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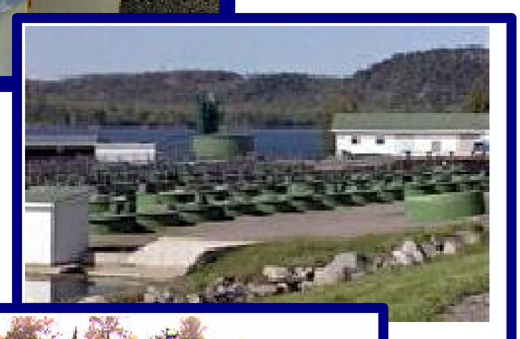
ENVIRONMENTAL ASSESSMENT OF LAND-BASED FRESHWATER AQUACULTURE FACILITIES: GUIDELINES FOR THE CONSIDERATION OF ENVIRONMENT CANADA EXPERT INFORMATION



Environmental Assessment Section
Pollution Prevention Division
Environmental Protection Branch
Environment Canada
Atlantic Region

June 2001

Canada

ENVIRONMENTAL ASSESSMENT OF LAND-BASED FRESHWATER AQUACULTURE PROJECTS: GUIDELINES FOR CONSIDERATION OF ENVIRONMENT CANADA EXPERTISE

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This guidance document will be reviewed and updated on a regular basis. Updates will be required to ensure the guidance reflects the most recent research findings, changes in aquaculture technologies and practices, and new legislative and policy initiatives. Comments or feedback on the content and format are welcome and will be incorporated into future revisions as appropriate.
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1.0 ENVIRONMENT CANADA AND THE ENVIRONMENTAL ASSESSMENT OF LAND BASED AQUACULTURE FACILITIES

1.1 Introduction

Land-based freshwater aquaculture involves the culture of fish species in a variety of structures including ponds, hatcheries, and holding tanks. These facilities typically offer better control over the culture environment and discharges to the ambient environment than open-water operations. Land-based operations utilize either flow-through re-circulating water processes with water withdrawn from surface or underground sources. In a flow-through system, water is drawn from a source, circulated through the holding tanks or ponds and directly or indirectly released into a receiving waterbody. Recirculating facilities reuse some portion of the water a number of times before discharging. Settling ponds, filtration systems, and constructed wetlands may be utilized to treat the effluent before it is discharged to a receiving waterbody. Much of the freshwater aquaculture activity in Canada presently involves the rearing of salmonid species, primarily rainbow trout, brook trout, and Arctic char.

Environmental management of aquaculture projects from design through decommissioning, is a shared responsibility of both industry and government. Environmental assessment is a management tool directed at identification, analysis, and mitigation of potential impacts on important environmental values. An environmental assessment conducted under the *Canadian Environmental Assessment Act* is also directed at investigating how the environment (e.g. water quality, weather) can impact the project.

Environment Canada participates in the environmental assessment of freshwater aquaculture projects as an expert department with relevant information and knowledge. Project proponents and environmental assessors are encouraged to consult these guidelines to help ensure that this knowledge and information is incorporated early in the planning and design of a project and the conduct of an environmental assessment. Application of best practices and avoidance of environmental impacts ultimately contributes to the success of the industry.

1.2 Environment Canada's Mandate and Expert Knowledge

Environment Canada's expertise stems from the Department's responsibility for administration of legislation and the associated regulations that are applicable to freshwater aquaculture projects. Environment Canada is also the lead federal department in promoting a variety of federal environmental policies and programs relevant to this industry. The potential applicability of Environment Canada's legislated mandate to the different phases of an aquaculture project is summarized in Table 1.

Table 1
Summary of Environmental Legislation and Potential Areas of Applicability

Legislation	Potential Applicability to Aquaculture
Canada Wildlife Act Enables EC to provide information on species at risk. Regulations under the Act allow for the designation and management of National Wildlife Areas.	• Permits are required for any activities that take place in National Wildlife Areas.
Canadian Environmental Protection Act Enables control of such environmental issues as: • Toxic substances • Pollution prevention and control at federal facilities • Nutrients • Disposal at sea	• Identification of chemical products to be used to determine applicability of New Substances Notification Regulations; • Disposal at sea of dredged material, sludge and fish waste; • Control of toxic substances (pesticides, cleaning agents, etc.).
Department of Environment Act Enables the department to advocate the preservation and enhancement of the natural environment, including water, air and soil; renewable resources, migratory birds and other non-domestic flora and fauna.	• Broad applicability to the provision of advice and promotion of best practices in all phases of aquaculture.
Fisheries Act (Section 36-3) Prohibits deposition of deleterious substances into waters frequented by fish.	• Erosion and sedimentation during construction; • Spills and releases of hazardous materials.
International River Improvements Act The Minister may issue a license for any projects involving construction work (temporary or permanent) that potentially have an impact on water levels and flows in rivers that flow across an international border.	• Predicted hydraulic impacts on river at various locations proposed - location with least impacts preferable; • Predicted short term hydraulic impacts of any temporary works to construct the project.
Migratory Birds Convention Act Allows for the conservation and protection of	• Permits are required for certain activities that take place within migratory bird sanctuaries;

Legislation	Potential Applicability to Aquaculture
migratory birds and associated habitats. The Act and its Regulations provide for designation and management of migratory bird sanctuaries, establishment of hunting restrictions and placement of controls on impacting (e.g., killing, taking, injuring) birds, eggs, or nests for purposes other than hunting. Migratory birds include those species described in the CWS Occasional Paper *Birds protected in Canada under the Migratory Birds Convention Act*."	• Proximity to areas where concentrations of breeding, staging, or overwintering migratory birds are known to occur; • Disturbance during breeding, nesting and other sensitive periods; • Control and deterrence of birds attracted to the site. Permits may be required.

Environment Canada is also the lead federal department in promoting a variety of federal policies and programs concerning the environment and the federal government's commitment to environmental protection and conservation including:

- The "Toxic Substances Management Policy" outlines a framework for making science-based decisions on the effective management of substances that could harm the environment or human health;
- "Pollution Prevention - A Federal Strategy for Action", "A Guide to Green Government" and "Code of Environmental Stewardship" are among the policy and program documents outlining the federal government's emphasis on prevention of pollution at the source and sustainable development principles;
- The “Federal Policy on Wetland Conservation” which has the objective of promoting the conservation of Canada’s wetlands to sustain their ecological and socio-economic functions now and in the future.

These guidelines relay Environment Canada’s recommendations on information to be presented, potential environmental effects to be addressed, and mitigation measures which should be considered in the environmental assessment of each phase of a freshwater, land-based aquaculture project. Accordingly, Sections 2.0, 3.0, 4.0, and 5.0 are specific to each of the individual project phases (i.e. siting and design, site preparation and construction, operation and maintenance, decommissioning). Section 6.0 focuses on how the environment and changes in the environment can impact aquaculture facilities. Section 7.0 discusses impact prediction and follow-up plans. These guidelines also emphasize the value of taking proactive siting and design measures that will minimize the potential for impacts and allow the environmental assessment to be focused accordingly.

2.0 SITE SELECTION AND FACILITY DESIGN

2.1 Site Selection

Environmental conditions present constraints and opportunities related to siting a land-based aquaculture facility. Consideration of environmental conditions is important to anticipating and avoiding many of the adverse impacts that could result from establishing an aquaculture project at a particular site. An understanding of weather, hydrology (surface waters and groundwater), other human activities in the area, environmental quality, migratory birds and species at risk

must be applied to the assessment of an aquaculture project. Environment Canada is in possession of knowledge and information on these factors.

In support of an environmental assessment, the location of the proposed project should be clearly identified on good a quality topographic map. Both receiving waters and process water sources, as well as any other watercourses in the area should be clearly marked on the maps. A site sketch should be prepared which includes the coordinates (latitude and longitude) and layout of the facility to allow reviewers to visualize the proposed development.

2.1.1 Past and Existing Activities Influencing the Site

The assessment should document and take into account the following potential influences on the project and the environment related to past, existing, and reasonably foreseeable human use of an area:

- Areas of known or suspected contamination including exposed acid generating rock;
- Existing infrastructure;
- Proximity of other aquaculture operations;
- Resource uses and activities that result in effluent discharge and contaminated drainage;
- Resource uses and activities that place a demand on the water resource.

2.1.2 Hydrology

Water requirements for land-based hatcheries will vary depending on the size of the facility and whether recirculating technology is used. Water supplies can be obtained from both surface water and groundwater sources and they are often used in combination, depending on water quality, temperature requirements and seasonal availability. The following hydrological factors should be investigated and documented as part of the assessment:

- Description of general hydrogeological characteristics of the area;

- Potential surface and/or groundwater sources for water supply, including estimated reserve and recharge rates. Other water users in the area should be identified;

- Flood potential of the development site, noting historical trends;

- Soil type (permeability and stability) and geological characteristics where ponds will be located (Rocky, sandy or gravel soils, highly fissured tills, notably limestone substrata, or old stream beds should be avoided);

- Risk of acid drainage from exposure of acid-forming rocks (e.g. pyrrhotite).

2.1.3 Water Quality

A facility must have access to an uncontaminated water source for production and it is equally important that the water quality at the discharge point not be degraded. Baseline information should be collected and evaluated in relation to predicted changes resulting from discharges from the proposed aquaculture facility or other inputs to the receiving waters. Canadian Council

of Ministers of the Environment (CCME) Guidelines for Freshwater Aquatic Life and other published water quality objectives should be referenced as appropriate. Among the considerations for baseline studies and ongoing monitoring programs are:

- Dissolved oxygen (DO) is the most important parameter influencing fish productivity. In general for salmonids, DO levels should be above 5 ppm;
- Seasonal temperatures (water and air). Water temperature affects the activity, behavior, feeding, growth, and reproduction of all fishes;
- Levels of pH outside the normal range of 6.5 and 9.0 can result in slower fish growth, reduced reproduction, and increased susceptibility to disease;
- High levels of suspended solids can decrease water clarity and impair invertebrate and vertebrate feeding. Applicable guidelines or objectives for turbidity and suspended solids must be met (e.g. CCME Guidelines, Ontario's Provincial Water Quality Objectives which require there not be a change in secchi disk readings of greater than 10%);
- Phosphorus is one of the most important nutrients in freshwater systems. Excessive nutrient releases can lead to hypernutrification (increase in dissolved nutrient concentration) and/or eutrophication (increase in primary production). This can contribute to the proliferation of phytoplankton blooms and subsequent die-offs that lead to depletion of DO.
- Other nutrient and biological related characteristics influencing water quality including:
  - Nitrates/nitrites and ammonia;
  - Biological oxygen demand (BOD);
  - Vegetation cover and general riparian habitat;
  - Propensity for algal blooms;
  - Chlorophyll a concentration and distribution;
  - Types and abundance of biological communities;
  - Fish community characteristics including fish types and abundance and feeding habits.

If there are other aquaculture operations, agricultural and/or other industrial activities present (or if there may be in the future), the assimilative capacity of the receiving water should be considered. Assimilative capacity can be determined by a number of physical, chemical and biological factors. Physical factors include river or lake-water volume, flow rate management, and sediment volumes. Chemical factors may include nutrient levels (such as phosphorus) and toxic chemicals from industrial discharges. Biological factors include plant composition and abundance; fish types and abundance; and, the composition of invertebrate populations.

2.1.4 Migratory Birds, Species at Risk, and their Habitats

Interactions with and conflicts between aquaculture operations and wildlife species have become significant management issues for proponents and regulatory agencies. Concentrations of easily accessible fish are a tempting food source for a variety of migratory birds and mammals. At the same time, the expanding aquaculture industry is placing an increased demand on the habitat of species at risk and migratory bird habitat important for feeding, staging, wintering and nesting.

Proponents are encouraged to consult with the local Canadian Wildlife Service (CWS) office of Environment Canada during the site selection process so that the potential for interactions is reduced and any negative impacts on migratory birds and species at risk are minimized. Avoidance of any area where migratory birds and species at risk may be impacted by the construction and operation of an aquaculture project is the preferred approach. In support of such a strategy, the description of the proposed project area should include information on the terrain, biological settings, habitat types, and wildlife use.

The site map should identify all environmentally significant areas and other types of protected areas within a 1 km radius of the proposed site that have been established, in part, to protect migratory birds, species-at-risk and their habitats. Among the designated areas that should be identified are:

- Migratory Bird Sanctuaries (http://www.ns.ec.gc.ca/wildlife/wetlands.html);
- National Wildlife Areas (http://www.ns.ec.gc.ca/wildlife/wetlands.html);
- Western Hemisphere Shorebird Reserve Network sites (http://www.ns.ec.gc.ca/wildlife/wetlands.html);
- Ramsar Sites, as identified by the Ramsar Convention (Convention on Wetlands of International Importance Especially as Waterfowl Habitat) (http://www.ns.ec.gc.ca/wildlife/wetlands.html);
- Important Bird Areas (http://www.bsc-eoc.org/national/cmmn.html or http://www.ibacanada.com/).

2.1.4.1 Migratory Birds

Attention should be given to:

- Species of migratory birds likely to be present, their seasonal occurrence, relative or absolute abundance, and population trends;
- Areas of migratory bird concentration such as breeding areas, colonies, spring and fall staging areas, and wintering areas;
- Ongoing or proposed recovery, rehabilitation, remediation, or improvement plans for migratory birds. Recovery teams should be consulted;
- Food sources and/or feeding areas for migratory birds.

2.1.4.2 Species at Risk

A number of provincial jurisdictions have enacted regulatory protection for species at risk and the proposed federal *Species at Risk Act* will provide protection of both those identified plants and animals and will provide a legal definition of their habitat. This makes it is very important to determine whether any species at risk are using the proposed site either permanently or temporarily. Attention should be given to:

- Presence of species at risk listed with, or under review by, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), under provincial designations, and species ranking S1, S2, or S3 by the Nature Conservancy ranking system (used by Conservation Data Centres).
- Information on species listed by COSEWIC can be obtained at http://www.speciesatrisk.gc.ca/Species/English/SearchRequest.cfm;
- Ongoing or proposed recovery, rehabilitation, remediation, or improvement plans for species at risk. Recovery teams should be consulted;
- Food sources and/or feeding areas for species at risk.

2.1.5 Wetlands

A wetland is described as land in which the water table is at the surface or which is saturated for a long enough period to promote wet-altered soils and water-tolerant vegetation. Wetlands, including bogs, fens, marshes, swamps, and shallow open water, are highly productive natural systems and provide habitat for a great diversity of vegetation and wildlife in Canada. Efforts should be directed toward avoiding any type of activity in or near wetlands. In cases where federal lands and/or money are involved in helping an aquaculture project proceed, the goals of the *Federal Policy on Wetland Conservation* (Environment Canada, 1996) should be considered. This policy has a stated goal of no net loss of wetlands or wetland functions such as providing habitat, flood control and protection, water quality improvement, groundwater upwelling or recharge areas.

The CWS Wetlands Environmental Assessment Guideline (Milko 1998) identifies information requirements and considerations for an ecosystem approach to assessing effects on wetlands. Reference to the guideline will help to identify issues and concerns, as well as mitigation strategies.

2.2 Facility Design

Technologies and infrastructure used for the land-based culture of finfish species can take many forms. When choosing a location for a proposed aquaculture operation, the proponent must ensure that the project fits the conditions of the site. The environmental assessment should include a review of preliminary design details including identification of the species to be cultured (provide common and scientific names), water supply, effluent treatment options, supporting infrastructure and equipment. Opportunities for incorporating mitigative measures into the design should also be discussed such as those that will reduce interactions with migratory birds and impacts on species-at-risk.

2.2.1 Water Supply

Structures and technologies to be used for processing the water through the proposed system including provisions for treating and monitoring should be discussed. Such a discussion should include:

- An estimate of proposed water withdrawal rates (L/min or m^3/d);
- Locations of the water intake and release structures (shown on the site map);
- Equipment needed to treat and monitor incoming water to meet required culture conditions (e.g. temperature, aeration, conditioning, etc.);
- Whether a recirculating or flow-through system (or a combination) will be utilized.

2.2.2 Effluent Treatment

As part of the environmental assessment, the proponent should include details on the following:

- Type(s) of wastewater treatment to be used;
- Disinfection technique to be used, if required;
- Proposed effluent quality objectives to be met;
- Proposed monitoring plans;
- Provisions for the collection and treatment of sludge material and site drainage;
- Management plans for overflows and system upsets.

A variety of technologies are available for the treatment and containment of solid and liquid wastes generated as part of land-based aquaculture operations. Effluent volumes, cost, and available land space are often primary considerations in choosing treatment systems. Among the technologies that can be considered are:

- Recirculating systems. In a recirculating system a portion of the process water is reused a number of times, after filtration or other treatment, before being finally discharged;
- Filter or screening systems. Biological filtration removes suspended solids through bacterial action while mechanical filters provide a physical barrier (e.g. sand, screens) that traps particulate matter;
- Settling ponds. Settling ponds are one of the simplest and most common structures used for particulate removal. The velocity of the effluent is slowed in a large tank or pond and the particulate matter is allowed to settle to the bottom for later removal. The following factors should be considered when evaluating the suitability of settling ponds:
  - Ponds should be adequately sized to handle the flow from the facility along with storm events (e.g. 1 in 10 year storm) and site runoff. Flow into the ponds should be evenly distributed with minimal turbulence and resuspension of settled material;
  - Ponds should be lined with an impermeable material such as compacted clay, concrete or synthetic materials;

– Sludge should be removed from the ponds at least once per year. Where possible two ponds should be constructed so that one can continue to receive wastewater while the second one is being cleaned and drained.

- Constructed wetlands and greenhouses which take up excess phosphorus;
- Other treatment processes include ultraviolet radiation, aeration and ozonation.

2.2.3 Related Infrastructure and Equipment

Wherever possible, existing infrastructure at the site should be incorporated into the operation. Any upgrades and alterations should be planned to minimize environmental disturbance. The need for or presence of the following should be discussed:

- Access roads, ramps, docks;
- Storage and processing facilities;
- On-site personnel accommodations;
- Equipment for harvesting and on-and off-loading.

2.2.4 Reducing Interactions with Migratory Birds

Even if migratory birds are not present at the time an aquaculture facility is established, they may be attracted to a site if it provides a food source, a safe area for breeding and loafing, or shelter. Design options and alterations to reduce the attractiveness of a facility and the potential for depredation include:

- Eliminating safe perching places;
- Installing tank covers, predator nets, or other barrier systems (netting, streamers, wires) over grow-out and containment units;
- Placing growing units at a sufficient depth below the water's surface in ponds;
- Locating young/small stock where they are inaccessible to predatory birds.

Table 2
Siting and Facility Design
Summary of Impacts and Mitigative Measures

Potential Effects	Mitigative Measures
Impacts on quantity and quality of groundwater and surface water supplies and receiving waters.	• Identify potentially contaminated water sources and avoid siting where conflicts with other water users may arise or where there are already several sources of discharge into the receiving waters including other aquaculture facilities (Sec. 2.1.1); • Undertake baseline water quality and watershed characterization studies to identify limiting factors related to carrying capacity and to determine treatment or conditioning requirements for culture water (Sec. 2.1.3);

Potential Effects	Mitigative Measures
	• Ensure groundwater requirements will not exceed the natural rate of replenishment or recharge (Sec. 2.1.2, 2.2.1); • Ensure surface water requirements and effluent quality will not significantly impact on downstream riparian uses and fish habitat, particularly under low flow conditions (Sec. 2.1.3, 2.2.2); • Identify parameters for a water monitoring program to detect changes in water quality early (Sec. 2.1.3, 2.2.2); • Evaluate wastewater treatment technologies (Sec. 2.2.2).
Modification, Degradation, and Loss of Habitat and disturbance of migratory birds and species at risk.	• Avoid siting near environmentally significant areas (i.e. protected wetlands, Migratory Bird Sanctuaries, National Wildlife Areas), areas where species at risk are present, and areas supporting high concentrations of migratory birds (Sec. 2.1.4, 2.1.5); • Incorporate design features to make the site less attractive to migratory birds and other predators (Sec. 2.2.4).

3.0 SITE PREPARATION AND CONSTRUCTION

3.1 Description and Schedule of Activities

A variety of support facilities and structures such as access roads, wells, trenches, fences, rearing and holding tanks, settling ponds and effluent treatment facilities are associated with an aquaculture operation. Preparing a site for construction can involve clearing and grubbing of vegetation, excavation, and grading and infilling. In-water work can include the installation of water intake and discharge structures. Construction activities can require the use of a variety of hazardous materials and can result in the subsequent accumulation of hazardous and non-hazardous waste. The following should be considered in support of an environmental assessment:

- Time-frame and schedule for site preparation and construction activities;
- Areal extent of any disturbance both on-land and in-water;
- The methods, materials, and equipment to be used for on-site activities;
- Provisions for storage and handling of materials and response measures for spills or releases;
- Provisions for waste management.

3.2 Environmental Effects

Machinery, equipment and personnel associated with construction activities represent sources of sensory disturbance (e.g. noise, light) to migratory birds and species at risk. Depending on the time of year, the result can be altered feeding patterns and disrupted breeding and staging activities. Certain species (e.g. cliff nesting birds, colonial birds) are prone to panic. Even temporary abandonment of nests by adult birds as a result of such sensitivities can cause an increase in predation of unguarded eggs and young. Land disturbance leading to erosion can degrade water quality and some materials and wastes pose hazards to environmental quality, migratory birds and species at risk.

3.3 Building Best Practices into Project Management

3.3.1 Disturbance of Migratory Birds and Species at Risk

Strategies for enabling compliance with the *Migratory Birds Convention Act (MBCA)* and mitigating impacts on migratory birds and species at risk should include:

- Maintaining a buffer zone where no activity occurs in proximity of important habitat;
- Scheduling site preparation and construction activity outside of the breeding season for migratory birds and species at risk;
- Avoiding concentrations of migratory birds when using boats and other machinery;
- Educating construction personnel in the identification of and measures for avoiding the disturbance of migratory birds and species at risk.

3.3.2 Land Disturbance

An erosion and sedimentation control plan should be developed and implemented to facilitate mitigation of adverse impacts on water quality. The plan should demonstrate a preventative approach with the first priority placed on avoidance followed by control and treatment of sediment-laden water. Elements of the plan should include:

- Scheduling of construction activities to take into account seasonal constraints and to avoid periods of heavy precipitation (e.g. consult extended range [3-5 days] and monthly/seasonal forecasts);
- Installing sedimentation control structures prior to any land disturbance;
- Directing sediment-laden water to settling ponds;
- Maintaining vegetated buffer zones between disturbed areas and waterbodies or wetlands;
- Designing of access roads and structures to maintain natural water flow. Existing drainage patterns should be maintained and ditches should not be permitted to flow directly into any surface water;
- Monitoring suspended solids levels prior to releasing water from settling ponds or other sediment control structures to verify that no further treatment is required.

3.3.3 Management of Materials and Waste

Construction activities may involve the use of hazardous substances such as petroleum products, fresh concrete, concrete additives, preservatives, paints, solvents, process chemicals, and cleaning agents. Hazardous wastes such as waste oil and residual chemicals may be generated as a result of using these products. A strategy for the management of materials and waste should reflect a consideration of the following best practices:

- Placing a priority on using the least toxic products;
- Storing materials in a designated area away from any water bodies/wetlands or flood prone and in accordance with applicable regulations;
- Refueling and maintaining equipment and machinery in a designated area away from any water bodies/wetlands or flood prone areas;
- Applying preservatives in a designated area in accordance with manufacturer's instructions;
- Developing contingency plans to enable a quick and effective response to an event following the accidental spill or release of hazardous materials and substances. All spills and releases should be reported to the appropriate 24-hour emergency response line;
- Incorporating careful planning to reduce the volume of surplus and waste material (e.g. order only the amount of material that is required, purchase pre-fabricated structures);
- Placing a priority on opportunities for reuse or recycling of products. Waste and surplus material should be disposed of at approved sites and in accordance with applicable regulations.

Table 3
Site Preparation and Construction
Summary of Impacts and Mitigative Measures

Potential Environmental Effects	Mitigation Measures
Impacts on Migratory Birds, Species at Risk (Sec. 3.2).	Avoiding Disturbance of Migratory Birds and Species at Risk (Sec. 3.3.1): • Schedule activities to occur outside sensitive periods (e.g. nesting, migration); • Establish and maintain a buffer zone around sensitive areas and species; • Minimize areal and temporal extent of disturbance; • Educate construction personnel on how to reduce disturbance.
Erosion and sedimentation reduced water and habitat quality (Sec. 3.2).	Avoiding and Minimizing Erosion and Sedimentation (Sec. 3.3.2): • Coordinate activities within seasonal constraints; • Consult extended range weather forecasts; • Predetermine shutdown criteria for precipitation events; • Minimize areal and temporal extent of disturbance of soil and vegetation; • Maintain vegetated buffer zones; • Stabilize disturbed areas as soon as possible; • Direct sediment laden water to settling ponds or other control structures; • Monitor sediment and water and treat as required prior to release.
Spills or Releases of Hazardous Products (Sec. 3.2).	Management of Materials and Wastes (Sec 3.3.3): • Consider use of less-toxic alternatives to hazardous products; • Designate areas for storage and refuelling, application of chemicals (e.g. preservatives) with proper containment that are away from watercourses/wetlands; • Prepare an Emergency Spill Response Plan; - Contain spills and treat contaminated soil and water as required.
Contamination/Degradation From Solid Waste Accumulation.	Management of Materials and Waste (Sec. 3.3.3): • Order only the amount of materials necessary and purchase pre-fabricated structures where possible; • Collect all surplus material and look for opportunities for reuse and recycling; • Ensure material is disposed of at an approved location and in accordance with regulatory requirements. •

4.0 OPERATION AND MAINTENANCE

As part of the ongoing operation and maintenance of aquaculture operations, there are continual inputs of food, medications, and chemicals into the system. Consequently, large volumes of unconsumed feed, residual chemical substances and faecal and metabolic matter may be present in effluent discharged from a facility. In sufficient quantities these materials will contribute to the degradation of the ambient water quality by decreasing dissolved oxygen content and increasing the concentrations of suspended solids, dissolved phosphorus and nitrogen compounds, ammonia and organic matter. Other periodic or intermittent operational and maintenance activities which could generate adverse environmental effects include harvesting, cleaning of equipment, re-application of preservatives, and removal of sludge from settling ponds. The assessment should include a description of operational and maintenance procedures that incorporate best management practices and opportunities for pollution prevention and reduction.

4.1 Management of the Cultured Species

The assessment should include a brief description of the production and management of the cultured species during operation, including:

- The proposed stocking rate (also called stocking density) should be discussed with reference to any relevant guidelines;
- Initial weight, and anticipated harvest weight (in kg);
- Estimated mortality rate (percent per year).

4.2 Feeding

Developing and maintaining an efficient feeding regime requires an understanding of interactions and relationships between fish size, feed type and formulation, feeding rates and methods, and water temperature. The selected feeding regime has important implications for environmental impacts.

4.2.1 Overview of Environmental Impacts Related to Feeding

Two general types of waste are generated from feeding fish:

1. Solid material, settleable and suspended solids which may include faeces, uneaten feed, organic matter, and nitrogen-phosphorus containing compounds.

2. Soluble material including dissolved nitrogen and phosphorus that originates from fish metabolism and the breakdown of wastes. In their soluble form these nutrients are difficult to remove from wastewater. Nitrogen tends to be quickly transported out of the system in soluble form while phosphorus is more readily incorporated into the sediments and slowly released in soluble form.

Dispersion of wastes depends on the current regime and water depth at the discharge point. Abundant or extensive waste accumulation can have adverse effects on the aquatic environment and should be addressed in the assessment. An increase in dissolved nutrient concentration can lead to hypernutrification and contribute to eutrophication of the surrounding freshwater environment. Eutrophication is the increase in primary production (as measured by chlorophyll α and algal biomass) and often results in growth and subsequent die-off of noxious algae or excessive growth of higher plants.

Phosphorous is most often the limiting nutrient for biological production in freshwater systems. That is, if all available phosphorous is used up, plant growth will cease, regardless of the amount of nitrogen and other nutrients available. If more phosphorus becomes available from feed waste generated by aquaculture activities, this would allow plants to assimilate more nitrogen before the additional phosphorus is depleted. Consequently, if sufficient phosphorus is available, high concentrations of nitrates will lead to increased phytoplankton (algae) and macrophyte (aquatic plant) production. Phosphorus levels should be managed to avoid algal blooms and associated die-offs, and should meet applicable permit requirements or water quality guidelines (e.g. Ontario's Provincial Water Quality Objectives state phosphorus should be less than 0.03 mg/L).

Another problematic soluble material generated by fish farms is ammonia which fish excrete into the water as waste. Ammonia levels in excess of the recommended limits may harm aquatic life by altering metabolism or increasing body pH (National Research Council, 1979). Dangerously high ammonia concentrations are usually limited to water re-circulation systems found in some land-based saltwater systems, but ammonia should also be regularly monitored in cage facilities. Recommended levels of ammonia concentrations depend on the salinity, temperature, and pH of the water.

4.2.2 Utilizing Optimized Feed Formulations

Fish feeds are specially formulated to ensure nutritionally and economically optimal fish growth. Feeds that are nutrient-dense and high in energy have improved feed conversion efficiencies (the amount of feed required to produce one pound of cultured fish) that result in less waste. The environmental assessment should demonstrate a commitment by the proponent to selecting feed formulations that can have the least environmental impact. Among the factors to be included in the discussion:

- Utilizing feeds with low nitrogen and phosphorous content which achieves a higher feed conversion efficiency ratio and a reduction in excreted waste. Feed that is high in lipids can also reduce nitrogen excretion;

- Supporting and where possible participating in research directed toward reducing the percentage of fishmeal in cultured fish. This helps relieve the pressure on wild fisheries which comprise a large proportion of fishmeal and can reduce the phosphorus content. Substitutes that might be considered include soybean meal, corn gluten meal and blood meal;

- Ensuring that the feed formulations are suited for the age-classes of fish being cultured. Different nutritional requirements at different stages of development necessitates continual re-evaluation of nutrient content of the feed;

- Utilizing feeds with a low percentage of fines (inedible pieces of feed) and free of low digestibility binders and fillers;

- Ensuring proper storage to maintain the nutritional quality and palatability of feed. Several key nutrients (particularly vitamin C) will degrade over time.

4.2.3 Utilizing Optimized Feed Types

Fish feed is available in a variety of types with either wet or dry, and floating or sinking pellets being the most common. Characteristics to consider in feed selection include pellet formation, size, digestibility, and palatability. Selection of the feed type, in terms of physical attributes, can also greatly influence the amount of waste produced at a facility and the resulting environmental impacts. The following factors should be considered in selecting feed types:

- Floating (extruded) feeds allow the operator to visually monitor the fish as they come to the surface to feed. With sinking feeds, it is more difficult to determine the proportion of fish that are feeding;

- Floating and dry pellets have greater stability which enables the pellet to remain intact longer;

- Selection of appropriate pellet size for the age and size of the fish will help reduce feed wastage.

4.2.4 Optimization of Feeding Regime and Techniques

The amount of feed, the rate and manner at which it is given to cultured fish can influence the amount of waste produced. As with feed particle size, feeding regimes will vary with different species, age, size, sexual development, health of the fish, and the time of year. The following factors should be considered in optimizing feeding regimes and techniques so as to reduce potential environmental impacts:

- Water temperature and the amount of daylight (or artificial light) are the primary influences on feeding. In a hatchery environment, the operator has the ability to control these parameters to optimize conditions to suit the physiological stages of the fish;

- Adherence to manufacturer’s guidelines and feed charts for recommended feeding rates;

- Evaluation of different feeder types and feeding techniques:

  - *Hand feeding* allows the operator to better monitor the behavior of fish and more quickly detect health problems and stress factors;
  - *Automated feeders* can be set to dispense feed more evenly over the entire water surface;
  - *Demand feeders* help to ensure fish eat when they are hungry and can reduce feed wastage.

- Avoiding the use of mechanical feeders that produce fines, or consider the use of on-site re-pelleting technologies (sieving the pellets through a vibrating screen and then re-pelleting the collected dust and particles);

- Feeding smaller amounts more often to prevent overfeeding;

- Use of technologies such as video surveillance or hydroacoustics that can detect when feed has reached the bottom indicating that fish are satiated.

4.3 Chemical Use

A variety of chemical substances are used during the operation of an aquaculture farm. The purposes for chemical use include water treatment, enhancement of natural aquatic productivity, feed formulation, manipulation and enhancement of reproduction, growth promotion, health management, and added value to the final product. For these guidelines, chemical substances are divided into the categories outlined in the Table 4 below:

Table 4
Types of Chemicals Used in Aquaculture

Medicinals	Often called chemotherapeutics, therapeutants, or pharmaceuticals. Includes: • Antibiotics - used to treat infections caused by variety of bacterial and fungal diseases (commonly administered by mixing with feed or applying topically in a bath); • Vaccines - administered to produce or increase immunity to particular diseases. Approved by the Veterinary Biologics Division of the Canadian Food Inspection Agency; • Anaesthetics - used to sedate or immobilize during handling or transportation.
Additives	• Water treatment and conditioners - include flocculants and conditioners to reduce turbidity. Lime may be used to control pH of the water and zeolites may be used to remove ammonia; • Fertilizers are used during pond preparation to enhance production of natural food in the ponds; • Vitamins - vitamins C and E are often added to fish feed; • Hormones - added to fish feeds to control sex, growth rates and ovulation; • Colourants - dyestuffs and organic pigments added to feed to produce artificial colouration in the tissue and flesh.
Pesticides	Chemicals used as anti-foulants, such as insecticides, algaecides, fungicides, herbicides, parasiticides. Pesticides must be approved by the Pesticide Management Regulatory Agency (PMRA) of Health Canada.
Disinfectants	Chemicals used primarily for cleaning growing structures and other equipment. The most common disinfectants used are chlorine and chlorine compounds and formaldehyde and iodine derivatives.

Others	Preservatives and other chemicals associated with structural materials such as plastics, and some metal compounds.

Many of these chemicals are subject to federal legislation and must be registered for use in Canada. Permits may be required for the use of some of these products at an aquaculture site. In addition, the New Substances Notification Regulations under the *Canadian Environmental Protection Act (CEPA)* require any person who proposes to import or manufacture a "new" substance (i.e. not listed on the Domestic Substances List), to provide a prior information package to Environment Canada and to allow the toxicity of the substance to be assessed

before introducing the substance into the Canadian marketplace. To determine the potential applicability of these Regulations, and to confirm approval for use of these products in Canada, Environment Canada recommends that the proponent submit:

- A complete list of products to be used at the facility;
- Material Safety Data Sheets (MSDS) for each product;
- Intended purpose of each product;
- Method of application.

The discussion on chemical use should include the potential environmental impacts of each proposed product and how best practices and water quality monitoring will be implemented to help mitigate such impacts.

4.3.1 Environmental Effects of Chemical Use

Whenever chemicals are used or applied, residual amounts of the substances may enter the environment via the effluent discharged from the facility. Chemical releases to the environment through routine inputs of feed and faeces containing various additives are likely to occur continuously at low concentrations. Chemical inputs at higher concentrations can occur during certain periods of the production cycle, such as during high growth periods and equipment cleaning. Understanding the persistence of chemicals in the aquatic environment, inhibition of microbial activity and toxicity of these chemicals to non-target species are key to assessing potential impacts. Environmental fate and persistence modelling could be used as a tool in predicting environmental concentrations of chemicals. Monitoring can then be used to verify predictions in conjunction with environmental quality guidelines to ensure resource uses are not being impaired.

4.3.1.1 Persistence in the Aquatic Environment

The persistence of chemical residues is highly dependent on the ambient environmental conditions. Many of the chemicals used in aquaculture degrade rapidly in aquatic systems while others may persist for long periods, retaining their biocidal properties. In general, residues in water are less likely to be of long-term concern depending on application rates and the persistence of individual substances. Residues incorporated into sediments however, may persist for long periods. Depending on the types of chemicals used, monitoring of sediments and sludge may be necessary prior to removal from the site.

4.3.1.2 Toxicity to Non-Target Species

Direct and indirect exposure of contaminants to other fish, shellfish, wildlife, and plant life may result when chemicals are improperly stored, handled, or applied. For example, feed mixed with chemicals may be eaten by birds or other animals. Indirect exposure of contaminants to other fish, wildlife, and plant life may occur via the release of waters containing chemicals.

Non-target species can become sick, exhibit growth or reproductive problems, or die as a result of pesticide exposure. For example, pesticides used to treat parasites may also be lethal to many other invertebrate species, and may have acute and sub-lethal effects on phytoplankton,

macroalgae, and zooplankton. Certain chemicals have the tendency to bioaccumulate, or build-up, in the tissues of species. High concentrations of contaminants in a species can sometimes lead to toxic effects on growth, reproduction and survival. As well, certain bioaccumulative contaminants can also biomagnify or increase tissue concentrations in higher trophic level species such as predatory fish, birds and mammals.

4.3.2 Management of Chemical Use

Efforts in chemical management should first be directed toward reducing overall chemical use through preventative medicine techniques and alternative treatment options combined with good husbandry and operating practices. When use of chemicals is required, procedures should be in place to ensure their safe and effective application. This includes educating site personnel on product knowledge and health and safety procedures, as well as the appropriate selection, handling and application of chemical substances.

4.3.2.1 Preventative Medicine Practices

Maintaining healthy fish stocks is helped by practicing preventative medicine. In promoting and maintaining fish health, the operator should focus on opportunities to optimize nutritional requirements, feeding strategies, and hygiene conditions. Preventative medicine practices aimed at reducing chemical use and associated environmental impacts include:

- Stocking certified fish that are free of pathogens and parasites;
- Minimizing the risk of introduction and spread of infectious disease agents, through adherence to standard fish introduction and transfer policies and protocols;
- Maintaining optimal stocking densities. Optimal stocking densities in tanks and ponds are species specific and should also be reflective of ambient environmental conditions such as oxygen levels and exchange rates;
- Separating year classes at the facility. The practice of stocking only one generation of fish at the site at one time can reduce the risk and spread of disease and parasites from parents to progeny;
- Avoiding the overuse of antibiotic drugs to prevent rather than to treat a disease. The potential for development of antibacterial resistance poses a threat to the long-term efficacy of a drug;

- Implementing a vaccination program. Vaccinations are routinely used as a tool for disease prevention and to promote good health in aquaculture species. Any vaccination program must be administered under the advice and direction of a licensed veterinarian;

- Regularly monitoring fish growth and behaviour and adjusting feeding strategies, stocking rates and treatments accordingly.

4.3.2.2 Good Operating Practices

The day-to-day activities at an aquaculture operation should be guided by good operating practices that are focused on the maintenance and management of equipment and environmental controls. Following these practices can help to reduce stress in the cultured fish

and possibly the requirements for chemical applications. Among the practices that should be incorporated into the operation of a facility are:

- Monitoring and maintaining optimum water quality parameters, including dissolved oxygen, pH, and temperature;

- Avoiding unnecessary disturbances by restricting activities around the tanks;

- Using deep, cylindrical tanks rather than shallow, square tanks;

- Avoiding unnecessary or excessive handling of fish;

- Reducing the use of algaecides by boosting oxygen levels with aerators;

- Promptly removing diseased and dying fish.

4.3.2.3 Selection and Application of Chemicals

The proper selection of chemicals can help maximize product efficiencies and reduce unnecessary waste and losses. Only chemicals approved under appropriate legislation (e.g. Pest Control Products Act) are to be used. Operators should apply each product in accordance with the schedule, dosage rates, and methods recommended by the manufacturer. Detailed records of treatments and dosages should be maintained. Additional practices that could also serve to reduce environmental impacts include:

- Applying antibiotics and some other selected treatments to clusters of tanks or ponds at the same time. This can increase the effectiveness of treatments and reduce the need for repeated applications;

- Maintaining optimum environmental conditions in the system while treating fish;

- Using the minimum amount of chemical to meet the approved objectives;

- Disposing of unused product and product containers in accordance with appropriate regulations.

4.4 Waste Handling and Disposal

In addition to the sludge which accumulates in ponds and tanks, there are other sources of solid and liquid waste which require special provisions for containment and disposal. In particular, mortalities, bloodwater and offal generated during harvesting and processing must be dealt with in accordance with a variety of municipal, provincial and federal requirements. Non-hazardous solid waste will also be generated as part of the operations of an aquaculture facility. Some of the management options which should be considered in the assessment include:

- Prompt collection of mortalities and disposal at an approved site. Composting should be considered where facilities are available;
- If harvesting takes place on-site, bloodwater and offal should be contained and disposed of in accordance with appropriate regulations;
- Purchase feed and supplies in bulk and consider opportunities for recycling and reuse;
- Store solid waste in a secure location and dispose at an approved location.

4.5 Management Options for Interactions with Migratory Birds and Wildlife

In general, the enclosed nature of many freshwater land-based aquaculture operations reduces the likelihood of interactions with migratory birds and wildlife. However, the potential for attraction of birds and depredation still exists and can result in a number of problems for the operator including the direct loss of fish from consumption, injury or stress. Predators can also cause damage to holding facilities.

The presence and activities of predatory birds in the vicinity of the operation should be regularly monitored by the proponent. The species, approximate numbers, behaviour, and time of year should be documented and proponents are encouraged to report to and seek advice from CWS as appropriate. It is important that measures be implemented as soon as the presence of birds begins to interfere with the operation of the aquaculture site. Opportunities to improve feeding and husbandry practices that will reduce the attraction of birds to the site should be considered. Scare techniques should also be considered on a contingency basis.

4.5.1 Feeding and Husbandry Practices

Reducing the attraction of birds and other wildlife requires diligent site maintenance including keeping the site free of feed waste and mortalities. A discussion of best practices should include:

- Restricting access by maintaining covers or netting on tanks and ponds;
- Promptly removing and appropriately disposing of mortalities;
- Promptly cleaning-up and securely storing solid-waste, fish feed, etc.

4.5.2 Scare Techniques

As part of the assessment, the proponent should prepare a plan for preventing bird predation at the facility. This plan should be developed in consultation with and submitted to CWS and other appropriate regulatory authorities for review. A combination of scare tactics, including visual and acoustic deterrent devices, may be necessary. Bird scaring techniques have limitations and disadvantages and in many cases, are only temporary solutions because birds soon habituate to routine disturbances.

4.5.2.1 Visual Deterrent Devices

Deterrent methods should be used as soon as birds are detected near the cage site so that feeding patterns do not become established. Among the common visual deterrents to be considered are:

- Regular human presence;
- Tethered dogs;
- Scarecrows that are moved regularly to reduce habituation;
- Flashing lights and night lighting. Such lighting arrangements may scare and confuse birds, thus reducing their ability to catch fish. However, some factors to consider before installing lighting include:
  - Aesthetic impacts and disturbance to nearby residents;
  - Lighting attracts wild fish species which may could lead to increased depredation and disease transmission.
- Water sprays, rotating sprinklers. Sprays from these devices placed around ponds or holding tanks may repel certain birds, especially gulls and herons. The water movement deters the birds, plus the sprays reduce visibility of the fish in the water.

4.5.2.2 Acoustic Deterrent Devices

Noise deterrents should be used when depredation becomes a significant problem. Habituation to repetitive disturbances can be prevented by using devices which produce a random pattern of sounds at different frequencies and intensities. These devices include whistles, sirens, firecrackers, recorded distress or predator calls, and automatic exploders. Electronic sound systems emitting a randomly selected range of sounds may also prove to be effective. A scare permit is required from the Canadian Wildlife Service (CWS) before such measures as firearms or aircraft are used. The CWS has a policy on issuing Scare Permits (Appendix 3) that requires operators to demonstrate that depredation problems were considered in the siting and planning of the operation and that other feasible deterrent techniques are employed at the site.

While many scare techniques will assist in reducing migratory bird predation, operators must also consider the potential effects of the deterrents on the target species, as well the surrounding environment. For example acoustic deterrent devices can:

- Disturb nearby residents and sensitive wildlife;
- Alter normal bird movement patterns. This could become permanent and lead to appreciable loss of access to habitat;

- Interfere with animals' communication signals and with passive listening abilities, due to "acoustic masking";

- Damage the hearing of birds and other wildlife that are not deterred by the devices.

Table 5
Operation and Maintenance Phase
Summary of Impacts and Mitigative Measures

Potential Effects	Mitigative Measures
Wastewater effluent can be high in nutrients and other contaminants leading to eutrophication and degradation of water quality (Sec. 4.2.1).	Waste Reduction: • Use optimized feed formulations which have low phosphorous and nitrogen content, low percentage of fines, high digestibility and palatability, and high conversion rates (Sec. 4.2.2); • Use optimal feed types including dry, floating, appropriately sized pellets (Sec. 4.2.3); • Implement an efficient feeding regime (including optimal techniques and frequencies) to reduce feed waste, faeces production and hypernutrification (Sec. 4.2.4); • Regularly monitor feeding behaviour and adjust feeding accordingly. Waste Management and Treatment: • Incorporate recirculating water system into facility design (Sec. 2.2.3); • Filter effluent (Sec. 2.2.3); • Discharge water through settling ponds, constructed wetland, greenhouse structure, etc. (Sec. 2.2.3); • Regularly monitor water and benthic habitat quality (Sec. 2.1.3, 2.2.3).
Mortalities, Bloodwater, Offal	Reducing Mortalities: • Maintain environmental quality at optimal levels (Sec. 2.1.4, Sec. 4.3.2); • Implement measures for preventing/reducing predation (Sec. 2.1.5, 2.2.4, 4.5); • Minimize other sources of stress (Sec. 4.3.2); • Buy feed and supplies in bulk.
Non-Hazardous Solid Waste	Management of Mortalities and related wastes: • Promptly collect and appropriately dispose of mortalities, bloodwater, offal, etc. (Sec. 4.3.2, 4,4).

Potential Effects	Mitigative Measures
	Reducing Waste Generation (Sec. 4.4): • Purchase feed and supplies in bulk; • Promptly collect and securely store waste feed and other refuse for disposal; • Consider opportunities for recycling, reuse.
Accumulation of chemical contaminants in water, sludge, and surrounding environment from the use of medicines and other chemical applications on site (Sec. 4.3.1).	Reducing Chemical Use (Sec. 4.3.2): • Minimize potential stress factors; • Stock with certified fish that are free of pathogens and parasites; • Implement an effective vaccination program; • Avoid excessive use of medicines and chemical products for preventative purposes which may build-up of resistance. Effective use of chemicals (Sec. 4.3.2): • Appropriate selection, usage, and proper application of medicines and chemical additives; • Use only approved products and only for their intended use; • Apply during optimal weather and environmental conditions; • Train facility workers in the safe and effective use of treatment products; • Regularly monitor fish health and the growing environment; • Contain broad applications as much as possible, (e.g. use tarps); • Adhere to manufacturer's suggested withdrawal times; • Ensure chemical levels are maintained below recommended CCME or provincial water, sediment and biota guidelines.
Interactions with migratory birds (Sec. 4.5).	Managing Migratory Bird Interactions: • Regularly monitor migratory bird activity; • Consult CWS; • Promptly remove and dispose of mortalities, waste feed, bloodwater, etc. (Sec. 4.4, 4.5.1); • Incorporate visual and acoustic scare techniques (Sec. 4.5.2, 4.5.3, 4.5.4).

5.0 DECOMMISSIONING

The environmental assessment should include consideration of facility decommissioning. Decommissioning should be viewed as a long-term approach to progressively restoring a site to a natural state that can support the desired natural values (e.g., fish and migratory bird habitats). This may be achieved through natural processes, the application of remedial technologies, or a combination of both. Implementation of the planning and operational practices advocated in these guidelines will help focus efforts on restoring or maintaining environmental quality once it is decided to cease aquaculture activities. The following considerations, articulated in the management goals for the operation, will help to ensure the site can be restored to the desired state:

- Good baseline information, data from monitoring programs and thorough record-keeping including chemicals, feed formulations and other products used at the site will help to identify parameters that would be candidates for ongoing monitoring and determine a time line before water and site quality might be expected to reach acceptable levels;
- Maintaining the site in accordance with applicable environmental quality guidelines and standards throughout the operational life of the facility will help minimize remedial efforts;
- Documenting the history of other activities near the site to identify other potential influences on environmental quality;
- Incorporating progressive rehabilitation within a lease site where possible (e.g. when cage sites are permanently moved to a new location, monitor and implement appropriate rehabilitative measures as soon as possible).

6.0 EFFECTS OF THE ENVIRONMENT ON AQUACULTURE ACTIVITIES

For projects subject to assessment under the *Canadian Environmental Assessment Act*, there is a requirement to consider the effects of the environment on the project. Among the environmental parameters which can impact land-based, freshwater aquaculture operations, are those related to climate, meteorological conditions and water temperature. The possible effects of changes in these factors are:

- Extreme precipitation events can cause overflow of both rearing and settling ponds;
- Dry periods can affect the distribution, availability, and quality of freshwater;
- Abrupt or changes in the ambient water temperature can induce physiological stress on fish. Changes in production levels and incidents of high mortality have been attributed to water temperatures outside the seasonal norms.

7.0 IMPACT PREDICTION AND FOLLOW-UP

7.1 Predicting and Mitigating Impacts

Impacts on the environment can be avoided or at least minimized if provisions are made to incorporate the applicable best management practices into the siting, design and operation of an aquaculture facility. However, even with implementation of best management practices, an aquaculture operation will likely result in adverse environmental impacts and these should be predicted for key environmental resources of concern. In terms of Environment Canada's mandate, and as already established, these resources include migratory birds, species at risk, and aquatic systems (e.g. water quality, benthic communities). The information needed to predict impacts on these resources of concern or Valued Ecosystem Components (VECs) has already been identified. In general, impact predictions:

- Should be presented as differences between the condition of a VEC without the project, and the condition of a VEC with the project, over a time frame that takes into account the life span of the proposed facility;
- Must take into account cumulative effects. This requires consideration of how other past, present, and reasonably foreseeable projects and activities could combine with the impacts of the proposed aquaculture project;
- Should be expressed quantitatively where practicable with uncertainties clearly recognized.

Mitigation measures that build on the best practices already integrated into provisions for project management should be identified and implemented to alleviate the predicted impacts. With attention to these guidelines, however, the potential for impacts to be significant should be minimized and the need for additional mitigation should be reduced.

7.2 Verifying Predictions and Mitigation Effectiveness

A follow-up program should be designed to verify impact predictions, to establish the effectiveness of the mitigation measures implemented and to enable timely adjustments to management of the project. In light of the uncertainties in predicting impacts and in the effectiveness of mitigation, alternate management approaches and contingencies should be reviewed and prepared. In managing a project that is allowed to proceed, impact predictions should be adjusted to reflect changes to the project (e.g. expanding the site) and changes in the environment (warmer water temperatures) that can lead to 'different' environmental effects.

Repetitive and systematic monitoring of variables indicative of actual effects is important to follow-up. Monitoring standards to be considered in designing a follow-up program that can test impact predictions and mitigation effectiveness related to aquatic systems, migratory birds and species at risk are set out as below.

7.2.1 Verifying Predicted Impacts on Water Quality

The influent and effluent can be monitored directly in a hatchery operation. A number of variables have been broadly recognized as being the most appropriate for monitoring. These

variables include: total water flow, suspended solids, pH, dissolved oxygen, biochemical and chemical oxygen demand, total nitrogen and phosphorous, and ammonia. Other parameters may be prescribed by provincial and federal regulatory agencies. Sampling should also be performed 100 m downstream (if discharged into a river) for large operations (i.e. >100,000 fish) and/or operations situated in an environmentally sensitive area (LGL Ltd., 1995).

Sampling should also take into account seasonal fluctuations in nutrient concentrations such as in the fall when water levels are low. The sampling regime should ensure that high concentrations are detected during these seasonal changes that may not necessarily fall within the summer months.

7.2.2 Verifying Predicted Impacts on Migratory Birds and Species at Risk

Regular monitoring of the behaviour and activities of migratory bird and species at risk found interacting with the aquaculture facility and in the vicinity of the site should be conducted. Monitoring may include maintaining records of types and number of birds and animals attracted to the site, and predation incidences. To monitor breeding activity of birds, nest counts can be conducted by qualified personnel during breeding season.

8.0 REFERENCES

Boghen, A. 1995. Cold-Water Aquaculture in Atlantic Canada, Second Edition. The Canadian Institute for Research on Regional Development.

Milko, R. 1998. Wetlands Environmental Assessment Guideline. Biodiversity Protection Branch, Canadian Wildlife Service, Environment Canada.

Risks to Migratory Birds: Industrial Point Sources of Toxic Chemicals in Atlantic Canada. 1995. P. Lane and Associates Limited.

Avian Predators: Frightening techniques for Reducing Bird damage at Aquaculture Facilities. 1990. Southern Regional Aquaculture Center Publication No. 401.

Milko, R. 1998. Environmental Assessment Guideline for Forest habitat of Migratory Birds.

Miko, R. 1998. Migratory bird Environmental Assessment Guideline.

Masser, M., J. Rakocy, and T. M. Losordo. 1999. Re-circulating Aquaculture Tank Production Systems - An Overview of Critical Considerations. Southern Regional Aquaculture Center Publication No. 451.

Masser, M., J. Rakocy, and T. M. Losordo. 1999. Re-circulating Aquaculture Tank Production Systems - Management of Re-circulating Systems. Southern Regional Aquaculture Center Publication No. 452.

Zitko, V. 1994. Chemicals in Aquaculture (An Overview). *In*: Proceedings of the Canada-Norway Workshop on Environmental Impacts of Aquaculture. Eds: Ervik, K. and P. Kupka Hansen og V. Wennevik. pp. 97.

Towards a Safe and Effective Use of Chemicals in Coastal Aquaculture. 1997. Food and Agricultural Organization of the United Nations GESAMP Reports and Studies No. 65.

Scarratt, D. J., R. H. Cook, R. E. Drinnan, and F. Sander. 1987. Impact of Climate on Aquaculture in Atlantic Canada. *In*: Proceedings of the Workshop on Impact of Climate on Fisheries May 11, 1987. Ed: William Richards.

Implications of Climate Change for Small Coastal Communities in Atlantic Canada. 1990. Environment Canada.