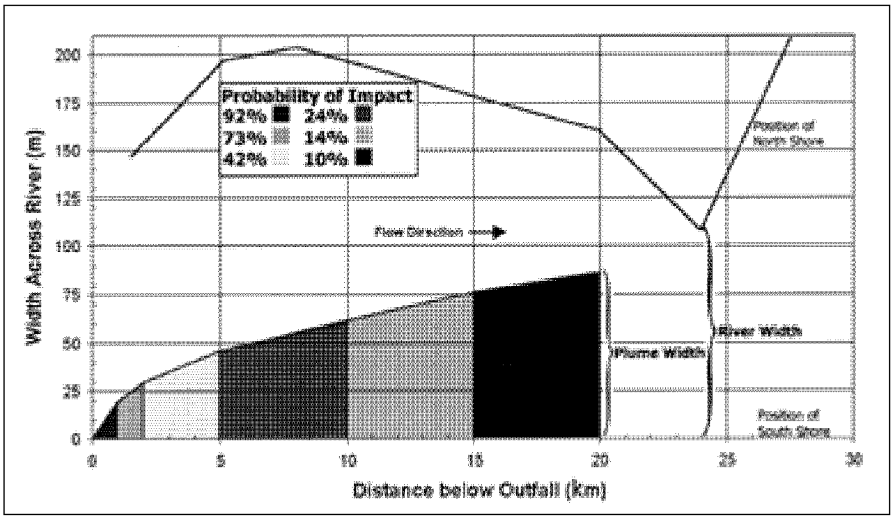
From this analysis, there is a significant likelihood of an ecological impact from the release of ammonia in sewage effluent from Edmonton's sewage system in the summer months. In this Assessment Report, the chronic impact is a 20% decrease in the rate of growth or inhibition of reproduction. Significance can be quantified in the matrix of probabilities of impacts with distance downstream of the outfall (Table12), such that we can predict that there is a 42% probability of a chronic impact on 5% or more of freshwater species in the North Saskatchewan River at 5 km below the outfall. This can be extended to predicting a 10% probability of this impact in a plume that is 20 km long by 80 m wide. The potential impacts are not likely to be as great in any other month, with very little impact expected from November to May.

The City of Edmonton is committed to reducing the ammonia concentration in its effluent to 5 mg/L in summer and 10 mg/L in winter by the year 2005 (Sawatzky, 1999).

3.1.2.3.3 Red River

The screening procedure for high ammonia concentrations in national rivers identified the Red River downstream of Winnipeg as a possibly impacted river (refer to the technical supporting document [Environment Canada, 2000]). Of the

Figure 24 Probability of impacts in the North Saskatchewan River



samples analysed by the province of Manitoba from 1988 to 1997, 27% of them exceeded the screening criteria of 0.02 mg un-ionized NH_3/L. This site was on the Red River at Selkirk, downstream of the Lockport Dam. The City of Winnipeg monitors water quality at the dam; 10% of samples were in excess of the chronic CTV of 0.04 mg un-ionized ammonia/L. These numbers warranted a detailed review of the data from the City of Winnipeg (data were provided by R. Ross, City of Winnipeg Water Pollution Control Centre, Chemistry Laboratory).

Winnipeg operates three sewage treatment plants: two on the Red River, called the South End Water Pollution Control Centre (SEWPCC) and the North End Water Pollution Control Centre (NEWPCC), and one on the Assiniboine River, called the West End Water Pollution Control Centre (WEWPCC). The CORMIX screening exercise identified the North End and West End plants as being potentially problematic (Figure 25).

The West End plant is the smallest of the three plants and discharges secondary-treated effluent to the Assiniboine River near the western boundary of the city. The South End plant is located in the southern half of the city (St. Vital) on the Red River. It handles the second largest volume of sewage.

The North End facility is the City of Winnipeg's largest-capacity plant, discharging to the Red River about 24 km downstream of the confluence with the Assiniboine River, near the northern boundary. Lockport Dam 20 km downstream backs up the water through Winnipeg, so that it has an average width of 175 m and an average depth of 3.5 m at low flow. As the river is relatively deep with slow currents, this leads to slow vertical mixing but rapid horizontal mixing. The Red River provides relatively low rates of dilution at full mixing, ranging from about 11:1 to 69:1 at low and average river flows, respectively.

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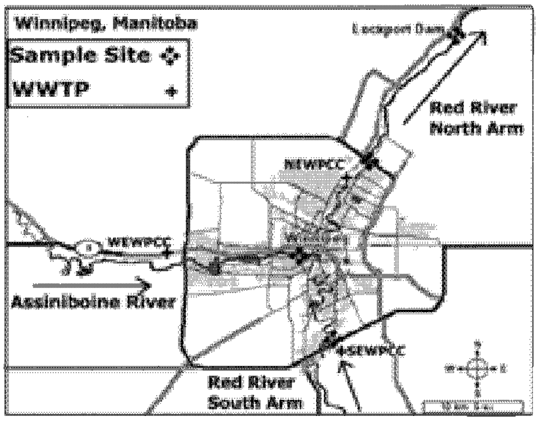
FIGURE 25 Winnipeg sewage treatment plants and sample sites

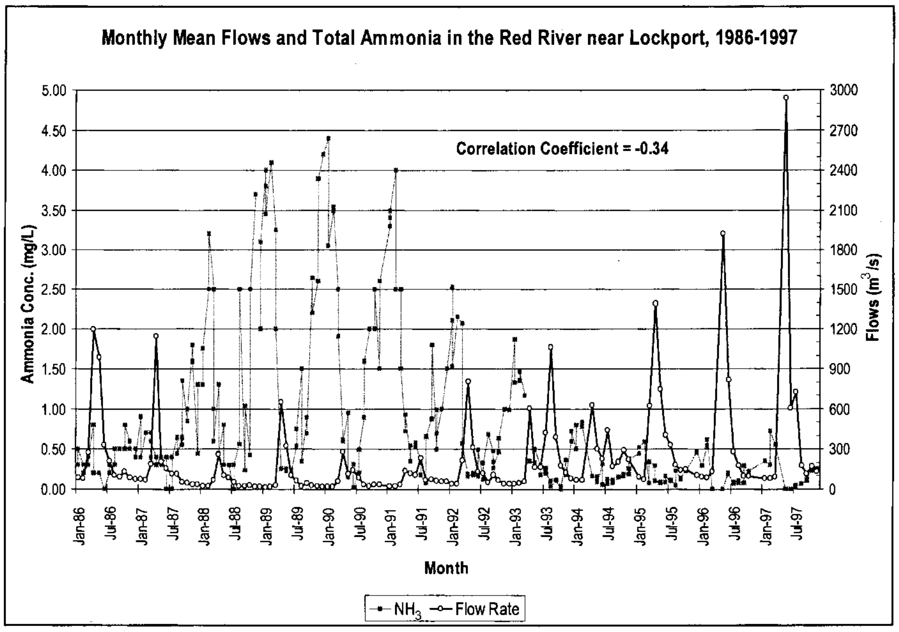


The City of Winnipeg monitors ammonia concentrations at four locations: (1) on the Assiniboine River at Winnipeg's Main Street Bridge, (2) on the Red River at Lockport Dam north of the city, (3) at Perimeter Bridge just north of the North End plant, and (4) at Winnipeg's Fort Garry Bridge downstream of the South End plant.

As shown in Figure 26, total ammonia concentrations have varied considerably at Lockport Dam, although the ammonia concentrations from the three WWTPs have not changed appreciably in the past 20 years. The City of Winnipeg did not change its sewage treatment processes during the period of data presented (1986–1997) in Figure 26 (Ross, 1998). A comparison of river flow data for the Red River with the total ammonia concentration at Lockport shows a weak negative correlation (–0.34).

There are some distinct patterns identifiable for flow rates and total ammonia concentrations. The predominant ones are the periodic fluctuation in both flow rates and total ammonia concentrations. Flows peak in the spring, while total ammonia peaks in late summer General trends can be observed between high ammonia concentrations and low flows for the years 1988–1991 and between low ammonia concentrations and high flows, exemplified by the years 1995–1997.

FIGURE 26 Red River monthly mean flows and total ammonia concentrations



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The highest ammonia levels in the Red River occur from August to November. Therefore, this time frame was chosen for estimating risks to aquatic biota. Because the concern is for chronic effects, the appropriate temporal scale for estimating exposures is monthly (many chronic toxicity tests in fish are close to 1 month in length). In a chronic exposure scenario, high exposures on some days tend to be balanced out by low exposures on other days, such that overall exposure tends towards some measure of centrality. The appropriate measure of centrality in the case of ammonia concentrations in water is a geometric mean, because the underlying distribution for concentrations of contaminants in the environment is typically lognormal (Ott, 1995). Developing CDFs (probability of being in an exposure range versus ammonia concentration) for ammonia exposure also requires a measure of dispersion about the geometric mean of the ammonia concentration. Because we are concerned with chronic exposures, the measure of dispersion should not be used to estimate day-to-day variation. Rather, the dispersion measure should be used to account for year-to-year variability of the monthly mean. As the wastewater treatment practices and receiving environment conditions had not been significantly altered in the last decade, the long-term monitoring data were used to make predictions about possible exposures in the future. That is, the variation in monthly geometric means in the past 11 years can be used to estimate expected variation in the future. Therefore, for each sampling station and each month, exposure CDFs were developed as described in Appendix E.

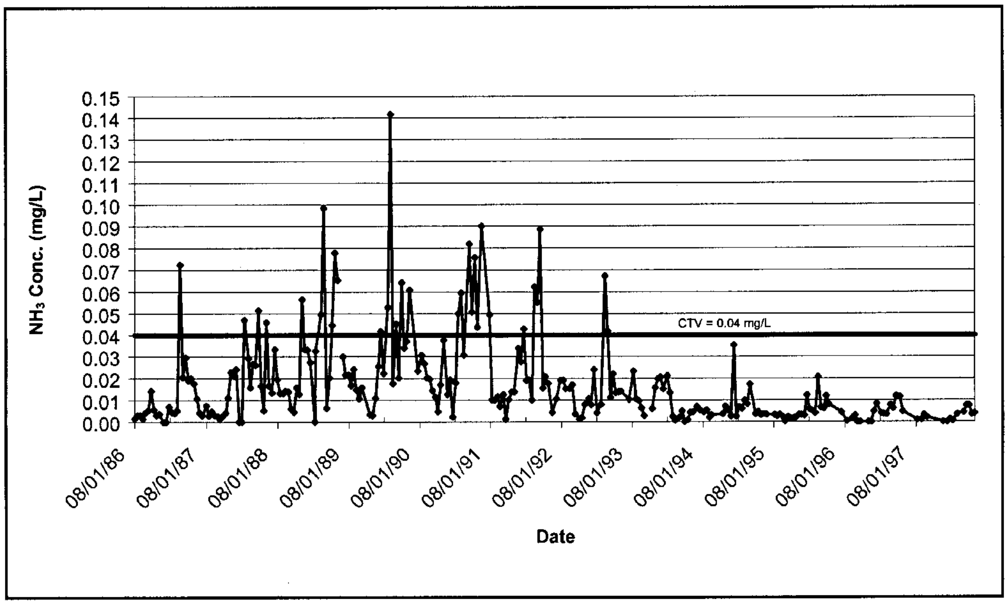
At Lockport Dam, approximately 20 km north of the city (Figure 25), the un-ionized ammonia concentrations exceeded the CTV for most of the months from July to January for the period 1986–1993 (Figure 27, grab samples taken weekly). This is not the pattern seen at the North Perimeter station upstream. At Lockport Dam, the periods when the CTV is exceeded occur in both low and high water flow periods. The months of high concentrations extend from July occasionally to January. This may have something to do with the effect of the dam on flows in this area of the Red River.

From these data, it appears that a major factor in high ammonia levels downstream of Winnipeg is the flow rate of the Red River. The Lockport Dam creates a still-water area for some 20 km back past Winnipeg. The combination of moderately high pH (usually above 8) and warm temperatures in the Red River drives the un-ionized ammonia concentrations above 0.04 mg/L. The City of Winnipeg provided sufficient information from its water quality monitoring program to conduct an analysis to determine the probability of impacts.

For each of the four sampling stations, and for each month under consideration, a risk curve was derived by combining the exposure CDF (as derived from exposure characterization) and the concentration–response curve (as derived from effects characterization). This was done by calculating the un-ionized ammonia concentration that caused effects ranging from 1% to 99% of species affected in 1% increments. Each effect concentration was then compared with the appropriate CDF for exposure in order to determine the proportion of the exposure values that exceeded the effects concentration. For 0% effect or more, 100% of the exposure values were greater; hence, each risk curve starts at 100% on the left-hand axis. The risk curves are presented in Figures 28–43. A good point of comparison between the risk curves is the probability that 5% or more of the species will be affected by the ammonia in the river. For example, in August at the Lockport Dam site, there is a 24.4% probability of at least 5% of the species exhibiting a 20% inhibition in growth or reproduction.

Table 13 lists the probabilities of an effect (20% reduction in growth/reproduction) on varying proportions of the aquatic community for each month at the four monitoring sites in the Red and Assiniboine rivers.

FIGURE 27 Un-ionized ammonia concentrations in the Red River at Lockport Dam, north of Winnipeg



From this analysis, there is a significant likelihood of an ecological impact from the release of ammonia in sewage effluent from Winnipeg's sewage system. In this assessment, the "toxic impact" is defined as a 20% decrease in the rate of growth or inhibition of reproduction. Significance can be quantified in that probabilities of impacts to the most sensitive 5% or more of freshwater species in the Red River are from 10% to 31%, depending on the month of exposure and the location. Probabilities of the same degree of impact to the most sensitive 10% or more of species range from 5% to 21%, depending on the month and location. The stretch of river encompassed by this study is roughly 30 km in length.

Significant impacts on freshwater biota in the Assiniboine River, roughly 20 km downstream of the discharge, are not likely, although some degree of impact might be expected at this site in November Impacts upstream of the bridge could not be quantified.

The City of Winnipeg is currently conducting a site-specific ecotoxicological assessment of its municipal effluents.

3.1.2.4 Discussion of uncertainty

Uncertainty analyses seek to describe and interpret lack of knowledge that may be present in the implementation or interpretation of a risk analysis. The goal of uncertainty analyses is to provide the risk manager with the most complete information available on the expected outcomes of exposures. In risk analysis, scientific uncertainty derives from many sources, including inadequate scientific knowledge, natural variability, measurement error, sampling error and incorrect assumptions. Uncertainty can also arise from model mis-specification, including errors in statistics, parameters and initial conditions and failure to appropriately capture expert judgement (SETAC, 1997).

There are several major sources of uncertainty associated with the environmental risk assessment of ammonia. The principal source of uncertainty is the estimation of a chronic CTV at the low end of the toxicity scale. In this case, it was estimated to be 0.041 mg/L, with 95% prediction limits of 0.02–0.06 mg/L, which is just below the lowest measured EC_{20} estimated from

TABLE 13 Probabilities of impacts at four sites around Winnipeg

Month	Probability of 5% of species affected	Probability of 10% of species affected	Probability of 15% of species affected	Probability of 20% of species affected	Probability of 25% of species affected
Red River — Fort Garry Bridge					
August	19	11	7	5	4
September	21	13	9	7	5
October	10	5	3	2	0
November	18	11	8	7	5
Red River — North Perimeter Bridge					
August	31	21	16	13	11
September	25	15	11	8	6
October	16	10	7	5	4
November	19	12	8	6	5
Red River — Lockport Dam					
August	24	14	10	7	5
September	21	10	6	4	3
October	18	11	7	5	4
November	20	11	7	5	4
Assiniboine River — Main Street Bridge					
August	0	0	0	0	0
September	0	0	0	0	0
October	0	0	0	0	0
November	11	6	4	3	3

published toxicity studies. Other major sources of uncertainty are the period of actual exposure in fish, the application of a generic assessment to specific situations, the lack of recent ambient concentration data in most Canadian media, and the potential confounding toxicity from other components of sewage effluents.

Regarding environmental exposure, there could be concentrations of ammonia in Canada that are higher than those identified and used in this assessment. Limited data were available for ammonia levels in air where the largest Canadian releases occur. For example, ammonia deposition rates at present across Canada are relatively low, although they can be very high in certain locales, typically associated with intensive livestock operations (i.e., the Lower Fraser Valley).

Of the three case studies used for WWTPs, two, Hamilton Harbour and Winnipeg, had well-documented water quality monitoring studies, and Edmonton had an intense, short-term study to determine ammonia dispersion in the plume that enabled modelling of the plume under variable conditions.

Analysis of ammonia released from pore water by the disposal of dredged sediment suggests that marine species might be adversely affected. However, this analysis should be viewed with caution due to the paucity of data with respect to marine species.

Regarding effects of ammonia on aquatic and terrestrial organisms, uncertainty inevitably surrounds the extrapolation from available toxicity data to potential ecosystem effects. The ammonia assessment is based on a few well-done freshwater field studies, modelling and extrapolation from laboratory toxicity work. The relatively small number of organisms that can be routinely cultured and tested in laboratory toxicity studies leads to this uncertainty when

FIGURES 28–31 Risk curves for Fort Garry, Red River

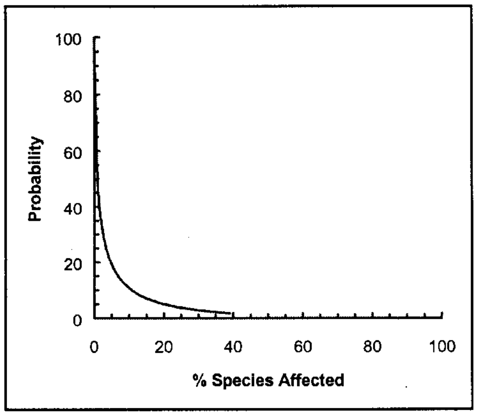


Figure 28: August

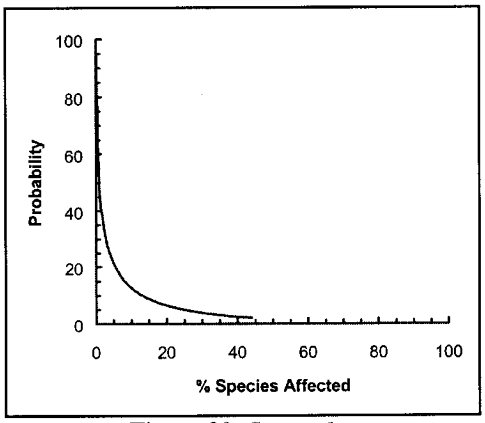


Figure 29: September

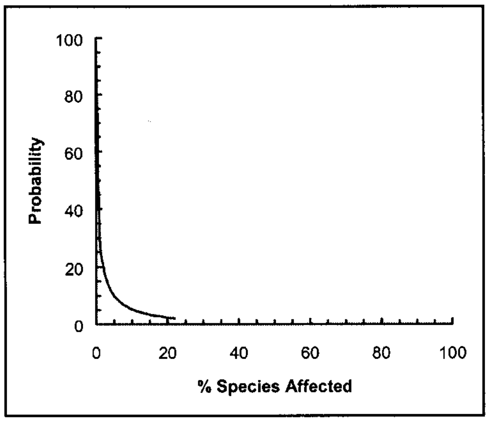


Figure 30: October

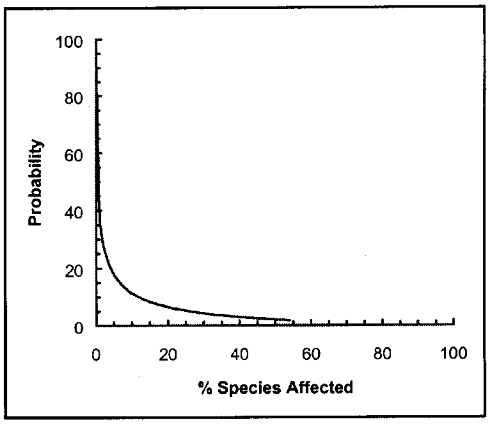


Figure 31: November

extrapolating these toxicity results to responses of natural populations. That said, the Europeans have documented ecological changes in their sensitive ecosystems likely as a result of the atmospheric deposition of ammonia. Canadian ecosystems will likely respond in similar ways.

To account for some of these uncertainties, conservative application factors were used as appropriate in the environmental risk analysis to derive ENEVs. An application factor is useful when few toxicity data are available and is, in general, environmentally protective, as it is a conservative approach. In addition, when there are many sources of uncertainty (e.g., sources of uncertainty in toxicity testing or exposure concentrations), application factors provide a relatively easy way to aggregate the multiple sources of uncertainty. In these cases, complicated statistical analysis may be impractical and costly.

The toxicity of ammonia to warm-water species is limited; however, the database for toxicity of ammonia to cold-water species is good. The problem of determining actual periods of exposure is difficult due to the mobility of many fish species in rivers. Toxicity estimation in the North Saskatchewan River is problematic

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FIGURES 32–35 Risk curves for Perimeter Bridge, Red River

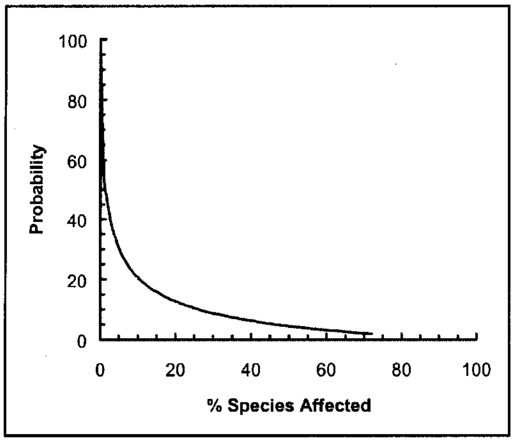

Figure 32: August

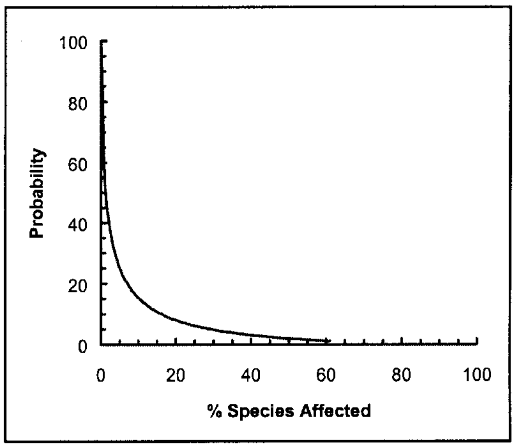

Figure 33: September

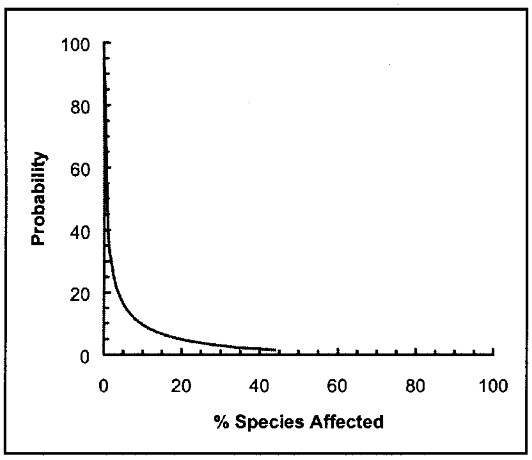

Figure 34: October

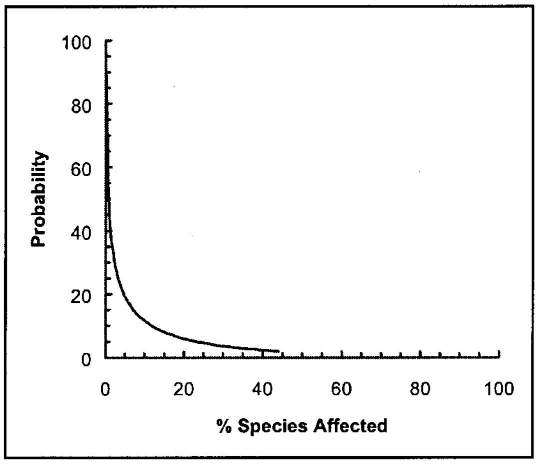

Figure 35: November

due to the unrestricted nature of the river and the mobility of fish. However, benthic surveys above and below the outfall support the conclusion of toxicity from the sewage effluent, although not necessarily from ammonia. In the Red River, there is limited travel for fish below the Lockport Dam, and Hamilton Harbour has a greatly restricted water flow, with Lake Ontario restricting fish travel. Thus, the likelihood of overestimating risk to species critical to the structure and function of the community or ecosystem was judged to be acceptable.

The use of a generic group of aquatic species that are native to much of Canada may still present a source of uncertainty, for this group of species is not resident in all sewage discharge situations across Canada. Some of the species used were not commonly found in each of the three case studies, although they were all potentially resident. The use of site-specific assemblages of species would eliminate this uncertainty, although toxicity information is sparse for many species commonly found across Canada. A site-specific assemblage of species would not necessarily be less sensitive than the

FIGURES 36–39 Risk curves for Lockport Dam, Red River

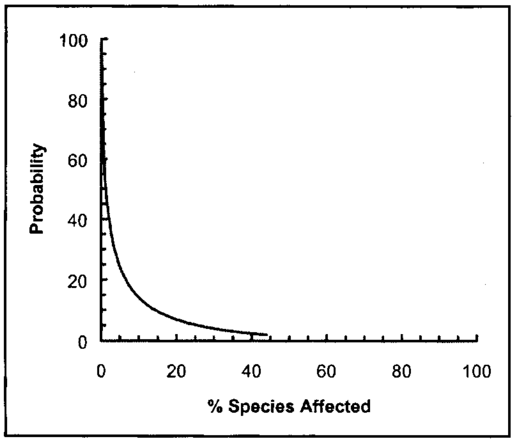

Figure 36: August

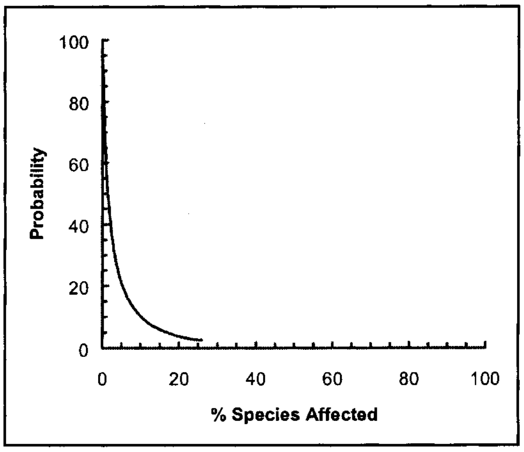

Figure 37: September

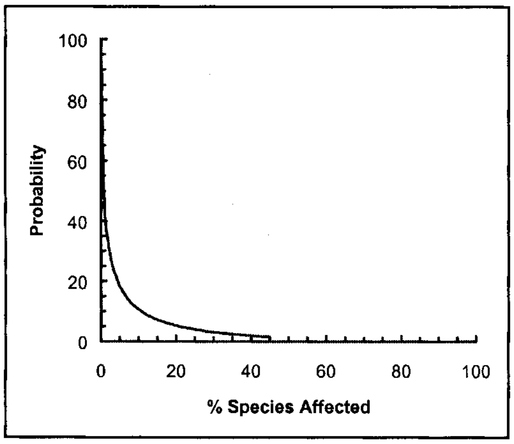

Figure 38: October

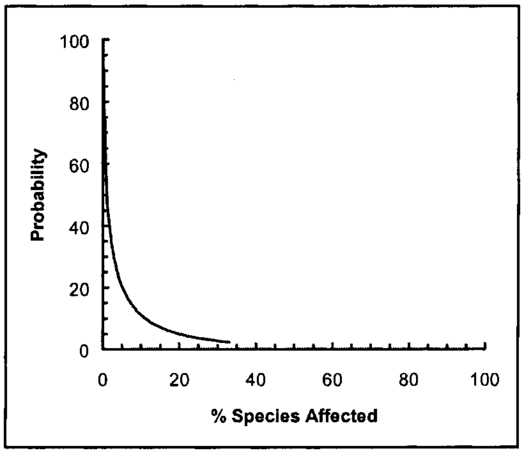

Figure 39: November

generic one chosen; some local species, mountain whitefish (*P. williamsoni*), for example, are more sensitive than rainbow trout (*O. mykiss*) to ammonia.

The major reviews of data conclude that pH has a larger effect than temperature on acute toxicity (WHO, 1986; U.S. EPA, 1998). There are no proven correlations between temperature and chronic toxicity due to the paucity of data. The effect on this assessment of assuming that toxicity increases, rather than decreases, with temperature is to make the late summer/early fall months the critical periods, whereas the risk from toxicity may be more spread out from spring to fall. In this case, this assessment would underestimate toxicity from ammonia in some months and overestimate it in others.

The probabilistic approach used for the case studies allows for a quantitative estimation of risk (analysed as a distribution of effects and exposure concentrations) and therefore incorporates many of the uncertainties associated

FIGURES 40–43 Risk curves at Main Street Bridge, Assiniboine River

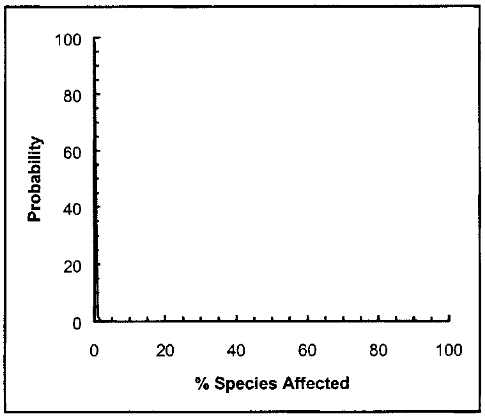

Figure 40: August

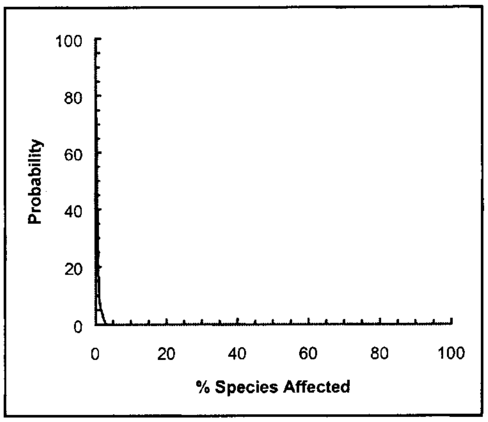

Figure 41: September

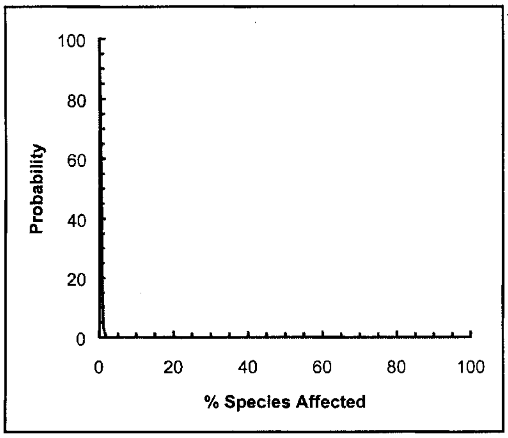

Figure 42: October

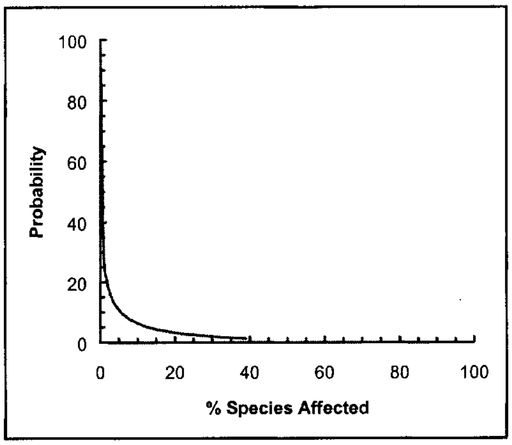

Figure 43: November

with the effects and exposure characterization discussed above. The largest source of uncertainty lies in the estimate of the CTV.

In addition to uncertainty in the exposure and effects data, biological and ecological uncertainty needs to be considered. This includes consideration of the potential for organisms such as plants to recover from exposure and the effects of multiple stressors that are likely present. Ammonia is a constant component of sewage, but the concentrations will vary considerably based on social fluctuations from the city generating the effluent. It has been shown that organisms will tolerate higher concentrations of ammonia if the exposure is pulsed, rather than constant. Sewage effluent is also a complex mixture and is released to a variety of different ecosystems that will respond differently. Typical ecosystems include coastal marine/estuary systems, lake systems, and small and large river systems. Potential impacts are not strictly from ammonia, but could also be from excess chlorine, chlorinated compounds, chloramines, biochemical oxygen demand, chemical oxygen demand and metals.

In the North Saskatchewan River below Edmonton, confounding toxicity could arise from chloramines, as the City of Edmonton chloraminates its drinking water. A PSL toxicity assessment of chloramines is being conducted. Dissolved oxygen is typically high in the river, so lack of oxygen is not likely a component of the toxicity "package." Excessive organic matter could also generate an enriched environment that some pollutant-tolerant organisms will find attractive.

Hamilton Harbour is seriously impacted by the many industries and cities lining its shores. The sediments are generally contaminated with metals, polychlorinated biphenyls and polycyclic aromatic hydrocarbons. The bottom waters of the harbour become anoxic in summer, likely due to a combination of poor water exchange with Lake Ontario, biological degradation of organic matter from sewage, nitrification of ammonia and biological degradation of sediments.

Winnipeg does not disinfect its sewage, so there are no problems with excessive chlorine. It uses chlorine for drinking water, however, so there may be excessive chlorine from this exposure as well as some short-term exposure to chloramines as chlorine and ammonia react.

The Red River below Winnipeg is slow moving, but relatively deep. Some oxygen sag has been noted in previous surveys; however, excessive algal growth below the WWTPs augments this somewhat.

The information presented in this risk assessment shows that ammonia is a chemical of concern. However, it is important to remember that ammonia toxicity is being assessed independently of all other stressors, including other effects of ammonia, such as its effects as a nutrient on primary production and its effects on dissolved oxygen concentrations from nitrification and plant respiration.

3.1.2.5 Interpretation of ecological significance

The toxicity of ammonia downstream of a sewage outfall varies with many parameters, the most important of which are the concentration of ammonia in the effluent, the temperature of the water, the pH of the water, the flow rate of the water system and the flow rate of the effluent. Secondarily, the way in which the effluent enters the receiving environment is important; a multi-port diffuser dilutes the ammonia more rapidly in the water column so that it poses less of a risk than an effluent that enters a water system as a single plume. Discrete plumes from a point source tend to disperse slowly in water systems unless they are highly energetic, i.e., exposed to tides or strong currents. Temperature cannot be separated from the toxicity equation due to a lack of adequate information on the relative toxicity of ammonia at different temperatures.

The maximum risk of acute and chronic toxicity in an aquatic ecosystem downstream from a sewage outfall or other point source of ammonia occurs at a combination of low flows, high temperatures and high pH values, typically in late summer and early fall. The temperature and pH conditions will drive the proportion of un-ionized ammonia to chronically toxic levels, and the low flows ensure that there is not sufficient dilution capacity in the water system to accommodate the amount of ammonia present. The toxic risk is very low for waters all across Canada from December to April due to the low water temperatures and reduced pH levels. Most agricultural runoff of ammonia occurs in early spring before it can bind to soil and will not have a significant impact on aquatic ecosystems.

The ecological impact of ammonia in aquatic ecosystems is likely to occur through chronic toxicity to benthic invertebrates and fish populations as a result of reduced reproductive capacity and reduced growth of young. These are subtle impacts that will likely not be noticed for some time below an outfall. Typically what happens is a decline in the numbers of a sensitive species. Unless there is continual recruitment from unaffected populations, the affected population may die out over time. Toxic impacts on aquatic ecosystems can extend for many kilometres below a large sewage outfall. Impacts on fish populations are very difficult to determine due to the mobile nature of many fish species and to recruitment of fish from non-impacted areas. Benthic invertebrates are a much better indicator of impact, as they are not very mobile for much of their life cycle. Below the outfall at Edmonton, the diversity and benthic community structure were severely disrupted for over 20 km. Some of the pollution-sensitive insects did not make a comeback at 100 km downstream. It is difficult to determine if this impact is from ammonia, one of the other major components of sewage effluent, or a combination of factors.

Ammonia is a fundamental building block of life; as such, it is a nutrient for primary producers. Some terrestrial ecosystems in Europe, especially coniferous forests, moors and fens, are being seriously affected by excess nitrogen, much of which is in the form of ammonia. The ammonia raining down on the Netherlands, Belgium, Germany and the United Kingdom is largely from intensive agricultural operations. In these cases, the ecological disturbance is through terrestrial eutrophication and a toxic reaction to beneficial mycorrhizae symbiotically associated with tree roots. The nutritional balance of the ecosystems is being upset so that the existing dominant plants are being destroyed or pushed out by plants more capable of using nitrogen. This same phenomenon is not happening in Canada, as we have more space with which to dilute the ammonia, and we do not have as many sensitive ecosystems in close proximity to ammonia sources. That said, there are potential instances of this occurring in Canada, in particular in the Lower Fraser Valley.

Aquatic eutrophication is generally limited not by ammonia, but by phosphorus. This was confirmed recently by a joint review by Environment Canada, Fisheries and Oceans Canada and Agriculture and Agri-Food Canada. Therefore, there is little ecological impact from aquatic eutrophication due to excessive ammonia concentrations. It follows that at least one example of a nitrogen-impacted water system exists in Canada. The Qu'Appelle Lakes in Saskatchewan downstream of Regina are likely impacted by ammonia loadings. The City of Regina does not remove nitrogen from its sewage effluent.

Benthic organisms and aquatic macrophytes below the Edmonton WWTP have been severely affected by the effluents, a major component of which is ammonia. The distribution and abundance of many aquatic insects have been altered, and the growth of aquatic macrophytes increases dramatically downstream of the outfall. Much of this can be attributed to excessive nutrients, including ammonia.

Due to the interaction between receiving water pH and temperature, those waters most at risk from sewage-related ammonia are those that are routinely basic in pH with a relatively warm summer temperature combined with low flows. In Canada, winter temperatures, regardless of pH, are low enough to keep the formation of un-ionized ammonia below the toxic threshold. Potentially toxic conditions typically start in May and can continue through to early October, depending on the water system and the yearly variation in pH, temperature and dissolved oxygen. In general, waters potentially sensitive to ammonia from WWTPs are found in southern areas of Alberta, Saskatchewan and Manitoba; southern Ontario; and the south shore of Quebec.

Most of the urban populations in the Maritime provinces and British Columbia discharge to a large river (St. John River, Fraser River), to lakes or directly to the ocean. There is little information on, or evidence of, potentially significant impacts of these discharges on their receiving environments, due largely to the high dilution capacity of the water bodies.

3.2 CEPA 1999 64(b): Environment upon which life depends

Ammonia does not deplete stratospheric ozone or contribute significantly to the formation of ground-level ozone, and its potential contribution to climate change is negligible.

3.3 Conclusions

CEPA 1999 64(a): Based on available data on releases of ammonia from municipal wastewater treatment plants and the aquatic conditions routinely found downstream of many such outfalls in Canada, it has been concluded that ammonia is entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Therefore, ammonia is considered to be "toxic" as defined under Paragraph 64(a) of CEPA 1999.

CEPA 1999 64(b): Based on available data, it has been concluded that ammonia is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger to the environment on which life depends. Therefore, ammonia is not considered to be "toxic" as defined under Paragraph 64(b) of CEPA 1999.

Overall conclusion: Based on critical assessment of information on ammonia relevant to the aquatic environment, ammonia is considered to be "toxic" as defined in Section 64 of CEPA 1999.

3.4 Considerations for follow-up (further action)

The conclusion of this assessment is based on analyses of risks posed by releases of ammonia from municipal WWTPs. Priority should therefore be given to consideration of options to reduce exposure to ammonia from municipal wastewater systems. Since the toxicity of ammonia is dependent on many site-specific variables, options to reduce exposure to ammonia from municipal wastewater systems should be examined on a site-specific basis. If a city or region has a water body with a large dilution capacity, then ammonia control may not be necessary, or perhaps an improved dilution system may be required. If, however, there is not a sufficient dilution capacity, then additional treatment may be required. This typically takes the form of converting ammonia to nitrate. A further step of converting nitrate to nitrogen reduces the possibility of nitrate toxicity and oversupply of nutrients, but is considerably more costly.

Results of conservative screening-level assessments suggest that releases of ammonia from several other sources may also be causing environmental harm, but available data were insufficient to establish the extent and magnitude of such harm. It is therefore recommended that additional data be obtained to determine whether options to reduce exposure to ammonia from such sources should be undertaken. The following data needs are listed in order of priority:

- concentrations in waters receiving inputs of ammonia from strong industrial point sources,
- concentrations in Canadian streams and rivers receiving runoff from agricultural sources, including manure-fertilized fields and intensive livestock operations (feedlots and dairies),
- deposition of ammonia from the atmosphere, both in background areas and near point and area sources in Canada, and
- concentrations of ammonia in Canadian marine waters at municipal wastewater outfalls.

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APPENDIX A 1995 AMMONIA EMISSIONS INVENTORY FOR AIR FROM VARIOUS SOURCES

CATEGORY / SECTOR	NFLD	PEI	NS	NB	QUE	ONT
Animal Husbandry (TOTAL)	**672.69**	**2 253.42**	**4 401.95**	**3 019.39**	**57 469.31**	**70 193.60**
Commercial Fertilizer (TOTAL)	44.96	583.75	433.93	603.37	9 904.09	20 665.13
AGRICULTURAL (TOTAL)	**717.65**	**2 837.18**	**4 835.88**	**3 622.77**	**67 373.40**	**90 858.74**
Industrial Total (TOTAL)	33.72	0.75	9.77	10.58	83.92	466.36
Non Industrial FUEL/ Combustion (TOTAL)	132.26	34.90	215.35	155.31	611.96	945.21
Transportation (TOTAL)	345.50	99.09	592.69	564.11	4 995.58	7 370.34
Incineration (TOTAL)	14.92	0.64	8.45	26.51	49.36	84.82
Miscellaneous (TOTAL)	147.21	34.62	239.41	194.07	1 874.63	2 833.29
Open Sources (TOTAL)	4.25	0.12	1.20	1.40	650.04	1 264.99
NON AGRICULTURAL (TOTAL)	**677.84**	**170.13**	**1 066.86**	**951.97**	**8 265.49**	**12 965.00**
CANADA (TOTAL)	**1 395.49**	**3 007.31**	**5 902.74**	**4 574.73**	**75 638.90**	**103 823.74**

CATEGORY / SECTOR	MAN	SASK	ALTA	BC	YUK	NWT	CANADA
Animal Husbandry (TOTAL)	29 466.46	35 646.70	74 832.41	16 140.81			294 096.75
Commercial Fertilizer (TOTAL)	29 135.61	65 130.43	50 443.28	3129.12			180 073.69
Agricultural (TOTAL)	**58 602.07**	**100 777.14**	**125 275.69**	**19 269.93**			**474 170.44**
Industrial (TOTAL)	21.34	100.42	463.42	184.35	0.46	4.42	1 379.51
Non Industrial FUEL Combustion (TOTAL)	59.67	62.88	206.83	288.19	6.47	34.79	2 753.83
Transportation(TOTAL)	726.02	642.37	2 061.38	2 250.68	28.94	16.42	19 693.12
Incineration (TOTAL)	2.84	3.04	24.47	123.93	0.00	2.70	341.65
Miscellaneous (TOTAL)	290.24	259.55	702.63	960.74	7.73	16.80	7 560.92
Open Sources (TOTAL)	2 381.70	3 048.87	1 131.20	218.54	472.88	5 174.14	14 349.33
NON AGRICULTURAL (TOTAL)	**3 481.80**	**4 117.14**	**4 589.93**	**4 026.44**	**516.48**	**5 249.29**	**46 078.37**
CANADA (TOTAL)	**62 083.88**	**104 894.28**	**129 865.62**	**23 296.37**	**516.48**	**5 249.29**	**520 248.81**

* Note: Agricultural data was not available for the Yukon and Northwest Territories; therefore, ammonia emission estimates were not calculated for these regions.

APPENDIX B PROVINCIAL BREAKDOWN OF RELEASES OF AMMONIA FROM INDUSTRIAL SOURCES (NPRI 1996)

Province	Quantity released (tonnes)
Alberta	17 665 (7773 to deep wells)
Ontario	7 552
Quebec	1 914
British Columbia	1 802
Manitoba	1 291
Saskatchewan	865
New Brunswick	789
Nova Scotia	106
Northwest Territories	41
Newfoundland	13
Prince Edward Island	None reported
Yukon	None reported

APPENDIX C TOP 12 URBAN CENTRES FOR AMMONIA LOADING RATE (TONNES/YEAR) IN 1995 OR 1996

City	Province	Facility type	Average yearly effluent flow rate (million m^3/year)	Yearly avg. NH_3 conc. (mg/L)	NH_3 loading rate (tonnes/ year)
Montreal Urban Community	QC	Primary	930	6.59	6128
Metro Toronto	ON	Tertiary	463	12.0	5938
Greater Vancouver	BC	Primary/secondary	432	14.0	5741
Winnipeg	MB	Secondary	83	26.02	2152
Metro Edmonton	AB	Secondary	91	21.42	1946
Hamilton	ON	Tertiary/secondary	115	13.00	1499
Longueuil	QC	Primary	114	9.79	1121
Calgary	AB	Tertiary/secondary	146	5.02	996
Metro Quebec City	QC	Secondary	57	11.63	667
Victoria Region	BC	Primary	26	13.89	377
Burlington	ON	Tertiary	27	13.89	370
Saskatoon[1]	SK	Enhanced primary	30	11.78	352

[1] Saskatoon's loading rate was considerably less after May 1996, due to tertiary treatment. In 1998, they achieved an average ammonia concentration of 0.68 mg/L; the loading rate was approximately 21 tonnes/year (Clark, 1999).

APPENDIX D DEVELOPMENT OF EXPOSURE CDFS FOR THE NORTH SASKATCHEWAN RIVER

The following steps were taken to enable development of exposure CDFs for the North Saskatchewan River.

- A rough sensitivity analysis was carried out to determine which input variables had the most influence on predicted ammonia levels in the river (see "Sensitivity analysis of river parameters on the size of the potentially toxic zone" in technical supporting document [Environment Canada, 2000]).

- Based on the results of the sensitivity analysis, five important input variables were identified; these were river flow, temperature, pH, effluent flow and total ammonia concentration. There were concerns with uncertainties about the monthly geometric mean for ammonia levels in the North Saskatchewan River. Thus, monthly arithmetic means were estimated for the normally distributed input variables (river temperature and pH) and monthly geometric means for the lognormally distributed variables (river and effluent flow, effluent ammonia concentration). Using the calculated means, normal distributions were fit to temperature and pH (the latter is already on a log scale), and lognormal distributions were fit to the remaining three input variables.

- For each of these five parameters, the available data were analysed to develop distributions of each. Each parameter distribution was then fed into a statistical package (i.e., Crystal Ball) to expand the distribution using Latin Hypercube sampling so as to develop a larger data set with which to make predictions. The measured correlations between the input variables (e.g., effluent flow and ammonia concentration) were specified prior to the sampling exercise.

- Five hundred sets of parameters were then developed and fed into CORMIX to develop predictions for a typical August at six distances downstream of the effluent outfall (1, 2, 5, 10, 15 and 20 km). The outputs from this exercise were 500 estimates of un-ionized ammonia levels (mid-plume) at each of several distances between 1 and 20 km downstream of the plant. Lognormal distributions were then fit to the data at each distance downstream.

- This distribution of data points was divided into ranges equal in size (each range was 0.000 58 units). The number of data points in each range was used to develop an exposure CDF for each of the distances (1, 2, 5, 10, 15 and 20 km) downstream of the Gold Bar WWTP.

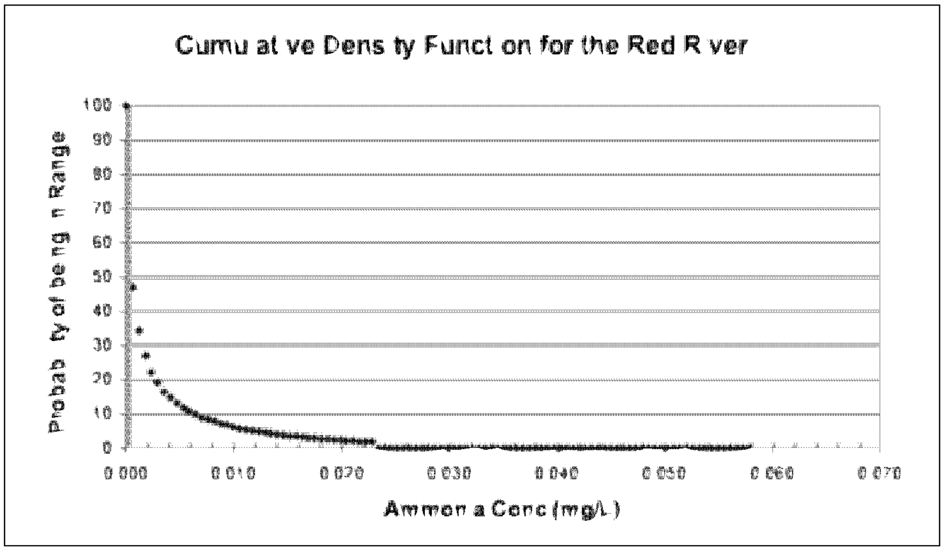
Appendix E Development of Exposure CDFs for the Red River

The following steps were taken to enable development of exposure CDFs for the Red River from August to November.

- For each of August, September, October and November, geometric means were calculated for each year in the database (1986–1997) for each sampling station (see "Winnipeg water quality data" in the technical supporting document [Environment Canada, 2000]).
- For each month (n = 4) and sampling station (n = 4), a lognormal distribution was fit to the monthly geometric means for the period 1986–1996 using the statistical modelling program Crystal Ball. Once a lognormal distribution was fit, Crystal Ball was used with a Latin Hypercube sampling technique to expand each data set to 10 000 data points.

This expanded data set was split into a large number of small ranges equal in size. The number of data points in each range was tallied to develop a CDF for each month at each sampling site (as an example, see Figure 44).

Figure 44 Cumulative density function for Red River at Fort Garry Bridge, August



APPENDIX F SEARCH STRATEGIES EMPLOYED FOR IDENTIFICATION OF RELEVANT DATA

Environmental assessment

Data relevant to the assessment of whether ammonia is "toxic" to the environment under CEPA were identified from existing review documents, published reference texts and on-line searches conducted between January 1996 and January 1999. The following scientific databases were searched: Aquatic Science and Fisheries Abstracts (Cambridge Scientific Abstracts; 1978–1996), AQUIRE (Aquatic Toxicity Information Retrieval, U.S. Environmental Protection Agency), Biosis Previews (1969–1996), CESARS (Chemical Evaluation Search and Retrieval System, Ontario Ministry of the Environment and Michigan Department of Natural Resources), CHRIS (Chemical Hazard Release Information System, U.S. Coast Guard; 1964–1985), Current Contents (Institute for Scientific Information; 1996–1998), ELIAS (Environmental Library Integrated Automated System, Environment Canada library), Enviroline (R.R. Bowker Publishing Company; 1975–1996), Environmental Bibliography (1974–1995), MUD (Municipal Water Use Database, Environment Canada; 1996), NTIS (National Technical Information Service, U.S. Department of Commerce; 1964–1996), Pollution Abstracts (Cambridge Scientific Abstracts; 1970–1996) and RTECS (Registry of Toxic Effects of Chemical Substances, U.S. National Institute for Occupational Safety and Health), as well as water quality databases from Environment Canada, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, New Brunswick and Newfoundland and Labrador and the National Pollutant Release Inventory (Environment Canada; 1994–1996). Searches were also performed between 1997 and 1999 on library systems across Canada. Surveys of Canadian industry and municipalities, other than in Quebec, were conducted to determine the use and release of ammonia. Additional relevant information was obtained voluntarily from municipalities and companies. Data obtained after January 1999 were not considered in this assessment unless they were critical data received during the 60-day public review of the report (May 13 to July 12, 2000).

ORCA SAND AND GRAVEL PROJECT

COMPREHENSIVE STUDY REPORT

WITH RESPECT TO
THE REQUIREMENTS OF A COMPREHENSIVE STUDY PURSUANT TO THE
CANADIAN ENVIRONMENTAL ASSESSMENT ACT

JUNE 30, 2005

EXECUTIVE SUMMARY

PROJECT

Orca Sand and Gravel Ltd. (the Proponent) proposes to construct, operate and decommission a sand and gravel quarry and associated ship loading facilities for the production and export of construction aggregates (the Project), approximately 4 kilometres west of Port McNeill, on Northern Vancouver Island (the Project).

The Project was subject to review under both the *Canadian Environmental Assessment Act* (CEA Act) and the *BC Environmental Assessment Act* (BCEAA). A single coordinated environmental assessment was conducted pursuant to the *Canada-British Columbia Agreement for Environmental Assessment Cooperation*.

The Project includes the following on-site and off-site components:

- ship loading facility and associated conveyor;
- gravel/sand deposit extraction;
- processing plant;
- land-based conveyor system; and
- all other works associated with the construction, operation, and decommissioning of the Project (e.g. settling ponds, stockpile area, water supply, site access, power supply and any off-site or on-site compensation and mitigation works as required).

The Project would be located on private lands owned by Western Forest Products Ltd, with the exception of the ship loading facility, which is proposed for provincial Crown foreshore and nearshore in Broughton Strait. The Project's lifespan is anticipated to be 30 years, with annual production capacity estimated at 4-6 million tonnes. The Proponent anticipates that construction aggregates from the quarry will be shipped to Pacific coast markets, particularly California. The Project location is shown in Figure 1.

The scope of the environmental assessment included: hydrology and water resources; geology and soils; vegetation; species at risk; fish and fish habitat; wildlife and wildlife habitat; waste management; air quality, visuals, noise, navigation, and public health and safety; and, social, economic, cultural and heritage values. The following were also included to meet CEA Act requirements: alternative means of carrying out the Project; effects of the Project on the environment; environmental effects of accidents and malfunctions; cumulative environmental effects; and, the requirements of a follow-up program.

Capital cost of the Project was estimated by the Proponent as approximately $55 million, which would be invested during a one year construction program, with annual expenditures in the local economy estimated at $11 million. The Project is expected to create 50 direct, non-seasonal jobs over the anticipated 30-year lifespan.

Orca Sand and Gravel Ltd. is a private company, incorporated in British Columbia in 2004, and is the vehicle through which the Project's co-proponents Polaris Minerals Corporation and the 'Namgis First Nation hold their partnership interests in the Project.

INFORMATION DISTRIBUTION AND CONSULTATION

Orca Sand and Gravel Ltd., and its predecessor, Polaris Minerals Corporation conducted a consultation program over a period of more than three years with relevant levels of government, First Nations, community organizations, and the general public. Public consultation included the operation of a Port McNeill office / information centre, provision of field tours and presentations, and numerous meetings to collect local knowledge and information. During development of the Application and its review, the Proponent continued to meet with these interests and agencies.

Since 2002, the Proponent has maintained dialogue and sought advice from federal, provincial, and local government agencies. An inter-agency / First Nations project working group was established as the primary source of policy and technical expertise for assessment of the Project. The Orca Sand and Gravel Project Working Group (WG) was comprised of representatives of federal, provincial and local government agencies and the First Nations. WG meetings were held in August and September of 2004, and in February and March of 2005 to identify specific issues and concerns, provide information, and resolve issues.

The Project area lies within the Douglas Treaty area, the asserted traditional territory of the Kwakiutl First Nation (Fort Rupert) and the 'Namgis First Nation. The two First Nations were invited to, and participated in the Project Working Group and thereby provided with opportunities for formal review and comment on the Application.

PUBLIC ACCESS TO INFORMATION

Relevant information, meeting records, and correspondence related to the Project were made available electronically through the EAO electronic Project Information Centre (ePIC) and on the Proponent's web site (www.orcasand.ca) and the federal Canadian Environmental Assessment Registry. The public was notified of the availability of information and the opportunity to comment on the Scoping Document, the Application and the Comprehensive Study Report.

During the Application Review stage, the public was invited to provide comments on the Application during a formal public comment period. In general, the public comments expressed support for the Project. The few expressions of public concern, primarily made at the open houses, were focused on possible impacts on the Cluxewe River, on ground water levels, on foreshore marine habitat and marine mammals, on public health, on the Cluxewe Resort, and on the nature of job creation and economic benefits. Responsible authorities are satisfied that public comments received during the environmental assessment review have been properly considered.

Appendix B of this report contains a complete list of issues identified by the public during the review of the Proponent's Application, as well as the Proponent's response to those issues. All issues raised by the public during the review of the Project, that were deemed to be within the scope of the review, were considered in the Application review process and the documents generated became part of the review.

SUMMARY OF KEY ISSUES CONSIDERED DURING THE REVIEW

Key issues considered during the Project review are described below.

Environmental Effects and Mitigation for the Biophysical Environment (see Part B – Section 2.1)

The primary issues raised were related to water and freshwater ecosystem effects, marine ecosystems and marine mammals, and terrestrial ecosystem components. Water and freshwater ecosystem issues included: effects on groundwater levels, and on water levels in the Cluxewe River and Mills Creek; impacts on Cluxewe River and Mills Creek fisheries and habitat; effects on other groundwater users; and the quality and quantity of water used in operations and possible effects of it being discharged into the environment.

Commitments were made to ensure pit excavation remains above the groundwater table; to undertake monthly groundwater level monitoring during construction and operation; to maintain buffers along the Cluxewe River; to monitor groundwater quality on an annual basis; to regularly assess bank stability of the Cluxewe River; and to discharge process water only into sediment control ponds or other on-site locations for infiltration and not into the Cluxewe River or Mills Creek.

Marine ecosystems and marine mammal issues included: design for minimizing effects on the inter-tidal and sub-tidal habitat; requirements for construction of marine works; requirements for marine habitat compensation; noise effects from the conveyor system and ship loading activities on fish and marine mammals and their migration routes; refuelling, sewage and bilge water discharge from ships at the loading facility, and the potential effect on shellfish harvesting; and effects on *Species at Risk Act* (SARA) marine protected species and their ecosystems, and monitoring requirements.

Commitments were made to: utilize pile drilling, as opposed to pile driving, during construction of the ship loading facility; to conduct Project construction in the marine environment using marine construction methodology approved by DFO, including timing windows, mitigation, and monitoring; to provide underwater noise monitoring; to adapt construction to avoid noise impacts on marine mammals; to design mooring buoys to minimize underwater noise; and to discuss additional orca monitoring requirements associated with SARA.

Terrestrial ecosystem issues included: effects of the conveyor system on large mammal migration and RC ecosystem (poorly drained sitka spruce-skunk cabbage ecosystem);

effects on habitat fragmentation; effects on migratory birds and bird habitat; and effects on SARA protected species, and rare, endangered or threatened species.

Commitments were made to design the conveyor system to minimize effects on the RC ecosystem; to monitor drainage and vegetation changes and alter conditions if noticeable ecosystem changes occur; to allow for large mammal passage at two locations along the conveyor; to conduct a bird nest survey prior to any tree clearing along the conveyor line taking place between April 1 and July 31; to comply with the BC *Wildlife Act* and the federal *Migratory Birds Convention Act* regarding protection and buffering of inactive and active nests of protected bird species along the conveyor line; and to monitor the presence of Harlequin Ducks. It is noted that the pit area being cleared by the land owner, Western Forest Products (WFP), is also governed by provincial and federal laws respecting timber harvesting and fish and wildlife management.

Environmental Effects and Mitigation for the Socio-Economic and Cultural Environment (see Part B – Section 2.2)

The primary issues raised were related to: air quality impacts to human health, noise effects, visual effects, economic effects, navigation effects, effects on archaeological resources; and effects to First Nations current use of lands and resources for traditional purposes.

The air quality issues included: dust from the Project, and its potentially adverse effect on the Cluxewe Resort; and airborne emissions from plant machinery.

Commitments were made to use the wet processing plant to control dust emissions, and use water sprays during hot weather, if necessary; and to operate the plant with low emission engines on site, and encourage similar equipment to be used by contractors.

The noise issue was focussed on a potential noise level increase and its effects on the Cluxewe Resort and on residents of Pulteney Point on Malcolm Island.

Commitments were made to undertake an independent baseline noise study at these locations; and to implement further noise mitigation measures when operations commence, if pit and ship loading noise becomes an issue at these locations.

The visual effects issue related primarily to ship loader lighting and its potential effects on visual quality at the Cluxewe Resort and on residents of Pulteney Point on Malcolm Island.

Commitments were made to design the ship loader to minimize use of lighting especially over water; and to minimize lights on the ships.

Economic effects issues included: effects on local employment and contracting opportunities; potential adverse effect on local commercial fisheries activities; and potential adverse effects on private property values on land near Pulteney Point.

Commitments were made to recruit the majority of employees from the North Island; to provide training for operational positions where necessary; to give preference to North Island businesses for contracting opportunities; to uphold First Nations employment agreements; to avoid effects on fisheries through design of the ship loader; and to minimize property value effects through noise and visual impact mitigation measures.

Regarding navigation, the primary issue raised was the possible effect of the ship docking and loading facility on navigation and traffic in Broughton Strait.

Commitments were made to avoid adverse navigational effects through design and location of the ship loader, and to comply with Transport Canada NWPA requirements.

The primary issues raised by First Nations that related to environmental, public safety and health, socio-economic, navigable waters, and other aspects of the review were incorporated into those sections. Related issues raised by First Nations outside of these specific topics included: inclusion of plants traditionally used by First Nations in reclamation and potential for dust from conveyor system to negatively affect the quality and palatability of traditionally harvested edible seaweed..

The Proponent committed to agreements with First Nations respecting employment opportunities and other matters; to encourage WFP to consult First Nations on replanting of native plant species; to provide opportunities for possible First Nation companies to salvage native plants ahead of operations; to provide an archaeologist to monitor the two areas of moderate archaeological potential; and to follow protocol and legal requirements if artefacts or human remains are found during earth moving.

The 'Namgis First Nation provided a letter on March 24, 2005 indicating that it had been adequately consulted and accommodated by the Proponent and the federal and provincial governments with respect to the Project. On March 23, 2005 the Kwakiutl First Nation provided a letter of support for the Project and confirmed that it had been adequately consulted and accommodated by the Proponent and that federal and provincial Crown obligations related to consultation and accommodation had been fulfilled with respect to the Project.

Additional CEA Act Requirements
(see Part A – Section 2.3 & Part B – Sections 3, 4, 5 & 6)

The CEA Act has specific requirements that also must be considered in the environmental assessment, including: effects of the Project on the environment; environmental effects of potential accidents or malfunctions; and cumulative environmental effects. As well, a comprehensive study under the CEA Act has further requirements for consideration, including: the purpose of the Project, alternative means of carrying out the Project; and the requirements of a follow-up program. These topics were discussed by the Working Group, and in some cases, the public and First Nations also raised a number of issues. Where appropriate, the Proponent has made commitments to minimize or mitigate associated effects to address these issues.

CONCLUSIONS

Based on the information contained in the Application; communications with agencies and First Nations, and the public; and the Proponent's responses and commitments, the responsible authorities concluded that the Project is not likely to cause any significant adverse environmental effects.

Part A – Comprehensive Study Background

1. Introduction

Orca Sand and Gravel Ltd. (the Proponent) proposes to construct, operate and decommission a sand and gravel extraction operation and associated ship-loading facilities for the production and export of construction aggregates on northern Vancouver Island (the Project).

The Project includes the construction and operation of a 15,000 to 22,000 tonnes per day processing plant (4 to 6 million tonnes per annum) and an associated marine terminal designed to handle vessels larger than 25,000 tonnes deadweight (DWT). The extraction site and marine terminal are located immediately alongside Highway 19, the Island Highway, 3.8 kilometres west of Port McNeill (see Figure 1). The proposed Project lies within the asserted territories of the Kwakuitl and 'Namgis First Nations.

Transport Canada initiated the federal environmental assessment process pursuant to the *Canadian Environmental Assessment Act* (the CEA Act) in relation to the Project. The CEA Act triggers and the associated responsible authorities include: a possible subsection 5(1) approval pursuant to the *Navigable Waters Protection Act* from Transport Canada for the construction of the marine terminal; a possible subsection 35(2) authorization pursuant to the *Fisheries Act* from Fisheries and Oceans Canada (DFO) for works associated with the marine terminal; and, possible funding under the Major Business Projects Program from Indian and Northern Affairs Canada (INAC). To assist in the environmental assessment process, Environment Canada has provided expert advice in relation to the Project. The proposed Project was also subject to review under the B.C. *Environmental Assessment Act*.

1.1 Purpose of the Comprehensive Study Report

In accordance with sections 16 and 21 of the CEA Act, when a project is described in the Comprehensive Study List Regulations, the responsible authorities must ensure that a Comprehensive Study Report (CSR) is prepared in relation to the project. The CSR must identify the potential environmental effects of the project including the environmental effects of any malfunctions or accidents that may occur in connection with the project and any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out. The Report must also describe measures that are technically and economically feasible to mitigate any significant adverse environmental effects of the project.

The responsible authorities must also report on all public concerns raised in relation to the project and how they have been addressed. Based on the CSR and the public comments the responsible authorities must then provide conclusions with respect to whether the project is likely to result in significant adverse environmental effects. Responsible authorities must also assess the need for and requirements of any follow-up program, as defined by the CEA Act.

The Minister of the Environment then reviews the CSR and any public comments filed in relation to its contents. If the Minister is of the opinion that additional information is necessary or actions are needed to address public concerns, the Minister may request the responsible authorities or the proponent address these concerns.
Once any concerns are addressed, the Minister issues an environmental assessment decision statement that includes:

- the Minister's opinion as to whether the project is likely to cause significant adverse environmental effects; and
- any additional mitigation measures or follow-up program that the Minister considers appropriate.

The Minister then refers the project back to the responsible authorities for a course of action or decision.

If it has been determined that the project is not likely to cause significant adverse environmental effects, a responsible authority may exercise any power or perform any duty or function that would permit the project, or part of the project, to be carried out. With respect to the Orca Sand & Gravel Project, DFO may issue its *Fisheries Act* authorization for potential impacts to fish habitat associated with the marine terminal, Transport Canada may issue its *Navigable Waters Protection Act* approval for construction of the marine terminal, and INAC may release the funding under the Major Business Projects Program.

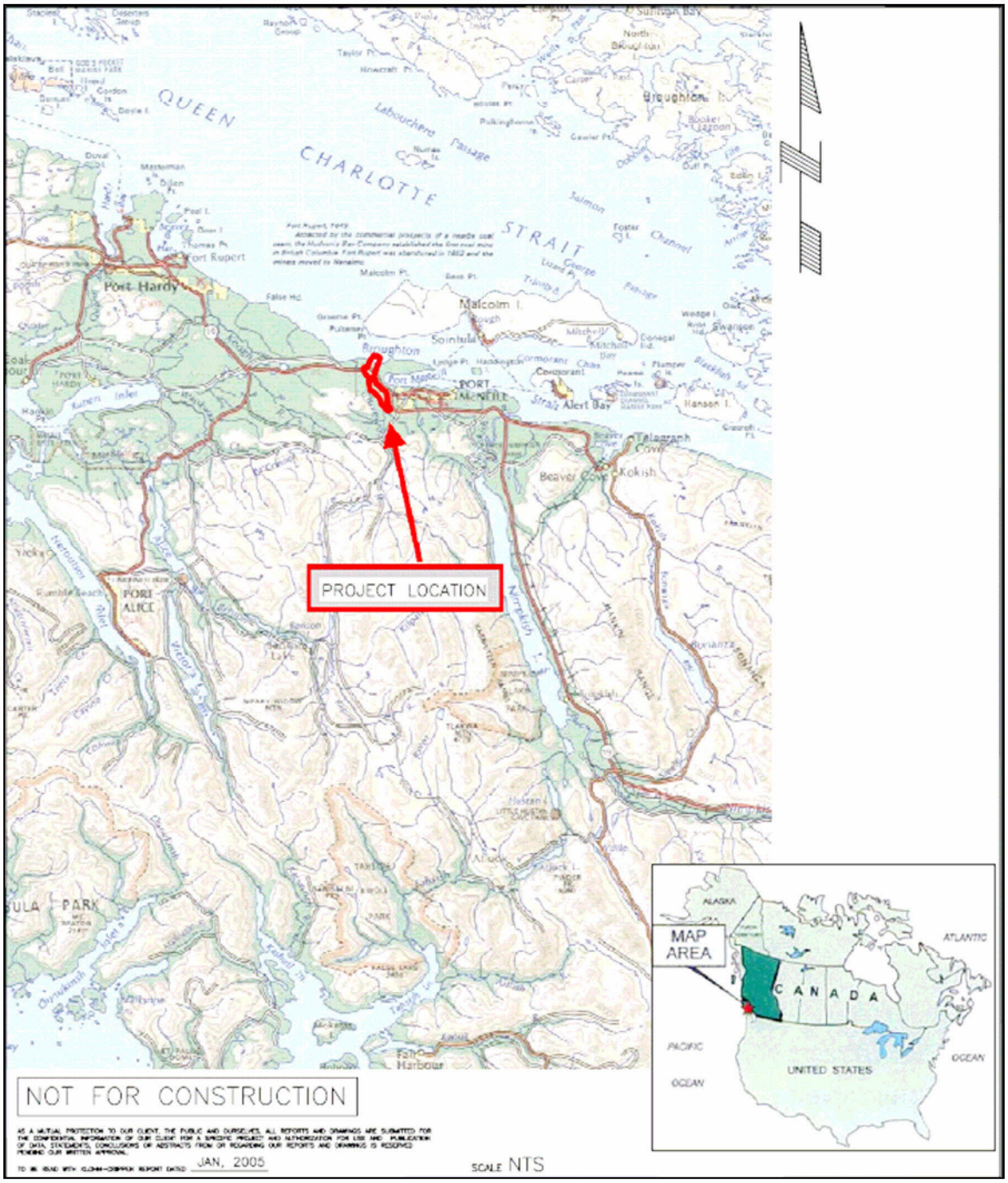


Figure 1. Project Location Map (Orca Sand & Gravel Ltd., 2004).

1.2 The Federal Review Process
An environmental assessment (EA) of a project is required under the CEA Act, if a federal authority will be required to exercise certain powers or perform certain duties or functions in respect of a project for the purposes of enabling the project to be carried out, in whole or in part.

Transport Canada, DFO and INAC will be required to exercise the following powers or perform the following duties or functions with respect to the Project:

- the proposed ship loading facility will require a formal approval by Transport Canada pursuant to paragraph 5(1)(a) of the *Navigable Waters Protection Act*;
- any disturbance to fish habitat from construction of the ship loading facility will require formal approval from the Department of Fisheries and Oceans under ss. 35(2) of the *Fisheries Act; and,*
- a federal funding request under the Major Business Projects Program to Indian and Northern Affairs Canada (INAC) from the 'Namgis First Nation.

By triggering the CEA Act, Transport Canada, DFO and INAC became responsible authorities thus requiring them to undertake an environmental assessment of the Project. A comprehensive study under the CEA Act is required when a proposed project meets at least one of the requirements in the Comprehensive Study List Regulation. In this case, the Project meets two sections of the regulation because it proposes to construct, decommission or abandon both:

- a stone quarry or gravel or sand pit with a production capacity of 1 000 000 t/a or more (s.18(i)); and,
- a marine terminal designed to handle vessels larger than 25 000 DWT unless the terminal is located on lands that are routinely and have been historically used as a marine terminal or that are designated for such use in a land-use plan that has been the subject of public consultation (s.28(c)).

The comprehensive study process requires public consultation with respect to the proposed scope of project for the purpose of the EA, the factors proposed to be considered, the proposed scope of those factors, and the ability of the comprehensive study process to address the issues relating to the project. To accomplish this, responsible authorities prepare a "project scoping document" that is made available to the public for review and comment. Following public consultation, responsible authorities prepare a report and recommendation, which is submitted to the federal Minister of the Environment. The Minister then determines whether the assessment will continue as a comprehensive study or whether the project will be referred to a mediator or a review panel.

If the assessment is continued as a comprehensive study, responsible authorities must ensure that a CSR is prepared. The CSR is submitted to the Canadian Environmental Assessment Agency, which administers a public comment period on the report. Upon completion of public review, the CSR and the comments filed in relation to it are forwarded to the Minister of the Environment for a decision.

For the Orca Sand and Gravel Project, Transport Canada and DFO, in consultation with the CEA Agency, prepared the Project scoping document, and advertised its availability for public review. A 21 day public review period ended on October 20, 2004. The ensuing report to the Minister of the Environment led to confirmation, on January 13, 2005, that the environmental assessment under the CEA Act would continue as a comprehensive study. Indian and Northern Affairs declared itself a responsible authority on April 7, 2005.

1.3 The Provincial Review Process

On September 30, 2003, the B.C. Environmental Assessment Office (BCEAO) issued an order under section 10(1)(c) of the British Columbia *Environmental Assessment Act* (BCEA Act), designating the Project as reviewable under the BCEA Act, and requiring the Proponent to obtain an environmental assessment certificate before proceeding with the Project.

On November 24, 2004, the BCEAO issued an order under section 11 of the BCEA Act outlining the scope, procedures and methods to be applied in the pre-Application and Application review stages of the BCEA Act assessment.

Terms of Reference for the Application were developed by the Proponent, with input from the BCEAO, federal and provincial agencies, local governments and First Nations. These Terms of Reference were approved by the BCEAO in November 2004 as the information required under section 16(2) of the BCEA Act. Federal agencies provided approval-in-principle only at that time, pending the outcome of a public review of the proposed scope of the review, as required under the CEA Act and final confirmation by the federal Minister of the Environment of the appropriate level of review.

In December 2004, the Proponent submitted an Application to the BCEAO. The Application was screened against the Terms of Reference, and accepted by the BCEAO with minor revisions on January 17, 2005.

1.4 The Federal/Provincial Cooperation Agreement

The Canada-British Columbia Agreement for Environmental Assessment Cooperation (2004) provides for a coordinated environmental assessment process to avoid uncertainty and duplication where a project is subject to review under both the BCEA Act and the CEA Act.

The cooperative assessment of the Project was conducted in accordance with a joint federal-provincial work plan.

During the cooperative review process, the BCEAO developed an Assessment Report (AR) to report on the results of the EA. That report was developed collaboratively to meet the requirements of an AR under the BCEA Act and to inform the Comprehensive Study Report (CSR) under the CEA Act. The federal responsible authorities considered the provincial AR and used it as a basis for the CSR. The CSR is meant to fully describe the federal environmental assessment process that was undertaken and the conclusions of the federal responsible authorities with respect to whether the Project is likely to result in significant adverse environmental effects.

2. Project Description and Scope of Assessment

2.1 The Proponent

Orca Sand and Gravel Ltd. (the Proponent) is a private company incorporated in British Columbia in 2004. It is the vehicle through which the Project's co-proponents (Polaris Minerals Corporation and the 'Namgis First Nation) hold their partnership interests in the Project. Polaris is a private company based in Vancouver, incorporated in 1999 to pursue the establishment of a coastal aggregates export business. The Kwakiutl First Nation (Fort Rupert) and 'Namgis were offered equal equity partnership interests in the Project by Polaris. An Impacts and Benefits Agreement (IBA), dated March 9, 2005 was negotiated between the Kwakiutl and the Proponent, and ratified by Kwakiutl community members on February 26, 2005. The Kwakiutl provided a formal letter of support for the Project on March 23, 2005.

2.2 Project Overview

The Project is located 4 kilometres west of the town of Port McNeill, on North Vancouver Island, British Columbia on private lands owned by Western Forest Products Ltd, with the exception of the ship loading facility, which is proposed for provincial Crown foreshore and nearshore in Broughton Strait. The area is shown in **Figure 1**.

The Project site is adjacent to and accessed from the Island Highway (Highway 19), a paved provincial highway that runs the length of Vancouver Island from Victoria to Port Hardy. Products will be transported under Highway 19 by conveyor to the stockpile and ship loading facilities which will be situated north of the Highway.

The sand and gravel lies in a terrace approximately 3,000 metres in length by 800 metres wide. The proposed quarry site is forested with second growth and covered with organic overburden 1 to 3 metres thick. An initial forest area will be cleared, organic overburden carefully removed and stockpiled for future progressive reclamation, exposing the high quality sand and gravel deposit.

The quarry will be mined at a rate of up to 15 - 22,000 tonnes per operating day. The exposed sand and gravel will be removed with mobile equipment, such as scrapers and loaders, and placed onto a field conveyor system for delivery to the processing plant. During normal operations the production operations will operate on a two-shift basis, totalling 16 hours per day and up to seven days per week.

Processing will consist of using water to liberate the sand from gravel, which will then be screened with any oversize gravels being crushed. The sand will be classified and dewatered to remove silt size fractions with the wash water being sent to sedimentation ponds for settling out of any silt and recycling of water. This water will be recycled through a settling pond and filtration system to remove fine particulate matter prior to any excess water discharge into the receiving environment. The source of process water will be natural precipitation retained in settling ponds. Any additional make-up water during the dry summer period will be obtained from boreholes within the resource area. There is very little silt material in the deposit and the site lends itself to progressive reclamation of the land back to productive forest cover.

Products will be stored in individual stockpiles in preparation for shipping. A conveyor reclaim system will deliver the product to Panamax class ships for distribution. At maximum production rates, the operation will expect to load two vessels per week each being at berth for up to 24 hours.

The ship loading facility has been located so that it is a) east of a developed campground (Cluxewe Resort) on Kwakiutl Indian Reserve #7 and b) largely hidden from line of sight by the topography of the shoreline. The ship loading facility will be visible from Broughton Strait, part of the "Inside Passage", a deep water navigable channel used extensively by large vessels, particularly during the cruising season.

All products will be shipped from the operation in ocean going bulk carriers, although small quantities could be utilized to maintain the local road network. The Proponent anticipates that construction aggregates from the quarry will be shipped to Pacific coast markets, particularly California.

BC Hydro power lines run throughout the area, and electrical power to the plant site is anticipated to be directly available from the BC Hydro power grid.

The Project's lifespan is anticipated to be 30 years, with annual production capacity estimated at 4-6 million tonnes.

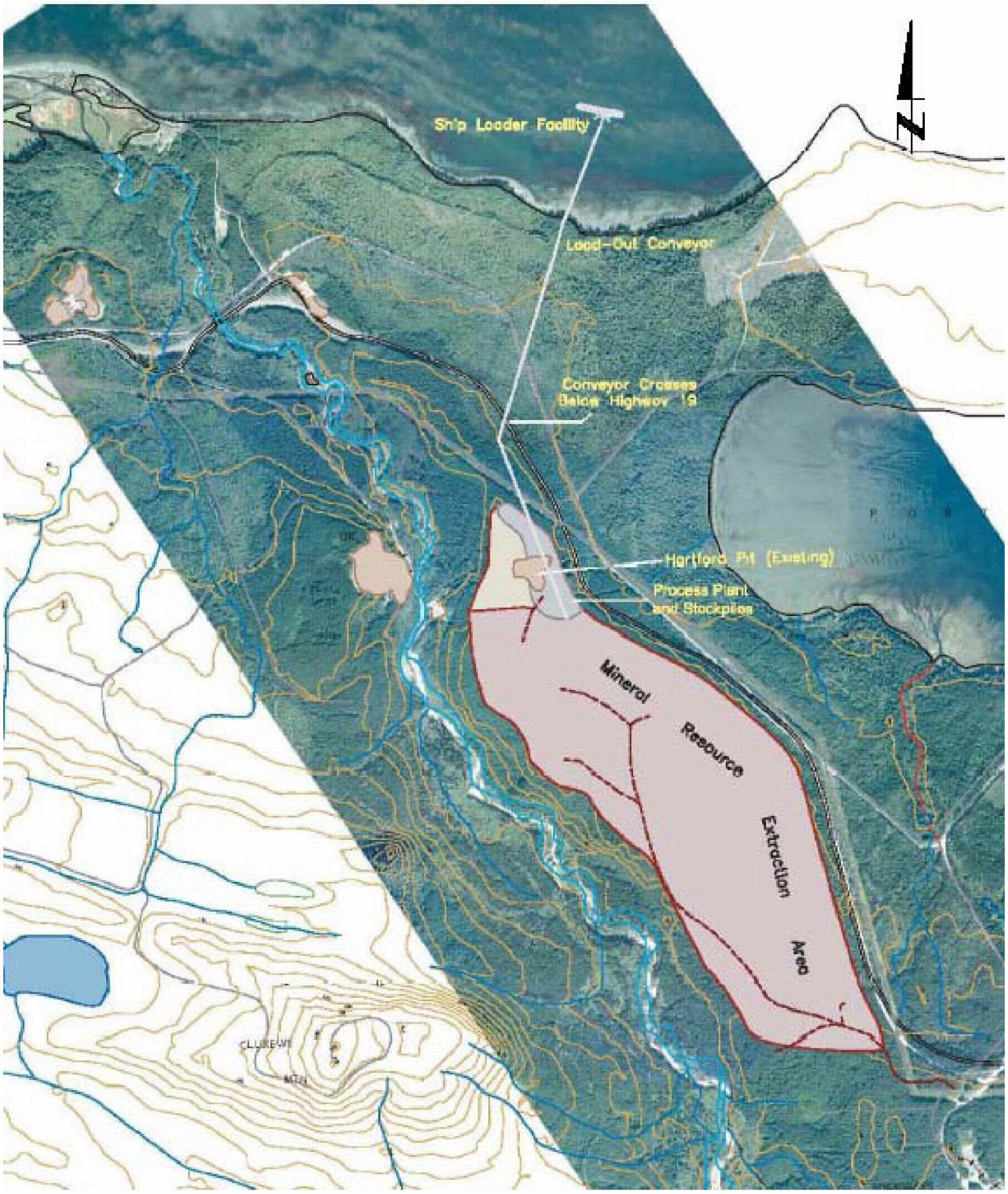


Figure 2 – Project Overview (Orca Sand & Gravel Ltd., 2004)

2.3 Project Need/Alternatives Assessment

2.3.1 Project Need/Purpose

The Proponent described the need for the Project as being directly related to the emerging market for imported construction aggregates, particularly sand and gravel, along the western seaboard of the United States. Aggregate demand in California was described as growing by over four million tonnes per year, driven principally by the continuing growth in population. The Proponent contended that this increased demand, when coupled with the accelerating depletion of the local aggregate resources in California, will force the need for a significant increase in the external supplies of aggregate products to the California markets.

The Proponent stated that the purpose of this Project was to develop a sand and gravel export business capable of winning a significant market share of the identified demand along the U.S. western seaboard.

2.3.2 Alternatives To the Project

Based on the ongoing need for construction aggregates in the California market, alternatives to undertaking the Project would include moving sand and gravel to coastal California markets from inland California sources via truck or train, or shipping from alternative sources along the western Canada, U.S. or Mexico coastline.

The Proponent conducted an extensive site selection study of a large number of potential aggregate producing sites from Alaska to Mexico, and selected Vancouver Island as the most favourable source area on the Pacific coast of North America. The site selection study included:

- evaluation of the markets for aggregates in California;
- considerations relating to the development of reception docks in the San Francisco Bay and Los Angeles markets;
- review of the geological and resource data, and physical testing of samples;
- review of the options for shipping;
- review of the appropriate quarrying, processing and reclamation plans; and,
- review of the social, economic, infrastructure and environmental planning factors.

The Proponent focussed on development of a coastal resource that would deliver aggregates to its intended markets via large ocean freighters. The Proponent described how, in many areas of the developed world, including the eastern coast of the United States, local aggregate supplies had been supplemented or replaced entirely by aggregates delivered by ocean-going vessels. Low shipping costs, using large self-discharging bulk carriers, had made this an economically competitive and viable option compared to land transportation in the major coastal urban centers of California. In fact, the Proponent noted that aggregate exports by sea from British Columbia to the western United States were already underway. Shipments of sand and gravel commenced in 2000 from Sechelt, British Columbia to San Francisco Bay, and crushed rock was being shipped from quarries on Texada Island to the ports of Los Angeles and Long Beach. As well, British Columbia had serviced much of the Puget Sound area (Washington State) demand with shipments of these materials for years.

During the site search, the Proponent enlisted local consultants to help evaluate potential sites in Mexico, particularly the Baja California peninsula, which was judged to be within economic shipping distance of the target markets. During this evaluation, it was quickly determined that the geology was unsuitable and that there was little established infrastructure, compounded by a severe shortage of the fresh water required for washing aggregate. The evaluation of potential sites in Alaska identified the economic disadvantages of much greater shipping distances, the complications of the U.S. *Jones Act* (which requires that cargo moving between U.S. ports be carried in ships which are U.S.-owned, U.S.-built and U.S.-crewed) and by significant adverse weather and infrastructure considerations.

The Proponent determined that the coast of British Columbia had several good quality sand and gravel deposits that could potentially meet the emerging demand from the California markets. However, the number of economically viable and commercially competitive sites was determined to be severely limited. To be capable of successful development by the Proponent, a site needed to meet the following criteria:

- the deposit must be adjacent to the ocean shoreline;
- the location must have deep and safe water which allows for loading large ocean-going bulk vessels up to Panamax Class (75,000 DWT);
- the deposit must be large enough to achieve economies of scale and justify large-scale and long-term investment;
- the deposit must be relatively consistent and homogeneous;
- the operation must have minimal impact on the environment;
- the site topography must allow for low cost open pit extraction methods;
- the project must produce a product that meets all California and US national specification requirements;
- the project must have local support;
- the project area must have appropriate infrastructure and labour availability; and
- the project must satisfactorily address and accommodate any Aboriginal title and rights.

A small number of potential deposits were identified on the B.C. mainland coast, but initial screening eliminated all of them from further consideration due to problems with tenure or serious environmental concerns. The Orca Sand & Gravel Project site was the only potential resource identified which met all of the site selection criteria and was considered by the Proponent to have the best potential to be a viable investment.

The Proponent selected the Project site for the following principle reasons:

1. The sand and gravel was adjacent to navigable tidewater suitable for large vessels with a capacity of up to 75,000 Deadweight (DWT) tonnes.

2. The site lent itself to minimizing effects on the environment. There were no habitations within close vicinity and the Project area did not contain any surface water flows and therefore no fish-bearing streams. Logging of old growth had already taken place over the entire Project area.

3. Bathymetric surveys subsequently confirmed that the area was an ideal location for the ship loading facility.

4. The topography of the site was ideal for the intended purpose.

5. The quality of the sand and gravel significantly exceeded all California and U.S. national specifications. Products would include concrete sand and two sizes of gravel up to a maximum diameter of 1 inch (25 mm).

6. The identified resource would have a life expectancy of approximately 30 years, sufficient to justify the required capital expenditure.

7. Positive relationships with First Nations, in whose asserted traditional territory the Project lies, were established at the outset. No significant cultural or traditional use values were identified.

8. Port McNeill and its surrounding area had an established industrial base offering a labour force and all necessary services. In addition, it was seeking new industries to diversify the industrial base and reduce the dependency on the logging industry.

2.3.3 Alternative Means of Carrying Out the Project

The CEA Act considers alternative means of carrying out a project as the various ways, which are technically and economically feasible, that a project can be implemented or carried out. This could include alternative locations, routes and methods of development, implementation and mitigation.

Given that the location of the resource was fixed, the Proponent considered whether or not there was an alternative development possible by relocating the ship loader. Studies of the cost of aggregate production at coastal locations have consistently confirmed that the economics demand that the vessels be loaded by conveyor directly from the processing plant. To the west of the chosen ship loading site in Soldier Bay is the Cluxewe Resort and estuary and further west is an environmental conservation area. The presence of these areas prevents consideration of moving the ship loading facility further west. To the east is Port McNeill which has only shallow water depths and is quite unsuitable for the self-discharge vessels essential to the Project. To move further east than the port would require the use of a large fleet of highway trucks which would add significant costs to the Project, making it uneconomical for the Proponent. Therefore it was concluded that the use of Soldier Bay was the only acceptable means to undertake the ship-loading aspect of the Project.

Table 1 outlines the various alternative means of carrying out the Project that were examined by the Proponent. A brief description of the economic feasibility and potential environmental effects associated with each alternative is also included.

Table 1 Alternative Means of Carrying out the Orca Sand & Gravel Project

ALTERNATIVE MEANS	ECONOMIC FEASIBILITY	POTENTIAL ENVIRONMENTAL EFFECTS
Extend extraction area closer to the Cluxewe River	Economically feasible	Potential effects on bank stability. Potentially reduced important riparian zone for aquatic resources and wildlife (such as elk).
Extraction to a shallower depth than proposed	Not as economically viable	No change in environmental effect.
Extraction to a deeper depth than proposed	Economically feasible	If extraction is below groundwater table, remediation would not allow for reforestation.
Extraction of water from the Cluxewe River rather than groundwater	Economically feasible	Year-round reduction in flows in the Cluxewe River.
Trucking from stockpiles to existing port (Port McNeill)	Project not economically viable as port is too shallow.	Increased traffic, noise, emissions and dust plus possibilities for collisions.
Conveyor moved to east or west of current location	Economically feasible	Potential to cross wetland area west of conveyor near shore.
Ship loading facility moved	Cannot be moved to shallower water east, south or west of proposed location. Could move to deeper water, but at greater cost.	Moving facility to deeper water would result in a longer conveyor over the water and greater changes to habitat with more piles.

Based on the above exercise, the Proponent concluded that the proposed means of undertaking the Project was the most economically feasible of the options outlined. As well, all of the other economically feasible options outlined would result in greater environmental, and in some cases social, impacts than the proposed Project.

2.4 Scope of Project

Transport Canada's regulatory trigger under the Law List Regulation of the CEA Act for the Project was the need for a subsection 5(1) approval under the *Navigable Waters Protection Act* for construction of the marine terminal and conveyor system. DFO's regulatory trigger was the need for a subsection 35(2) authorization under the *Fisheries Act* for the potential Harmful Alteration, Disruption or Destruction (HADD) of fish habitat in the intertidal and subtidal marine environment that would result from construction of the marine terminal and conveyer system. INAC also became a responsible authority due to a federal funding request under the Major Business Projects Program with respect to the Project from the 'Namgis First Nation.

As noted previously, Transport Canada evaluated information provided by the Proponent and determined that the Project met the thresholds of two of the sections of the Comprehensive Study List Regulations, and therefore required that a comprehensive study assessment track be undertaken.

In accordance with section 15 of the CEA Act, the responsible authorities determined that the scope of the proposed Project would be the following physical activities not associated with physical works, and the construction, operation, maintenance / modification and decommissioning of the following physical works:

- *Ship Loading Facility and Associated Conveyor*: The conveyor would carry product from a land-based storage area, across the intertidal and subtidal area to the ship berth, which would have the capacity to handle vessels up to or larger than 75 000 DWT. At maximum production rates the operation is expected to load two vessels per week, each being at the berth for up to 24 hours.
- *Gravel/Sand Deposit Extraction*: 200 hectares of second growth forest and organic overburden layers will be removed in phases for sand and gravel extraction.
- *Processing Plant*: A processing plant will be constructed for washing and sizing of extracted gravel, and limited crushing of oversized gravel.
- *Land-based Conveyor System*: A land-based conveyor system will be used to transport washed and sized products from the processing plant to the stockpile area; another system will be used to transport products from the stockpiles to the ship loader.
- All other works associated with the construction, operation, and decommissioning of the Project (e.g. settling ponds, stockpile area, water supply, site access, power supply and any off-site or on-site compensation and mitigation works as required,

and any other physical works or activities which form an integral part of the Project).

2.5 Scope of Assessment

2.5.1 Factors to be Considered

As defined under the CEA Act, "environmental effect" means, in respect of a project:

a) any change that the project may cause in the environment, including any change it may cause to a listed wildlife species, its critical habitat or the residences of individuals of that species, as those terms are defined in subsection 2(1) of the Species at Risk Act

b) any effect of any change referred to in paragraph (a) on

i. health and socio-economic conditions

ii. physical and cultural heritage

iii. the current use of lands and resources for traditional purposes by aboriginal persons, or

iv. any structure, site or thing that is of historical, archaeological, palaeontological or architectural significance, or

c) any change to the project that may be caused by the environment

The factors considered in the environmental assessment, pursuant to section 16 of the CEA Act, were the following:

- *the environmental effects of the Project, including the environmental effects of malfunctions or accidents that may occur in connection with the Project and any cumulative environmental effects that are likely to result from the Project in combination with other projects or activities that have been or will be carried out;*
- *the significance of the environmental effects referred to above;*
- *comments from the public that are received in accordance with this Act and the regulations;*
- *measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the Project;*
- *the purpose of the Project;*
- *alternative means of carrying out the Project that are technically and economically feasible and the environmental effects of any such alternative means;*
- *the need for, and the requirements of, any follow-up program in respect of the Project; and,*
- *the capacity of renewable resources that is likely to be significantly affected by the Project to meet the needs of the present and those of the future.*

2.5.2 Scope of Factors to be Considered

The following outlines the scope of the factors considered in the environmental assessment.

- hydrology and water resources;
- geology;

- soils;
- vegetation;
- species listed on Schedule 1 of SARA;
- fish and fish habitat;
- wildlife and wildlife habitat;
- waste management;
- noise;
- air quality;
- current use of lands and resources for traditional purposes by Aboriginal persons;
- land and resource use;
- local communities;
- worker health and safety;
- public health and safety;
- navigation;
- heritage and historical cultural resources;
- palaeontological resources.

<u>Malfunctions and Accidents</u>
The probability of possible malfunctions or accidents associated with the Project, and the potential adverse environmental effects of these events (e.g. accidental spills, contingency measures for responding to emergencies, and risks of facility malfunctions).

<u>Effects of the Environment on the Project</u>
The environmental hazards that may affect the Project and their predicted effects, including: seismic activity, icing and winter operations, erosion, fire, flooding, and slope stability.

<u>Cumulative Environmental Effects</u>
The cumulative environmental effects that are likely to result from the Project in combination with other projects or activities that have been or will be carried out.

<u>Spatial and Temporal Boundaries</u>

Spatial boundaries:
The main Project site was bounded to the west by the Cluxewe River, to the east by the Island Highway, to the north by Broughton Strait, and to the south by the southern extent of private lands under the administration of Western Forest Products Ltd. The environmental assessment covered the ecological footprint of the Project.

Temporal boundaries:
The temporal boundaries encompassed the lifespan of the Project (expected to be approximately 30 years). The environmental assessment examined potential effects of the Project beginning with the construction phase and throughout the operations phase

(including maintenance and/or modifications) and through to the completion of the decommissioning phase.

Follow-up Program
The environmental assessment included the consideration of the need for and requirements of an environmental monitoring and follow-up program.

3. Information Distribution and Consultation

3.1 Federal Coordination

Transport Canada initiated the federal environmental assessment process on August 10, 2004 by posting the Notice of Commencement on the Canadian Environmental Assessment Registry. Federal Coordination Letters were also sent out on August 10, 2004 to DFO, INAC, Natural Resources Canada, Health Canada and Environment Canada. The CEA Agency acted as the federal environmental assessment coordinator for the Project.

On August 17, 2004, DFO declared itself a responsible authority for the Project as it would likely be required to authorize, under subsection 35(2) of the *Fisheries Act,* the potential HADD of fish habitat in the intertidal and subtidal marine environment that would result from construction of the Marine Terminal and Conveyer system. Within the overall scope of project and assessment, DFO focused its assessment on project components that would require DFO regulatory approvals.

Environment Canada provided specialist knowledge and information which informed the federal-provincial harmonized environmental assessment.

On April 7, 2005, INAC declared itself a responsible authority for the Project, as defined in Section 5 of the CEA Act resulting from the 'Namgis First Nation applying for funding under the Major Business Projects Program. INAC determined that the scope of project undertaken by Transport Canada and DFO was satisfactory and it was not necessary to redefine the scope of project or scope of assessment.

3.2 Public Consultation in Accordance With The CEA Act

3.2.1 Section 21 – Public Participation Regarding Proposed Scope of Project
Under subsection 21(1) of the CEA Act, for a comprehensive study, responsible authorities must ensure public consultation on the proposed scope of the project, the proposed factors to be considered in the environmental assessment, the proposed scope of those factors and the ability of the comprehensive study to address issues relating to the Project. An invitation for members of the public to review and comment on a scoping document was advertised in community newspapers, during the weeks of September 27 through October 11, 2004 and also placed on the Canadian Environmental Assessment

Registry (CEAR). At the same time, members of the public were made aware of the availability of Participant Funding for public participation in the comprehensive study process and review of the comprehensive study report. The notice appeared in the North Island Gazette, Victoria Times Columnist, and L'Express du Pacifique. The Project Registry included a notice for the public to contact Transport Canada for a copy of the scoping document. Copies of the scoping document were made available at the following locations: an Open House held September 23, 2004 in Port McNeill, the Proponent's project office in Port McNeill, the 'Namgis and Kwakiutl First Nations' Band offices, the Town of Port McNeill office and the local DFO office. A 21-day review period was provided which concluded on October 20, 2004.

Three sets of public comments on the scoping document were received. Most comments related to improving the wording of future scoping documents with one exception requesting that Mills (Bear) Creek be included within the scope of the assessment. As Mills (Bear) Creek was not specifically excluded from the originally proposed scope of assessment, this request did not result in any change to the scope, but the responsible authorities clarified that the potential effects of the Project on Mills (Bear) Creek would be considered during the conduct of the comprehensive study.

The Environmental Assessment Track Report was submitted to the Minister of the Environment on November 19, 2004. This report reflected the opinion of the responsible authorities, in consultation with the expert federal authorities, that the comprehensive study could fully address issues related to the Project.

Transport Canada and DFO received a letter dated January 6, 2005, from the Minister of the Environment, stating that the Orca Sand and Gravel Project review should continue as a comprehensive study pursuant to the CEA Act.

3.2.2 Section 21.2 – Public Participation in the Comprehensive Study

As part of the cooperative provincial/federal review of the Project, the responsible authorities shared the formal public comment period on the Application as prescribed in the BCEA Act. In the Application Review stage, the public was provided the opportunity to review and comment on the Application during a 30-day public comment period from January 29 to February 28, 2005. The BCEAO received 56 written comments from members of the public during this period, in addition to a number of comments provided during five open house meetings held in local communities. These comments were provided to the responsible authorities and the CEA Agency. In general, the public comments expressed support for the Project. The few expressions of public concern, primarily made at the open houses, were focused on possible impacts on the Cluxewe River, on groundwater levels, on foreshore marine habitat and marine mammals, on public health (dust and noise), on the Cluxewe Resort, and on the nature of economic benefits (job creation).

In written submissions and at public meetings, members of the public identified six issues about the Project description and potential accidents related to the Project; five issues about reclamation and potential Project–related impacts on wildlife and vegetation; nine issues about potential Project effects on rivers and groundwater; seven issues about potential Project effects on marine habitat and life; one issue related to the potential Project impacts on culture and heritage; and twelve issues on the Project's potential socio-economic effects.

Issues raised by members of the public during the environmental assessment were fully considered by the responsible authorities during the review of the Application. All issues raised by members of the public during the course of the review and the means by which those issues were addressed have been tabulated and included in Appendix B.

3.2.3 Section 22 – Public Access to Comprehensive Study Report

A third opportunity for pubic input on the Project and the associated environmental assessment is through commentary on this report. The CEA Agency will facilitate public access to the CSR, including administering a formal public comment period. All comments submitted will be provided to the responsible authorities and considered public and will become part of the public registry for the Project.

3.3 Provincial Consultation Measures

The BCEAO, as the provincial agency coordinating major project environmental assessment in British Columbia, also consulted with First Nations, the public and local, provincial and federal government representatives. The BCEAO established an inter-agency / First Nations project working group as the primary source of policy and technical expertise for assessment of the Project. The responsible authorities participated in the working group which provided a means to obtain the views of federal expert authorities, other government agencies and First Nations.

The BCEAO carried out public consultation in accordance with its November 25, 2004 section 11 order. The BCEAO made the certificate Application available for public comment during a 30 day review and comment period from January 29, 2005 until February 28, 2005, and participated in and monitored the February 7-11, 2005 open houses that it required the Proponent to hold. Representatives of the federal government (DFO, EC and CEA Agency) participated the open houses held in Alert Bay and Port McNeill on February 8 and February 9, 2005 respectively.

The BCEAO utilized its electronic Project Information Centre (ePIC) to post relevant information, meeting records and correspondence related to the Project. The Proponent also utilized a web site (www.orcasand.ca) and other means of public distribution throughout the process, in accordance with BCEAO requirements. Both BCEAO and the Proponent notified the public of the availability of information and opportunity to comment on the Application.

3.4 Consultation Measures Undertaken by Proponent

Orca Sand and Gravel Ltd., and predecessor, Polaris Minerals Corporation initiated and conducted a consultation program over a period of more than three years with relevant levels of government, First Nations, community organizations and the general public. Public consultation included the operation of a Port McNeill office / information centre, provision of field tours and presentations, and numerous meetings to collect local knowledge and information. During development of the Application and its review, the Proponent continued to meet with these interests and agencies. Such meetings included a September 2004 combined open house and public forum in Port McNeill, attended by approximately 350 visitors. The Proponent held public open houses in Fort Rupert, Alert Bay, Port McNeill, Sointula and Port Hardy during the period of February 7-11, 2005 to provide opportunities for formal public comment on the Application. These meetings were attended by approximately 274 people.

Since 2002, the Proponent has maintained dialogue and sought advice from federal, provincial and local government agencies. A day-long presentation, meeting and site tour was held in March, 2004 and attended by agency personnel, as well as First Nations leaders and their advisors. The Proponent has actively participated in the government agency and First Nations working group established by the BCEAO to review the Project.

3.5 First Nation Consultation and Project Review

The Project area lies within the Douglas Treaty area, and is within the asserted traditional territories of the 'Namgis First Nation and the Kwakiutl First Nation (Fort Rupert).

Transport Canada initiated the environmental assessment process on August 10, 2004 and contacted the 'Namgis First Nation and Kwakiutl First Nation indicating the commencement of the federal review on September 17, 2004.

As per section 21 of the CEA Act, the responsible authorities provided opportunities to the two First Nations to comment on the scope of the project, the scope of assessment and the ability of the comprehensive study process to address the issues. Copies of the scoping document were deposited in each Band office for the length of the 21 day comment period.

The responsible authorities were also able to work with First Nations members of the Orca Sand and Gravel Project Working Group to identify issues of concern during the environmental assessment. All First Nations comments on the Application submitted during the 60 day comment period were considered by the responsible authorities when developing conclusions.

DFO also met with the 'Namgis First Nation and Kwakiutl First Nation on February 8 and 9, 2005 respectively, and with both First Nations again on June 6, 2005, in accordance with its responsibilities under the *Fisheries Act*. DFO continues to work with both First Nations in developing appropriate compensation works for fish habitat impacted by the ship loading facility.

The Proponent also devoted considerable effort and resources to consulting First Nations and securing their support for the Project. This included the funding of independent studies and professional advisors for both Bands and developing agreements and business arrangements. Kwakiutl and 'Namgis members participated in virtually all phases of Project evaluation, including exploration, environmental, archaeological, traditional use, socioeconomic studies, as well as in Project coordination and office assistance. Information meetings included an orientation field tour attended by First Nation representatives and agencies in March, 2004, an open house meeting for all First Nations people in the Port McNeill area in February, 2004, and numerous other events.

Both the Kwakiutl First Nation and the 'Namgis First Nation have provided letters to the federal responsible authorities and the BCEAO indicating that they have been adequately consulted and accommodated with respect to the Project by the Proponent and by the provincial and federal governments.

Part B – Comprehensive Study Assessment

1. Description of the Existing Environment

1.1 Description of the Biophysical Environment

1.1.1 Hydrology and Water Resources

Watersheds

Cluxewe Watershed

The Cluxewe River is 27.1 km long and drains northward into Broughton Strait. The watershed has an area of approximately 95 km^2 and, except for the approximate 40 ha of Kwakiutl First Nation Reserve land at the lower end, is entirely managed by Weyerhaeuser Company (approximately 70%) and Western Forest Products Limited (approximately 30 %).

The watershed has a long narrow north trending shape. Small tributaries and streams drain directly into the Cluxewe River. There are two tributary sub-basins in the portion of the watershed in the Project footprint, about a kilometre upstream of the southern Project boundary, on the east and west sides of the river. There are no identified streams or tributaries within the project area.

The portion of the watershed in the Project area consists of bedrock, till, and the glaciofluvial deposits that make up the Project area. Bedrock in the watershed includes siltstone, shale and limestone. Cluxewe Mountain, located on the west side of the watershed, is an isolated volcanic cone.

The headwaters of the river originate in moderately steep mountainous terrain and the highest point in the watershed is 1356 metres above sea level at the southern most point. The western side of the watershed consists of sub-parallel till drumlins. The river cuts through deep glaciofluvial deposits, which occur along the western Project boundary. Slopes to the east of the river are moderate to gentle with steep slopes acting as escarpments along the river. The river has a low-gradient channel with low terraces and extensive channel bars.

Eighty-two percent of the watershed is forested; the balance is above the tree-line. As there are no glaciers or areas of late-persisting snow and as the area of lakes is less than 1% of the watershed area, there is no significant water storage except in the form of groundwater reserves through infiltration. Infiltration of rainfall and snowmelt into the deep soil deposits sustain streamflow during dry periods.

Mills Creek Watershed

A portion of the Project area lies in the Mills Creek Watershed (locally known as Bear Creek). This watershed has an area of 16 km^2 and is located east of the lower Cluxewe watershed. The watershed extends from the shoreline approximately 12 km to the south. Less than 1% of the watershed area is covered by lakes.

Stream Characteristics
Runoff Coefficients and Stream Flows
Regional stream flow data are not available for Cluxewe River or Mills Creek and therefore estimates of stream flow rates were developed on the basis of catchment areas, runoff coefficients, and estimated evapo-transpiration rates. The catchment areas of Cluxewe River and Mills Creek are primarily comprised of forested regions. It was assumed that the flow from these catchments areas would be a result of the net runoff from precipitation, with evaporation/evapo-transpiration taking place over the entire catchment area.

Mean annual precipitation and evaporation were estimated to be 1654 mm and 463 mm, respectively. Considering the above assumptions, the net runoff would be equivalent to 1191 mm and the average runoff coefficient would be 0.72. This runoff coefficient can be then used for extended monthly or annual hydrologic modeling. For short durations, less than 24 hours, a runoff coefficient of 1.0 may be considered.

Flow Estimation for Cluxewe River and Mills Creek
To estimate the average monthly flow of the Cluxewe River and Mills Creek, the mean monthly precipitation data was employed, and compared to monthly flow data from the Nimpkish River. It was found that the monthly precipitation closely correlated to the monthly flows, suggesting that snowmelt is a minor contributor to the runoff.

Surface Water Use
The only known licensed user of water from the Cluxewe River is the OK asphalt plant located on the west side of the river.

1.1.2 Geology and Soils

The regional geology of the Project area consists of landforms and deposits resulting from two cycles of glaciation during the Quaternary period. However, the absence of multiple till sections, indicating more than one glaciation, implies that the area north of Quatsino Sound has been glaciated only once, most likely during the Late Wisconsin. The near-surface Port McNeill till and Port McNeill de-glacial sediments relate to the last phase of glaciation and de-glaciation, the Fraser Glaciation, which occurred 25,000 to 9,000 years ago.

The site deposits were probably formed by sediment-laden water channelled down the Cluxewe and Nimpkish Rivers from the receding mountain glaciers, 12,000 to 9,000 years ago. The deposit has features that are typical of esker and kame deposits. An esker has been identified to the southeast of the project area, with an orientation that indicates flow towards the project site.

Sand and gravel, between 60 to 100 m in thickness was deposited in a delta at the mouth of the Cluxewe River, bounded by stagnant ice and bedrock highs to the west and a large stagnant ice mass to the east. The deposits rest on flat lying Cretaceous Age sediments of the Nanaimo Group. These sedimentary rocks consist primarily of coarse sandstone grit with minor intercalated shales and coal seams. These sediments have been intruded by a series of Tertiary Age intrusives that were emplaced along a northeast structural trend through the north central part of Vancouver Island.

Thick sand and gravel, between 60 to 100 m in thickness is present in the Project Area overlaying flat lying sandstone bedrock. The sand and gravel deposit is overlain by up to 2.5 m of overburden material consisting of podzolic soils that are formed under cold and temperate coniferous forest conditions from the degradation of needles.

1.1.3 Vegetation

The Project Area is situated within the Coastal Western Hemlock biogeoclimatic zone (CWHvm), – submontane variant (CWHvm1), the most common biogeoclimatic unit in the Vancouver Forest Region and found at low to middle elevations roughly between sea level and 900 m. In general, western hemlock, which regenerates freely under a canopy of mature stands, is the dominant tree species. Western red cedar also occurs frequently throughout the zone, as does Douglas fir although it is most abundant in drier areas. Amabilis fir and yellow-cedar are common only in wetter parts of the zone, while grand fir, western white pine, and bigleaf maple occur in warmer and drier southern parts of the zone. Shore pine is present within subzones, primarily in wet boggy areas. Other tree species that occur to various degrees in this zone are western yew and, in disturbed areas (i.e., areas impacted by logging, development and settlement), red alder. The floral characteristics of the CWHvm biogeoclimatic zone are a predominance of western hemlock, a relatively sparse herb layer, and the common occurrence of several moss species, especially step moss and lanky moss.

Shrubs, flowering plants, ferns, sedges, grasses, lichens and mosses comprise the understory plants. Salal is ubiquitous throughout the area and occupies a high percentage of ground cover. Common fruit-bearing shrubs include gooseberry, salmonberry, thimbleberry, blackberry, blackcap, Pacific crabapple, red huckleberry, Alaskan blueberry, bunchberry, and wild strawberry plants. Skunk cabbage and devil's club also occur in moist areas.

The project site falls into the "Enhanced Forestry" Resource Management Zone in the Vancouver Island Land Use Plan. The area was logged in the 1930's through 1960's. Currently, a relatively dense coniferous canopy and a vegetation-poor forest floor covers the proposed extraction area. The fluvial terraces of the Cluxewe River, west of the project area, are more productive and include Western hemlock, amabilis fir, and Sitka spruce on the upper terraces and mostly red alders on medium to low terraces, where the disturbances are more recent. The region to the north of the project area experiences very wet conditions as a result of groundwater discharging from higher elevations. Cover includes western red cedar, western hemlock, shore pine, salal, red huckleberry and false azalea. A small artificial wetland, created by the impedance of drainage by a logging road parallel to the shoreline, occurs adjacent to the site and is rich in skunk cabbage and other plant species.

1.1.4 Species at Risk

Species of concern are those listed provincially (red or blue-listed species) and federally through the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the *Species at Risk Act* (SARA), as well as those specifically identified by regulators, First Nations, and stakeholders during preliminary meetings and discussions.

Species at risk are classified at the federal level by COSEWIC, and at the provincial level by the B.C. Conservation Data Centre in Victoria. COSEWIC defines species at risk as endangered, threatened, or vulnerable. Species defined by COSEWIC receive legal protection when the species is accepted for listing on Schedule 1 of SARA. British Columbia fauna and flora that are considered at risk are classified as either "red-listed" or "blue-listed". Blue-listed species are considered to be vulnerable and sensitive to disturbance. Populations of red-listed species are considered to be endangered and threatened in British Columbia.

The Proponent queried the B.C. Conservation Data Centre but it identified no known occurrences of rare, threatened and endangered species in the project study area. As well, the Proponent found no rare, threatened or endangered plant species during the field survey.

Terrain Ecosystem Mapping undertaken by the Proponent within the Port McNeill Forest District revealed that one red-listed and two blue-listed plant communities occurred within the terrestrial resources study areas. The red-listed community, Sitka spruce/salmonberry, occurs on the high fluvial terraces of the Cluxewe River. One of the blue-listed communities (Black cottonwood/red-osier dogwood) also occurs on the terraces and shares many of the same important qualities as the red-listed community. The other blue-listed community, Western red cedar, Sitka spruce – skunk cabbage, occurs north of the pit area and west of the conveyor area, in the vicinity of the small artificial wetland (just south of the old logging road). Deer, black bear and Roosevelt elk are likely to occur in the Project study area. Harlequin ducks, which may soon be listed as a species of concern under SARA, are found in the Project study area, along with several migratory bird species. The Northern red legged frog, also a species of concern under SARA, occurs in some wetlands outside the Project area.

1.1.5 Fish and Fish Habitat

1.1.5.1 Freshwater Ecosystem

While no watercourses were identified within the Project area, several watercourses are located nearby, draining the areas surrounding the deposit and upstream of the deposit, or potentially receiving groundwater from the project area. The watercourse of greatest significance is the Cluxewe River, whose channel is located adjacent to the western edge of the deposit. Mills Creek (Bear Creek) located to the east of the deposit, may receive groundwater from the project area. A number of small streams located to the west of Mills Creek may also be affected by groundwater from the deposit.

Cluxewe River
The Cluxewe River watershed encompasses an area of 96.3 km^2. It originates in moderately steep, mountainous terrain to the southeast of the Project area, and empties into Broughton Strait northwest of Port McNeill. The lower 6 km of the Cluxewe River is a low-gradient, alluvial channel with low, erodable terraces and extensive channel bars. Short sections of the channel are confined by high till or glaciofluvial banks. Less than 1% of the watershed area consists of lakes, and the Cluxewe system therefore has limited water storage.

The Cluxewe River supports significant runs of pink salmon, as well as small runs of coho and chum salmon. Chinook and sockeye salmon are also present but in very low numbers. Summer and winter run steelhead are also present in significant, but declining numbers.

Fish habitat surveys undertaken by the Proponent indicated that fish habitat within the lower reaches of the Cluxewe River has been impacted by historical logging practices. The river was described as currently exhibiting the following habitat features:

- limited pool frequency and pool area;
- limited in-stream large woody debris;
- lack of in-stream cover;
- moderate to severe aggradation;
- lateral channel instability; and
- alder dominated riparian vegetation (young seral stage).

The Proponent noted that although there are abundant quantities of spawning substrate, the quality of these substrates is somewhat degraded by the significant quantity of fines associated with the gravel. The gravel is also highly mobile, further reducing its overall quality.

The Proponent identified ample evidence of channel over-widening was observed in both historical air photos and during its field assessment. The presence of flats vegetated in pole-sapling alder and younger alder forest is indicative of their relatively recent inclusion in an area of mainstem flow.

Despite the degraded quality of fish habitat within the lower reaches of the Cluxewe River, the Proponent provided evidence that the river and associated riparian zone is beginning to recover from the effects of historical logging practices. For example, the growth of shrubs and young forest (primarily alder) on benched flats along the river indicates the start of riparian recovery and channel belt width narrowing. The Proponent noted however, that the benches are also characterized by significant deposits of woody debris, isolated ponds, infilled (vegetated) back channels, and old braids, indicating that these areas are still at least partially inundated during flood events.

Mills Creek
Mills Creek arises in moderately steep, mountainous terrain to the south of the Project and drains into McNeill Bay to the west of Port McNeill. A community hatchery is currently in operation on Mills Creek, enhancing the stream's pink salmon and coho salmon stocks.

Chum, coho, pink and sockeye salmon are known to be present in this stream. Of these species, coho and pink salmon are the most abundant. The numbers of coho, chum and pink salmon spawners within this system have been highly variable over the period of available data.

Fish habitat surveys undertaken by the Proponent characterized the west branch of Mills Creek as a confined, well-shaded, sinuous channel, with channel substrates and channel banks consisting of ~99% coarse sand, organic fines, silts and clays and ~1% small gravels. The channel gradient was estimated at 1-2 %. The riparian vegetation was characterized by a mixed mature forest, and Large Woody Debris (LWD) was frequently found in the channel. The channel appeared stable, with little evidence of channel migration.

The water was described as being clear, with a slightly basic pH and high dissolved oxygen content during the survey period. No barriers were noted, with the exception of steep gradients and diffuse flows (undefined channel) near the headwaters at Highway 19. No fish were observed during the Proponent's survey. While in-stream and overhead cover was plentiful, the available in-stream fish habitat was limited due to limited stream depths and absence of significant pools.

1.1.5.2 Marine Ecosystem
Background information on the marine environment in the study area was obtained by the Proponent from a variety of sources, including DFO, the Northern Island Straits Coastal Plan, First Nations, and local stakeholders. In addition, intertidal and subtidal surveys were undertaken by the Proponent in the vicinity of the proposed conveyor and ship-loading facility in order to assess existing habitat values.

Intertidal
A wide variety of flora and fauna were observed along the shoreline during the intertidal assessments including numerous types/species of macroalgae (i.e., seaweed), invertebrates, and fish. A total of thirty-one species of seaweeds were identified in the study intertidal area. The majority of these species were restricted to the lower intertidal zone. The subtidal assessment identified an additional four species: thick ribbed kelp, sugar wrack, wrinkled kelp, and "macrophyte green on eelgrass". Several flowering

plants (Anthophyta) were also identified, including surfgrass and eelgrass. Of particular importance is the presence of eelgrass within the study area. Edible seaweeds, which are of considerable importance to First Nations, were also found in the study

A wide range of invertebrates were collected and observed in the intertidal area including: Sponges; Cnidarians (e.g., anemones); Worms (e.g., sand worms and tube worms); Mollusks (e.g., chitons, limpets, clams); Arthropods (e.g., crabs, amphipods, isopods, barnacles); Bryozoans; Echinoderms (e.g., starfish, urchins, sea cucumber); and Tunicates. Common invertebrates included periwinkles, dogwinkles, limpets, barnacles, amphipods, and isopods. Purple shore crab was also observed in large numbers in the intertidal area, particularly the mid-intertidal zone.

The presence/absence of shellfish was assessed in the small areas of sand that exist within the study area, both to the west and east of the proposed loading/conveyor. Each area was evaluated at low tide, and several species of shellfish were observed including littleneck and butter clams, although in relatively low numbers. Based on the findings of the survey and discussions with local stakeholders, the Proponent determined that the area in the vicinity of the proposed ship loading facility did not appear to provide significant habitat for a productive shellfish community.

Several species of fish were also observed along the shoreline during the intertidal assessment including: pricklebacks; gunnels; Pacific clingfish; and sculpins). Pricklebacks, gunnels and clingfish were found under larger boulders and cobbles along all sections of shoreline at low tide. The sculpins were found in small pools throughout the intertidal area.

Subtidal

Subtidal surveys conducted by the Proponent identified the substrates of the subtidal area to be highly variable, ranging from sandstone bedrock outcrops to areas of sand and gravel. Sands and gravels were found to be the dominant substrate types in the subtidal area and these coarser materials tended to be correlated well with higher densities of eelgrass. Eelgrass, in turn, supports macrophyte algae that provide food and protection to a large variety of animals (fish, anemones, nuibranchs, and crabs). Solid substrate (rock and boulder) areas showed colonization of sessile (attached) invertebrates and larger algae. Invertebrate biological activity in this area was limited to relatively small, low profile organisms such as sea stars, urchins, small crabs, and anemones.

Deeper subtidal areas contained larger boulders and rock, which provided invertebrates protection from prevailing currents. The larger substrates also provided habitat for larger anemones, urchins, and octopus. In addition, the larger rocks and boulders were found to be the main attachment substrate for algae (seaweed). It was noted that larger seaweeds, such as kelp, provide protection and food for other marine organisms (urchins, fish and crabs). Pipefish, hydroids, bryozoans, snails, and crabs were all observed in or near the kelp patches.

Particularly noted by the Proponent was the presence of northern abalone. This species is generally found clinging to rocks in kelp beds along exposed and semi-exposed coasts within 6 m of the surface. Abalone has been closed to all forms of harvest since 1990 due to chronically low stocks. In April 1999 the northern abalone became the first Canadian marine invertebrate to be designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as "threatened". The northern abalone is protected in Canada under the federal *Species at Risk Act*. (SARA).

The Proponent identified eelgrass and kelp beds during its intertidal and subtidal surveys, but determined that these were not "significant" in comparison to other coastal areas. Eelgrass and kelp beds were noted as providing important habitat for a range of marine organisms. In the Application, the Proponent summarized some of the existing studies and literature regarding the use of eelgrass and kelp beds by fish. The emphasis was on salmon and rockfish, although other fish species and invertebrates also rely on these types of habitat.

The Application also included a discussion of the use of near-shore habitat by juvenile salmonids and other fish species based on a review of relevant literature and other information sources. It was noted that juveniles of all five species of Pacific salmon and anadromous cutthroat trout are known to use nearshore habitats as part of their migration route from their natal streams into marine offshore waters. Further, estuaries and nearshore coastal waters are important rearing habitats for juvenile salmon, particularly from Spring to Fall. Steelhead trout, in contrast, pass through nearshore areas very quickly, but are known to feed on small fish migrating and rearing in these areas. Holding areas for juvenile fish likely correspond to the presence of areas of kelp and eelgrass.

The Application also discussed the use of near-shore habitat by adult salmon, noting that all five species of salmon, as well as cutthroat trout and steelhead may be found in Broughton Strait and Queen Charlotte Strait at some time of the year. However, with the exception of a resident chinook population ('winter chinook'), all of these species are migratory fish, appearing in the straits only as mature animals in summer and fall months en route to spawning beds in many north Island rivers, in particular the Cluxewe, Keogh and Nimpkish. Coastal areas near the mouths of salmon spawning streams can provide important holding areas for adult salmon prior to spawning. In many cases, these holding areas can be located in a bay or behind a point of land that will provide a back-eddy from opposing tidal flow. With respect to the Project area, Nimpkish River sockeye have been observed to stage in the proposed ship loading areas prior to moving into the river. Nimpkish River chum are also reported to stage in the proposed ship loading area prior to moving into the river.

The Application included an overview of the presence of marine mammals in the vicinity of the Project. Most information was taken from the BC Cetacean Sightings Network and this was supplemented with scientific literature, field observations, and interviews with people knowledgeable about marine mammal fauna of the region. As well, in early September 2003, a reconnaissance flight using a fixed wing aircraft was flown along the coastline, within approximately 5 km of the proposed marine ship-loading facility. The flight was completed to survey the vicinity of the project area for marine mammals and to identify potentially important habitat areas (e.g., seal haul-out locations). Observations of marine mammals were also made by the project team fisheries biologists during other field surveys.

The Application described the relatively diverse number of marine mammals that are found in the vicinity of the Project. The species identified included: toothed cetaceans (whales, dolphins, porpoises); baleen whales; seals; sea lions; and sea otters.

1.1.6 Wildlife and Wildlife Management
The Proponent made use of various sources of existing information on wildlife and wildlife habitat in the general vicinity of the Project area as well as conducting several project-specific studies for amphibians and birds (breeding birds and marine birds) with general surveys for the occurrence of or evidence of use by other terrestrial wildlife such as ungulates and carnivores.

Amphibians
Amphibians were surveyed using two Resource Inventory Standards Committee (RISC) survey techniques: systematic surveys, and time-constrained searches. One western red-backed salamander, a terrestrial species, was found within the proposed sand and gravel extraction area. However, only a limited amount of searching was devoted to this area because of the lack of breeding habitat for listed amphibian species (*i.e.,* red-legged frog). The clouded salamander is the only other terrestrial salamander occurring on northern Vancouver Island and may occur in the project area. All other salamanders were located in the lowland buffer between the escarpment and the river or north of the proposed extraction area.

The only listed amphibian species on northern Vancouver Island is the red-legged frog. It is blue-listed (threatened) by the CDC and classified as a species of special concern on SARA Schedule 3. Red-legged frogs were only recorded in a pond outside the Project area (approximately 600 m west of proposed conveyor route). Ponds along the Cluxewe River provided some potential red-legged frog habitat although, overall, they were less suitable because of the paucity of aquatic vegetation required for egg attachment. This species prefers forests with abundant vegetation and ground litter, which occur along the ocean shoreline and in the lowland forests along the Cluxewe River. The Application noted that no ponds or wetlands occur within the project footprint and that the extensive riparian buffer proposed for the Project will protect wetland habitat along the Cluxewe River.

The Application stated that northwestern salamanders were by far the most abundant and ubiquitous amphibian species. Their egg masses occurred in most forested ponds encountered, but were absent from the ponds occurring at the edge of the river gravel bars. They occurred in some backwater ponds that exhibited very little flows with the exception of the confluence with the mainstem Cluxewe River. One adult was found near a beaver pond adjacent to the Cluxewe River, to the northwest of the proposed Project Area. The Proponent concluded that resource extraction activities in the proposed Project Area would have little, if any, impact on this species.

Three other species of amphibians occur on northern Vancouver Island: long-toed salamander, western toad, and Pacific tree frog. Of these species, evidence was found only of Pacific tree frogs. Eggs were found in the ponds behind the beach access road. Croaking was reported in the gravel pit pond by the river, west of Hartford Pit, but no eggs were found and the pond was not considered to provide suitable quality habitat. The extraction area provides poor habitat for these three aquatic-breeding species.

Birds

The Proponent conducted surveys for possible breeding Harlequin Ducks along the Cluxewe River in May/June and August 2003 but no Harlequin ducks were observed during these surveys. The Proponent concluded that this indicated that the river adjacent to the proposed Project did not appear to provide appropriate nesting habitat for Harlequin Ducks. Although no Harlequin Ducks or broods were observed during the surveys, three riverine bird species (Belted Kingfisher, Spotted Sandpiper, and American Dipper) and Bald Eagles were recorded during the August survey.

The Proponent conducted waterbird surveys along the Soldier Bay shoreline and Cluxewe River estuary in 2003 and 2004. These surveys identified several species of marine birds that winter in Soldier Bay and the adjacent shoreline east of Cluxewe Spit. Based on bird densities for all surveys, Soldier Bay appeared to receive as much as 50% more use per unit length of shoreline than east of Cluxewe Spit. Within Soldier Bay, the central rocky intertidal area received more use by more species than other parts of the bay. The proposed conveyor passes through the west edge of the central rocky area.

The relative abundance of species in the area east of Cluxewe Spit and Soldier Bay during the August to early May survey, and during mid-May to early June surveys between Cluxewe Spit and Lady Ellen Point, had many similarities. During all surveys conducted in these areas, Harlequin Ducks and Surf Scoters were observed to be the most abundant species, while White-winged Scoters and Buffleheads also consistently ranked high in abundance.

Breeding bird surveys were completed at the end of May and in mid June, 2003. Twenty-nine (29) breeding bird species were observed during the spring 2003 surveys within the Project area. None of these species are blue or red-listed by the BC Conservation Data Centre or federally listed under SARA. Some of the most common species observed on the surveys included: Winter Wren; Golden-crowned Kinglet; Chestnut-backed Chickadee; Swainson's Thrush; and, American Robin. Additional breeding bird species observed beyond the survey points included Bald Eagle, Canada Goose, Common Loon, Common Raven, Common Yellowthroat, Glaucous-winged Gull, Great Horned Owl, Northern Flicker, Northwestern Crow, and Red-breasted Nuthatch.

The Proponent also conducted raptor nest surveys and call-back surveys within the Project footprint and along the Cluxewe River. During the spring 2003 survey an active Bald Eagle nest was located at the west end of a small island in the Cluxewe Estuary. No other nests of raptors were located during the surveys. A previous aerial survey conducted by Western Forest Products (WFP) has detected most eagle nests in the Project area. None of the nests mapped by WFP occur in the Project area or in line with the proposed conveyor.

In May 2003, the Proponent completed a survey to detect the presence of Great Blue Heron within the Project footprint. The Great Blue Heron is provincially blue-listed and is also listed as a species of special concern under the federal *Species at Risk Act*. Although no Great Blue Heron were observed within the Project footprint, several were observed during shoreline surveys in Soldier Bay, McNeill Bay, and the Cluxewe River Estuary.

Terrestrial Mammals
General wildlife reconnaissance surveys were conducted by the Proponent in conjunction with other field surveys. The Proponent noted that wildlife species richness was about four times greater in the riparian and lowland forests along the Cluxewe River than in the interior areas where gravel extraction is proposed. Wildlife abundance, although not quantified, appeared to follow a similar trend. The interior coniferous forest had lower wildlife diversity because of the lack of habitat diversity. Interior forests were uniform and dense, with little undergrowth in most areas. No wetlands were present. No species of provincial or federal management concern were located in the interior forest.

The lowland and riparian forests, in contrast, contained diverse habitat features, including seasonal wetlands, a beaver pond, stands of coniferous, deciduous, and mixed forest, coniferous blow down, and open river edge. Animal trails occurred along the river's edge and along the interior hillside overlooking the river. Along the river trail, evidence of use was noted for four mammal species: wolf (1 scat), black bear, deer, and an unidentified mammal, possibly a member of the weasel family (1 scat). Black bear signs were fresh and abundant, consisting of scats, often with huckleberry seeds (scats near the ocean contained salal berry seeds); a possible back-rubbed tree; and wasps' nests dug out of the ground.

Terrain Ecosystem Mapping (TEM) was completed for the entire Project area in early July 2003. This was used as a framework for applying habitat capability and suitability ratings. Capability is defined as the ability of the habitat, under optimal natural conditions, to provide the life requisites of a species, regardless of its current habitat condition. Suitability is defined as the ability of the habitat, in its current condition, to provide the life requisites of a species. Habitat polygons identified by the TEM mapping were evaluated in further detail by a wildlife biologist to allow the completion of suitability and capability assessments for black-tailed deer and black bear.

The resource extraction area is covered almost entirely by a young, second-growth western hemlock and amabilis fir forest with a fairly sparse understory. Consequently, there is good shelter from precipitation but little food. Near the resource extraction area, habitats in the buffer zone adjacent to the Cluxewe River provide high-quality food and cover. The conveyor will pass over mainly wet habitat with early structural vegetation stages (e.g., shrubs, sedges, skunk cabbage, horsetail, etc.) that produce deer forage in early spring and late summer-fall, but overall, this wet habitat is of limited value to deer. The habitat adjacent to the shoreline provides limited food for deer, mainly on the edge facing Broughton Strait. The most valuable habitat for Black-tailed Deer is that found within the proposed buffer zone adjacent to the Cluxewe River.

With respect to black bears, there is some food-producing habitat in the Project area, but denning habitat (large diameter western red cedar and yellow cedar) is lacking. The resource extraction area provides good shelter from precipitation but little food for bears. Near the resource extraction area, habitats in the buffer zone adjacent to the Cluxewe River provide high-quality food and cover for bears. For bears, food is particularly abundant when migrating salmon enter the river; at such time they use the adjacent areas for travel and as secure places to consume salmon. The stockpile area has relatively low potential to support bears. The dense tall shrub and pole-sapling structural vegetation stage dominant in this area provides some food and cover value during spring and summer. Early structural vegetation stages (e.g., shrubs, sedges, skunk cabbage) produce food for bears in spring and fall. Habitat adjacent to the shoreline also provides cover and resting places for bears and they frequently forage in the intertidal zone. The most valuable habitats for black bears are those in the buffer zone adjacent to the Cluxewe River, which is protected under the project development plan.

1.1.7 Waste Management
Reference to existing local waste management was included in the Application. The Proponent noted that local contractors carry out solid waste collection in the local communities and the rural areas. The regional district operates the Seven-Mile landfill and recycling facility off Highway 19, between the Port Alice and Port McNeill junctions with Highway 19. All non-hazardous solid waste generated within the regional district is disposed of in the Seven-Mile landfill.

1.1.8 Noise
In the Application, the Proponent provided a brief description of the ambient noise levels in the Project area. The Proponent noted that currently, the only significant sources of noise are from the paved and unpaved roads in the area. Highway 19 runs south of Port McNeill, east past the Project site and south of the Klickseewy IR #7. This highway is used by all types of road compliant vehicles. One unpaved road (Rupert Main) runs parallel to Highway #19 and these are used by both logging trucks and private vehicles.

The Proponent also stated that additional background noise sources in the area may include cargo and passenger ships traveling through Broughton Strait, local fishing boats in Broughton Strait, local aircraft, and equipment at existing gravel pits to the northwest and southeast of the Project site.

1.1.9 Air Quality

In the Application, the Proponent stated that the only significant sources of air pollutants currently in the Project area are from the roads adjacent to and on the Project site. The unpaved roads are primarily east of and adjacent to Highway 19 and are used by logging trucks during the day, and by private vehicles during both the day and night. The sole paved road near the Project area is Highway 19. Western Forest Products and Weyerhaeuser indicated that approximately 80 logging trucks and an estimated 160 private vehicles per day drive on the Rupert Main unpaved road. Statistics collected by the Ministry of Transportation indicate that the average annual daily traffic for north and southbound traffic on Highway 19 is approximately 2,100 private vehicles. Pollutants include dust (PM_{10} particles), and gaseous emissions, including NO_x, SO_x, and CO. Other sources of air pollution near the Project area include recreational boats/water vehicles, commercial fishing vessels, container and cruise ships traveling through Broughton Straight, and local transportation vessels.

The Proponent compiled an emissions inventory for the unpaved and paved road traffic based on its current use. The results indicated that: 123 tonnes of PM_{10}, 46 tonnes of NO_x, 3 tonnes of SO_x and 31 tonnes of CO are produced per year. Using a simple air quality prediction equation for linear sources based on the elevation of the road and assuming a wind direction from the perpendicular to the road, concentrations at a distance 1 km from the unpaved and paved roads of PM_{10}, NO_x, SO_x and CO were estimated. The estimated values were compared to the Canadian Council of Ministers of the Environment (CCME) guidelines for PM_{10}, NO_x, SO_x and CO. All estimated values were significantly lower than CCME guidelines (refer to Table 2).

Table 2 Current Air Quality Estimates (Orca Sand and Gravel Ltd. 2004)

PARAMETER	ESTIMATED VALUE	CCME GUIDELINE
PM_{10}	0.06 – 16 $\mu g/m^3$	25 $\mu g/m^3$
NOx	0.02 – 5.9 $\mu g/m^3$	60 $\mu g/m^3$
SOx	0.002 – 0.42 $\mu g/m^3$	30 $\mu g/m^3$
CO	0.02 – 4.1 $\mu g/m^3$	6,000 $\mu g/m^3$

1.2 Description of Socio-Economic and Cultural Environment

1.2.1 Current Use of Lands and Resources for Traditional Purposes

The Proponent undertook *Heritage Overview Assessments* (HOAs) of the Kwakiutl and 'Namgis First Nations to identify and record the archaeological sites, ethnographic sites, and traditional use areas in and around the Project area. The objective of these assessments was to identify any heritage areas that could potentially be impacted by the proposed Project. The Proponent collated published ethnographic, historic, and Traditional Use Site information for the study area and consulted with Elders from both First Nations. This consultation involved the gathering of any information they wished to share on known archaeological and traditional use sites in the area, and discussions with each group regarding the significance of any sites found during the study.

'Namgis Traditional Use

In addition to the two HOA studies, the 'Namgis First Nation conducted a series of interviews during the summer of 2004 with a wide range of band members including 'Namgis Elders in order to gather Project specific information. While TUS information was recorded based on the interviews, additional information was drawn from written texts.

Fishing and Seafood Collecting

The Dła̱ksiwe' (Cluxewe River) and nearby marine areas, located approximately 2.5 km west of the Project area, were identified as a notable area for salmon fishing. Fishing for ground fish at the mouth of the Dła̱ksiwe', located more than 2.5 km west of the Project footprint and near Lady Ellen Point, some 500 metres east of the Project area, was also recorded. In addition, most of those interviewed identified collecting sites at the mouth of the Dła̱ksiwe' for a variety of seafood including clams, mussels, eelgrass and seaweed.

Berry and Plant Gathering

There were several locations near the Project area where berry and plant gathering activities historically took place. Berry picking and plant gathering were carried out all around the Dła̱ksiwe' area. The following plants are known to have been collected in the area:

- Stinging nettles - used for making fishing line/nets;
- Alder - used for smoking fish and to make wooden spoons;
- Cedar - used as gifts for the potlatch in various ways;
- Berries - dried berries were treats of the past;
- Red ochre; and
- Apple trees and plum trees were planted in the area.

Medicinal Plants

Most native medicinal plants are found around the swampy areas south of the mouth of the Dła̱ksiwe' including:

- Balsam bark - the outer bark was used as a drink for arthritis and tuberculosis;
- Gum/pitch - used to heal sores;
- Devil's Club – used to treat digestive tract ailments; and
- Stinging Nettles – used for back problems.

In addition to the 'Namgis traditional use of this area, Kwakiutl members are also known to collect traditional use medicinal plants from the Cluxewe estuary.

Cluxewe River (Dłaksiwe')

The Dła̲ksiwe' was identified as a very important traditional area to First Nations. In addition to its value as a source of seafood, the river had a myriad of uses including:

- Ceremonial - use for ceremonial bathing initiation for certain dances;
- Spiritual - the river was a place where many went upstream for vision quests;
- Medicinal - water from the Dłaksiwe' was identified for medical and therapeutic uses;
- Water Supply - the Dłaksiwe' was identified as a traditional source of potable water and a main water supply;
- Transportation Routes – part of a trail from Dłaksiwe' to Nimpkish River; and
- Traplines - went along the foreshore and up the Dła̲ksiwe'.

Information related to specific sites was not revealed due to the confidential nature of the information. It should also be noted that many of the places mentioned by Elders are stated in terms of approximate locations, because band members did not wish to state the exact location or because the terrain had either changed or been logged over. In general, the 'Na̲mgi̲s 2004 TUS survey suggested that the majority of TUS sites were outside of the Project footprint.

Kwakiutl Traditional Use

As part of the environmental assessment process, the Kwakiutl First Nation undertook an independent study that provided an overview of the traditional use and socio-economic setting relevant to the proposed undertaking. The results of the study indicated that throughout its history the area around the Project was widely used by the Kwakiutl First Nation. Fishing, inter-tidal gathering, plant harvesting, hunting and trapping activities were identified as common traditional uses in, and around, the Cluxewe River and Port McNeill Bay; many of these traditional uses have been carried on to this day.

CMT Survey

The project area was logged in the 1930s through 1960s. However, to establish certainty that no culturally modified trees (CMTs) remained in the Project area, a 100% CMT inventory was conducted by the 'Namgis CMT crew with a Kwakiutl participant. No CMTs were found during this inventory and the complete absence of CMTs in the Project area was confirmed. Evidence of logging was observed throughout the entire area and all of the trees appeared to be second growth. The few cedar present were inspected for evidence of cultural modification with negative results.

1.2.2 Land and Resource Use

An overview of the existing land and resource use in the region was included in the Application. The Project would be located on private property owned by Western Forest Products Inc. within its Tree Farm Licence (TFL 6 Block 2). The ship loading facility portion of the Project would be an exception as it would be located over Crown foreshore land.

Forestry supports the largest percentage of the workforce in this important timber producing area. Commercial fishing has declined over recent years. Salmon and shellfish aquaculture is one of the few growing industries in the region. The largest mining operation, Island Copper, closed in 1995 and mining is currently limited to small-scale industrial mineral production at a few locations. Two wind energy projects were approved in Fall 2004 near the northern tip of Vancouver Island. Tourism has grown slowly over the last 20 years, with whale watching and sport fishing being popular activities. However, Soldier Bay is rarely visited by tourists for any of these activities.

The Cluxewe Resort, at the mouth of the Cluxewe River, is a summer campground owned and operated by the Kwakiutl First Nation and situated on their reserve, Klickseewy IR #7. This is the closest recreation site to the Project and is located 2 km west of the conveyor alignment at the beach. The Cluxewe Salt Marsh, a nature preserve located west of the Cluxewe estuary, is the closest protected area.

Highway 19 is the main transportation artery connecting the North Island and crosses through the project area. Broughton Strait is a commercial shipping channel and is also crossed numerous times daily by a ferry connecting the town of Port McNeill with Alert Bay and Sointula.

The North Island Straits Coastal Plan designated the unit within which the Project area is located as: "characterized by concentrated coastal uses that should be managed to accommodate a variety of existing uses and activities". The Regional District's A-1 classification of the Project area allows for mineral extraction and processing activities.

1.2.3 Local Communities
The Application included an overview description of local communities located near the Project. The Project is located in the Regional District of Mount Waddington which has a population of just over 13,000. Port Hardy, Port McNeill, Alert Bay, Port Alice, Sointula and Fort Rupert are the larger communities within the regional district. Unemployment is higher than the British Columbia average, at 10.7% in 2001. This reflects a generally declining local economy which has historically been dependent on primary resource industries such as: forestry, mining and fishing.

The Kwakiutl First Nation and the 'Namgis First Nation, with 639 and 1532 members respectively, have both asserted traditional territory rights over the Project land, as detailed in their Statements of Intent filed with the BC Treaty Commission. The Kwakiutl First Nation services ten reserves with the main community at Kippase IR#2 at Fort Rupert. The 'Namgis First Nation has eight reserves, with the main community on reserves on Cormorant Island.

1.2.4 Public Health and Safety
Existing community emergency services were described in the Application. The Project Area is within the administrative boundaries of the Vancouver Island Health Authority. There are hospitals in Port Hardy, Port McNeill, and Port Alice, all of which provide various medical diagnostic and treatment services. Cormorant Island Community Health

Centre located in Alert Bay provides emergency services and out-patient rehabilitation services and extended care. Port Hardy also has a regional health unit/community centre, while a home support program operates out of Port McNeill.

RCMP detachments and volunteer fire departments are located in Port McNeill, Port Hardy and Alert Bay. The BC Forest Service operates a forest fire base camp in Campbell River.

1.2.5 Navigation

An overview of existing shipping and navigation in the vicinity of the Project was included in the Application. The chosen location for the ship loading facility is in a bay on the south side of Broughton Strait, approximately 1 km west of Lady Ellen Point. This site is sheltered by Malcolm Island, Lady Ellen Point and Ledge Point, which offers protection from north and easterly winds. The site may occasionally be subject to heavy weather from storms from the northwest. A monitoring buoy was anchored on the ship berth station from October 2003 to May 2004 in order to record sea and meteorological conditions over a winter period. Data from the buoy indicated that during a normal year conditions will not be extreme. The site is well clear of the Broughton Strait shipping channel and does not interfere with navigation. A bathymetric survey confirmed the water depth and bottom profile in a 2½ km wide area centered on Soldier Bay. Inclement weather is normally from the south-southwest and heavy rainfall can occur at any time of the year. Tides range up to a maximum of 6 m.

Broughton Strait is part of the “inside passage” between Vancouver Island and mainland British Columbia. This is the main shipping route between Vancouver, Puget Sound and Seattle, and the north coast of North America and Alaska. As such, large vessels transit the strait on a daily basis. Pilots are picked up and dropped off at one of several pilot stations including Victoria, Pine Island and Port Hardy, depending upon seasonal traffic patterns and the intended journey route.

1.2.6 Archaeological, Heritage and Historical Cultural Resources

In June 2004, the Proponent conducted a detailed Archaeological Impact Assessment (AIA) to identify and record the archaeological sites, defined as physical evidence of past human activities within the proposed Project area. The objectives of the AIA were to identify, record and evaluate the archaeological resources within the area.

Involvement by both the Kwakiutl First Nation and the ‘Namgis First Nation included the selection of the archaeologist, the gathering of any information they wished to share on known archaeological and traditional use sites in the area, and use of Band members in all field work. All information gathered was incorporated, wherever possible, into the AIA, while respecting the confidential nature of the information provided.

An archaeological survey of the aggregate extraction and processing plant area was conducted along pre-cut lines that had been prepared for the seismic resource investigation. All seismic pit exposures and natural (tree throw) exposures along these seismic lines were thoroughly checked for cultural material. Cutbanks within the seismic holes were shovel cleared and deposits screened at many tree throws.

Where no suitable exposures already existed, subsurface shovel or auger tests were conducted at 50 m intervals. In addition to the seismic lines, traverses were made following the road system through the extraction part of the project area, around the margins of an existing gravel pit, and along the east bank (the terrace edge, rather than the channel margin) of the Cluxewe River. The roads have large flanking soil exposures that provided excellent sub-surface visibility. Additional sub-surface testing was conducted using auger and shovel tests in areas that were deemed to have higher archaeological potential.

The cleared conveyor centre line was walked and carefully checked for any soil exposures. Testing was completed along the centreline and up to 10m to either side at intervals of approximately 50m. The modern day shoreline and beach exposures were also thoroughly checked for cultural resources.

No archaeological resources were identified during the survey of the proposed aggregate extraction and processing area, and based on the intensive level of survey and subsurface visibility completed, the potential for undiscovered archaeological deposits is deemed to be low.

The conveyor line that extends from the north portion of the aggregate extraction area north to the highway was found to have low archaeological potential. About 10 subsurface tests were placed throughout this area and all tested negative for cultural material. North of the highway, the proposed conveyor route extending approximately 730 m, was also judged to be low in archaeological potential. Ten subsurface tests were conducted and all of these tested negative for cultural material.

The intertidal zone is a mix of sandstone shelf and sand/cobble beach. No archaeological features or materials were observed in the intertidal zone. Additional examinations were conducted away from the proposed conveyor route on the beach and inland, given the higher archaeological potential for this area. An archaeological site (named EdSs-T1 by the archaeologists) was discovered 8 m from the high tide line, to the east of the centre line of the conveyor route. This site consists of a small pocket of ash 10 cm below the surface, and fire cracked rock (boiling stones) scattered over a small area measuring about 4 m E-W by 3 m N-S.

In summary, the Proponent did not identify any archaeological resources during the survey of the extraction and processing area. Based on an intensive survey and sub-surface sampling, the potential for undiscovered archaeological deposits was deemed to be low.

2. Environmental Effects and Mitigation

2.1 Environmental Effects and Mitigation for the Biophysical Environment

2.1.1 Hydrology and Water Resources

Description of Potential Effects:

The gravel extraction activities associated with the Project were identified as having the potential to impact groundwater quantity and quality as well as possibly affecting the water levels in the Cluxewe River and Mills Creek. There was also concern that any effects to groundwater in the vicinity of the Project would also impact neighbouring groundwater users in Port McNeill, the Cluxewe Resort and on Malcolm Island. There was also some concern expressed over the quality and quantity of water used in the operations and possible effects of it being discharged into the environment.

Description of Proposed Mitigation:

The Proponent committed to undertake a monthly groundwater monitoring program using eight established wells in the Project footprint during construction and operation (until removed during extraction), and to use these and one up-gradient well for annual groundwater quality analysis during operations. In addition, the Proponent committed to mine only above the winter groundwater table, therefore eliminating potential for direct impact on the groundwater table.

Groundwater monitoring studies indicated that the flow to groundwater wells servicing Port McNeill, Cluxewe Resort and on Malcolm Island would not be affected by the Project as they are "up gradient" from the Project. In addition, the Proponent has committed to collect water samples from wells and analyze for key quality parameters once per year.

The sand and gravel is naturally wet in the ground and contains 3% moisture by weight when extracted. A net loss of water from the Project of 390,000 cubic metres per year at maximum capacity would arise because the sand and gravel is damp, after washing, when loaded onto the ships. The Project's operations would require the discharge of process water into sediment control ponds or infiltration. All process water would be recycled, so there would be no discharge of wastewater from the Project.

The Proponent identified the main sources of sediment as being the washing process for the aggregates and to a much lesser degree, the sediment associated with extreme rainfall events. Sediment from surface runoff will be contained on site and will settle on the floor of the active quarry area. A thickener will be used to accelerate settling of sediment and reduce the size of settling ponds that would otherwise be required.

It is proposed that two sedimentation ponds be used. A pond 40 m long, 20 m wide and 3 m deep will receive the thickener underflow containing 60% solids. A secondary sedimentation pond 115 m long, 35 m wide and 3 m deep will receive thickener overflow for final settling and water recycle. The ponds will be created by excavation into the pit floor level therefore no dykes or impoundments will be created and silts cannot be carried off site because of the surrounding, higher, buffer zones.

Lining of the sedimentation ponds may be required to limit seepage losses and reduce makeup water requirements. The liner could consist of low permeability soils or a combination of using the settled silt for lining the base of the pond and using an HDPE geomembrane or soil liner on the slopes of the pond. Cleanout of the sedimentation ponds will produce sediments that will be incorporated into site reclamation. This will involve placement of a 1 m to 2 m thick layer of silt over the areas to be reclaimed, prior to placement of the stockpiled soils, organic materials and re-vegetation.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project; responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that there will not likely be any significant adverse effects to hydrology and water resources.

2.1.2 Soils

Description of Potential Effects:
As the Project site is cleared of trees by Western Forest Products and mined for gravel by the Proponent, the site has the potential to lose all natural topsoil and nutrients for future reclamation activities of the site.

Description of Proposed Mitigation:
Over the life of the project sand and gravel will be removed resulting in the establishment of an area with flatter site topography. Progressive reclamation activities at the site are proposed to re-vegetate all disturbed areas with native species of trees, shrubs, and, where applicable, grasses.

Soil from the first two phases of operation will be recovered and stored for future use in reclamation activities. Topsoil will be recovered and stored separately from the lower subsoil horizons whenever practicable given the limited soil development over much of this site. Organic material, such as non-merchantable trees, brush and stumps, will be chipped and composted, or burned, and added to reclaimed soil. Because there is a limited supply of natural soil, sediment from the water recycle ponds will be used to supplement and improve the reclamation materials. Additionally, the Company will seek to identify other locally available amendment materials that will increase soil nutrient content, to the extent that such materials are practicable and economic

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to soil resources.

2.1.3 Species at Risk

Description of Potential Effects:
During the course of the environmental assessment, several possible effects of the Project on species at risk and their ecosystems were identified. Three marine species listed as threatened under the *Species at Risk Act* (SARA) were located in and around the Project area, specifically northern abalone and orca – northern resident and transient populations. Possible effects of the Project on terrestrial species at risk were also considered. The marbled murrelet (threatened), great blue heron (species of special concern), and red-legged frog (species of special concern) were identified within or adjacent to the Project footprint (conveyor/loadout area). Potential effects to the blue-listed RC (western red cedar-sitka spruce-skunk cabbage) vegetative community were also considered (refer to s. 2.1.5 for this discussion).

Description of Proposed Mitigation:
The Proponent is currently working with DFO and other stakeholders with regard to the identified aquatic marine species. Appropriate mitigation and monitoring measures for these marine species will form an integral component of the DFO *Fisheries Act* Authorization. The Proponent has made commitments to incorporate noise and light mitigation measures for orcas during construction and operations. The Proponent added commitments to document orca sightings from the ship loader on a year round basis for the first three years of operation. Additional monitoring requirements during the Project construction will be established under the *Fisheries Act* authorization in adherence with provisions set out in the SARA.

Both the Marbled Murrelet and Great Blue Heron were observed using the marine habitat on occasions. Given the small numbers of individuals observed and the low potential for interaction with project activities (i.e., ship loading), the potential impact to these species was considered very low. However, there may be minor, short-term disruption to Harlequin Duck habitat during Project construction, although the use of pile drilling (rather than pile driving) for the ship loading structure should minimize noise and the potential for habitat disturbance. During operations, it is expected that Harlequin Ducks and other marine bird species will become habituated to the narrow, elevated load out structure and ship loading activities. The Proponent committed to monitoring the presence of Harlequin Ducks near the marine construction site and adjusting seasonal construction timing accordingly. In the spring of the first operating year, Harlequin Duck presence will also be monitored during ship loading to determine any timing adjustments.

Wetlands occupied by the Northern red-legged frog were outside the Project footprint, approximately 600 m west of the proposed conveyor route. Project-related construction and operations would not impact the wetland/pond area in which the frogs were located. Further, the existing forested border around the wetlands and along the Cluxewe River would not be disturbed. As a result, the Project was not expected to negatively affect the identified red-legged frog habitat.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to species at risk.

2.1.4 Fish and Fish Habitat

Description of Potential Effects:
The potential impacts of the gravel extraction operations on fish and fish habitat in the Cluxewe River and Mills Creek were examined. Similarly, potential Project effects to the inter-tidal and sub-tidal habitat in the bay in which the ship loading facility was to be located were assessed. Eelgrass and kelp beds were specifically identified as important marine habitat that would be potentially impacted.

Approximately 75.5 m^2 of intertidal/subtidal habitats will be impacted, of which, 5.7 m^2 is comprised of eelgrass, 17.2 m^2 of kelp and 14.4 m^2 of surfgrass/edible seaweed. Through the review of technical information provided by the Proponent, DFO concluded that a harmful alteration, disruption and destruction (HADD) of fish habitat would occur within the marine environment. Accordingly, the Proponent must obtain an "authorization" for the HADD of fish habitat from DFO as per subsection 35(2) of the *Fisheries Act.*

In accordance with its No Net Loss (NNL) policy, DFO requires the Proponent to develop suitable measures to compensate for fish habitat loss attributable to the proposed Project. Under the NNL policy, DFO ensures that compensatory measures equal or exceed the productive capacity of the habitats affected. Using its hierarchy of preferences, the standard approach is to replace "like for like" habitats, within the same ecological unit, specifically the immediate area of habitat loss. The second option for compensation is to create or increase the productive capacity of "unlike" habitat in the same ecological unit. This involves compensating for one type of fish habitat with habitat of a different type. The final option of preference is to create or increase the productive capacity of habitat in a different ecological unit. In some cases, the final compensation plan could include elements of several options, with some like for like habitat and some unlike habitat created. In addition to the above, the ecological importance or value of the existing habitats affected must be considered when determining the appropriate compensation ratio to ensure NNL.

Description of Proposed Mitigation:
The Project was specifically designed to avoid any disturbance to the Cluxewe River and Mills Creek. The Proponent committed to maintain a 70 m wide fisheries sensitive zone along the Cluxewe, with the pit and plant boundaries approximately 150-350m from the edge of the Cluxewe River. It also committed to annual inspection of the Cluxewe channel to document changes and to assess bank stability every 5 years in the vicinity of the operating area.

The proposed ship berth design was submitted as an alternative to a rock fill jetty, which would create a larger footprint and greatly increased habitat destruction. The conveyor option design would offer the least habitat impact and shading commensurate with structural integrity. Minor alterations would include changes to the pile spacing and number of piles, based on engineering considerations that could result in slightly more or less of a footprint in eelgrass areas.

The Proponent has prepared a draft marine construction methodology for DFO review, which includes information on types of marine construction proposed, timing, and mitigation and monitoring (based on priorities set by DFO, the Province, and First Nations). In addition, the Proponent committed to employing and empowering an independent Environmental Supervisor (ES) to oversee and ensure compliance with terms and conditions of marine construction that are authorized by DFO. Details of the construction methodology, timing of operations and habitat compensation will be described within the *Fisheries Act* subsection 35(2) authorization. Inclusion of SARA-listed marine species, such as Northern Abalone, will also be considered in this authorization.

The Proponent will continue to work with DFO, the Provincial government and with First Nations to determine the appropriate marine habitat compensation that will be outlined in any *Fisheries Act* authorization by DFO. This is reflected in the Proponent's commitment to develop a construction methodology that includes compensation measures, as well as commitments respecting post-construction monitoring to ensure that any constructed compensatory works are functioning as designed.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause any significant adverse effects to fish and fish habitat.

2.1.5 Wildlife and Wildlife Management and Vegetation

Description of Potential Effects:
A concern was brought up during the review of the application on the possible effects of the conveyor system on large mammal migration and habitat fragmentation. Possible effects on the Project on the RC (western red cedar-sitka spruce-skunk cabbage) ecosystem were also considered. Activities associated with the project were also identified as having a possible effect on migratory birds and bird habitat.

Description of Proposed Mitigation:
Studies done by the Proponent indicate that the conveyor system will have no impacts on large mammal migration, including black bear and Roosevelt elk. The Proponent has committed to design the conveyor to provide passage at two locations, near shore and 250m from the beach at a bluff to allow large mammals to access to the inter-tidal area for foraging.

The conveyor system had been designed and located to minimize effects on the RC (poorly drained western red cedar-sitka spruce-skunk cabbage) ecosystem. The Proponent has relocated the conveyor as far as possible east to stay on Western Forest Products lands (lease area) and minimize the crossing of the RC ecosystem. Based on field studies, it is estimated that 0.14 hectares out of the 57 ha RC ecosystem will be lost. Culverts will be installed to maintain water movement in and around the conveyor system and not alter water levels in this ecosystem. In addition, the Proponent has committed to measuring and monitoring disturbance along the conveyor in summer and winter during construction, and to determine any changes in the first year of operation. Drainage alterations will be made across the conveyor and access road if a noticeable change in RC habitat type is observed.

Terrestrial habitat that will be altered by the Project footprint is low quality for most wildlife species. Proposed progressive reclamation will limit the area that is cleared at one time (estimated 30 ha at one time). Once extraction is completed, an area will be reclaimed and planted. Reclaimed areas will provide a variety of habitat types for small mammals and other wildlife. Higher quality habitat near the Cluxewe River and along the foreshore will be maintained and reduce habitat fragmentation.

Clearing of the Project area to allow the extraction of sand and gravel will be completed by WFP, under its harvesting licence. Harvesting is regulated by the Ministry of Forests. The Proponent made a number of commitments to address bird habitats and migratory bird concerns, including undertaking a bird nest survey prior to any tree clearing that would take place between April 1 and July 31 (the breeding period). Tree clearing would be required to adhere to Section 34(b) of the Provincial *Wildlife Act*, which requires protection and appropriate buffering of inactive and active nests of bird species protected under that legislation.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to wildlife or vegetation resources.

2.1.6 Waste Management

Description of Potential Effects:
The Proponent addressed waste management issues related to the Project, including land-based operations as well as the shipping component. Specific issues raised during the course of the environmental assessment included the potential impacts to shellfish and shellfish harvesting from ship refuelling and/or sewage and bilge water discharge from ships at the loading facility.

Description of Proposed Mitigation:
Wastes generated at through Project operations would be relatively limited. Generally, the production of construction aggregates is a natural process that does not use chemicals. However, ancillary operations, such as the clarification of process wash water, could require the addition of small doses of a reagent such as a flocculent to maximize efficacy. The Proponent noted that if this were necessary, it would attempt to identify a reagent that was biodegradable, or could be recycled, or was produced through an environmentally sustainable process.

Numerous hydrocarbon, inorganic and organic substances would be utilized for lubrication. There would be generally little toxic effect associated with lubricants because of the small volumes used. All waste oils would be collected in dedicated tank facilities and returned for recycling. The handling of lubricants would take place in a limited number of specific areas in the operation, such as the workshop, equipment wash area and processing plant around drives and gearboxes. As well, containment procedures would be in place in these areas and spills would be dealt with under a Spill Contingency Plan**.** Accumulated ground contamination would be dealt with under a Reclamation Plan.

The Proponent also stated that waste management systems for the handling and disposal of domestic, sanitary and hazardous wastes would be installed. Waste collection and disposal companies provide service in the local area and the Proponent intends to contract with them for provision of suitable dumpsters and collection of wastes. Scrap metal would be collected and recycled together with glass, plastic and paper. Used oils would be held in a suitable tank for return to a recycler.

Primary flows of wastewater would consist of washroom discharge and gray water from wash facilities. Sewage would be disposed of in a septic type system designed to accommodate the anticipated workforce. Volumes are expected to be a maximum of 8000 L per day. Approvals would be subject to the Ministry of Health.

Cleaning of mobile equipment would take place in a designated area. Wash water would be collected in a special purpose sump and an oil/water separator would be used when removing collected wash water to the main holding pond.

The Proponent also addressed the waste management issues associated with the bulk freighters that would be conveying the aggregates to the U.S. It was noted that, by law, bilge water cannot be discharged in Canadian coastal waters but must be pumped out in mid-ocean. In addition, the Proponent would require in its shipping contracts that ships include and adhere to Transport Canada's national ballast water management guidelines. The contracted ships would be required to have Transport Canada-approved sewage treatment plants that discharge only potable quality water. Further, the Proponent would not provide vessel fuelling or bilge discharge facilities at the ship loading facility. Working Group discussions confirmed that there is no automatic closure for shellfish harvesting since the proposed conveyor loading facility is not considered a dock, and the terminus of the facility will be located offshore, well beyond the 200m radius from known harvestable beaches.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects with respect to waste and waste management.

2.1.7 Noise

Description of Potential Effects:
The potential effects of noise from the conveyor system and ship loading activities on fish and marine mammals and their migration routes was identified during the

environmental assessment. As well, the Cluxewe resort and residents of Pulteney Point on Malcolm Island had concerns about a possible noise level increase impacting their business and current standard of living.

Description of Proposed Mitigation:
The Proponent has designed the conveyor and loading facility so that it would not impact fish or mammal passages and would not result in measurable shading or light to impact fish. The Proponent has also committed to limit noise impacts on whales and returning salmon to minimal sensory disturbance from construction activities and ship loading. These commitments include underwater noise monitoring, pile drilling instead of pile driving, monitoring of fish behaviour during construction, and monitoring of Orca presence and behaviour during any construction between July and November. Noise levels that are considered to be of concern for marine mammals would be discussed with DFO and used to set the construction timing for some activities.

Construction would be stopped under conditions associated with orca presence, as determined by and agreed upon with DFO. The Proponent has redesigned the loudest part of the ship loading facility, the mooring buoys, to reduce noise as a result of an underwater acoustic study on a similar, approved facility in Sechelt. With this design change, marine mammals may be able to hear some loading for a distance, but it is not expected to be any louder than movements of other ships.

The construction and operation of the Project is expected to generate localized increases in ambient noise levels. A noise survey was undertaken, which demonstrated that loading operations should not be heard at the Cluxewe Resort or Pulteney Point. Noise from the processing plant will be buffered by the edges of the pit and surrounding forest and will not be audible at these locations. Some noise may be heard during the four months of ship loader construction, and the Proponent has committed to pile drilling (rather than traditional pile driving) and no night construction work on the ship loader. The Proponent has redesigned the mooring buoys to minimize noise during ship loader operations.

As a result of the continued noise concerns, the Proponent committed to undertake an independent baseline noise study at the Cluxewe Resort and Pulteney Point to determine baseline noise levels. This will be used as a comparison for any future noise studies requested during Project activities, including ship loading and pit operations. The Proponent committed to implement further noise mitigation measures once operational, if feasible, if noise at these locations is an issue during operations and other mitigation measures are unsuccessful.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse noise-related effects to the surrounding environment and community.

2.1.8 Air Quality

Description of Potential Effects:

Concerns about potential effects from dust from the Project were considered in respect to the Cluxewe Resort during the environmental assessment. As well, the construction and operation of the Project is expected to generate some airborne emissions from increased highway vehicle traffic, extraction activities, pit vehicles, and ship loading activities including conveyor operations and ship's engines and generators.

Description of Proposed Mitigation:

The Proponent has committed to use the wet processing plant to control dust at the Project site, and to use additional water sprays during hot, dry periods if required. All materials being transported by conveyor and loaded onto ships will be wet, so dust should not be an issue.

The Project was designed to operate the plant with low-emission engines on site, and to encourage similar equipment to be used by construction contractors. The use of a conveyor system to transport material to the loading site eliminates trucking of product and an associated increase in engine emissions.

Conclusion:

During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to air quality.

2.2 Environmental Effects and Mitigation for the Socio-Economic and Cultural Environment

2.2.1 Current Use of Lands and Resources for Traditional Purposes

Description of Potential Effects:

Within the Proponent's application it was noted that traditional use concerns are often unique to individual First Nation communities. Contemporary and historical traditional uses are often considered sacred and secret and thus it was not possible to openly address these issues as part of the environmental assessment process.

While there was no identified contemporary traditional use in the project area for plant sustenance activities such as berry picking and cedar harvesting, the project may result in a reduction of opportunities to pursue such activities in the future. It was identified that there needed to be some consideration in having plants traditionally used by First Nations included in the site reclamation.

One other concern brought forward during the environmental assessment was the potential for sand and grit to fall from the conveyor during operation and possibly affect the quality and palatability of seaweed.

Description of Proposed Mitigation:
The Proponent's replanting is governed by an agreement with Western Forest Products (WFP) to plant harvestable native tree species under their direction. The interviews and studies led by the Kwakiutl did not identify current use of the Project land. However, the Proponent has committed to encouraging WFP to consult the First Nations regarding replanting of native species. The Proponent will also provide opportunities for possible First Nation companies to salvage native plants ahead of operations, where such plants are not being harvested by WFP.

The Proponent has also designed the project to ensure that the conveyor route will avoid potential impacts to areas where edible seaweed occurs.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to the current use of lands and resources for traditional purposes.

2.2.2 Land and Resource Use

The Project will be located on private property owned by WFP within its Tree Farm Licence (TFL 6 Block 2). WFP will log the property in phases throughout the lifetime of the gravel mine operation. Harvesting is regulated by the Ministry of Forests. Tree clearing is required to adhere to Section 34(b) of the Provincial *Wildlife Act*, which requires protection and appropriate buffering of inactive and active nests of bird species protected under that legislation.

The Proponent would depend upon the harvesting of the current forest to conduct its business. The Project therefore would have no potential effects on the current land and resource use of the site intended for the gravel mining.

2.2.3 Public Health and Safety

Description of Potential Effects:
The issues raised with respect to public health and safety were limited to potential health effects resulting from impacts to air quality and potential public safety issues associated with the operation of the conveyor system.

The environmental assessment under the CEA Act is limited to considering impacts that result from an environmental effect. As the safety concern with respect to the conveyor system was not related to an environmental effect, it was deemed outside of the scope of assessment for the CEA Act review. As the provincial environmental assessment legislation has no such restriction, the issue was addressed during the course of the harmonized review (refer to Commitment 16.2 in Appendix C).

Refer to section 2.1.8 for the discussion on Air Quality.

2.2.4 Navigation

Description of Potential Effects:
The design and location of the ship docking and loading facility may have a possible effect on navigation and traffic in Broughton Strait.

Description of Proposed Mitigation:
The Proponent located the ship docking and loading facility as close as possible to the shoreline, to avoid interference with navigation while maintaining required depths for docking. It is well outside the main navigational lane and should present no significant interference to navigation.

The Proponent would adhere to conditions established by Transport Canada for approval of the ship loading facility under the *Navigable Waters Protection Act.* The Approval provided by Transport Canada would also outline the provision of lighting for increased navigational safety.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause significant adverse effects to navigation.

2.2.5 Archaeological, Heritage and Historical Cultural Resources

Description of Potential Effects:

Following traditional use and heritage overview studies, an archaeological investigation was completed on the Project footprint and key areas beside the Cluxewe River and marine shoreline. The traditional use and heritage overview studies, an archaeological investigation, including elder interviews, did not indicate any burial grounds on or near the Project site. Despite this indication, the Proponent is still aware that the Project may have a potential to impact unknown archaeological sites, including burial grounds.

Description of Proposed Mitigation:

The Proponent has committed to having an archaeologist on site during earth moving at two small areas identified as having moderate potential (area adjacent to the beach and area 250m from the beach. The archaeologist will look for any archaeological materials and follow protocol (including halting work and contacting First Nations) if any artefacts or human remains are encountered.

The Proponent will also comply with all Provincial requirements, including contacting the Archaeology Branch, Ministry of Sustainable Resource Management in the event of an archaeological site being disturbed, and to provide an archaeologist to oversee activities in and near the site.

Conclusion:

During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to cause any significant adverse effects to archaeological, heritage and historical cultural resources.

3. Cumulative Environmental Effects Assessment

3.1 Introduction

Section 16(1) of the CEA Act, requires any screening or comprehensive study to include consideration of "any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out". Cumulative environmental effects are changes to the biophysical environment or socio-economic setting (only from a biophysical change) caused by an activity in association with other, past, present and future human activities. A cumulative effects assessment is done to ensure the incremental effects resulting from the combined influences of various actions are considered. These combined effects may be significant even though the effects of each action, when individually assessed, are considered insignificant.

3.2 Methodology

The Proponent focussed its cumulative effects assessment on the Valued Ecosystem Components (VECs) and Valued Socio-Economic Components (VSCs) selected for the environmental assessment. VECs and VSCs are basically the features of the regional environmental and socio-economic setting that were deemed to have ecological, social and economic value and that would be potentially affected by the Project. VECs focus on the ecological attributes of the biophysical environment, while VSCs are cultural, social, economic or health attributes which, if affected by the Project, would be a concern to local human populations and/or government regulators. As per CEA Act requirements, only those VSCs that would be affected as a result of a biophysical change from the Project were carried through to the cumulative effects assessment.

As described in Part B - Section 2 of this report, no significant adverse environmental effects were identified with individual VECs/VSCs. However, there was the potential for minor or "residual" effects, when combined with those of other existing or planned projects, to result in significant effects. Thus, this cumulative effects assessment was undertaken for those VECs/VSCs where residual effects were expected.

Temporal boundaries were set as those from start of construction to end of closure activities for the Project. Spatial boundaries for the cumulative effects assessment were set specifically for each VEC or VSC, based on "regional" pressures on the specific VEC/VSC and consultation with public, agencies and First Nations.

Other activities where effects occur on the VECs or VSCs within the temporal and spatial boundaries were outlined and effects noted. The cumulative effects were then discussed and their significance determined.

The residual effects discussed in the sections above were summarized and are found in Table 3.1.

Under a cumulative effects assessment, the effects from other existing, certain or reasonably foreseeable projects and activities on receptors (VECs and VSCs in this case) where residual effects are expected from the Project are considered.

The temporal scope of this cumulative effects assessment was from construction to closure. The geographic scope of the assessment varied by component as noted in Table 3.2.

Certain future projects are those approved, currently under regulatory review for approval, submission for review is imminent, or intent to proceed announced by a proponent to regulatory agencies. Reasonably foreseeable future projects are those directly associated with a project under review but conditional on project approval, identified in a development plan where approval is imminent, or not directly associated with a project under review but may proceed if that project is approved (induced).

Based on discussions with Western Forest Products and the Regional District of Mount Waddington, no certain or reasonably foreseeable future projects were identified when developing the cumulative effects assessment and were therefore not included.

Table 3.1 Project Residual Effects

ENVIRONMENTAL/ SOCIAL COMPONENT	VEC/VSC	PREDICTED RESIDUAL ADVERSE EFFECT
Atmospheric environment	Air quality	Some emissions from activity during project life outlined for operations.
	Noise	Some noise from activity during project life – projected from operations at ship-loader as 1.48 km before attenuation to background.
Hydrogeology	Groundwater flow	No residual effect - no measurable change in groundwater flow at edge of project boundary.
Fresh water environment	Salmonids in the Cluxewe River	No residual effect – as a result of no changes expected in hydrology, water quality and physical habitat.
Vegetation	RC ecosystem (Western red cedar/Sitka spruce-skunk cabbage)	0.14 ha lost/disturbed due to conveyor.
Wildlife	Harlequin Duck	Potential disturbance at shoreline from construction and ship loading.
	Black Bear (including habitat)	Minimal changes to passage – conveyor will allow passage under at beach, open forest beside beach, bench 250 m from beach and transmission lines as well as Hwy. 19 and Rupert Main. Gravel roadway along conveyor will provide a further migration route. Minimal loss of vegetation in areas frequented by bears. – Bears are most prevalent along the beach and 75 m wide adjacent forest, the old road parallel to the beach, the transmission lines and possible the Cluxewe River in the project footprint and vicinity. There will be a 10 m wide band of vegetation clearing along the conveyor route, affecting only the open SK ecosystem that allows bears to easily pass through at the beach. Clearing at the processing plant and pit area will be minimized to approximately 30 ha at one time.
Marine foreshore	Marine intertidal and subtidal habitat including eelgrass and kelp beds	No residual effect – habitat compensation plan to be prepared with DFO; habitat created on structure.
Marine communities	Salmon juveniles and adults	Potential sensory disturbance from construction, loading and ship movement.
	Marine mammals	Some sound generated from loading and ship movement and presence of ships which cause sensory disturbance.
Socio-economics	Employment and expenditures	No effect from biophysical change plus no adverse residual effect.
	Marine transportation	No effect from biophysical change.
	Visual Impact	Change in topography over time.
	Commercial fisheries	No effect from biophysical change plus no residual effect – no commercial fishing in ship loading or vessel transportation route.
Cultural and heritage resources	Traditional Use	No residual effect. Edible seaweed – No residual effect – No seaweed species of importance in path of conveyor.

3.3 Discussion

The Proponent provided a summary of the results of the cumulative effects assessment (see Table 3.2). It outlines the VECs/VSCs with anticipated residual adverse effects and describes the potential additional effects to those VECs/VSCs from previous and existing activities in the study area.

Table 3.2 Potential Effects of Past or Existing Activities within the Geographic Scope of the Assessment

VEC/VSC WITH RESIDUAL EFFECTS	GEOGRAPHIC SCOPE OF ASSESSMENT	OTHER EXISTING PROJECTS IN GEOGRAPHIC SCOPE	POTENTIAL EFFECTS OF OTHER PROJECTS ON VEC/VSC
Air quality	"Project environmental study area" including Broughton Strait, the lower Cluxewe watershed to the West Main Bridge and the Mills Creek watershed. Town of Port McNeill is excluded.	Highway 19	• Emissions from vehicles.
		Rupert Main and West Main logging roads	• Emissions from vehicles. • Dust from vehicle travel on gravel roads on dry days
		OK Pit	• Dust from aggregate extraction • Emissions from machinery incl. asphalt plant
		Weyerhaeuser dryland sort	• Emissions from vehicles
		Other gravel pits and rock quarry nearby	• Dust from aggregate extraction • Emissions from machinery
		Shipping	• Emissions from ships
Noise (in air) and associated disturbance to humans and wildlife	"Project environmental study area" including Broughton Strait, the lower Cluxewe watershed to the West Main Bridge and the Mills Creek watershed. Town of Port McNeill is excluded.	Highway 19	• Vehicle noise
		Rupert Main and West Main logging roads	• Vehicle noise
		OK Pit	• Vehicle and machinery noise
		Weyerhaeuser dryland sort	• Vehicle and machinery noise
		Other gravel pits and rock quarry nearby	• Vehicle and machinery noise
		Shipping	• Noise from ship engines.
RC ecosystem	TEM study area on WFP land – Cluxewe to shoreline to edge of TFL 6	Highway 19	• No known impact.
		Rupert Main and West Main logging roads	• No known impact.
		Logging	• Potential disturbance to RC ecosystems in past but possible creation of RC ecosystem near shore from construction of road changing water flows.
Harlequin Duck	Shoreline area from west of Cluxewe estuary to east of Port McNeill	Cluxewe Campground	• Change in habitat from development of campground • Presence of humans and associated sensory disturbance.
		Town of Port McNeill (including log boom area, docks, residences and sewage effluent	• Change in shoreline habitat from development • Presence of humans and associated sensory disturbance from boats, planes and shoreline activity

VEC/VSC WITH RESIDUAL EFFECTS	GEOGRAPHIC SCOPE OF ASSESSMENT	OTHER EXISTING PROJECTS IN GEOGRAPHIC SCOPE	POTENTIAL EFFECTS OF OTHER PROJECTS ON VEC/VSC
Black Bear	Cluxewe Watershed and foreshore (Cluxewe estuary to Lady Ellen Point)	Highway 19	• Potential loss of habitat, potential creation of edge habitat for food • Sensory disturbance from noise and vehicle travel • Potential for injury or death from vehicle impact • Creation of access corridor
		Rupert Main and West Main logging roads	• Potential loss of habitat, potential creation of edge habitat for food • Sensory disturbance from noise and vehicle travel • Potential for injury or death from vehicle impact • Creation of access corridor
		OK Pit and other gravel pits	• Loss of habitat • Sensory disturbance
		Cluxewe Campground	• Disturbance from human activity including additional food sources
		Logging and additional roads in the Cluxewe Watershed	• Loss and fragmentation of forest habitat • Sensory disturbance • Potential for injury or death from vehicle impact • Creation of access corridor
Marine salmon - juveniles and adults	Broughton Strait	Cluxewe Campground	• Fishing pressure
		Shipping in Broughton Strait	• Potential sensory disturbance
		Fin fish and shellfish harvesting in Broughton Strait	• fishing pressure
		Town of Port McNeill (including log boom area, docks, boats, residences and any effluent/runoff)	• Loss of habitat and water quality impacts • Potential sensory disturbance
		Hyde Creek	• No notable impacts
		Haddington Island quarry	• Change in habitat with rock in water but now heavily used by some fish (Lingcod) • Sensory disturbance
		Town of Sointula	• Loss of habitat and water quality impacts • Potential sensory disturbance

VEC/VSC WITH RESIDUAL EFFECTS	GEOGRAPHIC SCOPE OF ASSESSMENT	OTHER EXISTING PROJECTS IN GEOGRAPHIC SCOPE	POTENTIAL EFFECTS OF OTHER PROJECTS ON VEC/VSC
Marine mammals	Broughton Strait	Cluxewe Campground	• Little disturbance likely
		Shipping in Broughton Strait	• Sensory disturbance
		Fin fish harvesting in Broughton Strait	• Loss of food for some species and food chain effect for others
		Town of Port McNeill	• Minimal sensory disturbances other than boats
		Hyde Creek	• No disturbance likely
		Sointula	• Minimal sensory disturbances other than boats
Visual Impact	View from a ship traveling through Broughton Strait	Cluxewe Campground	• Some cabins and campsites visible when passing
		Town of Port McNeill	• Much of town including homes, roads, commercial development, industry, marina and lights visible from east of Ledge Point
		Hyde Creek	• Homes, roads and lights visible when passing
		Sointula (and Pulteney Point Lighthouse)	• Homes, roads and lights visible from much of Strait
		Logging on Vancouver Island, Malcolm Island and Haddington Island	• Minimal based on visual quality objectives from viewpoints on Broughton Strait

Air Quality

Public use of the area surrounding the Project involves vehicle traffic along the highways, the Cluxewe River and adjacent forested areas. The Cluxewe River upstream of the Highway 19 bridge was chosen as the worst case scenario for potential air quality impacts as it was commonly used by the public for fishing, it likely was already subject to dusty conditions due to its proximity to the Rupert Main bridge, and it was located near the intersection of the Project model boundary and Highway 19.

The air quality concentrations based on the cumulative effects of the baseline conditions and Project emissions is summarized in Table 3.3. Due to the conservative assumptions made in the baseline and project modeled emission calculations, the cumulative air quality effects area was considered to be conservative and the upper ranges should be viewed as absolute maximums (very dry and windy days at a time a logging truck has passed and all dust is blown up the river). It is important to note that the PM_{10} calculations did not consider watering for dust suppression on the site. As part of the Project operations, watering would take place to ensure PM_{10} emissions are at the low end of the range during dry and windy conditions.

Table 3.3 Summary of Cumulative Air Quality Effects

PARAMETER	AVERAGING TIME	CANADIAN ENVIRONMENTAL GUIDELINES ($\mu g/m^3$)	RESULTS OF AIR QUALITY MODELING		
			BASELINE EMISSION ($\mu g/m^3$)	PROJECT EMISSION ($\mu g/m^3$)	CUMULATIVE AIR QUALITY CONCENTRATION ($\mu g/m^3$)
PM_{10}	24 hr	25	0.1 – 16.0	0.03 – 8.4	0.03 - 24.4
SO_x	Annual Desirable	30	0.0 – 0.4	0.01 – 1.4	0.01 - 1.8
	Annual Acceptable	60			
NO_x	Annual Desirable	60	0.0 – 5.9	0.07 – 19.3	0.07 - 25.2
	Annual Acceptable	100			
CO	24 hr Desirable	6000	0.0 – 4.1	0.03 – 8.8	0.03 - 12.9
	24 hr Acceptable	15,000			

The Proponent noted that currently approximately 2,000 large vessels (freighters, cruise ships, fishing boats over 24 m, yachts over 30 m and tugs) travel past Pulteney Point annually. There were 23 cross-channel trips (12 round-trips) made by the Port McNeill ferry each day, or 4,380 return trips per year, the greatest traffic from a large vessel in Broughton Strait. In addition, a number of smaller craft (charter, private, whale watching, Coast Guard) travel the channel daily, with most traffic in the summer months. At maximum production, the Project would add two ships per week (104 per year) to traffic in the Broughton Strait.

Based on this, Project-related shipping would involve a maximum 1.6% increase in large vessel and ferry traffic in Broughton Strait. This led the Proponent to conclude that air quality impacts from large ship emissions in Broughton Strait are expected to increase by approximately 1.6% above current levels. Although air quality data was not available for Broughton Strait, given the low ship and road traffic and wind patterns, air quality in the Strait was not deemed to be a concern.

Based on the above factors, the Proponent concluded that the significance of cumulative air quality effects on land and in Broughton Strait would be low.

Noise

In the marine environment, noise from the Project operation will result from ship loading and movement. Based on the 1.6% increase in shipping traffic in Broughton Strait noted in the air quality section above, noise levels from ship movement would increase by approximately 1.6% above current levels within the Strait. Noise from shipping varies depending on location as ferry traffic occurs in southern Broughton Strait only and ship noise can only be heard above background noise (waves, wind, anthropogenic noise) within a varying proximity of the ships.

The Project land operations would generate noise from the mobile equipment working in the pit (scrapers, loaders, conveyors), from the crushing and screening operation and from product reclaim for ship loading. These activities would be located behind forest buffer strips, 150 – 350m wide along the Cluxewe river and 50m wide along Highway 19. It is expected that the operation would be audible from both the river and Highway 19, however the noise levels would not be expected to be heard above passing highway traffic for a pedestrian and would not be heard from within a vehicle. Anyone on the Cluxewe River may hear Project operations above the sound of the river at times, but it would be difficult to detect given the land and tree buffer. Any active operations at the existing OK Pit would likely be heard over the Project noise. It is unlikely that the Project noise will be additive to any existing activities on land.

Based on the above, the Proponent concluded that the significance of cumulative noise effects would be low.

RC Ecosystem

The Proponent stated that within the 158 ha study area of the TEM mapping, for which detailed habitat types are available, an estimated 0.14 ha of the total 57 ha of RC (western red cedar/Sitka spruce – skunk cabbage) ecosystem will be disturbed. Measures would be in place to prevent impacts to the adjacent RC habitat (flows allowed to pass under conveyor and gravel road via frequently placed culverts) and the conveyor and road would be removed during closure/final reclamation.

The Proponent noted that the current WFP biodiversity plan included management strategies for ecologically sensitive areas (including the RC ecosystem) and species at risk. This would minimize the potential for loss of the RC ecosystem. However, the area that includes the RC ecosystem within and adjacent to the Project would not likely be logged for 50 to 60 more years, outside of the temporal scope of this assessment.

The loss to the RC ecosystem as a result of the Project is a small area (0.14 ha), 0.25% of the immediate RC ecosystem. The Proponent concluded that the significance of the cumulative effect of this loss to the total habitat area would be low.

<u>Harlequin Duck</u>
The Proponent stated that, with respect to Harlequin Ducks, there would be a very small amount of shoreline habitat impacted by the conveyor pilings (approximately 25 m^2) over a 10 m shore length, although they could also be disturbed from noise and movement during construction, operation and decommissioning of the Project. Habitat disturbance and sensory disturbance from human presence at the Cluxewe campground, on the Cluxewe estuary could also have impacts on Harlequin Ducks. Development and activities along the Port McNeill waterfront also could have habitat and sensory disturbance impacts.

The Proponent noted that Harlequin Ducks are one of the most frequently observed waterbird species along the Cluxewe to McNeill Bay shoreline, foraging in the shallow waters. The Project would have minimal habitat impacts over the 10 m shore length. Shoreline modifications have occurred at the Cluxewe Resort and at the Town of Port McNeill. These two developments may have resulted in a disturbance of approximately 600 m of the shoreline area from the west side of the Cluxewe River to the east side of the Town of Port McNeill (approximately 14 km), a 4.3% disturbance in shoreline area. The 10 m length of habitat disturbance from the Project would only be a 0.007% disturbance over this 14 km shoreline.

Disturbance from shore and near-shore human activity is currently limited to foot traffic, pets and land vehicles at the campground, and foot traffic, pets, boats, float planes and nearby vehicles at Port McNeill over this 14 km shoreline. Sensory disturbances during construction would be temporary. Loading activities would occur over a maximum of 48 hours per week at the Project ship loader. Harlequin Ducks are known to become habituated to human-related activity.

Due to the small areas of impact over the 14 km shoreline area, and the non-continuous nature of sensory disturbance at the Project ship loader, the Proponent concluded that the significance of cumulative effects on Harlequin Ducks would be low.

<u>Black Bear</u>
The Proponent noted that although the Project would result in some vegetation loss, there would be minimal loss of vegetation in areas frequented by bears. The areas where bears are most prevalent in and adjacent to the Project footprint include: the beach, the 75 m wide adjacent forest, the old road parallel to the beach, the transmission line corridor and

possibly the Cluxewe River. There would be a 10 m wide band of vegetation clearing along the conveyor route, affecting only the open SK ecosystem that allows bears to easily pass through at the beach. The best habitat for bears – the beach and the Cluxewe River riparian area outside of the Project area, would not be impacted by the Project.

Clearing at the processing plant and pit area would be minimized to approximately 30 ha at one time. The progressive pit clearing would form part of the WFP forestry plan each year that logging would take place, and would consider cumulative vegetation and wildlife impacts over the TFL. Based on this, the Proponent concluded that the cumulative effects to bear habitat would be not be significant.

The Proponent also stated that only minimal adverse effects on bear movements would be expected from the Project. The conveyor would be constructed to allow passage at several locations: the beach, a 10 m wide area in the open forest beside the beach, a bench 250 m from beach, and under the transmission lines. With the exception of the bench, which may not be accessed currently due to dense salal, the other three areas are currently frequented by bears. Although not ideal, passage would also be allowed at Highway 19 and Rupert Main, where the conveyor would go under the roads. The gravel roadway along conveyor would provide a further migration route. This line was cut in spring of 2004 and was subsequently frequented by bears.

The Proponent also noted that bears could be disturbed by activities such as vehicle and conveyor movement, pit extraction and plant operations. During construction and operation, the pit, processing plant and conveyor would likely be avoided by bears when operating but would allow bear access and passage at non-active times. In addition, vehicle movement would pose a risk of injury and death from collisions. To address this, vehicles would be minimized at the site and the portions of the conveyors that are dangerous for humans or wildlife would be surrounded by high fencing.

Existing roads, such as Highway 19, Rupert and West Main, and other logging roads would also affect bear passage in the Cluxewe Watershed (area for cumulative assessment on bears). These roads create access corridors, often with food enjoyed by bears growing along the sides, but could result in sensory disturbance and can be dangerous due to the potential for collisions.

The Cluxewe Campground and OK Pit are areas with human presence that could cause sensory disturbance in bears.

The Proponent determined that there are a number of existing activities that affect the movement of bears and can cause sensory disturbance in the Cluxewe Watershed and foreshore area of the WFP TFL 6, but the effects of the Project would be minor and reversible. Although the Project effects were considered minor, given the existing moderate disturbance to black bears in the cumulative effects study area, the Proponent concluded that the significance of the cumulative effects on bears would be moderate.

Marine Salmon Juveniles and Adults

As per the requirements of the *Fisheries Act*, with habitat compensation undertaken, the Project would not result in any net loss of fish habitat for salmon. Sensory disturbance may occur during construction and ship loading activities but the expected noise levels would not be in the range to cause impacts on fish health. Fish could move away from an area if disturbances were not acceptable. As well, ship loading would not be located in the kelp bed, an area where juveniles are known to travel.

Additional pressures on salmon within Broughton Strait include: recreational and Native food fishing, shoreline impacts at the Town of Port McNeill, the Haddington Island quarry and Sointula, effluent from the Port McNeill sewage treatment plant and sensory disturbances from movement of various sized ships.

Given the small area of shoreline habitat disturbance in Broughton Strait, minimal water quality impacts, minimal fishing pressure compared to other areas (no commercial fishing in the Strait) and the ability for fish to move away from sensory disturbance such as ship movement, the Proponent concluded that the significance of cumulative effects on marine salmon juveniles and adults would be low.

Marine Mammals

Ship movements and associated noise during construction and operation of the Project could result in sensory disturbance to marine mammals. However, as previously discussed, ship movements would be slow and measures would be in place to minimize underwater noise.

Other activities in Broughton Strait that could affect marine mammals include fish and shellfish harvesting (removing food) and shipping and shore activities in Port McNeill and Sointula (creating noise). Marine mammals such as harbour seals, sea lions and white-sided dolphins are not often disturbed by human activity and are often attracted to it. With the exception of harbour seals and sea lions, marine mammals within Broughton Strait would generally stay away from shallower areas, such as the vicinity of the ship loader and the harbours of Sointula and Port McNeill. Therefore, the potential effects would be predominantly restricted to sensory disturbance to marine mammals in the open channel from ship movement and shoreline activity.

The estimated 1.6% increase in large vessel traffic within Broughton Strait resulting from the Project could result in a corresponding increase in marine mammal disturbances. However, it is difficult to accurately state the potential impacts on marine mammals, such as Orcas, from increased shipping.

Based on this, the Proponent concluded that the significance of cumulative impacts on marine mammals would be low.

Visual Impacts

As viewed from specific points in Broughton Strait, changes in topography from the Project over time would be visible from some locations. An extraction area would be visible from some viewpoints. The ship loading facility, and when present, the ship, would be visible from some viewpoints, north and west of the facility during daylight hours. At night, minimal lights for loading would be seen from these viewpoints. When a ship is not berthed, lights would be minimized to navigation lights.

Currently, as a ship travels through Broughton Strait, some blocks of younger trees are visible along Vancouver Island, Malcolm Island and Haddington Island. WFP manages forestry activities based on a landscape inventory analysis. As well, the Ministry of Forests can declare scenic areas. Within the spatial boundaries of this cumulative effects assessment, areas are given landscape sensitivity ratings and a visual quality objective based on viewpoints from near the centre of Broughton Strait. Each visual quality objective includes a strategy varying from complete modification (including roads, tree removal and structures) to preservation. Therefore, visual impacts from forestry activities along Broughton Strait are kept to a minimum.

Sointula is visible during the day and night from most locations west and south of the town. The Cluxewe Campground is only likely visible from the west end of the Strait. Port McNeill and Hyde Creek are visible from many points east of Ledge Point. Buildings, roads and marinas (at Sointula and Port McNeill) are seen during the day and lighting is seen at night. The Pulteney Point Lighthouse is visible for navigational purposes.

The regional zoning and North Island Straits Coastal Plan allow for a docking facility in the area of the proposed ship loader. This planning went through public consultation, which considered cumulative impacts of changes to the view from Broughton Strait.

Based on the above factors, the Proponent concluded that the significance of the cumulative effects to visual resources would be low.

3.4 Conclusion

During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the Project is not likely to result in any significant cumulative effects.

4. Effects of the Environment on the Project

The Proponent has considered various environmental conditions or events that may have the potential of occurring in the Project area and therefore have the potential to affect the Project. The Proponent considered the following:

- Cluxewe River bank erosion;
- High winds;
- High precipitation;
- Lightning;
- High waves;
- Seismic events; and
- Climate change.

4.1 Cluxewe River Bank Erosion

The Project is designed so that the pit would be 150 to 350 m from the current high water mark of the Cluxewe River, whereas the processing plant would be approximately 500 m away. In addition, the Kwakiutl First Nation has initiated a Fisheries-Based Watershed Sustainability Plan, which will include selecting high priority areas for habitat enhancement.

The Proponent is also committed to frequent monitoring of the river banks and bank stability. It is highly unlikely that the bank will erode close enough to the Project boundary to affect the Project.

4.2 High Winds

As trees are cut throughout the life of the project, windthrow potential would be assessed, including for catastrophic winds. Forest edges would be managed to reduce windthrow, including removing trees in narrow strips of high risk areas, and thinning and cutting trees along other edges. If trees do come down on the active site, they would be removed. Equipment can be easily repaired. Pilots would not bring vessels to, or away from, the dock in adverse wind conditions and a fully loaded vessel carrying 70,000 tonnes of aggregates would not be unduly susceptible to wind forces.

4.3 High Precipitation

The pit and processing area contours were designed so that any surface water would flow towards the sediment control ponds and/or active extraction area during extreme events, preventing flooding of the processing area and runoff from the site.

4.4 High Waves

Safe operation of a ship is the ship master's and ship owner's responsibility. All vessels arriving or departing would be under the control of a BC Coast Pilot (a mandatory requirement), and be assisted by two tugs. The BC Coast Pilots have advised that in poor weather conditions (e.g. strong north-westerly winds), they would not pass beyond Hardy Bay, where a safe anchorage is available. They would wait there for suitable safe weather before proceeding. The risk of a grounding was considered extremely small.

Tugs at present would have to come from Campbell River or Vancouver, however, the Proponent is working with interested parties to have at least one tug stationed close to the project and hopefully two. The Proponent has committed to developing and implementing an environmental contingency plan that would include this issue.

4.5 Seismic Events

The ship loader was designed according to the BC Building Code under which Port McNeill is presently in the highest category for seismic design standards. Tidal waves are not considered to be a significant risk because the shape and depth of the Broughton Strait reduces the potential for large waves in this area and the loader sits well above the water, even at high tide, and is a relatively open structure through which the waters can pass.

4.6 Conclusions

During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the environment is not likely to cause significant adverse effects to the project.

5. Environmental Effects of Accidents and Malfunctions

As per section 16(1) of the CEA Act, the environmental effects of malfunctions or accidents that may occur in connection with the Project were considered as part of the environmental assessment. Accidents or malfunctions could result from human activities undertaken either during the one year construction phase or the following operating phase of approximately 30 years. The Proponent considered the environmental effects of the following potential accidents and malfunctions:

- spills of hydrocarbons (diesel fuel, light or medium oils, hydraulic fluids or lubricants);
- accidental forest fires;
- spills of liquid concrete during construction of the ship loading facility;
- discharge of sediments during construction of the ship loading facility;
- discharges from ships; and
- ships going aground during arrival at, or departure from, the berth.

5.1 Hydrocarbon spills
The operation of a mobile plant during the construction or operation phases could result in accidents, malfunctions or other incidents. These would most likely occur during the storage and transfer of fuels that could result in accidental spills of hydrocarbons (e.g. diesel fuel, light or medium oils, hydraulic fluid or lubricants). Spills of these hydrocarbons could potentially impact soils, vegetation, aquatic life or wildlife.

The Project assessment considered the terrestrial environment and the marine environment separately in this context.

Terrestrial Environment
The Project was designed specifically to ensure that no operations would take place within the Cluxewe River channel or the 150 – 350m wide forested buffer zone presenting a high barrier between the Project operations and the river. There are no streams draining the Project area. The potential environmental effects of terrestrial hydrocarbon spills would most likely be limited to localized, short-term and reversible contamination of surface vegetation, soils and the underlying sand and gravel strata dependent on the size of the spill. The Proponent has committed to develop a Spill Contingency Plan to address this potentiality.

The Project site would be favourable for limiting any such spill to a localized area from which the soils and other strata could be quickly removed for remediation. Spill kits would be on site at high risk locations during construction and operation.

The risk of spills would also be minimized through the Proponent's proposed Best Management Practices including:

- diesel fuel will be stored and dispensed from truck equipped with a double walled storage tank meeting applicable Federal and Provincial requirements;
- all mobile equipment will be inspected for leaks on a regular basis and maintained in good working order; and
- mobile equipment will be refuelled, lubricated and serviced at designated and approved locations.

Marine Environment
The ship loader and equipment would contain only small quantities of hydrocarbons, unlikely to exceed 500 litres in total. Only hydraulic fluid and medium oils (for gearboxes) would be used. The hydraulic fluid storage would be located within an equipment room and provided with secondary containment of at least 110% of the tank's capacity. Gearboxes would be provided with catchment trays as would bearings where regular greasing occurs.

The limited quantities involved, and infrequent oil changes, mean that the potential for a spill into the marine environment would be very low. A spill in this area would be, however, very difficult to contain and recover. The Spill Contingency Plan would outline appropriate responses. During construction, spill kits would be on the barges and service boats.

In summary, the design and topographic features associated with this Project make it unlikely that significant spills of hydrocarbons into either the terrestrial or marine aquatic environments would occur. Consequently, the Proponent considered it equally unlikely that any potentially significant residual environmental effects to soils, vegetation, aquatic life or wildlife would occur within the Project area.

5.2 Accidental Forest Fires

The Proponent cited Ministry of Forests information which indicated that approximately 48% of wildfires in British Columbia were caused by human activity, but also noted that the Project area had never suffered a significant fire. The high level of rainfall and relatively low human presence in the area were cited as likely reasons. Forest fires are a naturally occurring phenomenon, but can have negative impacts on wildlife and their habitat.

During construction and operation, all activities taking place would be required to comply with the applicable provisions of the Forest Practices Code of BC and particularly the Forest Fire Prevention and Suppression Regulation. The following aspects of the operation would also mitigate the possibility of fires:

- the sand and gravel would be produced in a wet process plant;
- a large volume of water would be stored on site in the process ponds and available if needed for fire suppression;
- the mobile plant would be equipped with fire extinguishers; and
- the fixed plant would contain little combustible material.

Based on this, the Proponent determined that the risk of the Project causing an accidental fire would be low during all phases of the Project.

5.3 Concrete Spills

The risk of concrete spills at the Project site would be limited to the construction phase, as no concrete would likely be placed once the Project is operational. The quantity of concrete to be placed would be small relative to the capital cost of the Project since much of the plant was designed to be modular steel units requiring minimal concrete foundations.

Uncured liquid concrete is toxic to fish life due to its alkaline nature and therefore it should be prevented from entering the marine environment. This would be achieved by constructing concrete formwork required for the pile caps in a manner that would prevent fresh concrete or cement paste from leaking into the ocean. Chutes or concrete pump delivery lines would have joints and connections sealed and locked and crews would ensure that concrete forms would not be overfilled. Tools would be washed in fresh water that would be disposed in a suitably approved location on land.

The Proponent considered the risk of liquid concrete entering the freshwater aquatic environment to be very low as no work was planned in or near any watercourse. Tools would be washed at an appropriate location so that no wash water enters the aquatic environment.

5.4 Discharge of Sediments to Marine Environment

The discharge of a large volume of sediments into the marine environment would have the potential for negative effects to marine flora and fauna within a localized area. To address this, the pilings required to carry the ship loader would be placed by drilling, as opposed to pile driving, because the seabed in this location consists of sandstone bedrock which is either exposed or overlain by only a thin layer of sediments. The pile drilling equipment would return the cuttings to the surface where it would be settled-out in tanks on board the barge rig. The settled water would be returned from these settlement tanks to the sea and monitored for compliance with agreed turbidity limits prior to discharge. The cuttings would be disposed of in a local landfill.

The Proponent determined that there would be very little risk of sediments being released to the marine environment with the proposed method of pile placement.

5.5 Discharges from Ships

A potentially serious environmental problem arises when ballast water containing foreign aquatic species is discharged into coastal waters. An introduced species could become invasive, out-competing native species and negatively impacting the existing ecosystem. Ships transporting aggregates from the Project would be required to existing Transport Canada regulations which require mid-ocean ballast exchange for vessels entering Canadian waters. Other possible discharges, which could include bilge water and sewage, would be forbidden while at berth or within the jurisdiction of the Port McNeill Harbour Authority. No refuelling facilities would be available for vessels at the Project's ship loading facility.

5.6 Grounding of Ships

The grounding of a large transport vessel could have negative environmental impacts associated with potential fuel leaks or damage to marine habitat. The waters of Broughton Strait where the ship berth would be located are relatively sheltered. All vessels would be under the control of an experienced pilot from Pacific Pilotage during arrival and departure. At these times the vessels would be moving extremely slowly and accompanied by tugboats. These large vessels would represent a very high level of investment to their owners and would be equipped with extensive and modern radar and navigation aids. Given all these factors, the Proponent determined that the risk of a vessel going aground in the Project area would be extremely low.

5.7 Risk of accidents and malfunctions during decommissioning.
The processing plant and equipment would not contain any hazardous materials and should pose no significant risk for accident. Parts of the ship loading equipment could be dropped in the marine waters during removal, with some minor habitat disturbance prior to recovery. Although the risk of decommissioning failure is considered low by the Proponent, it committed to discuss closure and decommissioning with various agencies prior to its occurrence. This way, the most up-to-date practices for addressing possible accidents and malfunctions could be implemented for this phase of work.

5.8 Conclusions
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that potential accidents or malfunctions associated with the Project would not likely result in any significant adverse environmental effects.

6. Environmental Monitoring and Follow-up Program

The CEA Act requires that the need for, and requirements of, a follow-up program be considered during a comprehensive study. A follow-up program is different than compliance monitoring in that, compliance monitoring verifies the proper implementation of mitigation measures, whereas a follow-up program is used to determine the accuracy of environmental assessment conclusions and the efficacy of the required mitigation measures.

The Proponent's proposed environmental monitoring program was intended to collect data and compile information to detect potential Project impacts measured against an established baseline. Triggers for action were outlined so that appropriate action and adaptive management (developing improved techniques while conducting management activities) could be undertaken to reduce or eliminate environmental impacts.

The Proponent committed (see #17.1 in Appendix C) to undertake follow-up monitoring to determine the accuracy of the predicted environmental effects of the Project and efficacy of the proposed mitigation. With both environmental and follow-up monitoring, it is important to clearly define objectives, responsibility, methods, timing, reporting, triggers for action and planned actions.

In addition, some monitoring would take place for project planning purposes. For example, the total depth of excavation would be partially guided by groundwater level data collected during operations.

Table 4 provides a summary of the environmental monitoring, project planning and follow-up monitoring for the Project as proposed in the Application. The program was developed to answer specific questions related to the Project site and to meet the criteria outlined above. The intent would not be to monitor all components of the environment, but to focus efforts on those areas where VECs are expected to be affected from Project activities. The "triggers for action" would be key to a successful adaptive management strategy.

Table 4 Summary of Proposed Environmental Monitoring and Follow-up Program

COMPONENT AND PURPOSE	PROJECT PHASE	OBJECTIVES / HYPOTHESIS	MONITORING LOCATION AND PARAMETERS	FREQUENCY	TRIGGERS FOR ACTION / ACTION
Physical					
Groundwater Levels (environmental monitoring, project planning)	Construction	To continue to track groundwater levels within the Project footprint.	Water levels in 8 established wells within Project footprint.	Monthly	Adjust planned pit bottom, if required, to stay above water table.
	Operation	To continue to track groundwater levels within the Project footprint. Hypothesis is that groundwater level will rise with gravel extraction.	Continue to monitor water levels in wells not yet removed from extraction. Water supply well will also be monitored.	Monthly	Adjust planned pit bottom, if required, to stay above water table
Groundwater Quality (environmental monitoring)	Operation	To address potential concerns regarding groundwater quality, such as the introduction of hydrocarbons from fuelling. Predict that groundwater quality will not change during operation.	Details of monitoring including wells to be sampled, parameters, frequency, methods and QA/QC will be determined with regulator input during environmental assessment review.	Annually and as indicated by site activities.	Annually and as indicated by site activities.
Physical Stream Habitat (project planning)	Operation	Monitor movement of Cluxewe Channel over the life-span of project. Build upon interpretation of historical photos completed as part of the Environmental Assessment. Hypothesis is that the channel may move but not enough to be close enough for the extraction to affect river banks.	Evaluate subsequently available air photos for the area. Compare channel movement with previous air photos, with a focus on east bank location and stability between West Main and Highway 19 bridges.	Every 5 years (Frequency will depend on availability of air photos). Annual inspection of river banks adjacent to operating area	Channel movement has the potential to impact bank stability and remove streamside vegetation. Severe changes could cut in closer to the Project footprint. If excessive river movement and erosion noted, a field verification survey will be initiated. In the event that the channel has moved enough that there is a geotechnical risk of the extraction impacting river banks, remedial action such as rip-rap may be required.

COMPONENT AND PURPOSE	PROJECT PHASE	OBJECTIVES / HYPOTHESIS	MONITORING LOCATION AND PARAMETERS	FREQUENCY	TRIGGERS FOR ACTION / ACTION
Terrestrial					
Vegetation (follow-up and environmental monitoring)	Construction	Initial survey to provide baseline for future monitoring activities. Hypothesis is that 0.14 ha of RC habitat will be disturbed.	Measure area of RC habitat disturbance along conveyor and note vegetation type on both sides.	Twice: when skunk cabbage is out (summer) and when forest floor is wettest (winter) during construction	None proposed; initial surveys will provide baseline for future monitoring activities.
	Operation	Ensure no significant changes to blue-listed RC community (Western red cedar/Sitka spruce - skunk cabbage) adjacent to the conveyor. Predicted that adjacent RC habitat will not change.	Note vegetation type on both sides of conveyor through RC habitat to determine any changes.	Twice: summer and winter in first year of operation.	Change in vegetation from the RC habitat type (e.g., loss of skunk cabbage) or lack of surface water flow would trigger improvements to drainage across conveyor and access road.
	Operation	Ensure long-term success of progressive reclamation plan by making changes as required to ensure plant survival, growth, etc. Predicted that reclaimed forest will grow successfully, but some adjustments to plan may be needed to improve growth through Project life.	Monitor success of planted forest (survival, growth, health, spacing) in reclaimed areas. Details to be determined by a Professional Forester.	Annually by a Professional Forester.	Low/reduced survival of planted vegetation will trigger additional enhancement activities. Reduced success would trigger changes to plan such as species planted, use of soil enhancements, etc.
	Operation	Ensure long-term stability of proposed vegetated buffers and confirm predictions of windthrow study. Hypothesis is that with proposed mitigation in place, there is a reduced chance of windthrow but it could still occur.	Monitor health and integrity of the buffer along the Cluxewe River and the Highway 19. Details will be determined by a Professional Forester.	Annually by a Professional Forester.	Excessive blow-down/tree loss will trigger re-analysis of windthrow potential and activities (planting of additional trees, pruning, etc.)

COMPONENT AND PURPOSE	PROJECT PHASE	OBJECTIVES / HYPOTHESIS	MONITORING LOCATION AND PARAMETERS	FREQUENCY	TRIGGERS FOR ACTION / ACTION
	Closure	Ensure long-term success of progressive reclamation plan and the return of Project footprint to active forestry.	Monitor success of planted forest (survival, growth, health, spacing) in reclaimed areas. Details to be determined by a Professional Forester.	Annually for two years following final reclamation by a Professional Forester.	Silviculture activities to promote a harvestable forest, where deemed necessary by Forester.
Bird Nests / Nesting Birds (environmental monitoring)	Construction	Ensure compliance with the Wildlife Act. Predicted that with mitigation, Project will be compliant with the Wildlife Act.	Bird nest survey over any area to be cleared if clearing to be conducted April 1 to July 31.	If required.	No cutting trees with active birds nests or inactive eagle nests; maintain appropriate buffers around active trees.
	Operation	Ensure compliance with the Wildlife Act. Hypothesis is that with mitigation, Project will be compliant with the Wildlife Act.	Bird nest survey over area to be cleared if clearing to be conducted April 1 to July 31.	If required.	No cutting trees with active birds nests or inactive eagle nests; maintain appropriate buffers around active trees.
Marine Environment					
Harlequin Ducks (follow-up monitoring)	Construction	Confirm prediction that Harlequin ducks (and other shorebirds) could move temporarily during marine construction activities.	Count number of Harlequin Ducks present near construction and a control site (near shore and offshore) during active and non-active times. Methods will follow those conducted for the baseline study.	One during activity and one during equipment presence but no activity; timing will depend on construction window.	No specific trigger proposed. Data will provide information on accuracy of impact assessment.
	Operation	Confirm prediction that Harlequin ducks (and other shorebirds) could move temporarily during ship loading activities.	Count number of Harlequin Ducks near construction and control site during loading and non-loading times.	Two times during loading and two times when no ship present – all in spring of first year.	No specific trigger proposed. Data will provide information on accuracy of impact assessment.
Underwater Acoustics (environmental	Construction	Part of marine construction monitoring program. Ensure that no excessive underwater	Evaluate underwater noise levels during pile drilling at several distances from equipment (e.g.,	During three pile placements (shallow, mid-	Threshold levels at specified distances from equipment to be determined by DFO based on salmon presence.

COMPONENT AND PURPOSE	PROJECT PHASE	OBJECTIVES / HYPOTHESIS	MONITORING LOCATION AND PARAMETERS	FREQUENCY	TRIGGERS FOR ACTION / ACTION
monitoring)		noise is generated during pile drilling activities. Hypothesis is that noise levels from drilling will be lower than pile driving data collected by DFO in BC.	25, 50, 100 and 200 m) and several depths (near bottom, mid-water and near surface).	depth and deep). If thresholds are exceeded, increased frequency as discussed with DFO and Environmental Supervisor.	If levels are exceeded, specified mitigation measures will be followed, such as halting work while salmon are present. Details will be included in Fisheries Act Authorization.
Marine Fish Presence (follow-up and environmental monitoring)	Construction	Part of marine construction monitoring program. Predicted that fish will move away from areas they are not comfortable being in due to noise or machinery movement but that there will be no injured or killed fish.	Visual observations regarding fish presence and behaviour in the vicinity of construction activities. From water surface or with an underwater camera, where possible.	During three noise level measurements.	Presence of salmon within a certain distance from pile placement activity will be used to set noise threshold levels. Work will be halted if there are any fish kills or behaviour indicative of injured fish observed.
	Operation	Address concern regarding the potential for lighting to attract and congregate fish, resulting in increased predation. Predicted that increased fish pooling will not be observed due to lighting.	Observations of fish congregations in and around lighted areas compared to un-lit areas. Also observations of birds or marine mammals in the area to determine if predation is an issue.	Two early ship loadings.	If large congregations of fish are noted, initiate simple mitigation measures that are within safety requirements, such as adjustments of lights over walking path beside conveyor.
Marine Water Quality (environmental monitoring)	Construction	Part of marine construction monitoring program. Predicted that some turbidity and oil sheens will be noted but can be mitigated to be acceptable to DFO.	Turbidity during pile placement; observed oil sheens on water.	As required; determined by Environmental Supervisor based on conditions.	Acceptable turbidity levels at specified distances from equipment and discharge points to be determined by DFO. If acceptable levels are exceeded, specified mitigation measures will be followed, such as halting work temporarily or discharging onto land. Prevention of oil and fuel entering water.

COMPONENT AND PURPOSE	PROJECT PHASE	OBJECTIVES / HYPOTHESIS	MONITORING LOCATION AND PARAMETERS	FREQUENCY	TRIGGERS FOR ACTION / ACTION
Intertidal/ Subtidal Habitat (follow-up)	Operation	Habitat survey of pilings and compensation structures will be completed. Hypothesis is that piles will be colonized by marine life.	Fish habitat compensation to be monitored. Parameters (stability, fish use etc. depend on the type and location of compensation). Colonization and use of underwater ship loading facility structures (piles) to be determined through dive observations as required.	Compensation monitored annually for structural integrity for 5 years. Pilings monitored annually for 2 years.	Instability/degradation of compensation to trigger improvement works.
	Closure	Part of marine demolition monitoring program.	To be determined by DFO if/when loading facility is removed.	As required.	As determined in demolition plan.
Social					
Archaeology	Construction	Moderate potential for archaeology sites along conveyor line adjacent to beach and at a bench 250 m inland.	Archaeologist on site for earth movement adjacent to beach and 250 m from beach to look for archaeological resources.	Once	If potential resources noted during earth movement, work to be halted in area and Archaeologist to determine significance and disposition of material.

During the course of the environmental assessment, the requirements of the environmental monitoring and follow-up program were refined and several new components were added. With respect to groundwater quality monitoring, further specific requirements were developed. These included: groundwater samples would be collected from wells in operational areas and from an up-gradient well as a control for water quality analysis once per year – the proposed parameters would include general chemistry, PAH and metals (see Appendix C - #5.5).

To address concern regarding the potential effects of the Project on marine mammals, specifically orca, several monitoring and follow-up procedures were developed. Although some of the details were left to be developed through the *Fisheries Act* authorization. With respect to noise, independent monitoring of orca presence and behaviour would take place during any construction activities between July and November. Noise levels considered to be of issue for marine mammals would be discussed with DFO and used to set the timing for some marine construction activities. Construction would be stopped under conditions related to orca presence) to be determined and agreed upon with DFO (see Appendix C - #9.7).

The Proponent also committed to document orca sightings from the ship loader on a year round basis during times when people were present on the ship loader during daylight hours. As well, the Proponent was required to pursue mitigation options for orca disturbance during Project construction and operations. This would include any anticipated orca monitoring requirements associated with the implementation of the *Species at Risk Act (see Appendix C - #9.12 & #9.13)*.

The Proponent committed to undertake further measures to address potential noise impacts to the neighbouring Cluxewe Resort and the residents of Pulteney Point on Malcolm Island. Specifically, the Proponent would provide for independent baseline noise monitoring to be undertaken at the Cluxewe Resort and Pulteney Point prior to construction. This would be used as a comparison for future noise level studies if warranted. If noise levels from the pit or ship loading operations exceed acceptable levels and other noise mitigation measures are unsuccessful, the Proponent committed to implement further noise mitigation measures, if feasible (see Appendix C - #12.1 & #12.4).

The detailed requirements of all marine construction activities would follow the section 35(2) Fisheries Act authorization required for the Project. Subject to a positive CEAA conclusion, the authorization would confirm the compensatory works that have been negotiated and agreed upon by DFO and the Proponent. The authorization would also outline in detail the necessary post-construction monitoring measures to be completed by the Proponent to ensure that any compensatory works are functioning as designed.

For the constructions phase of the Project, and independent Environmental Supervisor (ES) would oversee environmental components. For works associated with the marine environment, the ES would be empowered to ensure compliance with the terms and conditions of the DFO authorization. The ES would also be empowered to stop work and direct implementation of any mitigation measures that are deemed necessary. The ES would provide weekly reports to agencies, First Nations and other stakeholders. For the non-marine construction period, where environmental monitoring will be less frequent, reports will be made monthly instead of weekly.

The Proponent would provide a draft construction methodology to DFO for review prior to finalizing the *Fisheries Act* authorization and would include information on types of marine construction, mitigation, proposed timing (based on priorities set by DFO and First Nations) and monitoring and follow-up requirements.

Conclusion:
During the environmental assessment, the responsible authorities have considered: the Application; additional Project review material listed in Appendix A; public, First Nations, and government agency comments on the potential effects of the Project, responses by the Proponent; and the discussions of the Working Group.

Based on this information, and provided that the Proponent implements the actions described in the summary of commitments listed in Appendix C - Table of Commitments, the responsible authorities are satisfied that the mitigation, monitoring and follow-up program developed during the environmental assessment, specific components of which will become further developed in the subsequent *Fisheries Act* authorization, will be sufficient to address any potential adverse environmental effects of the Project.

Part C – Responsible Authorities Conclusions

1. General

The conclusions from the review of the Project pursuant to the federal *Canadian Environmental Assessment Act* are based on the following documents and review process:

- the Proponent's Environmental Impact Assessment Application;
- all review material submitted by the Proponent and listed in Appendix A;
- the Proponent's Table of Commitments and Consultation Commitments, as updated and consolidated in Appendix C;
- input from members of the public during the course of the review;
- letters of support for the Project submitted by the Kwakiutl First Nation and the 'Namgis First Nation, acknowledging adequate consultation and accommodation by the Proponent and the Crown; and
- the environmental assessment collectively carried out by the Working Group of federal, provincial and local government agencies and First Nations.

2. Monitoring and Follow-up Program

As part of the mitigation measures summarized in Appendix C, the Proponent has committed to develop an Environmental Management Plan prior to the start of construction that provides a more detailed description of how various environmental impacts will be avoided, managed and mitigated. The Proponent would also undertake monitoring activities to identify environmental impacts that may occur and ensure that the implementation of mitigation measures are having the intended results and adequately mitigating potential impacts.

In addition to the Proponent's commitment's towards environmental management and monitoring, the Proponent would also be required to comply with specific mitigation, monitoring and reporting requirements for pre & post construction operations, habitat compensation operations, as well as those requirements identified for SARA listed species, as determined in the *Fisheries Act* Authorization.

3. Overall Conclusion

On the basis of this comprehensive study, the responsible authorities have determined that the Project is not likely to cause significant adverse environmental effects.

APPENDIX A

Review Documentation

August 5, 2004	Summary of Working Group Meeting #1
September 23, 2004	Letter from Marco Romero (Polaris Minerals Corporation) to John Bones (BCEAO) indicating that the Project Proponent has changed from Polaris Minerals Corporation to Orca Sand and Gravel Ltd.
September 24, 2004	Summary of Working Group Meeting #2
January 17, 2005	Application and supporting appendices for Environmental Assessment Certificate from Orca Sand and Gravel Ltd.
January 17, 2005	Letter from Herb Wilson (Orca Sand and Gravel Ltd.) to John Bones (BCEAO) requesting concurrent review of, and providing copies of: • Application to LWBC for foreshore tenure; and • Application to MEM for mine permit.
January 17, 2005	Letter from John Bones (BCEAO) re: Acceptance of revised Application for a Project Approval Certificate for the Orca Sand and Gravel Project, and acceptance of application for concurrent review of MEM permit and LWBC tenure applications.
February 9, 2005	Summary of Working Group Meeting #3
March 22, 2005	Report on Post-Application Consultation on Environmental Assessment Certificate Application. Orca Sand and Gravel Ltd.
March 23, 2005	Letter from Chief Marion Wright (Kwakiutl Band) to John Bones (BCEAO) advising of an Impacts and Benefits Agreement with Orca Sand and Gravel Ltd. The Letter provides support for permits or tenure acquisitions required by Orca, and acknowledges the Band has been adequately consulted and accommodated by Orca and by federal and provincial Crown with respect to the Project.

March 24, 2005	Letter from Chief William Cranmer (‘Namgis First Nation) to John Bones (BCEAO) confirming the ‘Namgis have been adequately consulted and accommodated by Polaris Minerals Corporation and federal and provincial governments regarding the Orca Sand and Gravel Project.
March 31, 2005	Summary of Working Group Meeting #4

APPENDIX B
Public Issues Tracking Summary
(From Proponent's Report on Consultation) found at:

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
TOPIC: PROJECT DESCRIPTION AND ACCIDENTS					
1	9-Feb. 05	Port McNeill open house. Audience question.	What will happen if the conveyor belt breaks down? Is there spillage and what will happen to any spillage?	The conveyor system is computer controlled and monitored and the system will immediately stop if any one belt has a problem. The transfer points from one conveyor to the next have a hopper which will catch the material if the receiving belt stops. The belt over the foreshore is provided with spill trays along its full length to catch any spillage.	No action required
2	9-Feb. 05	Port McNeill open house. Audience question.	Is the conveyor hydraulic? How many transfer points are there?	All conveyors will have electric drives. The over the foreshore will have a drive situated at the tail end, that is on-shore amongst the trees. There are three transfer points on the system.	No action required
3	9-Feb. 05	Port McNeill open house. Audience question.	Is there any revenue to the Crown?	The project is essentially situated on private land leased from WFP, however, the Crown will receive lease payments for the foreshore lands.	No action required
4	9-Feb. 05	Port McNeill open house. Audience question.	How will you control the electrolysis on the pilings?	The pilings are designed for strength in accordance with the BC Building Code and the appropriate seismic (earthquake) zone. After that either (i) the metal can be increased in thickness by 25% to allow for corrosion or, (ii) zinc sacrificial anodes can be used as they are on all steel hulled ships.	No action required

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
5	9-Feb. 05	Port McNeill open house. Audience question.	How does the loading work?	The loading is computerized with a conveyor underneath the stockpiles of products which then transfers required amounts of material along the conveyor system and into the hold of the ship.	No action required
6	9-Feb. 05	Port McNeill open house. Audience question.	Where are Canada Steamship Lines registered?	CSL is a Canadian public company with headquarters in Montreal. The registration of the vessels is not an issue for the proponent to consider.	No action required
TOPIC: EVIRONMENT – WILDLIFE, VEGETATION AND RECLAMATION					
7	25-Jan. 05	Port Hardy Council meeting. Audience question.	Do you foresee any species at risk?	No. Section 3 of the "Application Report" details the studies which reviewed potential wildlife species at risk in the regional marine and land areas. Terrestrial species and key habitats were not found within the project footprint although this does not mean that species cannot access the site or pass through. Marine species such as transient orcas use Broughton Strait. Abalone used to be abundant in Soldier Bay but the population has declined drastically. A single individual was observed in the sub-tidal area during one of the dive surveys.	No action required
8	9-Feb. 05	Port McNeill open house. Audience question.	Are you creating places for animals to wander?	Section 7 of the "Application Report" states that existing travel routes/passages will not be blocked by the conveyor which passes underneath the BC Hydro transmission line, Highway 19 and also the Rupert Main logging road. It will be raised above the beach and behind the foreshore. An additional passage will be created 250 m from the beach. The conveyor runs through dense salal where no wildlife trails were found.	Existing commitment

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
9	9-Feb. 05	Port McNeill open house. Audience question.	You have stated that 0.14 hectares of a sensitive habitat will be disturbed. Won't it be more with access to road and conveyor belt?	Refer to Section 7 of the "Application Report". The area disturbed includes the allowance for a maintenance access road along the conveyor. The 0.14 hectares is the footprint of the conveyor and access road within the "RC" ecosystem.	No action required
10	9-Feb. 05	Port McNeill open house. Audience question.	What will be done with the silt?	As described in Section 2 of the "Application Report", the silt will be added to the overburden soils from the site and placed on areas where extraction is completed prior to replanting. Replanting of forest will be done in phases. Replanting with native forest species will be done in phases with the involvement of WFP and a forester.	Existing commitment
11	11-Feb. 05	Port Hardy open house. Audience question.	How will the area be replanted?	It will be returned to productive forest consist with its status within TFL 6. Species to be planted will be agreed with the landowner, WFP.	Existing commitment
TOPIC: ENVIRONMENT – RIVERS AND GROUNDWATER					
12	10-Feb. 05	Sointula open house. Audience question.	Where will the water come from to wash to gravel?	Sections 2, 3 and 7 of the "Application Report" deal with the site water balance and groundwater issues. Appendix VII-3 presents the Groundwater Report in full. All process water is recycled and rain water will be captured as much as possible. Make-up water will be taken from a well approximately 750 m east of the Cluxewe River. All other water, such as drainage from stockpiles, is recycled back into the environment.	No action required
13 and 14	9-Feb. 05	Port McNeill open house. Audience questions.	Where will the extracted groundwater go? Concerned about exports of water. How much fresh water	The sand and gravel is naturally wet in the ground and contains 3% moisture by weight when extracted. A net loss of water from the project of 390,000 cubic metres per year at maximum capacity arises because the sand and gravel is damp, after washing, when loaded onto the ships.	No action required Existing commitment – no surface wastewater

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
			used/discharged and where will flows go?	All process water is recycled. There will be no discharge of wastewater from the project.	discharge
15	9-Feb. 05	Port McNeill open house. Audience question.	Who will be responsible for monitoring the water level at the Cluxewe?	A groundwater monitoring plan will be developed through several government agencies. The Ministry of Energy and Mines have indicated that they may link the annual monitoring requirement to the Mine Permit which is renewed every 5 years thus providing an ongoing regulatory oversight.	Existing commitment
16	9-Feb. 05	Port McNeill open house. Audience question.	Will you be monitoring the groundwater from the Port McNeill side as well as the Cluxewe?	The Town of Port McNeill wells are not affected as they are located on the far side (east) of Mills Creek and up-gradient from the project.	No action required
17	9-Feb. 05	BCEAO comment form from Bill W. Hawkins.	Requesting information on how much fresh water is used, where do the flows go and is there a net gain or loss.	The sand and gravel is naturally wet in the ground and contains 3% moisture by weight when extracted. A net loss of water from the project of 390,000 cubic metres per year at maximum capacity arises because the sand and gravel is damp, after washing, when loaded onto the ships. All process water is recycled.	No action required
18	24-Feb. 05	BCEAO comment form from Stephanie Coe.	Concerned that the project is sending significant quantities of water to the US without compensation and that a right to the water could be created under NAFTA. (Comment summarized by proponent).	The water is an integral part of the aggregate products (as is the significant water content in exported lumber) which are sold on a per tonne basis thus the water is treated as if it were also a product. BC has been exporting several million tonnes per year of washed construction aggregates to the US for many years now from Texada Island, Sechelt and Victoria and this has not created concerns under NAFTA.	No action required

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
19	24-Feb. 05	BCEAO comment form from Dale Scow.	Has anyone taken into consideration the fact that without the sand and gravel and top layer of foliage the water table will rise (not if) to leave a bigger buffer from the rising water table, and if so has the total tonnage of the area been recalculated?	Groundwater levels will continue to be monitored monthly in the existing wells located on the site by OSG. The groundwater modelling demonstrates that during operation the groundwater levels will rise. This has been incorporated into the mining plan and the resource calculation reflects the change, however, these are subject to correction while working and the operation will stay at least 3 metres above the winter water table whatever level that proves to be in practice.	Existing commitment – for monitoring and staying above water table
20	28-Feb. 05	Email to BCEAO from Robert McGregor.	Have any studies been carried out on the potential effects of the project on the groundwater supply from Kaisla Spring on Malcolm Island?	No studies have been carried out regarding Kaisla Spring. If the source of this spring is on Vancouver Island then it would be reasonable to assume that the same conclusions apply to the groundwater resource here as at the project area. The groundwater quantity is predicted to increase with levels rising slightly during operation and no adverse effects to water quality are predicted.	No action required
TOPIC: ENVIRONMENT – MARINE HABITAT AND LIFE					
21	9-Feb. 05	Port McNeill open house. Audience question	Will there be impacts on whales? What about returning salmon?	Section 7 of the "Application Report" discusses these issues. Impacts on whales and returning salmon are expected to be limited to minimal sensory disturbance from construction activities and ship loading.	Existing commitment
22	24-Feb. 05	BCEAO comment form from Don Ford.	Loss of habitat for migrating salmon and whales due to construction and loading facilities.	Measures are proposed to minimize noise during construction and loading. The conveyor and loading facility has been designed so that is will not impact fish or mammal passages and will not result in measurable shading or light to impact fish. There will be no net loss of habitat arising from the project as compensation will be provided for the small area only which is disturbed.	Existing commitment

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
23	9-Feb. 05	Port McNeill open house. Audience question.	Will there be any bilge water from the ships?	Bilge water is pumped out in mid-ocean, discharge in Canadian coastal waters is not allowed. The CSL ships have coast guard approved sewage treatment plants that discharge only potable quality water.	Existing commitment
24	21-Feb. 05	BCEAO comment form from Leslie and Jean Wilson.	It is important that these vessels (ships carrying products) are closely checked by the relevant government agencies to forestall oil spills, polluted water, or any other significant contamination of the area environment.	OSG has made it a condition of its shipping contract that the carrier must comply with the federal environmental guidelines for ballast water. Enforcement will remain the responsibility of the appropriate agency. The selected shipper is a Canadian public company and the largest operator of these specialist vessels in the world and operates in many Canadian ports on a daily basis.	Existing commitment
25	24-Feb. 05	BCEAO comment form from Don Ford.	Winds in the loading bay area can exceed 100 knots for prolonged periods every four or five years. If damage or grounding occurred who would be responsible and where would tugs be dispatched from? How would an oil spill be contained?	Safe operation of a ship is always the Masters responsibility and therefore the ship owners. All vessels arriving or departing will be under the control of a BC Coast Pilot, which is a mandatory requirement, and be assisted by two tugs. The BC Coast Pilots have advised that in poor weather conditions, such as strong north-westerly winds, they will not pass beyond Hardy Bay, where a safe anchorage is available, while they wait for suitable safe weather before proceeding. The risk of a grounding is considered extremely small. Tugs at present would have to come from Campbell River or Vancouver, however, OSG is working with interested parties to have at least one tug stationed close to the project and hopefully two. OSG will be implementing a spill prevention and control plan. Marine spill prevention equipment is already available in many north Island locations.	Existing commitments – use of pilots, spill plan New commitment – safe anchorage locations

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
26	9-Feb. 05	BCEAO comment form from Dan House.	One of my greatest concerns is the impact with the local fisheries and stream habitat.	No river or stream habitat will be impacted by the project - it is specifically designed to avoid any disturbance to the Cluxewe River. There will be a small loss of marine habitat due to placing the ship loading facility pilings and a habitat compensation plan is being developed together with Fisheries and Oceans Canada.	Existing commitment Permit issue
27	10-Feb. 05	BCEAO comment form from Lawrie Garrett.	Lady Ellen Point is an area of some recreational sport fishing opportunity.	The area around Lady Ellen Point will not be affected by the project and this sport fishing opportunity will continue to be available. The large vessels visiting the project will not be approaching close to the point.	No action required
TOPIC: CULTURAL AND HERITAGE SETTING					
28	15-Feb. 05	Email to BCEAO from Buster Wilson.	How can First Nations protect their land and heritage when mining projects are proposed and how can we be sure that the promised jobs will actually be created? (Comment summarized by proponent).	Sections 5 and 7 of the "Application Report" present the archaeological studies completed. Initially a Heritage Overview Assessment was completed by an archaeologist approved by the two bands who assert traditional territory rights over the project area. This HOA did not identify any known traditional use sites but recommended an Archaeological Impact Assessment (AIV) be carried out. The AIV was completed by an experienced archaeologist under a provincial permit and all field crews included members of both bands. The bands also completed their own intensive Culturally Modified Tree survey and none were found. This project has one of the First Nations as a co-owner and the second has recently ratified an Impacts and Benefits Agreement with OSG. The company is bound through legal agreements to honour its jobs commitment and will be monitored by its First Nation partners.	Existing commitment – archaeology, 'Namgis jobs New commitment – jobs with Kwakiutl IBA ratified

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
TOPIC: SOCIO-ECONOMICS					
29	9-Feb. 05	Port McNeill open house. Audience question.	Air quality, noise and light – what would be the worst-case scenario for each?	Sections 2 and 7 of the "Application Report" refer to air quality, noise and lighting of the operations. The operation will have only a small amount of mobile plant items with modern, well-maintained, low-emission engines and no change to air quality is predicted at locations where people may be, such as the Cluxewe Resort. The wet processing plant will control dust and additional water sprays will be used during hot, dry periods if required. When no ship loading is taking place, navigation marker lights on the mooring dolphins will be the only lights. Lighting will be minimal during ship loading – one light from the loader shining into the ship hold. The ships will have deck lights for safe movement of the crew. Lights will be guarded as much as possible to avoid light "spilling". Please refer to Question 30 below for noise assessment.	Existing commitments
30	24-Feb. 05	BCEAO comment form from Shirley Ford.	I am concerned about noise, especially if it affects the Cluxewe Resort. Noise travels.	Based on a study completed at the very similar Sechelt operation, sounds from the ship loading may be heard up to 1.4 km away over water, less on windy or rainy days and probably further on calm days. The closest people are at Cluxewe Resort and Pulteney Point, each 2 km away. Noise from the processing plant will be buffered by the edges of the pit and surrounding forest and won't be audible at the Cluxewe Resort. It is difficult to predict noise levels under all conditions because they are not only influenced by weather conditions but also by the surrounding terrain which is much more wooded than at	Existing commitments – further mitigation if required New commitment – baseline monitoring

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
				Sechelt where the measurements were over open water only. OSG intends to carry out baseline monitoring at the Resort and also at Pulteney Point prior to operations commencing and will develop mitigation measures once operational, if required.	
31	24-Feb. 05	BCEAO comment form from Don Ford	Compensation to Cluxewe Resort for loss of revenue due to noise and dust pollution.	Noise and dust pollution are not predicted to be issues at the Cluxewe Resort, the owners of which are the Kwakiutl whose members recently ratified an Impacts and Benefits Agreement with OSG which provides significant economic benefits from the project.	Existing commitment – noise mitigation New commitment – Kwakiutl IBA ratified
32	10-Feb. 05	Sointula open house. Audience question.	Your presentation states that there will be no impact on the Cluxewe Resort. How can you possibly take the position that there will be no impact?	Section 7 of the "Application Report" details the assessment's findings. There are no impacts predicted on the Resort based upon: no changes to air quality; a noise survey which demonstrated that loading operations should not be heard (noted above); no trucking traffic created; and the loading facility being 2 km away. Some noise may be heard during construction (4 months at ship loader) but measures are proposed to keep this to a minimum (pile drilling rather than traditional pile driving) and no night working. OSG will undertake baseline noise monitoring and thereafter develop a mitigation plan if noise is a problem.	Existing commitments New commitment – baseline monitoring
33	28-Feb. 05	Email to BCEAO from Robert McGregor.	I believe there will be a permanent (for the life of the operation) detrimental alteration of the ambient noise levels at my property (Pulteney Point).	Pulteney Point is the same distance from the project as the Cluxewe Resort and similar conditions are predicted. This location will also be covered in the proposed baseline noise monitoring survey.	Existing commitments – noise mitigation New commitment – baseline monitoring

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
34	26-Jan. 05 10-Feb. 05	Port McNeill Rotary meeting. Sointula open house. Audience question.	Individuals concerned about impacts to property values from Project to land which is near Pulteney Point and feels there will be impacts on Cluxewe Resort. Kwakiutl will be compensated with IBA, what about impacts to the individual?	Section 7 of the "Application Report" summarizes the proponents assessment of potential impacts. Cluxewe Resort guests should not be able to hear operations. OSG will undertake monitoring and then mitigation to the greatest extent possible if noise is perceived as a problem. The ship loader and ship will be visible from Pulteney Point, but the structure and lighting will appear minimal and these viewpoints are 2 km. away. The Kwakiutl IBA recognizes unresolved aboriginal rights claims, impacts to individual land values are outside of the scope of the environmental assessment process.	Existing commitments
35	28-Feb. 05	Email to BCEAO from Robert McGregor.	The visual impact on the view corridor from my property will also be negatively affected …. the ship loading operation will run 24 hours two times per week which will require bright lighting. This will significantly degrade the visual aspect from what it presently is.	The sand and gravel pit will be hidden from view from Pulteney Point, the ship loader will be visible but at a distance of 2 km and with only low-level navigation lights showing when loading is not taking place. The operation will be somewhat more visible when a ship is at the berth but lighting during night loading will be kept to the minimum for safety. Pulteney Point sits on a commercial shipping lane and the operation of the proposed vessels and loading facilities are "acceptable uses and activities" as described in the publicly approved North Island Straits Coastal Plan (December 2002).	Existing commitments
36	9-Feb. 05	Port McNeill open house. Audience question.	What impact will you have on the cruise ships?	None. The ship loader is well outside of the navigational channel that cruise ships and other vessels use.	No action required
37	9-Feb. 05	Port McNeill open house. Audience	Where will the work force come from? Project is needed for the economy.	OSG intends to hire the majority of all employees from the North Island, the availability of suitable and skilled labour is a major attraction of the location. Local contractors will be used for a number of services such as	Existing commitments

#	DATE	RAISED BY	ISSUE RAISED	OSG RESPONSE	PROPOSED ACTION
		question.		overburden stripping, tree planting and maintenance and fuel supply. OSG hopes that tugboats can be supplied locally, this would be another major local contract.	
38	10-Feb. 05	Sointula open house. Audience question.	How will you ensure 50% First Nations employment if another company takes over?	This undertaking is enshrined in legally binding agreements with the 'Namgis First Nation and those pending with the Kwakiutl following the positive ratification vote on February 26.	Existing commitment – with 'Namgis agreement New commitment – with Kwakiutl IBA ratification vote
39	10-Feb. 05	Sointula open house. Audience question.	Will there be any direct benefits to Malcolm Island residents?	As with other north island communities, Malcolm Island residents can apply for jobs and bid on service contracts if interested.	No action required
40	10-Feb. 05	Sointula open house. Audience question.	Will there be an open bidding competition for contractors?	Yes.	No action required

APPENDIX C
PROPONENT COMMITMENTS FOR THE ORCA SAND AND GRAVEL PROJECT

Commitment Number	Project Phase	Proponent (OSG) Commitment	Responsibility	Approving Agency/Group
1. PROJECT DESIGN				
1.1	Construction Operation Closure	Orca Sand & Gravel Ltd. (OSG) will design, construct, operate and decommission the Project as described in the Application Report including subsequent specific alterations required in forthcoming agency permits or authorizations.	OSG	All Agencies
1.2	Construction Operation Closure	The Project construction, operations, closure and reclamation will follow conditions to be provided by BC Ministry of Energy and Mines in the Mine Permit.	OSG	MEM
1.3	Construction	The ship loader will be designed and built to meet the BC Building Code under which Port McNeill is presently in the highest category for seismic design standards.	OSG	MEM TC
1.4	Operation	Orca Sand & Gravel Ltd. will develop the facility management and environmental monitoring plans indicated in the Application Report in association with the relevant agencies. The plans will be implemented fully at the appropriate time.	OSG	All Agencies
1.5	Operation	Operations will follow an environmental quality assurance program meeting ISO 14001 or similar standards.	OSG	MEM
1.6	Operation	Fuel storage and handling will follow Federal and Provincial requirements (Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Products) and the BC Fire Code.	OSG	MEM, WLAP, EC
1.7	Operation	Waste management systems for handling and disposal of domestic, sanitary and hazardous wastes will be installed.	OSG	MEM, WLAP, EC

Commitment Number	Project Phase	Proponent (OSG) Commitment	Responsibility	Approving Agency/Group
1.8	Operation	Environmental contingency and spill response plans will be developed.	OSG	MEM, WLAP
1.9	Operation	No trucks will be used to move the product to ships.	OSG	MOT
1.10	Closure and Decommissioning	OSG will discuss closure and decommissioning with affected agencies prior to their occurrence, in order to apply and implement the most up-to-date practices for this phase of the Project.	OSG	MEM, WLAP, DFO, EC
2. VEGETATION				
2.1	Construction	Monitoring - RC habitat disturbance along the conveyor will be measured and the vegetation type on both sides documented when the skunk cabbage is out (summer) and when forest floor is wettest (winter) during construction year.	OSG	WLAP
2.2	Operation	Monitoring - Vegetation type on both sides of the conveyor through RC habitat will be documented to determine any changes twice (summer and winter) in first year of operation.	OSG	WLAP
2.3	Operation	Improvements to drainage across conveyor and access road will be made if monitoring shows a noticeable change in vegetation from the RC habitat type (e.g., loss of skunk cabbage) or lack of surface water flow.	OSG	WLAP
2.4	Operation	Monitoring – The health and integrity of the trees within the buffers along the Cluxewe River and Highway 19 will be documented by a Professional Forester.	OSG	MEM, WLAP
2.5	Operation	Re-analysis of the windthrow potential and activities (planting of additional trees, pruning, etc.) will be undertaken if monitoring shows excessive blow-down/tree loss within the buffers.	OSG	MEM, WLAP DFO

Commitment Number	Project Phase	Proponent (OSG) Commitment	Responsibility	Approving Agency/Group
3. RECLAMATION				
3.1	Operation Closure	No soils will be removed from the site. All soils will be stripped by type - topsoil separately from sub-soils, and either used immediately for reclamation or stored for final reclamation. Sub-soil quality will be augmented by the addition of the silts recovered from the settling ponds. Native plant salvage will be permitted ahead of operations, if a First Nations company wishes to take plants not to be harvested by WFP.	OSG	MEM
3.2	Operation Closure	Vegetation will be planted as part of the reclamation plan. Revegetation will be governed by an agreement with WFP to plant harvestable native tree species under WFP direction. OSG will encourage WFP to consult First Nations regarding replanting.	OSG	MEM
3.3	Operation Closure	The reclamation program will include a plan for the control of noxious weeds.	OSG	MEM
3.4	Operation Closure	The success of planted forest (survival, growth, health, spacing) will be monitored in reclaimed areas annually by a Professional Forester and for two years following closure (through WFP).	OSG	MEM
3.5	Operation Closure	Within planted areas, silviculture activities to promote a harvestable forest will be undertaken, where deemed necessary by a Professional Forester (through WFP). Additional enhancement activities will be undertaken if monitoring shows a low / reduced survival of planted vegetation. Reduced success during operations will trigger changes to future areas to be reclaimed such as species planted, use of soil enhancements, etc as recommended by forester.	OSG	MEM

Commitment Number	Project Phase	Proponent (OSG) Commitment	Responsibility	Approving Agency/Group
4. WILDLIFE				
4.1	Operation	Passage for large mammals under the conveyor will be incorporated into the design at two locations (near shore and 250 m from shore). Existing passage along the beach, at the BC Hydro transmission line RoW, Highway 19 and Rupert Main (at ground level) will not be obstructed by Project operations.	OSG	WLAP
4.2	Construction Operation	The construction of the conveyor line will require the clearing of a path approximately 15 m in width from the plant site to the foreshore. The clearing of trees and vegetation along the conveyor line (approximately 15 m width) is the responsibility of OSG. A bird nest survey will be conducted prior to any tree clearing that takes place between April 1 and July 31 (the breeding window) and results reported to BC WLAP and EC for review and guidance. During clearing of the conveyor line, OSG will comply with all relevant federal and provincial legislation protecting birds, nests and eggs, including, section 34 of the BC *Wildlife Act* ,section 5 of the federal *Migratory Birds Convention Act*, and section 6 of the attendant Migratory Birds Regulation.	OSG	WLAP EC
4.3	Construction	Monitoring - Harlequin Ducks presence (#) near the marine construction and a control site (near shore and offshore) will be documented once during activity and once during equipment presence with no activity. Methods will follow those conducted for the baseline study and seasonal timing will depend on construction window determined by DFO.	OSG	EC
4.4	Operation	Monitoring - Harlequin Ducks presence (i.e. numbers) near the marine ship loader and a control site will be documented twice during loading and twice during non-loading times (no ship present). Methods will follow those conducted for the baseline study and timing will be the spring of the first year of operation.	OSG	EC

Commitment Number	Project Phase	Proponent (OSG) Commitment	Responsibility	Approving Agency/Group
5. GROUNDWATER				
5.1	Operation	Pit excavation will only occur above the groundwater table.	OSG	MEM
5.2	Operation	As much as possible, processing water will be recycled from the sediment control ponds with make up water from a groundwater source.	OSG	MEM
5.3	Construction Operation	Monitoring - Groundwater levels in the existing wells on site will continue to be monitored on a monthly basis until removed during extraction.	OSG	MEM
5.4	Operation	The planned pit bottom will be adjusted to stay above water table if monitoring indicates an effect on groundwater levels that is associated with the depth of excavation.	OSG	MEM
5.5	Operation	Monitoring – Ground water samples will be collected from wells in operational areas and from an upgradient well as a control for water quality analysis once per year. Proposed parameters will include general chemistry, PAH and metals.	OSG	MEM
6. RIVERS AND CREEKS				
6.1	Operation	Process water will be discharged to sediment control ponds or other locations on-site for infiltration, not to the Cluxewe River or Mills Creek, during the life of the Project.	OSG	MEM, WLAP DFO
6.2	Operation	Pit excavations will be located outside of the 70 m wide fisheries sensitive zone (as defined by the Forest Practices Code) for the Cluxewe River.	OSG	MEM, WLAP DFO
6.3	Operation	Monitoring - The Cluxewe channel will be inspected annually adjacent to the operating area to document any changes. Inspection information will be provided to WLAP and DFO.	OSG	WLAP DFO

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6.4	Operation	A review and comparison of available air photos for the Cluxewe channel between West Main and Highway 19 bridges will be undertaken approximately every 5 years or as air photos are available. The focus will be on identifying any changes to east bank location and stability. Observations will be provided to WLAP and DFO.	OSG	WLAP DFO
7. MARINE WATER QUALITY				
7.1	Construction	Monitoring - Turbidity levels will be monitored during pile placement and visual inspections for oil sheens on water will be undertaken during marine construction. The frequency will be determined by the Environmental Supervisor based on activity and conditions.	OSG Pile contractor	DFO
7.2	Construction	Acceptable turbidity levels at specified distances from equipment and discharge points will be determined by DFO. If turbidity level monitoring indicates that acceptable levels are exceeded, mitigation measures specified by DFO will be followed, such as halting work temporarily or discharging onto land, and prevention of oil and fuel entering water.	OSG Pile contractor and other marine contractors	DFO
7.3	Operation	OSG will not provide fuelling or bilge discharge facilities at the Project loading facility.	OSG	EC, TC
7.4	Operation	OSG will require in its contract for services with the shipping company that all ships used in the Project are to comply with Transport Canada guidelines for ballast water management.	OSG	TC

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8. MARINE FISH HABITAT				
8.1	Construction	Marine construction activities will follow the Section 35(2) *Fisheries Act* Authorization required for the Project. The Authorization will confirm the compensatory works that have been negotiated and agreed upon by DFO and OSG. The Authorization will also outline in detail the necessary post-construction monitoring measures to be completed by OSG to ensure that any constructed compensatory works are functioning as designed.	OSG	DFO
8.2	Construction	Monitoring - For the construction phase of the Project, an independent Environmental Supervisor (ES) will oversee environmental components. For works associated with the marine environment, the ES will be empowered to ensure compliance with the terms and conditions of the DFO Authorization. The ES will also be empowered to stop work and direct implementation of any mitigation measures that are deemed necessary. The ES will provide weekly reports to agencies, First Nations and other stakeholders. For the non marine construction period, where environmental monitoring will be less frequent, reports will be made monthly instead of weekly.	OSG Pile contractor	DFO
8.3	Construction	A draft construction methodology will be provided to DFO for review prior to finalizing the *Fisheries Act* Authorization and will include information on types of marine construction, mitigation, proposed timing (based on priorities set by DFO and First Nations) and monitoring. Once an independent environmental supervisor has been selected, OSG will sign a letter stating that the supervisor has the authority to halt work.	OSG	DFO
8.4	Operation	A spill tray will be installed under the conveyor and dust covers over the conveyor, where it is located over marine water.	OSG	MEM DFO

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8.5	Operation	Monitoring - Fish habitat compensation will be monitored. Parameters (stability, fish use etc.), duration and frequency will be determined on the basis of the type and location of compensation.	OSG	DFO
8.6	Operation	Monitoring - Colonization and use of the underwater ship loading facility structures (piles) will be determined through dive observations – proposed annually during first two years of operation, to be confirmed by DFO.	OSG	DFO
8.7	Closure	Environmental mitigation requirements will be determined through consultation with DFO when the loading facility is removed.	OSG	DFO
9. MARINE SPECIES				
9.1	Construction	Construction in the marine environment will be conducted within a timing window approved by DFO and with mitigative measures to be approved by DFO.	OSG	DFO
9.2	Construction	Pile drilling, as opposed to pile driving, will be used during construction at the ship loading facility.	OSG	DFO
9.3	Construction	Monitoring - Underwater noise levels (dB) will be evaluated during pile drilling at several distances from equipment (e.g., 25, 50, 100 and 200 m or further) and several depths (near bottom, mid-water and near surface) during three pile placements (shallow, mid-depth and deep).	OSG	DFO
9.4	Construction	Threshold noise levels (dB) at specified distances from equipment will be determined by DFO based on salmon presence. If noise monitoring indicates that levels are exceeded, specified mitigation measures will be followed, such as halting work while salmon are present.	OSG	DFO

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9.5	Construction	Monitoring - Visual observations will be made for fish presence and behaviour in the vicinity of pile drilling during noise level measurements. Observations will be made from water surface or with an underwater camera, where possible.	OSG	DFO
9.6	Construction	Presence of salmon within a certain distance from pile placement activity (to be determined by DFO) will be used to set noise threshold levels. Work will be halted if monitoring observations indicates there are any fish kills or behaviour indicative of injured fish.	OSG	DFO
9.7	Construction	Independent monitoring of orca presence and behaviour will take place during any construction between July and November. Noise levels that are considered to be of issue for marine mammals are to be discussed with DFO and used to set the timing for some marine construction activities. Construction will be stopped under conditions (related to orca presence) to be determined and agreed upon with DFO.	OSG	DFO
9.8	Operation	The mooring buoys (determined to be the loudest source of operational underwater noise at Sechelt), will be designed to minimize noise.	OSG	DFO TC
9.9	Operation	Navigation marker lights will be the only lights used on the mooring dolphins when no ship loading is taking place. Lighting will be minimal during ship loading, with one light from the loader shining into the ship hold. The ships will have deck lights for safe movement of the crew. Lights will be guarded as much as possible to avoid light "spilling".	OSG	TC MEM
9.10	Operation	Monitoring - Observations of fish congregations in and around lighted areas will be compared to un-lit areas at night during two ship loadings early in operations.	OSG	DFO

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9.11	Operation	If large congregations of fish are noted during light monitoring, simple mitigation measures will be initiated that are within safety requirements, such as adjustments of lights over walking path beside conveyor.	OSG	DFO
9.12	Operation	Orca sightings from the ship loader will be documented year round (when persons at ship loader during daylight hours) and will include location, number and activity for the first three years of operation.	OSG	DFO
9.13	Construction Operation	OSG will discuss options to mitigate for disturbance of orcas with DFO, including any anticipated orca monitoring requirements associated with implementation of the *Species at Risk Act.*	OSG	DFO
10. AIR QUALITY				
10.1	Operation	Pit and plant area roadways will be watered, as required, during dry periods to minimize dust.	OSG	MEM
10.2	Operation	All materials from the pit site will be damp-loaded onto ships, to avoid dust creation.	OSG	MEM
10.3	Construction Operation	Modern diesel equipment with low-emission engines will be used during operations on site. OSG will encourage similar equipment to be used by the successful bidder for the construction phase.	OSG	MEM
11. VIEWSHED				
11.1	Operation	Lighting will be minimal on the ship loading structure; and limited to navigation lights when a ship is not in berth and lights for ship operations, safety and loading when a ship is in berth.	OSG	TC MEM
11.2	Operation Closure	The visibility of the pit site will be minimized through the use of phased reclamation.	OSG	MEM

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12. NOISE				
12.1	Pre-construction	Monitoring - OSG will provide for independent baseline noise monitoring to be carried out at the Cluxewe Resort and at Pulteney Point prior to construction.	OSG	MEM
12.2	Construction	Noise impacts during construction at the ship loader will be minimized by the use of pile drilling (rather than traditional pile driving) and no night working.	OSG Pile contractor	MEM DFO
12.3	Operation	The mooring buoys will be designed to minimize noise effects on nearby facilities and communities.	OSG	MEM
12.4	Operations	OSG will conduct additional noise surveys at Cluxewe Resort and Pulteney Point on the request of MEM. If noise levels from the pit or ship loading operations are considered by MEM to exceed acceptable levels, OSG will determine with MEM any additional, feasible noise mitigation measures to be applied during operations.	OSG	MEM
13. EMPLOYMENT				
13.1	Operation	OSG will focus its Project job recruitment activities on the North Island.	OSG	
13.2	Operation	Training will be provided for many of the Project's operational positions either on the job, through the equipment manufacturer or at a local community college facility.	OSG	
14. ARCHAEOLOGY				
14.1	Construction	Monitoring – An archaeologist will be provided to look for archaeological resources during earth movement related to conveyor construction, at two sites with moderate archaeological potential (area adjacent to the beach and area 250 m from beach).	OSG	MSRM

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14.2	Construction Operation	If an archaeological site is identified during monitoring, an archaeologist will oversee activities in and near the site, under direction from the Archaeology Branch, if required. The archaeologist will contact the First Nations and will follow provincial legislative requirements if sites are disturbed.	OSG	MSRM
15. FIRST NATIONS				
15.1	Operation	OSG has made commitments to employment opportunities for Kwakiutl members and 'Namgis First Nations members, through agreements and business arrangements. These commitments include training programs. OSG will honour these commitments through its legal obligations to the First Nations.	OSG	Kwakiutl First Nation 'Namgis First Nation
16. SAFETY				
16.1	Operation	An occupational health and safety plan will be developed, including occupational health management, safety committee, wildlife management and training components.	OSG	MEM
16.2	Operation	At conveyor nip points, the conveyor will be guarded and securely fenced and locked. Sections under roads will be fenced and gated. The remainder will have a full length emergency stop cord. The conveyor line will be travelled and inspected before start up. Full fencing may be provided if safety concerns arise during operations. Prior to operations commencing, the conveyor installation will be inspected for safe access and additional fencing provided as necessary.	OSG	MEM
17. FOLLOW-UP MONITORING				
17.1	Operation Closure	Follow-up monitoring will be undertaken as proposed to determine the accuracy of predicted effects and efficacy of mitigation.	OSG	CEAA