Review of Approaches for Estimating Changes in Productive Capacity from Whole-lake / Stream Destruction and Related Compensation Projects

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REVIEW OF APPROACHES FOR ESTIMATING CHANGES IN PRODUCTIVE CAPACITY FROM WHOLE-LAKE / STREAM DESTRUCTION AND RELATED COMPENSATION PROJECTS

by

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ABSTRACT

An overview of approaches used for quantifying changes in fish habitat productive capacity resulting from whole lake and stream destruction and related compensation projects was prepared. The overview examines methodologies for quantifying the relative contributions of various habitat types for a range of species. The information presented was derived from a series of case studies presented in Appendix 1 that summarize approaches applied to whole lake destruction at diamond, metal and oil sands mining operations. Approaches to quantifying gains and losses in productive capacity in association with hydroelectric facilities are also discussed. An alternative approach to addressing fish habitat compensation through Habitat Equivalency Analysis is also discussed.

The following four approaches are presented: 1. Direct measurement and summation of the production rates of all fish species present; 2. Measurement of biological indices such as biomass, catch per unit effort (CPUE), sport or commercial yield, and possibly presence-absence; 3. Measurement of surrogate habitat variables (Minns 1995); 4. Measurement of the effectiveness of compensation measures in meeting the objectives established by Habitat Managers, without focusing on a rigorous balance sheet for overall gains and losses of productive capacity of fish habitat (added for the purpose of this discussion paper).

This overview of case studies and approaches was reviewed and discussed at a workshop on July 26, 2005 involving scientists and habitat managers from Fisheries and Oceans Canada. A report on the workshop is presented in Appendix 2.

It was agreed that next steps should include a gap analysis to identify outstanding policy, operational, and science issues to be addressed and the development of a Practitioners' Guide to monitoring that emphasizes a holistic approach to monitoring compensation projects (combining HADD assessment and compensation effectiveness evaluations into a single process) and strong scientific designs (i.e., Before After Control Impact designs).

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RÉSUMÉ

Nous faisons un survol des méthodes de quantification des changements dans la capacité de production de l'habitat du poisson découlant de la destruction de la totalité d'un lac ou d'un cours d'eau, des mesures de compensation, ainsi que des méthodes de quantification de l'importance relative de divers types d'habitat pour une gamme d'espèces. L'information provient d'une série d'études de cas présentées à l'annexe 1, qui résume les approches appliquées lorsque des activités d'exploitation des diamants, de métaux ou de sables bitumineux mènent à la destruction de la totalité d'un lac. Nous examinons également les approches utilisées pour quantifier les gains et les pertes de capacité de production qu'occasionnent les installations hydroélectriques, ainsi qu'une autre approche pour établir des mesures de compensation de l'habitat du poisson (analyse d'équivalence des habitats).

Les quatre approches suivantes sont présentées : 1. la mesure directe et le cumul des taux de production de toutes les espèces de poisson retrouvées dans les eaux visées; 2. la mesure d'indices biologiques, notamment la biomasse, les prises par unité d'effort (PUE), le rendement des pêches récréatives ou commerciale et peut-être d'indicateurs de présence ou d'absence; 3. la mesure de variables subrogatives de l'habitat (Minns, 1995); 4. la mesure de l'efficacité des mesures de compensation pour ce qui est de satisfaire aux objectifs établis par les gestionnaires de l'habitat, sans mettre l'accent sur un bilan rigoureux des gains et des pertes de capacité de production de l'habitat du poisson (approche ajoutée aux fins de ce document de travail).

Ce survol d'études de cas et d'approches a été passé en revue et discuté lors d'un atelier tenu le 26 juillet 2005, auquel ont participé des scientifiques et des gestionnaires de l'habitat de Pêches et Océans Canada. Le rapport de l'atelier figure à l'annexe 2.

Les participants à l'atelier ont convenu que les prochaines étapes devraient comprendre une analyse de carence pour identifier les points stratégiques, opérationnels et scientifiques en suspens qui doivent être réglés et la préparation d'un guide de surveillance à l'intention des praticiens mettant l'accent sur une approche globale de surveillance des projets de compensation (approche combinant l'évaluation de la DPPH et de l'efficacité de la compensation en un seul processus) et une conception scientifique solide (c.-à-d. une comparaison avant-après pour établir les effets).

PART 1: REVIEW OF APPROACHES

1.0 INTRODUCTION

In Canada, a number of types of development projects can involve the "harmful alteration, disruption or destruction of fish habitat" on a relatively large scale. These projects can involve the destruction of whole lakes either by de-watering for diamond mining and related purposes, or by conversion into pit water management basins or Tailings Impoundment Areas (TIAs) for metal mines. Hydroelectric projects can involve the conversion of lake, river and stream habitats into one large reservoir, and the changes in riverine flows and water levels downstream. Open pit oil sands mining projects can involve the excavation of streams and conversion to pits left behind after mining, which then fill with water and have the potential to be re-habilitated into fish habitat.

Subsection 35(1) of the federal *Fisheries Act* stipulates that the "harmful alteration, disruption or destruction of fish habitat" (HADD) is prohibited, unless authorized under s.s. 35(2) or carried out in accordance with a regulation. This section of the *Fisheries Act* came into effect in 1977. In 1986, the Fisheries and Oceans Canada (DFO) promulgated the "Policy for the Management of Fish Habitat" (Habitat Policy) to provide policy direction and guidance for decisions to issue s.s. 35(2) Authorizations. A guiding principle for the Habitat Policy is that there is to be No Net Loss (NNL) in the productive capacity of fish habitat when s.s. 35(2) Authorizations are issued by the Department. To ensure NNL, the Habitat Policy requires that fish habitat compensation must be implemented to replace fish habitat productive capacity lost as a result of the authorized HADD. Other strategies under the Habitat Policy are directed at achieving a Net Gain in fish habitat productive capacity through a variety of stewardship and enhancement measures.

The NNL Principle was recognized, at the time, as being the appropriate principle for DFO decision-making in light of its responsibility for the dual roles of fisheries resource stewards and regulator affecting economic development initiatives. It was, however, also recognized that there existed science and management challenges to successful operationalization.

Implementation of the Habitat Policy and the NNL principle has had a significant effect on how development projects are undertaken in Canada, with respect to their impacts on fish and fish habitat. Developers also contend that implementation has had a significant effect on project costs and timelines. Developers indicate that they require more clarity in terms of specific habitat compensation expectations and would welcome DFO participation in collaborative efforts that would improve the science base for habitat compensation decision making. Developers would like to have a standardized protocol or set of protocols for estimating predicted changes in productive capacity resulting from their projects, in order to guide the development of habitat compensation measures and the design and implementation of follow-up monitoring programs.

1.1 OBJECTIVE

The objective of this review initiative is to explore approaches and options for the development of a protocol, or protocols, for estimating changes in the productive capacity of fish habitat that result from whole-lake / stream destruction and associated compensation projects.

This review paper was used as the basis for an internal DFO workshop where regional managers discussed whole-lake and stream destruction from metal mining, diamond mining, placer mining, oil sands mining and hydroelectric development projects. The purpose of the workshop was to build consensus on a consistent and transparent methodology for assessing the loss of productive capacity from whole lake / stream destruction, and an acceptable method for measuring the effectiveness of habitat compensation to achieve NNL.

2.0 APPROACHES CURRENTLY USED – CASE STUDIES

2.1 DIAMOND MINES (EXISTING AND PROPOSED)

The diamond mines case studies that were examined were: Diavik Diamond Mine; Ekati Diamond Mine; Jericho Diamond Mine Project; and the Snap Lake Diamond Project. The details of the case study reviews are presented in Appendix 1. Overview discussions of key elements from these project case studies are presented below.

In summary, the methodologies applied to quantifying habitat productive capacity losses at the northern diamond mines were based upon established approaches that have been implemented for some time in more southerly locations. A key consideration and challenge for northern mines has been the fact that Habitat Suitability Index (HSI) models are not available for many species and those that are available were developed for application to more southerly aquatic systems. The applicability of these more southerly derived models must be re-evaluated when they are used; however, such detailed knowledge of the species biology in northern environments is generally not available. The judgment of professionals retained by proponents, and scientists from government and academia when available, is used to augment the existing scientific data.

2.1.1 <u>Diavik Diamond Mine, Northwest Territories</u>

The Diavik Diamond Mine consists of both open pit and underground mining facilities. The diamond-bearing kimberlite pipes are located beneath Lac de Gras, near the shoreline of East Island. In order to access the kimberlite pipes, the construction of containment dykes in Lac de Gras was required, which had an effect on fish habitat. A *Fisheries Act s.s.* 35(2) Authorization was issued by DFO in 2000.

Construction and operation of the mine resulted in both permanent and temporary alteration of small lake and stream habitats on East Island. In addition, a long narrow bay on the East Island (North Inlet) was by a dyke at the entrance, and used as part of the water treatment system. Dyke construction and infrastructure development have affected existing fish habitat. Fish species affected by the project include Arctic grayling, lake trout, round whitefish, cisco, lake whitefish, lake chub, longnose sucker, northern pike, burbot, and slimy sculpin.

In order to determine habitat loss, a modified Habitat Evaluation Procedure (HEP) was used to assign surrogate productivity values to fish habitat affected by mine construction and operation. The HEP procedure involved the calculation of Habitat Units (HUs) by combining surrogate habitat productivity values assigned in accordance with HSI models, with habitat quantity values in the form of calculated area. Multiplying the HSI value for each species and life stage (spawning, nursery, rearing and foraging) by the area for each type of habitat in the affected aquatic environment, generated a value for the number of HUs available for each species and life stage during each phase of the project (Diavik 1998, USFWS 1981).

The number of HUs available under baseline conditions was then compared to the number predicted to be available throughout the construction/operations phase to post-closure, to calculate the overall number of HUs that were predicted be altered, lost and created by the project, taking into account losses prevented through the application of mitigative measures.

In developing HSI models, values were developed for the suitability of each habitat type, for each fish species and life stage. Values ranged from 0.0 to 1.0 with a rating of 1.0 being optimal.

In the case of Diavik, the models used to determine HSI values were based on those available in the literature. Published models were available for lake trout, Arctic grayling, longnose sucker and northern pike. The models used for these species had been developed on the basis of data for southern environments and were reviewed to confirm their suitability for application in the Arctic aquatic environment at Lac de Gras. The lake trout and northern pike models were considered unsuitable (Diavik 1998). The lake trout model was considered not suitable because the variables deal primarily with oxygen and temperature in the hypolimnion during summer and Lac de Gras does not stratify. The model for northern pike clearly shows that all life stages are dependent on the presence of aquatic macrophytes, which are limited in abundance in Lac de Gras. The existing HSI models for longnose sucker and Arctic grayling were modified to fit Arctic conditions and applied to streams (Diavik 1998).

The lack of published models meant that it was necessary to develop simple models for lake trout, round whitefish, cisco, burbot, slimy sculpin, lake chub, and lake whitefish, to fit site specific conditions (Diavik 1998). A Delphi process was applied to develop the required HSI models for large lake habitat using the professional knowledge of government scientists and community knowledge. This methodology was applied for lake trout, Arctic grayling, round whitefish, and cisco to properly assess the value of habitat types such as shoals. Response from the 15 scientists asked to participate in the Delphi process was, however, limited to three scientists but confirmed the HSI models that were applied to the project.

Field observations were used to either refine or validate existing habitat models, (e.g. spawning preferences for lake trout). Where no published information on habitat preferences in Arctic environments could be found (e.g., cisco and round whitefish preferences for rearing habitat), field observations were used to develop new HSI models. These observations were at times the only source of information available on habitat use patterns for a particular life stage of a fish species.

Confidence in the models, or specific components of models varied between fish species. A high level of confidence was placed in the lake trout and northern pike models due to the large volume of literature available detailing their habitat requirements. Confidence in the longnose sucker and Arctic grayling models was also high since they were modified from existing HEP models. A lower level of confidence was attributed to the models for round whitefish, cisco, and burbot due to the relative lack of information on their habitat requirements in Arctic waters. This is especially true for the rearing habitat requirements for all three species. To compensate for this lack of confidence in certain models, conservative HSI values were used.

Based on these approaches, habitat losses predicted to accrue from the Diavik project were:

- Loss of a total of 2,432 HUs in Lac de Gras. It was considered that fish habitat compensation measures would fully offset the loss by creating approximately 2618 HUs, a surplus of 186 HUs being created.
- A total of 0.12 HUs of the 0.15 HUs of fish habitat in streams on the East Island were to be altered. Restoration of natural drainage patterns on the East Island upon mine closure would restore 0.02HUs of migration habitat for fish. Compensation efforts in the form of improvements to the stream that drains lake w1 on the West Island would result in a further gain of 0.24 HUs of migration habitat and 0.016HUs of spawning and rearing habitat.
- Compensation for the habitat loss in the small lakes on East Island was expected to result in complete offsetting of habitat losses due to construction, once fish communities are established, resulting in the creation of 244 HUs, and a surplus of 71 HUs relative to baseline conditions.

For all species, the greatest losses were expected to occur in spawning and nursery habitat. These losses were calculated to range from 1-2% of the total available spawning and nursery habitat in Lac de Gras. It was, however, determined that spawning habitat is not limiting in Lac de Gras and therefore no special efforts to create spawning shoals were proposed in the compensation plans. Surveys had indicated that shoals were numerous throughout Lac de Gras and the creation of new shoals would only result in a modest increase in spawning habitat. Changes in rearing and foraging habitat were usually <1%.

The losses resulting from the project were primarily in deep water portions of Lac de Gras, within the boundaries of dykes created for the mine. Deep water habitat was not considered limiting in Lac de Gras and therefore the focus of compensation was on the construction of shallow water rearing habitat.

Four monitoring programs were proposed in the No Net Loss Plan for Diavik. The first three programs were planned to begin during the operations period, with some components occurring at post-closure. The last monitoring program would take place at post-closure. The four monitoring programs are as follows:

1. Monitoring the Creation of Fish Habitat in Small Lakes

- This monitoring program was identified as being contingent upon stakeholder / regulatory direction to focus on re-creating small lake habitat, as opposed to focusing on Lac de Gras.

Requirements include:

- Monitoring to verify the success of the fish habitat enhancement in lakes e11, e14 and e17, and fish habitat creation in lake e2 to confirm compensation for the altered small lake habitats on East Island.
- Monitoring surveys on these lakes, primarily involving non-lethal capture methods, 1 and 3 years after completion of habitat creation and fish transfers. Two methods for testing the long term viability of the newly created habitats are to be applied:
  1. Verifying survival of stocked fish in the new habitat; and
  2. Verifying that reproduction has occurred.

  The target end-point would be Catch-Per-Unit-Effort values comparable to those realized in a reference lake.

2. Monitoring the Effectiveness of the Migration Corridor Habitat

Requirements include:

- Verification of the effectiveness of stream habitat improvements by confirming the presence of fish in the stream during spring spawning.
- Measurements of key habitat characteristics and comparison with other reference streams in the area.
- It was recognized that a lack of habitat use by fish may not be attributed solely to habitat suitability. Fish may not use the habitat due to behavioral mechanisms such as homing, as well as the relative abundance of the particular habitat type in relation to the number of fish using the habitat. If habitat use is not detected, the habitat characteristics are to be measured and compared to habitat preference criteria. It was concluded that, if the habitat exhibits suitable characteristics, it would be considered to have achieved the objective of compensating for loss of migration corridor habitat.

3. Monitoring the Effectiveness of the External Edges of the Dykes in Providing Fish Habitat

Requirements include:

- Verification of the use of habitat on the external edge of the dykes by observing fish behavior during the fall spawning period. Target species for this monitoring effort are lake trout, round whitefish and cisco.
- Limited gill netting to confirm that the observed fish are in spawning condition.

- Verification that spawning has occurred by confirming the presence of eggs on the substrates.
- Verification of nursery, rearing and foraging habitat use by relevant life stages by direct observation and limited gill netting.

Monitoring was to begin once the first dyke was in place.

4. Monitoring the Effectiveness of the Flooded Pits as Rearing and Foraging Habitat

Requirements include:

- Verify use on the interior dykes of mine pit A21 by fish first, since it will be the first dyke to be breached on closure.
- The evaluation will be conducted three years after breaching.
- Assessment of habitat use in the pit areas will be carried out using test gill netting.
- Visual assessment of habitat features at that time, to ensure they provide the required habitat types.
- Results will be compared to baseline data from the North Inlet.

2.1.2 Ekati Diamond Mine (Original License), Northwest Territories

The Ekati Diamond Mine Project includes open-pit and underground mining facilities and a processing plant that will receive 18000 tons of kimberlite per day at maturity. The project involves stripping up to 40 million tons of waste rock per year. Current plans call for the project to extend from 1995 to 2021. The original *Fisheries Act* s.s. 35(2) Authorization (approved in 1997) called for the loss of 12 lakes as well as the interconnecting and commonly ephemeral head water streams that would be diverted. It has since been determined that one of those lakes (Leslie Lake) would no longer be disrupted (DFO 2003). Fish species affected by the loss include Arctic grayling, lake trout, round whitefish, lake cisco, lake chub, longnose sucker, burbot, slimy sculpin, and nine-spine stickleback.

In order to compensate for loss of the lakes, BHP Billiton (BHP) was to provide DFO with the sum of $1.5 million. The method used for arriving at a compensation value was described in Rescan (1995), and modified following discussions with DFO in 1996, and is outlined below:

- Using available information, the existing habitat of each affected lake was quantified focusing on lake trout spawning habitat suitability because lake trout was the predominant and most important (social, economic) species and spawning habitat was considered the most important habitat type. The cost of replacing the lost habitat, at a ratio of 2:1 was estimated at $1.5 million and this was the value agreed upon between DFO and the company.

BHP was also required to develop a Stream Habitat Compensation Plan which included a provision for the approval by DFO of: detailed fish habitat creation and enhancement plans for the Panda Lake diversion channel; the construction of fish habitat creation and enhancement structures in the Panda Lake diversion channel; maintenance of the Panda Lake diversion channel and fish habitat structures as required and monitoring the effectiveness of structures as fish habitat; and the alteration or addition to fish habitat structures, as required by DFO, to attain the objective of stream habitat compensation (DFO 1997). A monitoring system was to be set up in order to assess the effectiveness of the Stream Habitat Compensation Program (DFO 1997).

In addition, annual reporting was required by DFO including physical habitat assessments and biological evaluations. An overview of the annual monitoring program is presented in the Ekati Diamond Mine Case Study in Appendix 1 and highlights are presented below.

A monitoring program was conducted to assess the effectiveness of the Panda Diversion Channel (PDC). Dillon Consulting (1999) provides an indication of the types of monitoring undertaken. PDC monitoring in 1999 addressed the following:

- Hydrology and hydraulics;
- Fish habitat utilization;
- Fish spawning and migratory behavior;
- Fish spawning success;
- High flow vs. low flow habitat assessments;
- Stability of constructed (“as-built”) habitat and habitat enhancements, including areas of erosion and sedimentation issues;
- Benthic invertebrate and periphyton communities; and
- Performance of enhanced habitat within the channel.

Arctic grayling were found to utilize the PDC for migration and spawning purposes during the 1999 freshet period. Monitoring results also indicated the ability of Arctic grayling to migrate from Kodiak Lake through the entire length of the PDC to North Panda Lake, as well as downstream into the channel from North Panda Lake. Arctic grayling spawning activity was observed at two locations in the channel, including an area where habitat enhancements were previously constructed. Lake trout were also captured migrating into the channel from both Kodiak Lake and North Panda Lake. It was considered that this species likely utilized the PDC for forage opportunities during the spring freshet period.

An Aquatic Environmental Effects Monitoring Program (AEMP) is undertaken each year. Rescan (2002) reports on results of the program conducted in 2002. This report provides an insight into the study design and parameters for overall aquatic effects monitoring at Ekati. The following comprise the major components of the monitoring program, with further details presented in the case study in Appendix 1:

- Water quality
- Physical limnology
- Phytoplankton
- Zooplankton
- Lake benthos
- Sediment quality
- Fish communities
- Streams

- Stream flow measurements
- Daily stream flow
- Water quality
- Stream benthos

In addition to the AEMP, Jones et al. (2003) reported on a study undertaken by DFO to assess the results of the habitat compensation measures. The following methods were applied to conduct this study. Data were collected during four summers, 1998 to 2001. Twenty natural streams, distributed throughout the study area and ranging in abiotic and biotic conditions, were surveyed for: basic physical characteristics; fish community composition and abundance; and the size of young of the year (YOY) grayling just before out-migration. Reference streams were selected based on the presence of visible water in the stream channel during aerial surveys in late July. A subset of nine natural streams, more centrally located around the artificial stream, was also sampled for benthic invertebrates, water chemistry, woody debris volumes, substrate coarse particulate organic matter (CPOM), and epilithon. In addition, two streams were subjected to more intensive fisheries and invertebrate drift investigations. Reference streams were established as standards against which differences in the artificial stream could be compared. The artificial stream was sampled for all of the above parameters as well.

Basic stream surveys included stream length, slope, bankfull width and depth, and substrate composition. Substrate composition and aquatic vegetation cover were quantified along transects. Mesohabitat composition (cascade, riffle, run, flat, pool, wetland, boulder garden, and culvert) was also quantified as a percent of the length of stream. Fish community composition and timing were assessed using larval drift nets and electro-shocking. Captured fish were enumerated, weighed and measured.

In addition to the above, three replicate water samples were collected from each stream in summer and analyzed for total nitrogen and total phosphorus. Woody debris volumes were measured. Numbers of shrub stems located within 1 m of the stream bank were counted along 40–150 m transects, along each stream bank, and converted to mean densities. Transects were also used to quantify the amount of grass and shrubs along stream banks as a percentage of the ground covered. Coverage of the streambed by aquatic macrophytes and bryophytes was determined in a similar manner. Substrate, epilithon and benthic invertebrate samples were obtained. Stream temperature was monitored continuously. The amount of cover for young-of-the-year (YOY) was visually estimated and draft was measured. Total fish density and biomass were measured in late July using the three-pass electro-shocking removal method and computations were made separately for Arctic grayling, slimy sculpin and burbot. The diet of YOY grayling from the artificial stream was determined by examining stomach contents.

Bioenergetics modeling was used to assess the relative effects of temperature.

As a result of this study, the Jones et al. (2003) concluded that:

- The average mass of YOY grayling at the end of summer was lower (57%) in the artificial stream than in natural streams.
- This difference in growth, in concert with estimates of grayling density, meant that the standing crop produced in the artificial stream averaged 37% of that found in natural streams.
- A bioenergetics model indicated that cooler water temperatures in the artificial stream had limited influence on growth.
- Instead, low amounts of autochthonous and allochthonous organic matter and poor physical habitat in the artificial stream appeared to limit the productivity of benthic invertebrates and fish.
- The explicit analysis of productive capacity will allow future compensation measures to focus on deficiencies in the artificial stream and on the improvement of its productive capacity as fish habitat.

2.1.3 Ekati Diamond Mine (King Pond License), Northwest Territories

In order to facilitate the development of Misery Pit at Ekati Diamond Mine, DFO authorized King Pond for development into a mine water settling facility (DFO 2000a). Habitat alteration involved the loss of 29.15 ha of fish habitat within King Pond and the King-Cujo streams (DFO 2000a). This loss includes the loss of migratory access to King Pond habitat from downstream due installation of a dam, reduction in King Pond water quality, and the deposition of sediments (Dillon 2000). Fish species affected by the loss include Arctic grayling, lake trout, and round whitefish.

The following method was used to evaluate a fish habitat compensation proposal for King Pond:

- Habitat Zones within King Pond were delineated.
- The Weighted Suitable Area (WSA) (which represents HUs) was then calculated by multiplying the area of the Habitat Zone (in hectares) by the HSI value for each life stage of each species.
- The sum of the WSAs was then multiplied by a life stage weighting that resulted in an overall WSA score for each life stage of the pond. The sum of all WSAs represents an expression of the overall HUs for the pond. That was the number that was then used in comparison calculations for NNL.
- HSI scores for King Pond, pre-development, were calculated to be 10.75
- HSI scores for King-Cujo streams, pre-development, were calculated to be 0.04.

Compensation will not be undertaken until the completion of mining at Misery Pit (2013). This will include:

- Removal of accumulated sediment from the cobble/boulder substrate of the pond's eastern shoreline.
- Enhancement of specific pond habitat targeting an increase in depth strata and resulting overwintering capacity for future fish communities.
- Removal of sediment containment curtains and partial dismantling of containment berm to enhance substrates, increase central basin cover, and re-establish pond access.
- Re-establishment of the King Pond outflow by partial dam removal.

- King-Cujo drainage enhancements to increase migratory accessibility of pond and tributary habitats to a more diverse fish community (DFO 2000a).

Fish habitat compensation monitoring will be undertaken to assess fish habitat compensation upon implementation (2013) (DFO 2000a).

2.1.4 Jericho Diamond Mine Project, Nunavut

Benachee Resources Inc. (a wholly owned subsidiary of Tahera Diamond Corporation Inc.) has proposed open pit and underground mining of kimberlite pipes at their Jericho Diamond Project mine site. Project mobilization began in 2005 and it is expected that this project will be in production in 2006 (Tahera 2004). As a result of the project, a causeway will be constructed and operated from the shoreline of Carat Lake to support a water intake facility to provide process water for mine operations. Storage of the fine fraction from processing will occur in the Long Lake System (made up of Long Lake, and unnamed pond north of Long Lake, and an unnamed pond west of Long Lake), which will be dammed and converted to a Processed Kimberlite Containment Area (PKCA). As a result, flows from the Long Lake System will be disrupted (DFO 2005). Fish species affected by the Project include Arctic char, Arctic grayling, burbot, lake trout, round whitefish, and slimy sculpin.

Samis, Birtwell, and Khan (2005) indicate that habitat losses and gains were quantified using the HSI approach, similar to the approach applied at Ekati Diamond Mine, with the ratio of gains to losses expected to be approximately 2:1.

Habitat losses include the destruction of 1,800 m^2 of fish habitat in Carat Lake, 100,300 m^2 of fish habitat in Long Lake, 7,100 m^2 of fish habitat in an unnamed pond north of Long Lake, 9,600 m^2 of fish habitat in an unnamed pond west of Long Lake, 2,153 m^2 of fish habitat in Stream C1, the disruption of 839 m^2 of fish habitat in Stream C3, and the harmful alteration of 313 m^2 of fish habitat in the lower section of Stream C1 (DFO 2005).

Habitat compensation will target the construction of high quality spawning, rearing, foraging and wintering habitat for resident species of fish, including Arctic grayling, Arctic char, lake trout, burbot, slimy sculpin and round whitefish (DFO 2005).

The following areas are to be developed as compensatory fish habitat:

- 607 m^2 of fish habitat in Carat Lake are to be enhanced during construction and operation of the causeway, by incorporating larger-sized rock material into the margins.
- 1,207 m^2 of fish habitat of Carat Lake are to be enhanced through the development of underwater rock shoal by excavating to at least 2 m below normal summer water levels during abandonment of the causeway.
- 940 m^2 of fish habitat in the 470 m long diversion channel are to be enhanced by incorporating natural channel features into the design.
- 21,000 m^2 of fish habitat are to be enhanced through the construction of 21 underwater shoals.

- 182 m^2 of fish habitat are to be enhanced in a connecting channel (Stream O21) to improve fish passage between Lake O2 and Lake O3 (DFO 2005).

A monitoring program will be undertaken to ensure compensation works are conducted according to the habitat compensation plan. Annual reports will be submitted to DFO including photographic records, details of the effectiveness of the compensation measures in achieving their objectives as fish habitat, "as constructed" drawings, and a description of contingency measures that were followed in the event that the compensatory habitat was not functioning as described in the compensation plan (DFO 2005).

2.1.5 Snap Lake, Northwest Territories

DeBeers Canada Mining Inc. is currently in the process of permitting the Snap Lake Diamond Project. Four components of the project are expected to affect fish and fish habitat. They include:

- Construction and operation of a water intake facility in Snap Lake;
- Construction of the mine water outlet in Snap Lake;
- Operation of a treated final effluent diffuser in Snap Lake; and
- Construction of a pile that will eliminate flow from Lake IL6 to stream S29 on the peninsula (Golder 2004).

In order to quantify fish habitats being lost or gained during construction and operation of the project, a modified HEP was used (USFWS 1980). As described earlier in this report, this method combines detailed habitat quality, defined by an HSI for each fish species of concern, with habitat quantity to calculate HUs. Multiplying the HSI value for each species and habitat class (spawning, nursery, rearing, foraging), by the area of each type of habitat, provides the number of HUs available for each species during each project phase. Changes to fish habitat in Snap Lake caused by the project were evaluated for all four habitat classes (spawning, nursery, rearing, foraging), while stream S29 was evaluated for one class of habitat (seasonal foraging habitat) (Golder 2004).

Comparing the number of HUs available under baseline conditions to those available during the construction and operation quantifies the overall number of HUs lost and gained by the project.

The major habitat types within the project area were surveyed in the summer of 1999. Eight habitats were identified in Snap Lake, including seven shoreline habitats and one deepwater habitat. Once these habitat types were identified and quantified, the total area (m^2) of each habitat type in Snap Lake was calculated (Golder 2004).

Stream S29 was identified as providing physical fish habitat in the lower-most 30m, at the confluence with Snap Lake. Based on a channel length of 30 m and an average width of 0.8 m the amount of fish habitat provided by stream S29 was calculated to be 24 m^2. Arctic grayling was the only species identified as using the stream S29 (Golder 2004).

HSI values for various species were based on previously developed models for arctic environments (i.e. Diavik) and the available literature. The HSI values for each fish species were applied to the specific habitat type present in Snap Lake. This allowed for a habitat ranking specific to Snap Lake for each species and life stage considered in the habitat evaluation (Golder 2004).

It is important to note that, in the case of the water intake and mine water outlet project components, of the species identified as being affected by the proposed development (lake trout, Arctic grayling, round whitefish, longnose sucker, burbot, slimy sculpin, and lake chub) the habitat losses and gains were only calculated for fish species most affected by the changes in habitat. Given that the habitats affected by these project components are primarily secluded shoreline, the fish species that will be most affected are small-bodied fish that require the cover provided by rocky shorelines to provide for life functions and avoid predation. Thus, fish species included in the calculations for these project components included lake chub and slimy sculpin (Golder 2004).

Once the HSI values were determined, HUs were calculated by multiplying the area of each habitat class by the appropriate HSI value for each species. The HUs were then used to predict potential habitat gains and losses for each species resulting from the development and operation of the structures.

The total estimated losses for each project component were:

- The total amount of habitat lost due to the construction of the water intake structure was calculated to be 2,022 HUs, although through compensation measures there will be a net gain of 2,371 HUs (DFO 2004).
- The total habitat lost due to the construction of the mine water outlet was calculated to be 4,370 HUs although through compensation measures there will be a net loss of only 1,477 HUs (DFO 2004).
- The operation of a treated final effluent diffuser in Snap Lake will result in the loss of 2,377 HUs (DFO 2004).
- The amount of habitat lost in stream S29 will be 6 HUs.

Habitat compensation will be created during construction of the water intake and mine water outlet, by the physical presence of the associated rock-filled embankments along the shoreline of Snap Lake. As a result, the water inlet will create a total of 1,097 m^2 of habitat. The total length of shoreline gained by construction of the water intake will be 82.8 m. The mine water outlet will create 471 m^2 of shoreline habitat. The zone of turbulence produced by the diffuser does not create any habitat, although once it has been removed, the zone of turbulence associated with the diffuser will no longer exist, reclaiming this area (Golder 2004).

Several options are proposed for the compensation of fish habitat within stream S29. The preferred option is the removal of a blockage in nearby stream S27, located on the peninsula, to compensate for the temporary loss of habitat. Other options include the creation of pool and riffle habitat in stream S1 or compensation in an unidentified area off site from the Snap Lake Diamond Project.

It is important to note that the fish habitat compensation plan for the DeBeers Snap Lake Project is still undergoing revisions. Compensation monitoring plans are yet to be developed (Golder 2004).

2.2 METAL MINES

The metal mines examined in detail in the case studies in Appendix 1 are: Doris North Gold Mine; Kemess South Gold-Copper Mine; and Voisey's Bay Nickel Mine. Overview discussions of key elements from these projects are presented below.

2.2.1 Proposed Doris North Gold Mine, Northwest Territories

The Doris North Gold Mine, is an underground mine proposed by Miramar Mining Corporation. Plans call for removal of five hundred thousand tonnes of rock over a two year period. Fish species affected by the project include Arctic char, lake trout, broad whitefish, lake whitefish, cisco, fourhorn sculpin, and least cisco. The project is currently in the approval process.

Estimated fish habitat losses for the Doris North Project include:

- Tail Lake will be taken out of biological production, as this lake will be the recipient waterbody for all process tailings and treated sewage. 34.8 HUs of fish habitat will be lost in Tail Lake.
- The natural flow in Tail Outflow will be disrupted by the tailings dam altering 0.027 ha of fish habitat.
- The float plane and boat dock will alter approximately 0.0004 ha of fish habitat in Doris Lake.
- The proposed jetty in Roberts Bay will alter approximately 0.130 ha of marine fish habitat.

Again, a modified HEP approach was used to calculate the quantity and quality of fish habitats being lost in Tail Lake. The HEP analysis combined habitat quality, defined by an HSI value, with a physical measurement of habitat quantity (area), to calculate HUs. Multiplying the HSI value by the area (in hectares) of habitat affected provides the number of HUs available/lost. As was previously discussed, this model was also developed for the Diavik Diamond Project and utilized in the Snap Lake Project (Diavik 1998, DFO 2000b).

Tail Lake

- Tail Lake was divided into three habitat types – two nearshore types and one deepwater.
- Each habitat type was assigned a numerical ranking of suitability based on the HSI.
- The area (ha) of each habitat type was multiplied by the appropriate HSI values to obtain HUs to predict potential habitat losses.

- Lake trout was the only fish species captured in Tail Lake, and therefore the only species evaluated.
- The habitat evaluation involved utilizing HSIs for each of the four life stages of fish (spawning, nursery, rearing, and foraging). HSI values ranged from 0-1.0, with a rating of 1.0 being excellent and 0 being unsuitable. Once HSIs were defined for all life stages, they were applied to the specific habitat types and HUs were calculated.
- The HUs were then summed to provide a total value.
- Species weightings were also incorporated into the model through the determination of their relative importance in terms of fish exploitation. Domestic/commercial species were given a weighting of exploitation importance of 0.4, sport species were given a weighting of 0.4, and forage species were given a weighting of 0.2. Since lake trout are considered both a domestic/commercial and a sport species, a weighting of 0.8 was assigned.
- Weightings were also developed to reflect the relative abundance of lake trout. They were given an abundance rating of 1.0. The final rating for lake trout for this specific lake was calculated as the mean of the exploitation and abundance weightings (0.9). This value was multiplied by the HUs calculated for each habitat type and life stage, giving a final value for habitat loss in terms of HUs (RL & L and Golder 2004).

<u>Waterbodies other than Tail Lake</u>

- Habitat losses caused by project specific activities (excluding Tail Lake) were quantified as total area, and not by the HEP analysis, since HSIs were not available for some of the affected species.
- The habitat losses, in terms of area and according to activity, are as follows:
    - Dewatering of Tail Lake Outflow and construction of tailings dam: 0.027 ha
    - Float plane and boat dock: 0.004 ha
    - Jetty: 0.130 ha

  It was determined that a net area of 0.161 ha of habitat will be negatively affected by the proposed project.

Habitat Compensation Measures

- Habitat compensation within Tail Lake was not considered an option because it will become a tailings pond.
- Proposed compensation elsewhere includes:
    - Increasing accessibility to nearby Roberts Lake and stream enhancement in Roberts Outflow
        - Construction of a step-pool structure fishway through the dense boulder garden that hinders fish passage at the outflow of Robert's Lake.
        - It is expected that the biomass of Arctic char, as well as reproductive success in this lake, will increase.
        - The HEP method was used to determine the number of HUs for quantifying the amount of compensatory habitat created. Species evaluated included Arctic char, lake trout, and broad whitefish.

    - The proponent considers that this compensation could potentially provide an overall gain of 132.16 HUs for Arctic char.
    - An overall gain of 0.69 HUs was predicted for the step-pool structure in Roberts Outflow resulting in a total gain of 132.85 HUs for Roberts Lake & Outflow.
- Rearing habitat enhancement
    - Creation of rearing habitat at three locations within Doris Lake to provide additional compensation for the loss of fish habitat in Tail Lake. Bathymetry data indicated that shallow in-shore rearing areas with large substrate are limited in abundance.
    - Rearing habitat would be created by placing rock on the ice during winter and this material would settle into place during ice melt.
    - While this rearing habitat is targeted for lake trout, these enhancement areas would also benefit lake whitefish and cisco.
    - The proponent estimates that this would provide an additional net gain of 0.188 ha of fish habitat, which would primarily benefit lake trout survival, the species being affected by the loss of Tail Lake production.
- Stream habitat enhancement
    - Additional pool habitat would be created in the lower portion of a small tributary to Roberts Lake, to provide additional rearing habitat and promote survival of juvenile fish (primarily Arctic char) in Roberts Lake.
    - The selected stream would be, either one that allows fish passage at the lake confluence, or a stream where a barrier could be removed.
    - A minimum of 2 pool habitats would be created within the selected stream.
- Compensation for loss of habitat in waterbodies other than Tail Lake
    - The creation of two additional rearing habitats within Doris Lake is proposed to compensate for the loss of 0.027 ha of fish habitat in Tail Outflow, as a result of disrupting the natural water flow.
    - The creation of rearing habitat to compensate for the loss of 0.004 ha of fish habitat at the proposed float plane and boat dock on Doris Lake is proposed in a bay to the south of the dock site.
- Roberts Bay Jetty
    - The jetty proposed in Roberts Bay will potentially affect 0.130 ha of fish habitat.
    - Compensation measures will include rock spurs and riprap to further enhance the diversity of the habitat available.
    - The proponent indicates that the rock spurs will create a total of 0.120 ha of fish habitat and the riprap located between each spur will create 0.018 ha of fish habitat, for a total of 0.138 ha.

A monitoring program will be conducted to assess the effectiveness of the compensation measures. The monitoring includes: rearing habitat areas created in Doris Lake; pool habitat creation in a tributary to Roberts Lake; rock spurs and riprap constructed for rearing and foraging habitat along the jetty; and fish movements/accessibility through the dense boulder garden in Roberts Outflow (RL & L and Golder 2004).

Snorkel or SCUBA surveys are to be undertaken in the rearing areas created in Doris Lake, to assess use of these areas by juvenile lake trout. Fish utilization of these areas will also be compared to that of natural shoreline areas. In the Roberts Lake tributary where pool habitat creation is to be implemented, backpack electrofishing surveys will be conducted, during the open water period, to assess the effectiveness of proposed structures. Fish fences will used to assess migrating anadromous char populations (RL & L and Golder 2004).

2.2.2 Kemess South Mine, Northern British Columbia

The Kemess South Mine project proposal involved a 40,000 tonnes per day open pit gold/copper mine-mill complex in the Thutade Lake watershed of the Toodoggone region of north central British Columbia. The approach used to quantify the area of stream habitat lost was to arrive at the total spatial area of habitat lost in categories according to life history for Dolly Varden and bull trout. The life history habitat categories were: spawning; fry rearing; and juvenile rearing. The habitat compensation program involved a variety of measures involving: new fishways; construction of spawning habitat; improving fish passage at beaver dams; maintaining access to channel inverts; and instream flow maintenance to replace the categories of habitat lost on a NNL basis.

The objective of the Compensation Plan was to ensure that overall Dolly Varden and bull trout productivity would remain at pre-development levels within the Thutade Lake watershed. Compensation strategies were ranked collaboratively by DFO, the province and the proponent, using the following factors:

- Suitability under DFO NNL policy;
- Probability of long term success;
- Amount of ongoing maintenance required;
- Technical viability;
- Environmental impact of the strategy; and
- Available findings (Kemess 1996, DFO 1996).

Due to the unavoidable uncertainty over the potential success of habitat replacement for Dolly Varden and bull trout, an adaptive management approach to habitat compensation was developed, supported by a comprehensive monitoring/applied research program. The approach outlines projects that are to be implemented and contingency projects, and specifies how those contingencies are to be triggered. The proponent committed, for the life of the mine, to undertake an annual scientific data collection and performance monitoring program as part of the Kemess Fisheries Management Compensation Plan. This program consists of: biological and physical data collection and evaluation; a program to determine the effectiveness of the compensation; and scientific data collection to provide more basic information on char biology. The questions to be addressed include: micro- and macro-habitat selection and preferences; quantifying habitat availability and use; determining normal recruitment rates from one life-history stage to the next and how they vary in perturbed and unperturbed systems; basic information on growth and reproduction; timing and duration of fish movements; and relation between lacustrine and riverine environments for bull trout in particular (Kemess 1996).

Fish habitat compensation program success criteria were developed that provide direction to the monitoring program and decision making. Key elements of the success criteria are discussed below:

- DFO, the province and proponent all recognized the difficulty inherent in measuring the success of the compensation projects by monitoring the overall productivity of the Thutade system. It was considered that measuring the overall productivity of the watershed would confuse the success or failure of each of the specific projects with any increases or reductions resulting from other factors (e.g. changes to fishing regulations) or natural population fluctuations resulting from disease, short term drought, flood cycles, or natural temporal barriers (Kemess 1996).
- It was decided that the success of each initiative would be measured on a project by project basis with the measure being project specific.
- To be considered “successful”, a project should achieve its desired objective structurally, functionally and biologically for the intended species and life stage. A timeline needs to be established within which a project can be considered successful, partially successful or not successful with this determination based on monitoring with pre-determined, measurable criteria.

Dolly Varden compensation projects were to be considered successful if:

- It could be demonstrated that each of the two transplanted stocks has established a healthy population in the respective transplant watersheds. “Healthy” was defined as a population where stocks of Dolly Varden are spawning in successive years and there is clear evidence that eggs, fry and juveniles are surviving to become adults and spawners. Target population numbers were established for the two identified transplant streams, with population size being measured by electrofishing, which is accepted as underestimating fish populations.

Bull trout compensation projects were to be considered successful if:

- 10 bull trout redds are established in identified locations. A successful redd was defined as one that fish spawn in and eggs survive to hatching. This minimum number of redds was to be repeated over a minimum of four successive years.

2.2.3 Voisey’s Bay, Labrador

Voisey’s Bay Nickel Company Limited received an Authorization from DFO in 2003 for HADD linked to a proposed nickel-copper-cobalt mine/mill at Voisey’s Bay, in northern Labrador. Construction activities with the potential to affect fish and fish habitat began in 2003 and mining and milling operations are expected to start in 2005 and continue for approximately 14 years (DFO 2003b). The project will affect Arctic char, brook trout, and three-spine stickleback. The project will result in HADD affecting approximately 59.19 units (1 unit = 100 m^2) of riverine habitat and 90.08 ha of lacustrine habitat equivalent units (DFO 2003b).

In order to quantify habitat loss/alteration in streams, detailed transects were constructed within each stream reach that had the potential to be affected. Transects were located in habitat considered to be representative of reaches important for fish utilization, with respect to water depth and wetted perimeter, and with consideration of sensitive biological time periods. Each transect was used to calculate the relationship of flow to wetted perimeter graphs. These plots were used to assess whether flows could be reduced within the streams to meet the mill/mine water demands and still maintain suitable habitat for fish species in the river, specifically brook trout and Arctic char. The information provided from each representative cross section in terms of changes in wetted perimeter and water depth was plotted and used to calculate the potential habitat loss in each stream section. The loss in horizontal stream width at each location was multiplied by the habitat in each represented stream reach, in order to develop an estimate of potential habitat loss, in HUs, for each habitat type (AMEC 2003a).

Habitat loss/alteration in ponds was quantified in terms of a composite habitat equivalence which reflects the product of the habitat's composite suitability rating for all present salmonids life cycle stages (spawning, nursery, rearing, foraging) and the actual surface area of each HU (AMEC 2003a). The methodology was developed by AMEC and Voisey's Bay Nickel Company in consultation with DFO, and was based on DFO draft Guidelines for Habitat Classification/Quantification of Lacustrine Habitat (DFO 1998). These guidelines include the following instruction:

Habitat Classification:

1. Bathymetry (m^2) of littoral and pelagic zones. The zones can be delimited using Secchi depth.
2. Map substrate type and any emergent or submergent vegetation in the littoral zone and provide area (m^2) for each distinct habitat type.
3. Collect several measures of the "condition index" for each lake under construction, including but not limited to total phosphorus and nitrogen, seasonal rate of C_{14} uptake, index of water quality, chlorophyll 'a', and flushing rate.

Habitat Quantification

1. Assign HSI values for each life history stage for each species and habitat type.
2. Calculate HUs as weighted suitable area (WSA).
3. Develop a consistent weighting scheme for combining species and life stage suitability ratings into a composite suitability for each habitat type.

Habitat suitability matrices were calculated as per Minns et al. (1995) using the lacustrine habitat requirements supplied by DFO (Bradbury et al. 1999) for Arctic char and brook trout.

In order to compensate for the loss of lacustrine, a nearby fishless lake (named Pond 61), located in a headwater system high on a plateau and draining with a cascade into Reid Pond, was to be repopulated, with nearby North Pond being used as a contingency. It was predicted that 116.4 ha of new habitat would be created.

Compensation for the fluvial habitat loss includes the enhancement of 58 units of relatively unproductive habitat within the Reid Brook watershed into 13 units of Type I habitat and 45 units of Type II habitat. This is to be achieved by placing substrate and altering flow patterns within stretches of existing unproductive habitat (AMEC 2003b).

A monitoring program was developed to evaluate the effectiveness of compensation measures undertaken and to provide information on fish species/life cycle stage utilization of the created habitat.

2.2.4 Seabee Mine, Saskatchewan

The Seabee Gold Mine project received authorization from DFO in 1992 for the HADD created by use of East Lake as a TIA. Fish species affected by the destruction of East Lake included walleye.

In order to quantify habitat loss, a modified application of the HEP approach was used to quantify the potential walleye spawning grounds (Sentar 1991, USFWS 1981). Each distinct section of the shoreline and shoals was ranked according to its suitability as walleye spawning habitat, with one of four categories being assigned. These categories were Good Spawning Habitat, Fair Spawning Habitat, Poor Spawning Habitat, and Unsuitable Spawning Habitat. All areas for each habitat category were summed and then multiplied by the HSI value for walleye (Sentar 1991). The total loss was calculated as 2,994 m^2 of walleye habitat.

In order to compensate for this loss of walleye habitat, an artificial spawning habitat was constructed for lake trout in Porky Lake, located 2 km from the mine. Effectiveness monitoring was conducted in 1992 and more recently in 2001. No lake trout eggs were collected at the artificially constructed reef (Samis, Birtwell, and Khan 2005).

2.2.5 Lac Doré Vanadium Project (Proposed), Québec

Mackenzie Bay International Ltd. is proposing to develop an open pit vanadium mine in the Chibougamau Region of Québec. The proposed mine is expected to produce a high purity vanadium-based electrolyte for vanadium redox battery technology over a period of 20 years, with possible expansion for another 20 years (Samis, Birtwell, and Khan 2005).

The principle fish species implicated by the project include brook trout, northern pike, burbot, lake whitefish, walleye, and perch. A limited Aboriginal fishery exists in the immediate area of the project. Lac Chibougamau, located approximately 10 km downstream from the TIA, supports a sport fishery.

Plans call for the following two waste rock disposal sites (north and south) located in natural depressions for a proposed 40 million m^3 of tailings:

- The south site would result in the destruction of a headwater lake, 8 ha in area, that drains toward Lac Jean; and
- The north site would cut off Lac Laugon and Lac Coil from Villefagnan Stream.

Tailings would be transported to the disposal sites by truck, requiring the construction of mine roads. Process tailings from the mill would be deposited via pipeline into the Rivière Boisvert watershed. The proposed TIA would encompass an area of 350 ha, and would be contained by a dyke 15 m high. The mill operation requires water at the rate of 400 m^3/h, extracted from Lac Brigon.

Construction of the TIA would result in the destruction of:

- Lac Chauve-Souris (3.75 ha);
- 3 unnamed lakes (total of 3.2 ha);
- 3.5 km of Sable Stream; and
- would cut off Lac Coco from the rest of the watershed.

The 400 m^3/h of water required to feed the mill would be extracted from Lac Brigon, resulting in a significant reduction of water levels in that portion of the Rivière Boisvert watershed.

Proposed fish habitat compensation involves blasting a waterfall in Villefagnan stream to provide access for walleye to 5,875 m^2 of potential habitat.

2.2.6 Rabbit Lake Mine, Saskatchewan

Cameco Corporation received *Fisheries Act* Authorizations for development of additional uranium ore reserves at the Rabbit Lake Mine located at Collins Bay on Wollaston Lake, Saskatchewan (DFO 1994a, DFO 1994b, DFO 1995a, DFO 1995b, TAEM 1994). The ore reserves extend under Collins Bay. To access the reserves, two dykes were constructed and two areas (A-Zone and D-Zone) of Collins Bay were dewatered, resulting in a loss of 9.3 ha of fish habitat in the A-Zone, and 4.9 ha of fish habitat in the D-Zone. Fish species affected included Arctic grayling, longnose suckers, white suckers, lake whitefish, and northern pike (TAEM 1994).

Two field surveys were conducted to collect the data needed to assess the relative importance of fish habitat in the A-Zone and D-Zone pit areas of Collins Bay. The study area included all of Collins Bay with specific emphasis on the A-Zone and D-Zone areas. The first field survey took place in the fall of 1993 and involved:

- Identifying concentrations of lake whitefish in reproductive condition through the use of spawning nets;
- Obtaining data on length, weight, and age of spawning individuals in Collins Bay;
- Mapping shoreline habitat and determining spawning habitat suitability indices for fish present in Collins Bay; and
- Obtaining general limnological data (dissolved oxygen profiles, temperature profiles, pH, specific conductance and secchi disk transparency).

The second field survey took place in June 1994 and involved:

- Identifying concentrations of spawning fish through the use of spawning nets and egg searches;
- Obtaining data on length, weight, and age of spawning individuals in Collins Bay;
- Completing the shoreline habitat mapping of Collins Bay and the mouth of Collins Creek, and determining spawning habitat suitability indices for fish present in the Collins Bay area; and
- Obtaining additional general limnological data (dissolved oxygen profiles, temperature profiles, pH, specific conductance and secchi disk transparency).

The HEP approach (USFWS 1981) was used to determine the quality of fish habitat, using a three step process that included:

1. Delineating HUs based on physical characteristics.
2. Describing each HU according to: depth 5m offshore, substrate, aquatic vegetation, and shoreline characteristics for each HU identified.
3. Developing the HSI value. For this task, each HU was rated for its suitability as spawning habitat for each of the species investigated (Arctic grayling, longnose suckers, white suckers, lake whitefish, and northern pike) and given a HSI value in one of four categories (not suitable, marginal, moderate, most suitable). This value was based on known spawning habitat characteristics for the species. The selection of fish species for which spawning habitat was evaluated was based on whether the species was known to occur, or potentially occurs, in the study area. By combining HUs and HSI values with active spawning investigations, an understanding of the relative contribution of the impact areas to the populations of the various fish species were made (TAEM 1994).

Fish habitat compensation included construction, within Collins Bay, of two lake whitefish spawning shoals (D-zone: 2,500 m^2 and A-zone: 3,000 m^2) and of two pike spawning and rearing marsh habitats (A-zone: 7,600 m^2 and D-zone: 650 m^2) (DFO 1994a, DFO 1994b, DFO 1995a, DFO 1995b).

Monitoring has been conducted to assess the effectiveness of habitat compensation measures, in accordance with requirements of the *Fisheries Act* Authorization. Samis, Birtwell, and Khan (Samis, Birtwell, and Khan 2005) indicate that the pike spawning marsh habitats have been utilized by pike for spawning, although the utilization has been somewhat lower in comparison to reference sites. This may change as the constructed marsh habitats continue to develop. Monitoring results were confounded by low water levels during the sampling years. Utilization of the constructed whitefish spawning shoals has been limited, but viable eggs have been collected at each of the shoals. Results have been confounded by failure to find a suitable reference site for comparison. The situation may be that the lake whitefish might be utilizing a large stream for the majority of spawning. The proponent has now presented a number of options for reconnecting one of the restored pits with the main part of Collins Bay.

2.3 MINES USING UNSCHEDULED TIAs

2.3.1 Iron Ore Company of Canada (IOC) – Wabush Lake, Newfoundland and Labrador

IOC began discharging tailings into Wabush Lake in 1962. IOC is now required, however, to confine its tailings within a dyke to ensure compliance with the *Fisheries Act* Metal Mining Effluent Regulations regarding tailings confinement and water quality maintenance in Wabush Lake. Tailings confinement within a dyke will also control "red water" in the unconfined area of Wabush Lake. The tailings confinement dyke will be 15 km long within Wabush Lake and is scheduled for completion by 2011.

Species affected by the loss of productive fish habitat associated with the construction and operation of the tailings confinement dyke include lake whitefish, longnose sucker, lake trout, round whitefish, white sucker, northern pike, burbot, ouananiche, brook trout, longnose dace, slimy sculpin, and lake chub.

Habitat loss was quantified first by defining the areas potentially affected using existing and project related mapping: base maps; lake bathymetry; and project drawings. The littoral zone was defined on the basis of Secchi depths. Substrate was described using a classification system based on Bradbury et al. (1999) and Power et el. (2000 Draft). Fish species identification in Wabush Lake was based on information derived from Beak (1995) and augmented by Jacques Whitford (2000a). Natural-lake HSI values were derived from Bradbury et al. (1999) and Power et al. (2000 Draft). HSI values for Wabush Lake were adjusted to account for the current state of habitat degradation habitat (reflecting effects of Turbidity on Production, Turbidity on Feeding, Sedimentation, Sediment Chemistry) to provide corrected composite suitability indices.

Estimated habitat loss was calculated to be:

Areas of habitat loss include:

Dyke Footprint	140 ha
Tailings Containment Area	2,567 ha
Area of Channel Deepening	0 ha
Area of Dredging	Nil
Hydro Pole Base Pads (12)	0.2 ha
Total Composite Equivalent HUs	2,707 ha

In terms of HUs the loss was estimated at:

Littoral Medium Substrate	73 HUs
Non-littoral Fine	410 HUs
Total	483 HUs

The following reflected consideration of the precautionary approach: depth of the littoral zone was overestimated; when substrate grain size variation was noted, the more sensitive size was used; all species in Wabush Lake and its tributaries were considered;

and the conservative assumptions provided in Bradbury et al. (1999) and Power et al. (2000 Draft) were applied.

Quantification of projected habitat gain was considered difficult because it involved consideration of the fact that the project as a whole would result in changing a highly degraded habitat to a less degraded habitat (Jacques Whitford 2000b, 2001b). To account for this, the following methods were used to quantify habitat compensation:

- Existing habitat outside the containment dyke was quantified using the same methods as the HADD calculation;
- The same amount of habitat was adjusted to account for the projected short- and long-term habitat conditions to indicate the HUs that will be provided by the lake; and
- The difference between HUs lost due to HADD and those gained due to improved conditions would be considered an HU equivalent gain. Calculations were based on the number of HUs post-project, after application of a correction factor to reflect improved HSI scores.

In addition, habitat is being created as follows: 10 ha of as a result of flooding an island area after quarrying; and 74 ha as a result of deepening the lake between the island and the eastern shore and the habitat associated with outside face of the dykes. New or improved habitat resulting from installation of the toe of the dyke and related lake dredging were not included.

A monitoring program was designed to track progress and detect changes over an extended period of time, because construction of the dyke will take 10 years to complete.

Jacques Whitford (2001b) developed an approach to undertake the long-term monitoring plan. This approach involves conceptually dividing Wabush Lake into monitoring Areas 1-5 that correspond to the existing basins in the unconfined portion of the lake. Selection and designation of the basins provides each area with a full range of depths, and presumably habitats, which can be compared as single sites over time and between sites at the same time. Area 6 would be established as a control site in Julienne Lake.

Monitoring parameters include the following:

- Secchi depth to re-define the extent of littoral habitat over time.
- Primary productivity, and plankton biomass and composition – to track improvements as iron partitioning of phosphorus reduces over time and lake transparency improvements increase the photic zone
    - Sampling three times per year (ice-out, mid-season, late-growing season)
    - Measurement of Incident Photosynthetically Available Radiation
    - Replicate water samples – alkalinity, Total Dissolved Inorganic Carbon, ^{14}C uptake, subsurface chlorophyll content, phytoplankton biomass and size distribution, zooplankton biomass and taxonomic categories.
    - Changes from baseline quantified spatially and temporally to index increased production in terms of chlorophyll and plankton biomass.

  - Summary statistics (Chi-square, *t*-test) to determine whether changes are statistically significant.
- Benthic productivity
  - Periphyton as an indicator of primary productivity
  - Artificial substrates
  - Organic content, biomass, chlorophyll content
  - Benthic invertebrates to determine changes at depths in current and projected littoral zones, changes spatially and changes in monitoring areas over time. Includes: 5 stations per depth – no replicates. Hard substrates – artificial substrate. Soft Substrates – Ekmann grab. Analysis to Order and Family level with samples archived.
  - Summary statistics using standard tests (ANOVA, diversity indices, non-metric multidimensional scaling NMDS) to determine whether changes are statistically significant.
- Fish Communities
  - CPUE to be used as an index of abundance
  - Focus on four numerically dominant species – lake trout, lake whitefish, round whitefish, longnose sucker – with all other catches recorded
  - Stomach analysis
  - 16 sampling stations
  - Standardized methods to provide comparable results – gang of experimental gillnets using mesh sizes intended to reduce mortalities from catching large lake trout by the teeth
  - Three times each year – spring, summer, fall
  - Shallow and deep sets – 12-16 hours
  - Use of a reference station in another lake
  - Record – species, length, weight, sex and maturity of mortalities, age for a representative sample
  - Analysis – total catch, catch frequency (ratio of occurrence in all sets), % of total catch, and CPUE for all species. Data to be used to determine: condition factor; weight at age; size at age; gonad weight; liver weight; egg size; and fecundity.
  - Previous studies had indicated that fish abundance in Wabush Lake was directly related to food availability and that use of habitat and spawning areas by fish was not limiting. This was taken to mean that an increase in benthic productivity would translate into increased fish abundance.

2.4 OIL SANDS MINES

The oil sands mines that were examined in the case studies in Appendix 1 were: Shell Jackpine, Phase 1 and the Horizon Oil Sands Project.

2.4.1 Shell Jackpine, Alberta

Shell's Jackpine project consists of a stand-alone oil sands development that includes facilities for the generation of approximately 200,000 barrels per day of bitumen product.

This includes an open pit mining and bitumen extraction operation that uses truck and shovel type mining with semi-mobile crushers as well as ancillary activities. The project includes alteration of drainage and fish habitat.

Fish species affected include northern pike, Arctic grayling, walleye, longnose sucker, white sucker, lake chub, brook stickleback, fathead minnow, pearl dace, slimy sculpin, spoonhead sculpin, and spottail shiner.

A HEP type of approach was used as an accounting system to document habitat quality and quantity (Golder 2003). Habitat quality was defined by HSI values which model the suitability of available habitat for specific species and life stages. Habitat quantity (stream area) was determined from watercourse measurements (e.g., channel width) taken directly during field programs and channel lengths estimated from large scale digital maps, using GIS. Stream area was calculated as the average channel width for a stream segment multiplied by the length of the stream segment. HUs were derived by multiplying the HSI value for habitat quality by the quantity of habitat (surface area in m^2). The number of HUs altered by the project were calculated and compared with the number of HUs to be created through habitat compensation measures.

Habitat assessments included a measure of the contribution of benthic invertebrate productivity and drift but the data were considered too sparse to provide information on productive capacity.

Fish species found in the watercourses, or proposed for stocking in compensation habitat, were used to estimate current habitat availability in the existing and compensation habitat. Species included: northern pike; Arctic grayling; lake whitefish; longnose sucker; lake chub; walleye; yellow perch; white sucker; brook stickleback; fathead minnow; pearl dace; slimy sculpin; spoonhead sculpin; and spottail shiner. A workshop with consultants, DFO, the Province and academics was held to develop the models. Previously published HSI models were modified by the group to determine HSI values for northern pike, Arctic grayling, walleye, longnose sucker, and white sucker. The group developed new models for species where previously published HSI models did not exist (e.g., lake chub, brook stickleback, fathead minnow, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner). The models were based on the literature, expert experience and judgment.

The models were designed to work where fish were known to be present. They did not include variables that would determine whether fish could exist in an area. The fish distribution data were derived from field sampling and professional judgement where data were scarce. Where the species presence records had spatial gaps in distribution, the species distribution was assumed to cover the entire watercourse between the known distributions.

Shell proposed to conduct monitoring as part of its overall commitment to environmental management, and to provide feedback on the suitability of the mitigation/compensation. Monitoring plans include monitoring streamflows, water levels and discharge rates; channel stability and morphology; water and sediment quality; littoral zone development; growth of aquatic vegetation; riparian zone vegetation; benthic macroinvertebrate communities; and fish populations. The monitoring will also sample fish populations for several years in both existing and compensation habitat and this will be used with the measured habitat characteristics to validate the models. If the models change, the habitat losses and gains will be recalculated to determine whether the compensation objectives have been met. If they have not been met, additional compensation will be required. This adaptive management approach is used to provide increased certainty that compensation objectives will be met.

Immediately prior to issuance of the *Fisheries Act* s.s. 35(2) Authorization, the Province of Alberta indicated that it would not likely permit Shell to construct its compensation lake as planned, because it would sterilize mineable bitumen resources under the lake. DFO subsequently negotiated a letter of credit, to be held by DFO, which reflects third-party costs to construct a compensation lake of the same size. This very large security (>$20M) will be held until the Province of Alberta allows construction of the compensation lake at the original site, or another compensation option acceptable to DFO can be agreed upon.

2.4.2 Horizon Oil Sands, Alberta

The Horizon Oil Sands Project is an oil sands mine 70 km north of the Fort McMurray area in Alberta. The project involves extensive mining in watersheds of the Tar and Calumet rivers and includes the construction and operation of an oil sands mining, extraction and upgrading facility. It was concluded that most of the Tar and Calumet watersheds would be destroyed. Construction was to begin in 2005.

Fish species affected include:

- Arctic grayling
- Northern pike
- Walleye
- Yellow perch
- Mountain whitefish
- Burbot
- Longnose sucker
- White sucker
- Brook stickleback
- Lake chub
- Brassy minnow
- Pearl dace
- Longnose dace
- Trout-perch
- Fathead minnow
- Slimy sculpin

The *Fisheries Act* Authorization for the Horizon Oil Sands project (DFO July 26, 2004) indicates that fish habitat losses were calculated as surface areas of fish habitat in hectares The compensation requirements include a compensation lake and a constructed river channel, but the Authorization was issued prior to determining whether the compensation is adequate. The proponent is responsible for conducting several years of monitoring in the Calumet River watershed and parts of the Tar River watershed prior to their destruction. There will be one year of data collection in the mainstem Tar River prior to its destruction. A surrogate stream that is nearly the same size as the Tar River in an adjacent watershed (Joslyn Creek) will be monitored in lieu of the Tar River. There will be one year of overlap in monitoring for the Tar River and Joslyn Creek.

Monitoring consists of determining the productive capacity of fish habitat as measured in weight of fish biomass produced per unit area per year. Representative types of watercourse are being sampled from lower mainstem reaches to upper low and high gradient tributaries. Sampling is being conducted on a mesohabitat (pool, riffle, and run) basis to allow comparison of waterbodies with varying mesohabitat composition. Sampling will include trapping, measuring and counting spawning migrants on both upstream and downstream migrations, fish population and biomass estimates in spring, summer and fall, determination of annual growth rates by species and life stage, measurement of downstream migration of fry and other lifestages, etc.

For the Horizon Oil Sands Project, a Compensation Ratio of 2:1 was required by DFO, as measured by fish biomass productivity. As for the existing habitat, the compensation habitat will be evaluated to determine productive capacity as determined by weight of fish biomass produced per unit area per year. If the Compensation Ratio is not met for Compensation Lake and diversion channel, other ecological and physical functional measures will be implemented until the 2:1 Compensation Ratio is met.

2.5 PLACER MINING

Placer mining and its effects on fish habitat have represented an ongoing challenge with respect to the *Fisheries Act* and the Habitat Policy. As a result of a review of past practices and their effectiveness, a new Integrated Regulatory Regime for Yukon Placer Mining (YPIC and YPWC 2005) was agreed upon in April 2005. A Secretariat will be established and the regime itself is expected to be in place by 2007.

The regime is intended to balance the objectives of a sustainable Yukon placer mining industry with the conservation of fish and fish habitat supporting fisheries. It combines a structured risk-based process for making regulatory decisions, careful monitoring at the watershed level, adaptive management, and compliance and enforcement measures. Above all, the regulatory regime sets clear, predetermined standards that will provide better protection for fish and fish habitat, and greater certainty for placer miners in planning and conducting their operations.

Key features of this regime include:

- Predetermined rules for mining activities that reflect the degree of risk to fish and fish habitat.
- The consideration of traditional knowledge as an essential part of assessing the condition of watersheds.
- Compliance and effectiveness monitoring that feeds into an adaptive management process to continuously improve the thresholds and standards for habitat protection and reduce uncertainties around the impacts of placer mining on fish habitat productivity.
- A new implementation structure to ensure that the regime is monitored and improved.

Key fish species relevant to the regulation of placer mining in the Yukon include chinook salmon, chum salmon, coho salmon, sockeye salmon, Arctic grayling, whitefish, northern pike, longnose sucker, and burbot.

The integrated regulatory regime is based upon:

- A Pathways of Effects tool.
- A guidebook of design standards and best management practices to be applied in the development of watershed authorizations to mitigate and avoid potential adverse effects.
- A Risk Framework (Matrix) for each of four categories of impacts that cannot be mitigated. The following activities are evaluated on the basis of impact severity, and habitat importance and sensitivity:
    - Sediment discharge;
    - Stream channel diversions;
    - Instream works; and
    - Water acquisition.
- Standards are established for operating in two types of watersheds (high sensitivity and lower sensitivity) and several categories of reaches with differing habitat requirements within those watersheds. These are reflected in regulatory approvals.

Indicators for watershed sensitivity and habitat suitability classification have been recommended for use in defining the condition / sensitivity, as set out below:

Physical Parameters

- Overall linear length of watercourses subjected to anthropogenic development where fish habitat productivity has been suppressed.
- Percentage of non-natal rearing habitat reaches suitable for juvenile Chinook salmon that have been subjected to anthropogenic activities where fish habitat productivity has been suppressed.
- Overall water quality expressed as an average of open water total suspended solids concentrations within the principal tributary.

Biological Parameters

- Presence of Pacific salmon spawning areas.
- Known spawning areas (spawning well documented).
- Likely spawning areas (indicators present, spawning not clearly documented).
- Traditional knowledge/historic areas (spawning not documented).

To be effective, this risk-based approach requires that monitoring of both compliance and effectiveness feed into an active adaptive management process to continuously improve thresholds and standards and reduce uncertainties around the impacts of placer mining on fish habitat productivity.

Key components of this regime are:

- Incorporation of Traditional Knowledge into watershed sensitivity classification, and environmental assessments.
- Implementation of watershed authorizations (Type A – High Sensitivity; Type B – Low Sensitivity) using templates created on the basis of DFO's standardized Authorization form. This is viewed as a an effective way to manage potential cumulative effects of reductions in productive capacity, while ensuring that regulators and placer miners have clear standards and conditions for decision-making. In situations where miners cannot meet the terms and conditions of the watershed Authorization, they can apply for a specific *Fisheries Act* s.s. 35(2) Authorization. A risk management approach will be used to review site-specific applications.
- Incorporation of watershed health monitoring which is discussed further below.

Watershed Health Monitoring

The regime incorporates indicators, practices and standards that were developed using the best available information, including empirical data, professional expertise, traditional knowledge and industry experience. There are uncertainties, however, requiring adaptive management and therefore an effective monitoring program.

The monitoring program associated with this regulatory approach will provide information to:

- Describe watershed health and the specific objectives set out for watersheds, including: water quality; degree of watershed development and restoration / reclamation of mined areas; and habitat productivity;
- Describe the overall status and health of the placer mining industry, including its socio-economic effects;
- Help to test specific assumptions including:
  - Adequacy of discharge standards to meet water quality objectives;
  - Predictions of cumulative downstream effects on water quality objectives;
  - Relationship of settling pond design standards to action and compliance levels;
  - Help to assess industry performance and compliance with respect to discharge standards and best management practices;
  - Help to assess the impact of the new regime on a number of mining operations during the implementation phase;
  - Establish a basis of information to measure progress in achieving a habitat net gain through the use of best management practices under the regime; and
  - Guide adaptive management of the regime.

The regime incorporates two timeframes for monitoring: annual monitoring; and medium-term monitoring / evaluation conducted every three to five years. Biological, water quality, industry activity and habitat productivity indicators are to be developed to measure watershed health. The biophysical indicators used to classify watersheds (e.g., presence of Pacific salmon spawning areas, overall length of watercourses affected by human development where fish habitat productivity has been suppressed) will also be used in watershed health monitoring.

To implement the regime, a number of protocols are being developed:

- Method of Measurement Protocol – techniques for measuring sediment discharges in ml/l and total suspended solids (draft April 2005).
- Protocol for Action and Compliance Level Approach – concepts of the action level approach and voluntary and required actions when the design target, action level or compliance level are exceeded (draft April 2005).
- Protocol for Identification of Physical Constraints to Settling Pond Design – criteria used by the Secretariat to identify physical constraints to settling pond design (draft May 2005).
- Water Quality Objectives Monitoring Protocol – techniques including sampling design, measurement and data analysis (draft April 2005).
- Watershed Health Monitoring Protocol – techniques including sampling design, measurement and data analysis (draft May 2005).
- Adaptive Management Protocol – concepts of the adaptive management approach, including the process and data requirements for program review (draft June 2005).
- Watershed Sensitivity and Habitat Suitability Classification Protocol – the indicators, measurement and scoring system (draft April 2005).

Watershed Sensitivity Classification

A series of indicators to establish the sensitivity of 19 designated watersheds is listed below:

- Physical Parameters
    - Overall linear length of watercourses subjected to anthropogenic development where fish habitat productivity has been suppressed.
    - Percentage of non-natal rearing habitat reaches suitable for juvenile chinook salmon that have been subjected to anthropogenic activities where fish habitat productivity has been suppressed.
    - Overall water quality, expressed as an average of open water total suspended solids concentrations within the principal tributary.
- Biological Parameters
    - Presence of Pacific salmon spawning areas.
    - Known spawning areas (spawning well documented).
    - Likely spawning areas (indicators present, spawning not clearly documented).
    - Traditional knowledge/historic areas (spawning not documented, restoration potential).

Each designated watershed was assessed through a systematic process that evaluated, categorized and “scored” the various indicators. A cumulative watershed score was then determined to identify the relative condition and allocate the watershed to one of two classifications, Type A and Type B.

Habitat Suitability Classification

The habitat suitability classification system for Yukon placer mining specifies six suitability categories:

- *High* includes all identified spawning areas for Pacific salmon species in the Yukon (chinook, chum, coho and sockeye) as well as spawning areas for lake trout, rainbow trout, bull trout and Dolly Varden. Spawning areas are identified using field data and current or historic records of spawning activity.
- *Moderate-High* includes highly suitable habitats for rearing juvenile chinook salmon. These areas may also be highly suitable for and used by non-anadromous resident fish species, such as whitefish species, Arctic grayling, and burbot.
- *Moderate-Moderate* includes moderately suitable habitats for rearing juvenile chinook salmon. As above, these areas may also be highly suitable for non-anadromous resident fish species.
- *Moderate-Low* includes habitats that are suitable for rearing juvenile chinook salmon but are unlikely to support large densities or abundance of fish due to limiting factors.
- *Low* refers to areas that are unsuitable for rearing juvenile chinook salmon, but may be highly suitable for and used by non-anadromous resident fish species, including northern pike and longnose sucker.
- *Low-Water Quality* refers to areas that may be inaccessible to fish but provide water flow and contribute nutrients to downstream habitats supporting them.

The proposed indicators for the Moderate and Low habitat suitability categories include stream gradient, proximity to juvenile chinook salmon production areas (identified as high habitat suitability areas) and general water quality (naturally occurring suspended sediment concentrations). The degree of prior disturbance is also to be considered by identifying habitat areas that have been developed and not restored or reclaimed to current standards.

Sites with prior disturbance and insufficient fish habitat restoration are designated “previously developed” (PD) in addition to their habitat suitability classification. This designation allows certain mining activities to be accommodated, providing there is an expressed commitment to restore the habitats to current standards once activities have ceased. It is anticipated that this approach will result in a net gain of productive fish habitat capacity. Once PD designated areas have been restored to the current restoration standards, the designation will be removed.

3.0 ASSESSING FISH HABITAT PRODUCTIVE CAPACITY

As mentioned above, projects that involve whole-lake / stream destruction are generally large scale projects that are primarily mining related. In addition, hydroelectric projects have implications for fish habitat productive capacity; and, must also be addressed under the Habitat Policy. The scale of these projects means that they often affect the watersheds of a number of watercourses and small lakes, encompassing a number of fish habitat types and fish species, making the assessment of fish habitat productive capacity very complex. Scientific research relevant to both categories of projects has provided guidance in terms of approaches for measuring fish habitat productive capacity that can be used as a basis for assessing habitat losses, developing compensation requirements, and designing monitoring programs to confirm whether implemented habitat compensation programs have achieved their objectives.

A number of strategies for the assessment of fish habitat productive capacity have emerged, with some variation in terms of DFO Region, geographic location (e.g. southern Canada vs. the Arctic), types of projects (e.g. mining vs. hydroelectric), and the experience / expertise of the proponents and their fish habitat advisors. These approaches are discussed below.

3.1 GUIDANCE FROM THE LITERATURE

DFO Science has been a leader in Canada in terms of the development of approaches for quantifying losses and gains in fish habitat productive capacity. Minns (1995) indicates that there are three alternatives for measuring or predicting fish productivity:

1. Direct measurement and summation of the production rates of all fish species present;
2. Measurement of biological indices such as biomass, catch per unit effort (CPUE), sport or commercial yield, and possibly presence-absence; and
3. Measurement of surrogate habitat variables.

Methods encompassed by Type 3 and to some extent Type 2 above are dependent upon the existence of prior studies showing that these indicators are in fact predictors of productivity.

Minns (1997) sets out a “net change equation” for assessing “No Net Loss” of productivity for fish habitat. The generalized “net change equation” in the terminology of a layperson is presented below:

$$\Delta P_{\mathrm{Now}} = \Sigma[(p_{\mathrm{Mod\text{-}1}} - p_{\mathrm{Now\text{-}1}})\cdot A_{\mathrm{Mod\text{-}1}}] - \Sigma(p_{\mathrm{Max\text{-}1}}\cdot A_{\mathrm{Loss\text{-}1}})$$

where:
ΔP_{Now} = Change in Maximum Productivity from Current Productivity
$p_{\mathrm{Mod\text{-}1}}$ = Modified Productivity of a Unit Area (e.g., Area-1)
$p_{\mathrm{Now\text{-}1}}$ = Current Productivity of a Unit Area (e.g., Area-1)
$A_{\mathrm{Mod\text{-}1}}$ = Area of Fish Habitat Modified in a Unit Area (e.g., Area-1)
$p_{\mathrm{Max\text{-}1}}$ = Original (=maximum or natural) Productivity of a Unit Area (e.g., Area-1)
$A_{\mathrm{Loss\text{-}1}}$ = Area of Fish Habitat Lost in a Unit area (e.g., Area-1)

Using this equation it is also possible to sub-divide large complex areas, such as a whole lake system, into Unit Areas 1, 2, 3, … *n*, to obtain an estimate of the total change in productivity of the overall habitat area affected by a project. Habitat productivity gains can also be added in, using the same “Productivity x Area” concept with an extended formula also presented in Minns (1997).

Considering this equation, it is evident that, while the measurement of “Area” is a fairly straightforward physical measurement, the measurement of “Productivity” is more complex.

Minns (1997) emphasizes the importance of establishing Fish Habitat Management Plans to provide context and guidance for assessing and taking decisions on activities that result in a change in overall habitat productivity over a large area or system.

Minns (1997) also raises the point that the present state of fish habitat science may preclude the estimation and assignment of a ‘Productivity Rate” to a unit area of habitat. The author notes that there is a range of estimation methods with varying degrees of scientific certainty. The range spans a spectrum from methods that directly estimate productivity values, through the use of surrogates based upon the habitat requirements of the species present (Minns et al. 1995), to the use of expert panels to develop consensus estimates of values for specific habitat / development combinations. Minns (1997) indicates that next steps in evolving this approach might include: a range of case study applications of the net change equations; development of standardized methods for measuring unit area productivity (i.e., estimating and assigning *p* values); further research on the links between suitable habitat supply and fish population dynamics; and prototype Fish Habitat Management Plans for a representative range of Canadian aquatic ecosystems.

As can be seen in the case studies presented in Section 2, the fundamental approach of Minns (1997) has been further elaborated since that time, by DFO and fish habitat experts retained by development project proponents.

Bradbury et al. (2001) is a step forward in this evolution and is particularly relevant to the issue of whole lake destruction. The approach set out in Bradbury et al. (2001) is applicable to lacustrine habitat and builds on the “productivity x area” relationship put forward in Minns (1997).

Bradbury et al. (2001) provides for the classification / quantification of lacustrine habitat productivity through application of HSI models that were developed by the U.S. Fish and Wildlife Service during the establishment of HEP (USFWS 1980). HSI provides surrogates of productivity that can be adopted, recognizing that direct measures of fish productivity are often unavailable or too time consuming and costly to obtain. The underlying premise of this approach is that the habitat requirements of various fish species and their life stages can be quantified to provide an index of habitat suitability, referred to as a Habitat Suitability Index (HSI).

For this approach to work, it is necessary to have information available on habitat use by the various fish species and their different life stages. For Newfoundland and Labrador, this information has been compiled for freshwater and anadromous/catadromous fish species (Bradbury et al. 1999). A limitation of Bradbury et al. (1999); however, is that it was necessary to supplement much of the dataset on habitat utilization by relying on studies from similar geographical areas within Canada, the United States and other northern temperate countries. Also, there is no assurance that various fish species will occur in these areas at any given time. Predator avoidance and competitive interactions may force younger and smaller individuals to occupy less preferred habitats.

In this approach, detailed in Bradbury et al. (2001), emphasis was placed on the use of lake habitats by species during some portion of their life cycle, as follows:

1. Spawning – individuals in spawning condition;
2. Young-of-the-year (YOY) – individuals under one year of age;
3. Juveniles – individuals older than one year of age, but not sexually mature; and
4. Adults – individuals that have reached sexual maturity, but are not in spawning condition.

Within these categories, preferences for the main physical habitat features including: water depth; substrate type; and cover, are categorized as: “Nil” – rarely associated; “Low” – infrequently associated; “Medium” – frequently associated; and “High” – nearly always associated.

DFO (1998) recommends that the habitat requirements of all species found within a project area should be considered in the classification/quantification of lacustrine habitat. Bradbury et al. (2001) indicates that in areas where the diversity of species is greater, and it is impractical to consider all species present, DFO may consider a “guilding” approach. Through this approach, a group of species having similar habitat and life-history requirements may be grouped into a “guild”, with the species having the highest HSI value generally chosen from each guild as a representative, and only that species is evaluated. The “guilding” approach is provided for in Bradbury et al. (1999). To apply the “guilding” approach a list of all species present within the lake, including their different life stages, should be compiled prior to grouping any species into “guilds”. In addition, a table outlining the complete list of species and how they are assigned to each “guild”, and a supporting rationale for assignment, is to be prepared. A flow chart illustrating the steps involved in quantifying lacustrine habitat is presented in Bradbury et al. (2001) and Figure 1.

Some key criteria in Bradbury et al. (2001) that are noteworthy in terms of comparison with other similar processes that proponents may bring forward include:

- Extent of the littoral zone may be defined by secchi depth, and may be supplemented by data defining the outer limit of plant growth and/or delineation of the mud zone.
- Substrate types are

Coarse	Medium	Fine
Bedrock	Rubble	Sand
Boulder	Cobble	Silt
	Gravel	Clay
		Muck

- Vegetative cover need only be considered if it is utilized by at least one life stage of the species present. Generally, only vegetative cover is used because habitat mapping is generally not at a level that is sufficiently detailed in lacustrine environments to justify the inclusion of other types of cover (e.g., overhead, *in situ*, etc.).
- The non-littoral zone is subdivided into two unique zones: benthic (or substrate dependent) zone; and pelagic (or open water) zone.
- Habitat type categories are:

Littoral / No Vegetation	Littoral / Vegetation	Non-Littoral
Littoral Coarse / No Vegetation	Littoral Coarse / Vegetation	Non-littoral Coarse / Pelagic
Littoral Medium / No Vegetation	Littoral Medium / Vegetation	Non-littoral Medium / Pelagic
Littoral Fine / No Vegetation	Littoral Fine / Vegetation	Non-littoral Fine / Pelagic

- For lakes ≤10m in mean depth, *substrate/no vegetation* HSI values are calculated, summed with appropriate pelagic values reported in Bradbury et al. (1999) and the average of the two reported. For lakes >10m in mean depth, it is considered that the pelagic zone would likely represent a much greater proportion of the non-littoral zone than the benthic zone. Therefore, to ensure that the pelagic zone receives appropriate representation, the relative proportion occupied by each respective zone should be determined and used to calculate the HSI values.
- Numerical values (referred to as HSI values) are assigned as:

High	– 1.00
Medium	– 0.67
Low	– 0.33
Nil	– 0.00

  Where no subjective ratings are available for vegetative cover from the literature, it is not included in the calculations; however, absence of information should not be interpreted that vegetative cover is not used by a particular species.
- The numerical values can be modified based upon scientifically valid documentation from site specific studies or more recent literature.

The specifics cited above serve to illustrate some of the information requirements and decision-making involved in applying the approach set out in Bradbury et al. (2001). They also inform discussions on future information gathering needed to further refine productivity assessment, in order to calculate losses and gains as per Minns (1997).

It is relevant to note that Bradbury et al. (2001) provides guidance on field methodologies for gathering data on:

- Lake morphometry
- Water chemistry
- Secchi depth
- Water temperature
- Bathymetry
- Substrate mapping

- Cover
- Fish sampling

Pearson et al. (2005) presents study design, methodology and case studies for assessing and monitoring changes in fish habitat productive capacity that can be used for upfront assessment, calculation of compensation and monitoring of compensation effectiveness. Key principles outlined are:

- Reference and control sites;
- Replication;
- Pre-impact information; and
- Application of a risk management approach for deciding on the level of effort assigned to data collection.

The approach is based upon a Before, After, Control, Impact (BACI) experimental design, utilizing a multi-metric approach to measuring habitat productivity. In applying this approach, habitat productivity is determined by measuring parameters that include: fish abundance/density and biomass; fish presence/diversity; fish growth rate/condition for a number of species/trophic levels; macroinvertebrates; periphyton; water quality; riparian vegetation density; and other measures of habitat attributes.

Pearson et al. (2005) recommend that fish abundance should be measured using estimates of density per unit area and/or quadrat counts, or mark-recapture methods. More easily measured indirect indices, such as CPUE, can be used following calibration to direct estimators of abundance.

Under the proposed BACI approach, these parameters, and/or other parameters considered appropriate to a given situation, are measured at Control and Impact sites, both Before and After implementation of a project. The paper provides guidance on experimental design aspects such as:

- Control site selection - should be established both “local” and “distant” in relation to the effect area, similar in characteristics, appropriate distance from impact site, free from confounding influences;
- Recommendation that a minimum of two years of baseline data be collected at the Control and Impact locations;
- Statistical design and power analysis be applied to determine the appropriate number of replicates; and
- Post-project monitoring should consist of pulsed, two-year periods (years 1 and 2, 5 and 6, and 9 and 10).

3.1.2 International Perspective

Information gained from the literature indicates that, in England and Wales, work is underway aimed at estimating the production of salmonids within catchments using models that integrate map based variables describing habitat suitability using GIS with those based on detailed site descriptions. To date this work has primarily focused on salmonids but future work aims to use similar techniques to describe distributions of coarse fish species (Hughes et al. 2001). Hughes et al. (2001) indicate that European

Directives will continue to reinforce integrated river catchment management, meaning that the habitat requirements of fish communities must be robustly represented among conflicting demands. Generally, there is likely to be more emphasis on fish communities than single species issues. The European Community Water Framework Directive enshrines an increasing use of quantitative fish stock and community reference conditions for assessing the consequences of management of the wider aquatic environment.

Jurvelius and Auvinen (2001) indicate that in Finland, knowledge of habitat preferences for fish eggs, fry, and juveniles is needed, and that gaining this information often requires experimental ecological research. The authors note that, at present, the best option for restoration is to create heterogeneous stream habitat in order to provide scope for variation in microhabitat selection for fish.

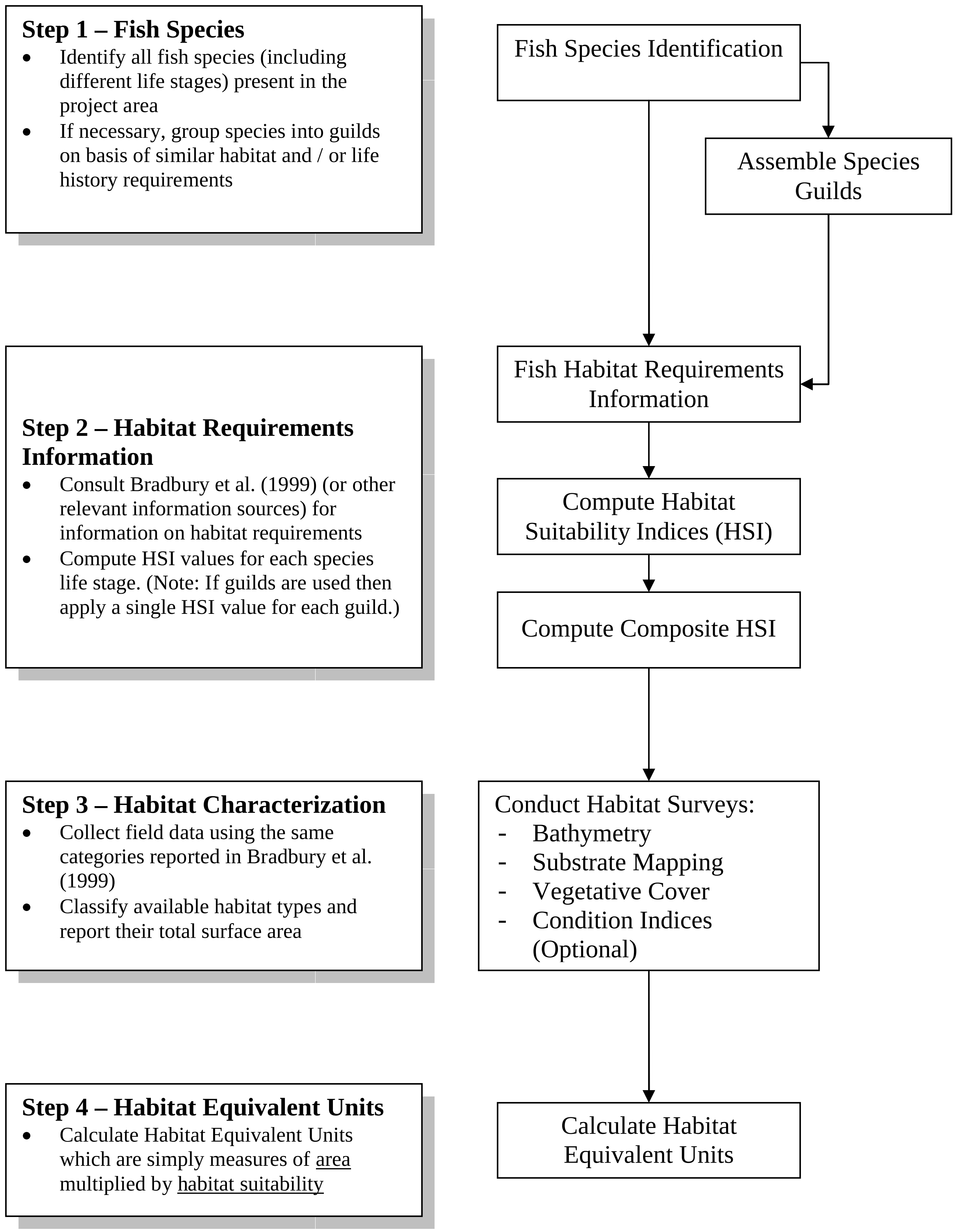

Figure 1. Flowchart illustrating steps for quantifying lacustrine habitat (Bradbury et al. 2001)

3.2 Approaches Proposed For Hydroelectric Developments

Assessing productive capacity and developing strategies for conforming to the NNL principle of the Habitat Policy is a challenge for major hydroelectric projects. Some of the challenges and constraints faced by Hydro Québec in assessing fish habitat productive capacity losses and include:

- Projects affect lake, river, stream and wetland habitat, sometimes over a wide area, making the completion of studies at the level of detail required by the models discussed above a significant challenge in terms of methodology, time and resources;
- Quantifying the interference of dams with natural fish movements upstream and downstream in terms of productive capacity;
- Inundation can create increased surface area that can be considered fish habitat but it may favour a different species assemblage;
- Reservoirs may show increased production due to nutrient releases; however, increased production may be negated by decreased spawning success due to fluctuating water levels and the stranding/freezing of spawn;
- There can be fluctuating production rates in a reservoir that require an extended period of time to reach equilibrium; and
- Reservoir creation in the Canadian shield can lead to mercury release that may render fish unsuitable for human consumption.

Hydro Québec has indicated that the Habitat Policy presents a major challenge for any project that modifies an aquatic ecosystem, such as a large hydroelectric project. Pure habitat surface area assessment methods generally assume that maintaining productive capacity is equivalent to maintaining an equivalent area of habitat. While this approach may be suitable for small projects, for large projects the analysis must go further to consider the effects on fisheries. It is contended that changes in habitat as measured by square metres are not an expression of the impact on fish populations.

Hydro Québec provides examples that indicate that not all habitats are of equal value to fish. For example, the models used to calculate maximum sustainable yields for salmon and brook trout are based on the abundance of rearing habitats, given that spawning habitats generally do not limit productivity. (Lachance and Bérubé 1999; Picard 1998).

Habitat use depends not only upon the species present, but also upon competition between species and the relative availability of habitat.

Hydro Québec indicates that for future reservoirs, calculating square metres of habitat per species and per life-history stage is an impossible task, considering not only the magnitude of the waterbodies, but also the fact that little is known about the shift in the way these areas are used by the species, which may differ from natural lakes.

Key aspects of approaches proposed by Hydro Québec are outlined below.

<u>Approach to Reservoir Area – Upstream of Dams</u>

- Choose a representative sample of lakes, rivers and streams to be flooded using high-resolution digital imaging and aerial photographs, and describe them in detail.
- Describe important ecological features such as bathymetry, substrate, water quality, and vegetation for each waterbody or stream.
- Describe the fish community and the way it uses different types of habitat by fishing with various types of gear.
- Describe habitat by species and biological function (spawning, rearing, adult feeding).
- Determine the actual use of potential spawning sites for target species.
- Calculate fish productivity estimates for all types of water bodies
    - Schlesinger and Regier (1982) equation – selected because it best suits northern lake conditions. Although use of the Morphoedaphic Index (MEI) alone for estimating fish yields may be controversial, the addition of temperature in a linear regression is considered by Hydro-Québec to be a significant improvement that should be used.
    - For calculating fish biomass, the approach outlined in Bruce (1984) is viewed as the closest approximation, based upon Biomass Per Unit Effort (BPUE) and mortality rates. Hydro-Québec prefers to start from a global yield estimate, and partition it according to the relative abundance of species and population characteristics.
    - Express the Maximum Sustainable Yield (MSY) as a percentage of production using the equation of Gulland.
    - The view is expressed that for large rivers to be flooded, the situation is more complicated. It is contended that there is no agreement on how to assess overall fish productivity in rivers, because rivers differ from lakes in that their productivity does not depend upon primary production, but on yearly carbon intake, which in turn depends upon many river characteristics such as flood regime, watershed area and substrate. Follow-up surveys of the La Grande complex have found that rivers have yields equivalent to 70% of those in surrounding lakes (with similar water quality characteristics) based upon standard CPUE data obtained with a standard set of gill nets.
    - Hydro-Québec expresses the view that it is appropriate to extrapolate these yield estimates to the entire area affected by a reservoir, using high resolution digital imagery, or simply aerial photograph interpretation. Using this approach, very precise surface areas of different types of waterbodies can be calculated and multiplied by various productivity related estimates.
- Calculate productivity for post-project conditions
    - Hydro Québec suggests that that it is possible to calculate future fishing yields of a reservoir according to the predicted bathymetry with 2-m precision curves and water quality predictions that allow for calculation of an MEI, combined with temperature simulations, using the same equation used for establishing baseline conditions. This assumption reflects the outcomes from previous follow-up studies of various reservoirs that have CPUEs similar to surrounding lakes. The prediction of species relative abundance would be based upon CPUEs from previous follow-up studies.

- This exercise is based upon a "habitat analysis" based upon hydraulic simulations of the future reservoir, with the objective of ensuring that key species in the reservoir are able to complete their life-cycle under operating conditions, taking into account the operating regime and predicted annual water level variations. Previous follow-up studies suggest that habitat use in reservoirs for some species (e.g., pike) changes, since certain species maintain high abundance even following considerable change to their habitat. Hydro Québec reportedly does not, however, have detailed information on habitat use in reservoirs.
- Fishery yield estimates based upon temperature and MEI can be improved by separating littoral habitat from pelagic habitat. In large lakes, the littoral zone is more productive, and in reservoirs the ratio of littoral to pelagic habitat changes significantly. Under such circumstances, the MEI may be too coarse and estimates could be misleading. This can be refined by estimating the yields separately, when the predicted bathymetry is sufficiently precise. More detailed mapping of future fish habitat in reservoirs, by species and life stage, is not possible, because there is no previous study of habitat use, and detailed features such as substrate and vegetation cannot be predicted with sufficient accuracy.
- Hydro Québec considers that mitigation is habitat compensation within the limits of a reservoir, since the reservoir is the creation of new habitat and mitigation is a way to ensure that predicted fisheries yields will be attained.
- Hydro Québec considers that compensation includes the creation of any habitat, or any fisheries project outside the boundaries of the reservoir. These measures are to be carried out if the overall productivity balance is not attained through the predicted productivity of the reservoir, with mitigation measures. The need for compensation and the types of compensation measures are related to regional fisheries objectives. Compensation should be based on these objectives, and not on the technical possibility of recreating an impacted habitat.
- Most Hydro Québec follow-up data are based upon CPUEs; however, further follow-up is planned in relation to habitat use by fish in reservoirs.

<u>Methodology for Downstream Reaches</u>

- For a river reach downstream of a dam, fish habitat can be modified through changes in flow velocity, depth, sedimentation or temperature. Access to habitat and fish passage can also be affected.
- The proposed methodology outlined by Hydro Québec relates to determining the effects of modified flow on habitat productivity. This methodology is used mainly for downstream reaches where there is a net reduction in flow during the summer (feeding) period. It may also be used for downstream reaches where productivity parameters such as temperature are subject to major changes even though there is little modification to summer flow.
- The contention is that it is more relevant to assess the effects on productivity of qualitative and quantitative changes in various fish habitats than to determine the overall productivity of the river reach.

- Hydro Québec's proposed approach is to:
    - Draw a fish mesohabitat map;
    - Use a Habitat Productivity Index (HPI) to determine the contribution of the various habitats to productivity,
    - Simulate changes during summer operations using a hydraulic river model, and
    - Re-calculate post-project habitat areas as weighted by their respective HPIs.
- Baseline Conditions
    - Fish habitat in the river is mapped using high-resolution digital imagery. Flow facies, substrate, and depth are the main characteristics traditionally used to separate habitat types.
    - Fishing yields are used to correlate habitat types with species, and habitats are pooled into fewer classes of significance to fish.
    - Only fish feeding habitats are considered, as they are most closely related to productivity.
    - Inventories of other important habitats such as spawning areas are compiled as part of the overall impact assessment, but they are not subject to any HPI calculation designed to weigh habitat importance and compare pre- and post-project conditions. This is because the approach is not to compare habitat availability before and after a project, but rather to establish overall habitat productivity. The intent is not to establish general habitat indices for all species at all stages of life.
    - Ideally feeding habitats should be divided into two classes for most species (juveniles and adults). This supposes, however, that the relative abundance of juveniles and adults in various habitats can be determined using common fishing gear, which is difficult.
    - The BPUE in different types of habitat is used as the main input to determine contribution to productivity. Hydro Québec suggests that Biomass Per Unit of Surface (BPUS) would be a preferable measure of productivity but concludes that in large rivers the data would be impossible to obtain.
    - HPI, largely inspired by the work of Randall and Minns (2000) and Minns et al. (1996) is proposed. All habitats are ranked on a scale of 0 to 1 for each species and the habitat surface areas are multiplied by this "habitat preference" for each species. It is noted that this method assigns equal importance to all species considered, regardless of their relative overall abundance in the river.
    - Post-project surface areas for the various habitat types are generated using a hydraulic simulation of the river reach.
    - The weighted area, based on the indices described above, is calculated again for the future summer conditions and the difference constitutes the impact on a given species.
    - A habitat analysis completes the exercise. In particular, ecologically significant features such as fish passage and the availability of spawning and rearing habitats are examined. The example is provided whereby, if the water level in a river reach is low enough to dry up spawning grounds during a

spawning period, the results of the described productivity balance would be considered invalid.
    - Important spawning sites may be subject to a 2-D habitat simulation as part of the study to determine instream flow.
    - Mitigation measures would be implemented in the downstream reach to ensure that productivity predictions are valid, including work to create habitat.
    - Compensation measures would be carried out off-site in accordance with regional fisheries objectives.
    - Hydro Québec has very little data on habitat use by various species in reduced flow reaches, although CPUE data are available. The company plans to implement further follow-up programs that focus on habitat use in modified-flow reaches.

<u>Methodology for Linking Upstream and Downstream Assessments and Establishing Compensation Priorities</u>

- According to Hydro Québec's proposed methodology:
    - The productivity balance of the reservoir is expressed in fisheries yields; and
    - The balance downstream is based on weighted areas of habitat (based on productivity).

  An overall balance would involve estimating some yields for the downstream reach.
- Follow-up surveys for the La Grande complex suggest that yields in large rivers are approximately 70% of those in surrounding lakes. This could be used as a basis for establishing a balance for other projects in the vicinity.
- Hydro Québec makes the point that users of the fisheries resource may be different upstream and downstream and suggests that separate upstream and downstream impact balances may be more useful in guiding further compensation needs.

Jacques (2004) presents an analysis of a number of approaches for quantifying productive capacity in relation to large hydroelectric projects and an analysis of Hydro Quebec's proposed methodologies.

4.0 HABITAT EQUIVALENCY ANALYSIS

Habitat Equivalency Analysis (HEA) is a methodology used to determine compensation for resource injuries. HEA has developed as a means of quantifying losses and associated compensation requirements. HEA appears to be most frequently applied to the assessment of injury resulting from incidents that cause environmental damage, such as oil spills. Its purpose, particularly in response to pollution incidents, is to assign a monetary value to a loss of habitat service, based on the cost and time delay to replace that service.

The principal concept underlying the method is that the public can be compensated for losses of habitat resources through habitat replacement projects providing additional resources of the same type. Natural resource trustees have employed HEA for vessel groundings, spills and hazardous waste sites. Habitats involved in these analyses have included seagrasses, coral reefs, tidal wetlands, salmon streams, and estuarine soft-bottom sediments (NOAA 2000).

The implicit assumption of HEA is that the public is willing to accept a one-to-one trade-off between a unit of lost habitat services and a unit of restoration project services (i.e. the public equally values a unit of services at the injury site and the restoration site). HEA does not necessarily assume a one-to-one tradeoff in resources, but instead in the services they provide. For example, if a marsh is considered as the resource and primary productivity a resource service, a replacement project may provide only 50% of the productivity of the marsh. In order to restore the equivalent of lost productivity per year, then, the replacement project requires twice as many acres of marsh. HEA is applicable so long as the services provided (i.e., net marsh productivity) are comparable.

The assumption of comparable services between the lost and restored habitats may be met when, in the judgment of resource managers, the proposed restoration action provides services of the same type and quality, and of value comparable to those lost due to injury. In this context, there is a one-to-one tradeoff between the resource services at the compensatory restoration site and the injury site (NOAA 2000).

Necessary conditions for the applicability of HEA include: (1) a common metric (or indicator) can be defined for natural resource services that captures the level of services provided by the habitats and captures any significant differences in the quantities and qualities of services provided by injury and replacement habitats; and (2) the changes in resources and services (due to the injury and the replacement project) are sufficiently small that the value per unit of service is independent of the changes in service levels. When choosing a metric to evaluate the quantity and quality of services provided per unit of habitat, natural resource managers should examine the *capacity*, *opportunity* and the *payoff* (*i.e.* benefits) of the services being provided as well as *equity* issues involved with the potential compensation projects (*i.e.* who loses and who gains as a result of the injury and the potential compensation projects). *On-site biophysical* characteristics (e.g., soil, vegetative cover, and hydrology) affect the *capacity* of an ecosystem to provide ecological and human services. *Landscape context* affects whether the ecosystem will have the *opportunity* to supply many of the ecological and human services and strongly influences whether humans will value the opportunities for services.

As described in NOAA (2000), HEA applies as a framework for scaling compensatory restoration. The basic steps for implementation include:

1. Document and estimate the extent and duration of injury, from the time of injury until the resource recovers to baseline, or possibly to a maximum level below baseline;
2. Document and estimate the services provided by the compensatory project, over the full life of the habitat;
3. Calculate the size of the replacement project for which the total increase in services provided by the replacement project equals the total loss of services due to the injury; and

4. Calculate the costs of the replacement project, or specify the performance standards in cases where the responsible party will be implementing the compensatory habitat project.

The first two steps require baseline numerical values for ecological parameters for both the injured site and the compensatory project site. Step three calculates the size of the compensatory project for which the total increase in services provided by the replacement project just equals the total loss of services (e.g., production of fish) due to the injury. Since they may occur in different years, there may be justification for discounting the losses and gains so that units reflect present worth. This makes units from different time periods comparable. The discount rate should incorporate standard economic assumptions that people place a greater value on having resources available in the present than on having their availability delayed until the future. The annual discount rate used in a HEA calculation represents the public's preference towards having a restoration project in the present year, rather than waiting until next year. The economics literature supports a discount rate of approximately 3% (NOAA 2000).

As indicated in NOAA (2000), the parameters necessary to complete a simple HEA are:

Injured Area Parameters:

- Baseline level of services (e.g., fish habitat productivity) at the injury site;
- Extent and nature of the injury: the spatial extent of injury (e.g., hectares) and the initial reduction in service level from baseline at the injured site (characterized as a percent of the baseline level of services). These parameters may be combined to measure the "effective-hectares" of an injury;
- Injury recovery function (with primary restoration or natural recovery): the rate of (incremental) service recovery and the maximum level of services to be achieved (characterized as a percent of the baseline level of services); and
- Recovery period for injured resources: the dates when recovery starts and when maximum level of services will be achieved.

Replacement Area Parameters:

- Initial level of services at the replacement project site, as measured in effective area (as a percent of baseline services at injury site);
- Replacement project maturity function: the rate of (incremental) service growth and the maximum level of services at the replacement project site (as a percent of the baseline level of services at the injury site);
- Maturity period for replacement resources: the dates when services begin to increase and when the maximum level of services will be achieved; and
- Replacement/creation project duration: lifetime of increased services.

Discount Rate

- Annual real discount rate.

Software has been developed to apply HEA.

In implementing HEA a fundamental requirement is the need for an accepted standard for converting habitat productivity into units (e.g., HUs).

HEA could be a tool for application to fish habitat compensation challenges when issuing Authorizations under the *Fisheries Act.* Implementation of such an approach would likely require the evolution of standardized methods and measures for valuing habitat (e.g., productivity) and policy decisions and direction on whether, and under what circumstances, HEA would be considered. Software has been developed to apply HEA calculations (Kohler and Dodge, http://www.nova.edu/ocean/visual_hea/); however, this would not reduce the need for standard methods and policy decisions.

5.0 APPROACHES FOR ASSESSING CHANGE IN PRODUCTIVE CAPACITY

As indicated in Section 3.1, Minns (1995) suggests that there are three alternatives for measuring or predicting fish productivity. (Note: For the purposes of this discussion, “fish productivity” and “productive capacity” are considered to be the inter-changeable. The rationale for this is that, while there may be relatively fine differences in the scientific interpretation of the two terms, discussions on the overall challenge are not yet sufficiently refined for the differentiation to be meaningful for decision-making at the program and policy levels.). A fourth alternative has been added due to the fact that, while it is not be as rigorous as the others, it represents the *status quo* approach that is actually being implemented in many cases, and therefore *de facto* represents an alternative for consideration. The four alternatives are listed below

1. Direct measurement and summation of the production rates of all fish species present (Minns 1995);
2. Measurement of biological indices such as biomass, catch per unit effort (CPUE), sport or commercial yield, and possibly presence-absence (Minns 1995);
3. Measurement of surrogate habitat variables (Minns 1995); and
4. Measurement of the effectiveness of compensation measures in meeting the objectives established by Habitat Managers, without focusing on a rigorous balance sheet for overall gains and losses (added for the purpose of this discussion paper).

Alternatives #2 and #3 above are dependent upon on the prior existence of studies showing that the indicators are predictors of productivity (Minns 1997).

In the following overview, the approaches derived from the case studies and literature are discussed in the context of these four categories.

5.1 MEASUREMENT OF SURROGATE HABITAT VARIABLES

The measurement of surrogate habitat variables is the method that has most frequently been applied in analyzing habitat gains and losses for projects involving whole lake destruction. This is consistent with statements in the Habitat Policy relating to interim measures for productive capacity, as well as initial reviews and discussions within the program relating to Habitat Policy implementation.

This approach has been implemented through the HEP / HSI / HU approach, the approach outlined in Bradbury et al. (2001), and is consistent with the “defensible methods” approach outlined in Minns et al. (1995).

In applying the HEP / HSI / HU approach, HEP procedures are used to define the relative sensitivity/contribution of the fish habitat by rating the various types of habitat affected by a project using a HSI Model. HSI is used as a surrogate for productive capacity.

HSI values are ratings of habitat suitability based on a blend of quantitative and subjective ratings of habitat characteristics for key life-history stages on a species by species basis. To illustrate, an example of HSI scoring is presented below:

HSI Value	**Habitat Description**
1.00	Excellent
0.75	Above Average
0.50	Average
0.25	Below Average
0.00	Unsuitable

Using this approach, scores are developed for each to following habitat types: Spawning; Nursery; Rearing: and Foraging.

The HSI values are then multiplied by the area of habitat having that HSI value, in m^2 (generally 100 m^2) or hectares, to generate a value referred to as a Habitat Unit (HU). The HU values for each habitat type are summed to provide a surrogate estimate of the overall “productive capacity” of the affected habitat.

HSI models for the most part are derived from models developed by the U.S. Fish and Wildlife Service in the late 1970’s and early 1980’s, largely through a process based on information in the literature and informed professional judgment, to establish habitat suitability scores for the various life-history stages of each species.

This approach is generally consistent with the Defensible Methods approach of Minns (1997) and Minns et al. (2001) and provides a methodology for defining the unit productivity variable in the productive capacity equations.

DFO Newfoundland Region has refined the same basic approach in a manual for use in lacustrine habitats in Newfoundland and Labrador (Bradbury et al. 2001). This manual adopts the use of “Guilds” as a means to avoid having to determine HSI for all individual species. The use of Key Indicator Species, identified with stakeholders and regulators, has been applied in C&A Region.

This approach has been adopted by a number of consulting companies operating in western Canada and the North, and is the approach required by Newfoundland Region through the application of Bradbury et al. (2001). Over the past 10 years or so, this has been the approach that has been applied most frequently to assessing productive capacity in Canada (Ekati, Diavik, Doris North, various oil sands projects, Voisey's Bay, IOC). The HSI models used as the basis for application of this method have been those of the U.S. Fish and Wildlife Service, adapted in some but not all cases for application to local conditions.

Pro

The method provides an analytical and rationalized approach to reflecting the relative contribution of habitat to fish production, as a surrogate for productive capacity. By assessing the amount of habitat and its suitability for each critical life-history stage, the method provides a focus for directing refinement of the information base for each species (e.g. variance for application in the North). Changes in HSI values can be assessed in the context of a Before-After-Control-Impact (BACI) study design approach.

The approach may be particularly applicable in northern, highly oligotrophic situations because the systems are simpler and there are fewer species than in southern Canada.

Con

The HSI models that exist were developed based upon southern conditions and may not be directly applicable in the North. For example, the HSI model for northern pike clearly shows that all life stages for the species are dependent upon the presence of aquatic macrophytes. Since aquatic macrophyte presence was limited at Diavik, the published model could not be applied (Diavik Diamond Mines Inc. 1998). In the case of Diavik, the Delphi approach was used as a method to apply informed, independent, professional judgement to adapt/develop the HSI scores; however, only three of the fifteen government and academic panelists responded to the questionnaire that was the basis for application of this approach. The conclusion was drawn that the responses received confirmed the HSI models developed for Diavik.

The HSI models that are the basis for this approach were developed on the basis of literature reviews and professional opinion. The model for northern pike clearly states that "use of these models for impact assessment requires the setting of clear study objectives and may require modification of the models to meet those objectives", and "The HSI models presented herein are hypotheses of species-habitat relationships, <u>not</u> statements of proven cause and effect relationships. The models have not been tested against field population data." (Inskip 1982). Similar caveats appear in the brook trout model (Raleigh 1982).

Application of this approach can be resource and labour intensive. In addition, it is difficult to integrate findings across species, to derive an overall estimate of productive capacity for natural fish species assemblages. In Jacques (2004), it is noted that this approach would require a number of adaptations before it could be applied to large hydroelectric projects, given the scope and nature of the habitats affected or created.

To ensure that this approach is fully defensible, a considerable amount of work would be required to ensure that HSI models are fine tuned/developed for application to indigenous species in the North. Even with this level of effort, the results would still fall within the category of ‘surrogate habitat indicators’ rather than actual measures of productive capacity.

5.2 MEASUREMENT OF BIOLOGICAL INDICES SUCH AS BIOMASS, CPUE, YIELD, PRESENCE-ABSENCE

Measurement of biological indices such as Biomass, CPUE, Yield, and Presence-Absence is the second alternative listed by Minns (1995). As indicated in Minns (1997), management of many of the world’s fisheries depends upon the interpretation of yield, CPUE and index fishing data. In applying this approach, habitat productivity is determined by measuring parameters that include: fish abundance/density and biomass; fish presence/diversity; fish growth rate/condition for a number of species/trophic levels; macroinvertebrates; periphyton; water quality; and other measures of production.

The multi-metric approach using the Before, After, Control and Impact (BACI) study design for quantifying changes in productivity, as described in Pearson et al. (2005), meets this requirement

In addition, a number of approaches are available for assessing fisheries productivity. Jacques (2004) reviewed some of these approaches, as follows:

- Vézina Method (Vézina 1978) – defines brook trout harvest potential from a lake based on assessment of average depth. This model was developed for the Laurentian area of Québec but has not been field validated for application in other areas.
- Morphoedaphic Index (MEI) (Ryder 1965) – is based upon the assumption that the production of fish in a lake is influenced by three main factors (i.e. climate, morphometry of the waterbody and the edaphic condition of the environment). The MEI allows for the definition of multi-species potential yield of a water body based upon the relationship between concentration of Total Dissolved Solids (TDS) and the average depth. The model does not take into account the complexity of the ichthyological community or the interactions (e.g., predation, competition) among species. Schlesinger and Regier (1982) provided refinement by development of an adapted equation which relates climate with MEIs of fish yields from natural lakes. Although use of the MEI alone may be controversial for estimating fish yields, the addition of temperature in a linear regression is considered by Hydro Québec to be a significant improvement that should be used.
- Assessment of phytoplankton production – Downing et al. (1990) determined that the annual production of phytoplankton is the parameter that most strongly correlates with the production of fish. Oglesby et al. (1977) indicated that the surface area of a water body, importance of the input of external nutritional

elements, and turnover rate, are factors that must be considered when models based upon primary production are used.

- Calculation of fish biomass, the approach outlined in Bruce (1984), based on Biomass Per Unit Effort (BPUE) can be used. Biomass corresponds to the abundance and average weight of a fish stock or defined fraction of a stock, by unit area, during a given period of time.
- Calculation of potential Yield (Y) which is the number or weight of living organisms harvested or likely to be harvested by unit area, for a given period of time (kg/ha/yr), based on harvest data or scientific population estimates.
- Calculation of Maximum Sustainable Yield (MSY) which represents the largest average harvest (kg/ha) that can be taken in a continuous manner from a fish stock under existing conditions without compromising the system's balance, based on harvest data or scientific population estimates.

Pro

The multi-metric approach using a BACI study design offers a comprehensive approach to estimating productivity.

Jacques (2004) suggests that the methods reviewed, if used, are generally more applicable to lakes, large rivers and reservoirs where the more detailed approach involving measurement of surrogate habitat variables may be impractical and less effective.

Con

The approaches outlined in Pearson et al. (2005) are labour intensive and can be quite costly, depending on the scale of the project. Obtaining baseline data over a period of two years, while optimal, may be challenging, depending upon the financial, market and timing circumstances facing the proponent. Obtaining and managing follow-up information over an extended period of time can also be a challenge for both DFO and the proponent.

The fisheries productivity measures discussed by Jacques (2004) can present difficulties that must be overcome, including: constraints linked to biological data collection, including spatial and temporal variability; difficulties in establishing and validating reference sites; variability associated with sampling; limits of sampling methods in certain habitats; and the fact that the absence of fish does not mean that there is no productive capacity. There are challenges in enumerating densities of resident fish in large rivers. MSY models are intended to under-estimate fish populations, as a safety factor, and the use of harvest data from aboriginal, commercial and recreational fishers is not always completely reliable. These approaches could be difficult to apply in the case of large scale projects.

5.3 DIRECT MEASUREMENT AND SUMMATION OF THE PRODUCTION RATES OF ALL FISH SPECIES PRESENT

Direct measurement of production rates is a challenge and the challenge is compounded when an array of species is involved. Some approaches include: the use of fish counting fences; and fishing out selected areas (e.g. a confined bay) with subsequent extrapolation to an entire lake. Summing the production for each species then provides a direct measurement of fish production for all species in the system. The measurements can be made using the BACI study approach.

Pro

This approach can provide a direct and accurate measure of fish production.

Con

This approach can be very labour intensive and costly (e.g. operating a counting fence) and may be difficult to apply on large scale projects. This approach can also result in an extensive amount of destructive sampling. Application of this approach will require further development of the methodologies.

5.4 MEASUREMENT OF EFFECTIVENESS OF COMPENSATION MEASURES IN MEETING THEIR OBJECTIVES WITHOUT A BALANCE SHEET APPROACH

This approach is likely the one most frequently applied on an ongoing basis across the DFO Habitat Management Program, particularly for smaller projects where the overall risks to fish habitat productive capacity are not great. This approach is fundamentally based upon judgement, in terms of lost habitat productive capacity and the amount of compensation needed to replace it. Compensation measures are developed that focus on creating similar habitat, with a safety factor, or address production limiting features of the existing habitat (e.g. spawning gravel; overwintering pools; etc.).

This is the approach that was applied in the case of the Kemess South Mine in British Columbia. A key feature of the application of this approach at Kemess has been the implementation of fairly intensive monitoring and adaptive management decision-making that is directly linked to pre-established criteria.

Pro

This is a practical approach that is focused and relatively inexpensive to apply, and is amenable to a risk management approach. Frequently it is not possible to precisely quantify the balance of losses and gains in production resulting from addressing production limiting aspects of the habitat. Where “bottlenecks” are addressed, it is actually likely that in many cases the gains far outstrip the losses, although this premise may not hold for projects involving whole lake destruction.

Con

The lack of rigour in this approach can lead to inconsistencies between staff and offices and/or the perception of inconsistencies by proponents. It is difficult to defend against claims by proponents that they are being asked to provide more compensation than is warranted. It is generally not possible to demonstrate conclusively that the NNL principle has been upheld. Application of adaptive management to address non-performance requires ongoing and active commitment to the involvement of DFO staff.

6.0 SUMMARY

The case studies and analysis presented in this study provide details on approaches used for whole lake and aquatic ecosystems to: quantify lost fish habitat productive capacity; compensate for that lost productive capacity; and monitor the effectiveness of compensation measures. To facilitate reference, individual case study scenarios are presented in Appendix 1.

As can be seen from the case studies and literature, the principle methodologies proposed and being employed tend to fall into the following macro-level categories:

1. Direct measurement and summation of the production rates of all fish species present (Minns 1995);
2. Measurement of biological indices such as biomass, CPUE, sport or commercial yield, and possibly presence-absence (Minns 1995);
3. Measurement of surrogate habitat variables (Minns 1995); and
4. Measurement of the effectiveness of compensation measures in meeting the objectives established by Habitat Managers, without focusing on a rigorous balance sheet for overall gains and losses (added for the purpose of this discussion paper).

In the case studies and analysis, a number of pros and cons emerge, and professionals working with these approaches will also have identified pros and cons.

From the analysis, it becomes apparent that the application of these approaches to large water shed scale projects, such as large hydroelectric developments, may warrant consideration as a separate matter for scientific debate and policy discussion. This is because of the number of confounding issues that differ from the whole lake destruction issue, including:

- The projects affect and create large reservoirs/impoundments that do not amount to complete destruction of fish habitat productive capacity, rather they result in a change in that capacity;
- The projects affect large rivers that present assessment challenges that differ from lakes;
- The projects can result in decreased downstream flows and diversions to another watershed which alters habitat; and
- The projects may result in mercury accumulation for a period of time, which is an as of yet unresolved policy issue in the context of NNL and hydroelectric development. The Habitat Policy does, however, focus on maintaining NNLs in productive capacity such that fish suitable for human consumption are produced.

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APPENDIX 1. CASE STUDIES

DIAMOND MINES

WHOLE LAKE CASE STUDY: DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES	
PROJECT	Diavik Diamond Mine, Northwest Territories
LOCATION	Diavik Diamond Mine is located on and adjacent to the eastern side of Lac de Gras, approximately 300 km northeast of Yellowknife in the Northwest Territories. Latitude 64°31’N, Longitude 110°20’
TYPE OF PROJECT	Open pit and underground diamond mine and facilities.
KEY COMPONENTS	Diavik Diamond Mines Inc. has developed open pit and underground mining of kimberlite pipes at its Lac de Gras mine site. The diamond-bearing kimberlite pipes are located beneath Lac de Gras, near the shoreline of East Island. Mining, primarily open pit, required the construction of containment dykes in Lac de Gras. Construction resulted in both permanent and temporary alteration of a small lake and stream habitat on East Island. In addition, a long narrow bay on the East Island (the north inlet) has been closed by a dyke at the entrance, and used as part of the water treatment system. Dyke construction and infrastructure development have affected existing fish habitat.
FISH SPECIES IMPLICATED	• Arctic grayling • Lake trout • Round whitefish • Cisco • Lake whitefish • Burbot • Longnose sucker • Slimy sculpin • Northern pike • Lake chub • Ninespine stickleback

HABITAT LOSS	
ESTIMATED LOSS	Estimated habitat loss for the Diavik Diamond Mine Project includes: • Fish habitat in small lakes known as e1, e6, e7, e8, and e10 on East Island lost due to mine development. • Fish habitat in streams on East Island lost due to mine development. Fish habitat in Lac de Gras lost due to the placement of rock in the lake to construct approximately 5 km of dykes and the loss of habitat inside the dykes due to open pit mining. • Fish habitat in the North Inlet of Lac de Gras lost due to the construction of a dyke across the mouth of the inlet, and use of the inlet as part of Diavik's water management system. • Fish habitat in Lac de Gras altered due to construction of a rock jetty to support a water intake structure. • Fish habitat in Lac de Gras altered due to the deposit of sediment as a result of dredging and dyke construction. In total, it was calculated that 2,432 HUs would be lost in Lac de Gras. It was considered that fish habitat compensation measures would fully offset the loss by creating approximately 2,618 HUs, a surplus of 186 HUs being created. A total of 0.12 HUs of the 0.15 HUs of fish habitat in streams on the East Island were to be altered. Restoration of natural drainage patterns on the east island upon mine closure would restore 0.02 HUs of migration habitat for fish. Compensation efforts in the form of improvements to the stream that drains lake w1 on the west island would result in a further gain of 0.24 HUs of migration habitat and 0.016 HUs of migration habitat and 0.016 HUs of spawning and rearing habitat. Compensation for the habitat loss in the small lakes on East Island is to result in complete offsetting of habitat losses due to construction once fish communities are established, resulting in the creation of 244 HUs, and a surplus of 71 HUs relative to baseline conditions. For all species, the greatest losses were in spawning and nursery habitat. These losses ranged from 1-2% of the total available spawning and nursery habitat available in Lac de Gras. Spawning habitat was not found to be limiting in Lac de Gras. Therefore, no special efforts to create shoals, which function primarily as spawning habitat, were proposed in the compensation plans. Shoals were observed to be numerous

	throughout Lac de Gras and the creation of new shoals would only result in a modest increase in spawning habitat. Changes in rearing and foraging habitat were usually <1%. The losses resulting from the project were primarily in deep water portions of Lac de Gras, within the boundaries of the dykes. Deep water habitat is not limiting in Lac de Gras and therefore the focus of compensation was on the construction of shallow water rearing habitat.
QUANTIFICATION METHOD	A modified Habitat Evaluation Procedure (HEP) was used to calculate the quantity and quality of fish habitats being altered, lost or created during all three phases (construction, operation, closure) of the Project. HEP analysis combines habitat quality defined by Habitat Suitability Index (HSI), with habitat quantity in the form of calculated area, to calculate Habitat Units (HUs), a measure that accounts for both quantity and quality of habitat available for the species of interest. Multiplying the HSI value for each species and life stage (spawning, nursery, rearing, and foraging) by the area of each type of habitat provided the number of HUs available for each species and life stage affected during each phase of the project. Comparing the number of HUs available under baseline conditions to those available during construction/operations and post closure, allows for calculation of the overall number of HUs altered, lost and created by the project, taking into account losses prevented through the application of mitigative measures. HSIs were developed for each fish species and life stage with values ranging from 0.0 to 1.0, with a rating of 1.0 being optimal. The choice of models used to determine HSI values for each species was determined by their availability in the literature. Published HSI models were available for lake trout, Arctic grayling, longnose sucker, and northern pike. The lake trout model was considered not suitable because the variables deal primarily with oxygen and temperature in the hypolimnion during summer and Lac de Gras does not stratify. In addition, the model for northern pike clearly shows that all life stages are dependent on the presence of aquatic macrophytes which are limited in abundance in Lac de Gras. The existing HSI models for longnose sucker and Arctic grayling were modified to fit Arctic conditions and applied for streams. The lack of published models/inapplicability of existing models necessitated the development of models for lake trout, round

	whitefish, cisco, burbot, slimy sculpin, lake chub, and lake whitefish. HSI models were developed for each species and life stage (spawning, nursery, rearing and foraging) (i.e., 36 HSI values were assigned for shoal habitat (9 species x 4 life stages). Published HSI models were available for only four of the nine species captured in Lac de Gras (lake trout; Arctic grayling; longnose sucker, and northern pike). The lake trout model was considered not suitable because the variables deal primarily with oxygen and temperature in the hypolimnion during summer and Lac de Gras does not stratify. In addition, the model for northern pike clearly shows that all life stages are dependent on the presence of aquatic macrophytes which are limited in abundance in Lac de Gras. The existing HSI models for longnose sucker and Arctic grayling were modified to fit Arctic conditions and applied for streams. The lack of published models necessitated the development of simple models for lake trout, round whitefish, cisco, burbot, slimy sculpin, lake chub, and lake whitefish, to fit site specific conditions. A Delphi process was applied to develop HSI models for large lake habitat using the professional knowledge of government scientists and community knowledge. This methodology was applied for lake trout, Arctic grayling, round whitefish, and cisco to properly assess the value of habitat types such as shoals. Response from the 15 scientists asked to participate in the Delphi process was limited to three scientists but confirmed the HSI models applied to the project. Field observations were used to either refine or validate existing habitat models, (e.g. spawning preferences for lake trout). Where no published information on habitat preferences in Arctic environments could be found (e.g., cisco and round whitefish preferences for rearing habitat), field observations were used to develop new HSI models. These observations were at times the only source of information available on habitat use patterns for a particular life stage of a fish species. Confidence in the models, or specific components of models varied between fish species. A high level of confidence was placed on the lake trout and northern pike models due to the

	large volume of literature on their habitat requirements. Confidence in the longnose sucker and Arctic grayling models was also high since they were modified from existing HEP models. A lower level of confidence was attributed to the models for round whitefish, cisco, and burbot due to the relative lack of information on their habitat requirements in Arctic waters. This is especially true for the rearing habitat requirements for all three species. To compensate for this lack of confidence in certain models, conservative HSI values were used. In order to develop these models, information was gathered from a literature review, a Delphi exercise, and field observations. By using all three sources of input, as well as professional judgment, each type of habitat was assigned a numerical ranking of suitability for each species. This information was formulated into a series of models describing the habitat needs for each of the 8 species. The HSI models were applied to habitat types (shoals, shorelines, etc.) in Lac de Gras and the small lakes and streams on the East Island for all fish species present in those locations. As a result, an HSI value was assigned to each habitat type for each life stage for all species present. The areas of each habitat type were calculated using GIS. They were then multiplied by the appropriate HSI value to obtain quantification of the number of HUs.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	The Hierarchy of Preferences from the Habitat Policy was applied to the greatest extent possible: • Wherever possible the proposed habitat compensation was "Like for Like" • Proximity to disturbance – habitat compensation alternatives were within the immediate vicinity of the altered habitat • Maximizing productivity of the fishery – Compensation was developed for all species present in the immediate vicinity of the mine, including Lac des Gras, and the small lakes and streams of the East Island. • Focus on affected species – measures were developed to maximize the production of the most important fish species in the region. Importance was placed on those species with the potential to support a fishery (e.g. lake trout, cisco, round whitefish, Arctic grayling).

PROPOSED	<u>Inland Lakes</u>
	• Compensation for the HADD of at least 4.6 HUs of inland lake habitat on the East Island is to be achieved by the enhancement of existing lakes within the Project area, namely:
	  • Creating connections suitable for water movement and fish passage among lakes designated as m1, m2, and m3 on the mainland to achieve a gain of approximately 3.7 HUs.
	  • Enhancing at least one East Island lake (lakes e11, e14, or e17) with the goal of enhancing limiting habitat types and structures such that productive capacity of the habitat in the chosen lake is increased for an approximate gain of 3.3 HUs.
	  • Ensuring that the total HUs gained:lost ratio for inland lake fish habitat is 1.5 or better.
	<u>Streams</u>
	• Compensation for the HADD of stream habitat on the East Island is to be achieved through the enhancement of a stream denoted as ws1 located on the West Island, between lake w1 and Lac de Gras, as well as incorporation of habitat features in the connector stream created between lakes m1 and m3 on the mainland.
	  • The habitat compensation is to be in the form of improving in-stream habitat and improving fish passage for those fish species identified as using streams in the project area.
	<u>Lac de Gras</u>
	• Compensation for HADD affecting at least 77 HUs within Lac de Gras (accounting for habitat lost due to the dyke footprints, North Inlet development, open pit mining, and the construction of the water intake structure) is to be achieved as follows:
	  • By the development of shallow rearing habitat, spawning shoals, and shoreline habitat within the dyked areas around the open pits in Lac de Gras upon completion of mining in each open pit.
	  • By ensuring that habitat features within the dyked areas, upon completion of mining in each open pit (including depth, substrate type, size, and configuration), are modeled after those features found in other productive areas of the lake, as well as incorporating traditional knowledge where applicable.
	  • By the enhancement of the outer edges of the dykes around the open pits for fish spawning by incorporating optimal features used by those fish such

	as substrate size and shape, slope, suitable wave exposure, and proximity to complementary habitat types and features; • Dyke enhancement on the lake side of the dykes is not to commence until Diavik Diamond Mines Inc. has satisfactorily demonstrated that water quality effects due to dyke leaching and potential effects due to blasting will not adversely affect fish targeted in the enhancement efforts. • By constructing the water intake support jetty with slopes and material as specified in engineering designs. • By ensuring that fish habitat compensation efforts in Lac de Gras will achieve a total HU lost:gained of 1:2 or better. • Fish salvage methods were to be implemented for moving fish from behind the dykes into Lac de Gras so as to minimize mortalities and allow complete documentation of species composition, numbers, and mortalities. • Diavik Diamond Mines Inc. was required report on the fish salvage inside each dyke within 3 months of completing dewatering of the respective dyke pools.
APPROVED BY DFO	An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in August 2000. An Authorization to Destroy Fish by Means other than Fishing was issued by DFO in August 2000.

MONITORING CONDUCTED

Four monitoring programs were proposed in the No Net Loss Plan for Diavik Diamond mine. The first three programs would begin during the operations period with some components occurring at post-closure. The last monitoring program would take place at post-closure. The monitoring programs are as follows:

Monitoring of the Creation of Fish Habitat in Small Lakes

- The monitoring program is identified contingent upon stakeholder/regulatory direction to focus on re-creating small lake habitat, as opposed to focusing the mitigative effects on Lac de Gras.
- The success of the fish habitats enhanced in lakes e11, e14 and e17 and created in lake e2 would be verified to confirm offsetting of the altered small lake habitats on the east island.
- The monitoring surveys, consisting primarily of non-lethal capture methods, would be conducted on these lakes 1 and 3 years after completion of habitat creation and fish transfers. The long term viability of the newly created habitats would be tested in two-ways:

3. By verifying survival of the stocked fish in the new habitat
4. By verifying that reproduction has occurred.

The target end-point would be Catch-Per-Unit-Effort values comparable to those in a reference lake.

Monitoring the Effectiveness of the Migration Corridor Habitat

- Stream habitat improvements would be verified during the spring spawning periods.
- The measure of success would be the presence of fish in the stream during spring spawning.
- Measurements of key habitat characteristics would be compared to other area streams.
- A lack of habitat use by fish may not be attributed solely to the suitability of habitat. Fish may not use the habitat due to behavioral mechanisms such as homing, as well as the relative abundance of the particular habitat type in relation to the number of fish using the habitat. If habitat use is not detected, the habitat characteristics would be measured and compared to habitat preference criteria. It was concluded that, if the habitat exhibits suitable characteristics, it would be considered to have achieved the objective of compensating for loss of migration corridor habitat.

Monitoring the Effectiveness of the External Edges of the Dykes in Providing Fish Habitat

- Use of habitat on the external edge of the dykes would be checked by observing fish behavior during the fall spawning period for lake trout, round whitefish and cisco.
- Limited gill netting would be used to confirm that the observed fish were in spawning condition.
- Verification that spawning has occurred would also be accomplished by confirming the presence of eggs on the substrates.
- Verification of habitat use for the nursery, rearing and foraging life stages would be carried out by direct observation and limited gill netting.
- Monitoring would be carried out once the first dyke is in place.

Monitoring the Effectiveness of the Flooded Pits as Rearing and Foraging Habitat

Verification of fish usage on the interior dykes would be carried out on mine pit A21 first, as it would be the first dyke that would be breached. The evaluation would be conducted three years after breaching. Assessment of habitat use in the pit areas would be carried out using test gill netting.

Habitat features would also be evaluated visually at that time, to ensure they are providing the desired habitat types. Results would be compared to baseline data from the north inlet.

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WHOLE LAKE CASE STUDY: EKATI DIAMOND MINE, NORTHWEST TERRITORIES	
PROJECT	Ekati Diamond Mine Development
LOCATION	Ekati Diamond Mine is located approximately 300 km NNE of Yellowknife in the Northwest Territories (Latitude 64°40’N, Longitude 114°
TYPE OF PROJECT	Open pit and underground diamond mining facilities. Initially, a processing plant will receive 9,000 tonnes per day, expanding to 18,000 tonnes per day of ore at maturity. Waste rock stripping will be up to 40 million tonnes per year. Duration of the project will be from mid-1995 to mid-2021, and possibly beyond. Tailings will be disposed of in Long Lake.
KEY COMPONENTS	• 6 lakes were dewatered to gain access to and exploit the underlying kimberlite pipes. • 1 lake was dewatered to access granular resources for construction. • 4 lakes were filled by process plant tails. • 1 lake was covered by a waste rock dump. • In addition, a number of interconnecting and commonly ephemeral head water streams will be diverted.
FISH SPECIES IMPLICATED	• Arctic grayling • Lake trout • Round whitefish • Lake cisco • Lake chub • Longnose sucker • Burbot • Slimy sculpin • Ninespine stickleback

HABITAT LOSS	
ESTIMATED LOSS	Estimated habitat loss for the Ekati Diamond Mine Project includes: • 6 lakes (Panda, Misery, Koala, Fox 1, Alexis, and Leslie) were to be dewatered to gain access to and exploit the underlying kimberlite pipes (Leslie was not dewatered). • Airstrip Lake was to be dewatered to access granular resources for construction. • 4 lakes (Brandy, Long, Willy, and Nancy) were to be filled with process plant tails. • West Panda was to be covered by a waste rock dump. • A number of interconnecting and commonly ephemeral headwater streams associated with the above lakes were to be diverted.
QUANTIFICATION METHOD	<u>Lakes</u> • Each lake was assessed on an individual basis. • "Habitat" and "productivity" were combined to determine a cumulative, site specific value for the affected resource. The monetary value of lost resources was established based on the cost to replace the habitat and achieve similar production, amortized over time. • Monetization was based on the cost of replacing the standing stock of each of the affected lakes and the value of domestic and recreational value fish within the project area (i.e., total production). • The value of the recreational fishery on a regional basis was estimated and the proportional contribution of the affected fish habitat was calculated. • For the domestic fishery, the average allowable harvest and the cost of replacement protein were calculated. • Cultural component values were also taken into account.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	<u>Stream Compensation</u> • BHP was to develop a Stream Habitat Compensation Plan which included the following: • Provision for the approval by DFO of detailed fish habitat creation and enhancement plans for the Panda Lake diversion channel. • Construction of fish habitat creation and enhancement structures in the Panda Lake diversion channel.

	• Maintenance of the Panda Lake diversion channel and fish habitat structures as required, and monitoring the effectiveness of structures in providing fish habitat. • Alteration or addition to fish habitat structures, as required by DFO, to realise the objective of stream habitat compensation. Lake Compensation • BHP was to provide DFO with the sum of $1,500,000 as compensation for affected lake habitats • The method used for arriving at a compensation value was described in Rescan (1995a) and is outlined below: o “Using available information, the existing habitat and productivity of each affected lake was quantified. Each lake was assessed on an individual basis. “Habitat” and “productivity” were combined to determine a cumulative, site specific value for the affected resource. The monetary value of lost resources was considered to lie in the cost to replace the habitat and achieve similar production, amortized over time. The value was arrived at based on the cost of replacing the habitat at a certain ratio and calculating the cost of damming Paul Lake to provide the quantity of newly flooded habitat.
APPROVED BY DFO	An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in 1997.

MONITORING CONDUCTED

A monitoring program was conducted to assess the effectiveness of the Panda Diversion Channel (PDC). Dillon Consulting (1999) provides an indication of the types of monitoring undertaken. PDC monitoring in 1999 addressed the following:

- Hydrology and hydraulics;
- Fish habitat utilization;
- Fish spawning and migratory behavior;
- Fish spawning success;
- High flow vs. low flow habitat assessments;
- Stability of constructed (“as-built”) habitat and habitat enhancements, including areas of erosion and sedimentation;
- Benthic invertebrate and periphyton communities; and
- Performance of enhanced habitat within the channel.

Arctic grayling (*Thymallus arcticus*) were found to utilize the PDC during the 1999 freshet period for migration and spawning purposes. Monitoring results also indicated the ability of Arctic grayling to migrate from Kodiak Lake through the entire length of the PDC to North Panda Lake, as well as downstream into the channel from North Panda Lake. Arctic grayling spawning activity was observed at two locations in the channel, including an area where habitat enhancements were previously constructed.

Additionally, lake trout (*Salvelinus namaycush*) were captured migrating into the channel from both Kodiak Lake and North Panda Lake. This species likely utilized the PDC for forage opportunities during the spring freshet period.

Artic grayling larvae were observed and collected within all six Reaches of the PDC, indicating successful spawning activity within the channel in 1999. These findings were similar to 1998 results when the presence of grayling larvae was also confirmed throughout the channel. Larvae emerged in the vicinity of both constructed and enhanced fish habitat and from a variety of substrate types. Conditions in the channel during the 1999 spring period were therefore considered suitable for the successful incubation and hatch of grayling eggs.

Additionally, observations of zooplankton and benthic macro-invertebrates during the period of larval fish sampling indicated the presence of an important food source for recently hatched fish.

More young-of-the-year (YOY) Arctic grayling were caught by electrofishing in 1999 than were captured in the PDC during the same period in 1998.

Benthic invertebrates are colonizing the PDC and associated habitat structures quite rapidly Invertebrate communities colonizing both natural and artificial substrates appear to be strongly influenced by physical habitat variables such as amounts of accumulated periphyton and detritus, substrate characteristics, and water velocity/flow. Invertebrate communities were dominated by chironomids, particularly collector-gathering and collector-filtering functional feeding groups.

A monitoring system was established to assess the effectiveness of the Stream Habitat Compensation Program.

The proponent is committed to conducting the following every year for 10 years:
- An assessment of the physical stability of the created habitat by using aerial photography and/or ground surveys;
- Biological evaluations to determine the success of fish habitat structures;
- Incorporating results into an annual report to DFO, including all relevant documents, data, and photographs.

Summary of 2002 AEMP Environmental Sampling Program (Rescan 2002)

Monitoring Parameter	Sampling Frequency During Open-Water Season	Replication
Lakes[1]		
Water Quality	3 times	n=2 @ 2 depths/lake
Physical Limnology	3 times	n=1/lake
Phytoplankton	3 times	n=3 @ 1 m/lake
Zooplankton	3 times	n=3/lake
Lake Benthos	1 time	n=3 @ 3 depth strata/lake
Sediment Quality	1 time	n=3 @ 3 depth strata/lake
Fish Communities	1 time	10-18 gillnet sets/lake # samples varied per lake
Streams		
Stream Flow Measurements	4 to 8 times	n/a
Daily Stream Flow	continuous	n/a
Water Quality	3 times	n=3/stream
Stream Benthos	1 time	n=5/stream

n/a = not applicable.
1. All lake sampling, stream water quality, and stream benthos sampling were conducted by Rescan with the assistance of BHPB personnel. All fish sampling was conducted by Rescan.
2. In addition to open-water sampling, winter water quality samples were obtained in April of 2002 at n=2 @ 2depths/lake by BHPB personnel
3. Dissolved oxygen measurements were also collected during the ice -covered season by BHPB personnel: approximately one time per month for Vulture, Moose, Nema, Slipper, Cujo, Nanuq, and Counts lakes (ice conditions and access permitting); one time in April for Lac de Gras and Lac du Sauvage, and approximately weekly for Kodiak Lake.
4. Only taxonomy samples from August were analyzed; biomass samples were analyzed from all three sampling periods.
5. The number of flow measurements per stream varied with location. BHPB personnel conducted the majority of stream flow measurements.

Phytoplankton and zooplankton parameters (biomass, abundance, and diversity) were monitored.

Lake benthos samples were collected from the lake sites in August. Samples were collected from a maximum of three depth strata per lake; shallow (0.0 – 5.0 m), mid (5.1 – 10.0 m), and deep (>10.1 m). Two lake benthos parameters were evaluated for possible effects; density (organisms/m^2), and the diversity of dipteran communities (as Shannon and Simpson diversity indices). Lake benthos densities were different between shallow and mid, and between shallow and deep depth strata. In general, densities were higher at shallow depths (ranging from 978 to 46,859 organisms/m^2) as compared to mid-depths (ranging from 578 to 15,689 organisms/m^2) and deep depths (ranging from 341 to 5,615 organisms/m^2).

Stream benthos samples were collected from five streams within the Koala Watershed (Vulture- Polar, Kodiak-Little, Moose-Nero, Nema-Martine, and Slipper-Lac de Gras), one stream within the King-Cujo Watershed (Cujo Outflow), and two external watershed reference streams (Nanuq Outflow and Counts Outflow). Artificial samplers were immersed for a 31-day period from July 31 to August 31, 2002. At all sites, stream benthic communities were primarily comprised of dipterans, which accounted for 36-90% of the communities. Stream benthos dipteran communities contained between six and nine genera per site, with two to four genera making up 90% of the dipteran community.

The first year of post- baseline monitoring for fish communities was 2002. The following parameters were evaluated for possible effects: length, weight, weight-length regressions, condition, age, growth in length, residual length-at-age, CPUE, sex ratio, percent sexual maturity, diet, and tissue metal concentrations. Evaluation of mine effects on fish populations of the Koala Watershed was based on samples of round whitefish and lake trout collected by index gillnets with a 3.8 cm stretched mesh. Fish captured with other methods (e.g., large-mesh gillnets, trap nets, angling and dip nets) were excluded to avoid introducing gear related biases.

Fish communities were sampled from five lakes in the Koala Watershed (Vulture, Kodiak, Moose, Nema, and Slipper lakes), Cujo Lake in the King-Cujo Watershed; and two external reference lakes in other watersheds (Nanuq and Counts lakes). Eight parameters were measured in the field and from laboratory analyses: length, weight, age, CPUE, sex, maturity, diet and tissue metal concentrations. Analysis of biological data was restricted to round whitefish and lake trout, the two most abundant species. Analyses included length, weight, and condition factor. All weight-length regressions were highly significant and explained between 94% and 99% of the variation. Regression slopes ranged from 2.7 to 3.3, bracketing the value of 3.0 assumed for calculating condition factor. Male-female sex ratios ranged from 0.5 to 1.3 and from 0.5 to 2.0 for round whitefish and lake trout, respectively. The wide range of sex ratios was mainly due to low sample sizes. Concentrations of cadmium, copper and zinc in the livers of round whitefish did not vary substantially among lakes. The metal concentrations in lake trout livers and muscle were higher than those in round whitefish, reflecting their differences in age, size and trophic position. Average liver mercury concentrations ranged from 0.08 mg/kg WW in Vulture Lake to 0.54 mg/kg WW in Slipper Lake, whereas muscle mercury concentrations ranged from 0.07 to 40 mg/kg for the same two lakes. A small number of samples (7 liver and 5 muscle) from very large lake trout (>440 mm long) from Kodiak, Moose, Nema and Slipper lakes exceeded Health Canada’s guideline. This was not unexpected because mercury concentrations above the guideline are occasionally observed in large fish from pristine lakes due to mercury biomagnification.

REFERENCES

Dillon Consulting Limited. 1999. Panda Diversion Channel Monitoring Program, 1999. Prepared for BHP Diamonds Inc. – Ekati Diamond Mine.

Rescan. 1995a. Fisheries Mitigation Strategy for “No Net Loss Policy”. Prepared for BHP Diamonds Inc., April 1995.

Rescan. 1995b. Towards a Fisheries Compensation Plan – Estimation of Fish Habitat in Koala District Lakes and Streams. Submitted to BHP Diamonds Inc., November 1995.

Rescan. 2002. 2002 Aquatic Effects Monitoring Program (AEMP) Technical Report. Prepared for BHP Billiton Diamonds Inc. Ekati Diamond Mine.

Department of Fisheries and Oceans (DFO). 1997. Fish Habitat Compensation Agreement – Ekati Diamond Mine.

<table>
<tr><th colspan="2">WHOLE LAKE CASE STUDY:
EKATI DIAMOND MINE (KING POND LICENCE), NORTHWEST TERRITORIES</th></tr>
<tr><td>PROJECT</td><td>Ekati Diamond Mine</td></tr>
<tr><td>LOCATION</td><td>Ekati Diamond Mine is located approximately 300km NNE of Yellowknife in the Northwest Territories (Latitude 64°40’N, Longitude 114°</td></tr>
<tr><td>TYPE OF PROJECT</td><td>Development of Misery Lake kimberlite pipe.</td></tr>
<tr><td>KEY COMPONENTS</td><td>Development of a water settling facility for initial lake de-watering, waste rock storage drainage, and pit de-watering.

King Pond will support settling pond functions.

Pond alteration will primarily result from construction of a dam that will obstruct the outlet drainage of the pond, raise existing pond water elevations by a maximum of 1.3m (1:100 year event) and permit the controlled pumping of water to the downstream lake. This will be preceded by partial dewatering of the pond to further increase its capacity for receiving pumped mine water from the Misery pit development and operation (Dillon 2000).</td></tr>
<tr><td>FISH SPECIES IMPLICATED</td><td>• Arctic grayling
• Lake trout
• Round whitefish</td></tr>
<tr><th colspan="2">HABITAT LOSS</th></tr>
<tr><td>ESTIMATED LOSS</td><td>• King Pond was developed into a mine water settling facility making 29.15 ha of fish habitat within King Pond and the King-Cujo streams unsuitable for the duration of the Misery Pit mining operation (13 years).</td></tr>
<tr><td>QUANTIFICATION METHOD</td><td>The following method was used to evaluate fish habitat compensation for King Pond:
• Habitat Zones within King Pond were delineated.
• The Weighted Suitable Area (WSA) (which represents Habitat Units (HUs)) was calculated by multiplying the habitat zone area (in hectares) by the HSI value for each life stage of each species.
• The sum of WSA was then multiplied by a life stage weighting that resulted in an overall WSA score for each life stage in the pond. The sum of all WSA values</td></tr>
</table>

	represents an expression of the overall habitat units for the pond. That was the number used in comparison calculations for No Net Loss. • HSI scores for pre-developed King Pond were calculated to be 10.75 • HSI scores for pre-developed King-Cujo streams were calculated to be 0.04.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	The following will be completed at Misery Pit following the completion of mining in 2013: • Removal of accumulated sediment from the cobble/boulder substrate of the eastern shoreline of the pond; • Enhancement of specific pond habitat targeting an increase in depth strata and therefore overwintering capacity for future fish communities; • Removal of sediment containment curtains and partial dismantling of containment berm to enhance substrates, increase central basin cover, and reestablish pond access; • Reestablishment of the King Pond outflow by partial dam removal; and • King-Cujo drainage enhancements to increase migratory accessibility of pond and tributary habitats to a more diverse fish community.
APPROVED BY DFO	An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in 2000 for King Pond Lake/King-Cujo Streams habitat alteration.
MONITORING CONDUCTED	
Fish habitat compensation monitoring will be undertaken to assess fish habitat compensation upon implementation in 2013.	
REFERENCES	
Department of Fisheries and Oceans (DFO). January 2000. Authorization for Works or Undertakings Affecting Fish Habitat #SC00028 – King Pond Dillon Consulting. 2000. King Pond Fish Habitat Compensation Program.	

WHOLE LAKE CASE STUDY: JERICHO DIAMOND MINE PROJECT, NUNAVUT	
PROJECT	Jericho Diamond Mine Project, Benachee Resources Inc.
LOCATION	The Jericho Diamond Mine Project is located within the Carat Lake watershed in Nunavut, near the northwest corner of Contwoyto Lake.
TYPE OF PROJECT	Benachee Resources Inc. (BRI) proposed to conduct open pit and underground mining of kimberlite pipes at the Jericho Diamond Project mine site. A causeway from the shoreline of Carat Lake will be constructed and operated to support a water intake facility to provide process water for mine operations. The Long Lake System will be dammed and converted to a Processed Kimberlite Containment Area will be used to store fraction material from the processing operation. As a result, flows from the Long Lake System to Lake C3 via Stream C3, will be disrupted during mine operations. To facilitate access to the open pit, a section of Stream C1 will be realigned away from the pit using a diversion channel. In addition, management of site water around and within the open pit will result in the reduction of flows in Stream C1 during operation (DFO 2005).
KEY COMPONENTS	Construction, operation, maintenance and abandonment of a 100 m long causeway to support a water intake facility in Carat Lake (DFO 2005). Construction, operation, and abandonment of a Processed Kimberlite Containment Area using the Long Lake system (DFO 2005). Construction, operation, maintenance and abandonment of a diversion channel, adjacent to Stream C1 (DFO 2005). Management of site water during mine operation within the Stream C1 watershed, adjacent to the open pit (DFO 2005).
FISH SPECIES IMPLICATED	• Arctic char • Arctic grayling • Burbot • Lake trout • Round whitefish • Slimy sculpin

HABITAT LOSS	
ESTIMATED LOSS	Construction, operation, maintenance and abandonment of a 100 m long causeway to support a water intake facility in Carat lake, will affect 1,800 m^3 of foraging, nursery/rearing, and over-wintering habitat for Arctic char, Arctic grayling, burbot, lake trout, round whitefish, and all habitat types for slimy sculpin (DFO 2005). Construction, operation, and abandonment of a Processed Kimberlite Containment Area using the Long Lake system including: • Long Lake, which will affect 100,300 m^2 of all habitat types for burbot and slimy sculpin. • An unnamed pond, north of Long Lake, which will affect 7,100 m^2 of habitat types for slimy sculpin. • An unnamed pond, west of Long Lake, which will affect 9600m^2 of all habitat types for Burbot and slimy sculpin. • Stream C3, which will affect 839 m^2 of nursery/rearing and production habitat for Arctic char, burbot, lake trout, and round whitefish, all habitat types for slimy sculpin, and nursery/rearing, spawning, and production habitat for Arctic grayling. Construction, operation, maintenance and abandonment of a diversion channel, adjacent to Stream C1, that will affect 2,153 m^2 of production habitat for Arctic char, Arctic grayling, burbot, lake trout, round whitefish, and slimy sculpin (DFO 2005). Management of site water during mine operations within the Stream C1 watershed adjacent to the open pit, which will affect 313 m^2 of production and nursery/rearing habitat for Arctic char, burbot, lake trout, and round whitefish, all habitat types for slimy sculpin, and nursery/rearing, spawning, and production habitat for Arctic grayling (DFO 2005).
QUANTIFICATION METHOD	Habitat losses and gains were quantified using HSIs, similar to the approach used at Diavik (Samis, Birtwell, and Khan. 2005). Using this model, the ratio of gains to losses was predicted to be approximately 2:1 (Samis, Birtwell, and Khan. 2005).

COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	Habitat compensation targeted the construction of high quality spawning, rearing, foraging, and wintering habitat for resident fish species, including Arctic grayling, Arctic char, lake trout, burbot, slimy sculpin, and round whitefish. The following areas are to be created as compensatory fish habitat: • 607 m^2 of fish habitat in Carat Lake is to be enhanced during the construction and operation of the causeway by incorporating larger-sized rock material into the margins. • 1,207 m^2 of fish habitat of Carat Lake is to be enhanced through the development of an underwater rock shoal by excavating to at least 2 m below normal summer water levels during abandonment of the causeway. • 940 m^2 of fish habitat in the 470 m long diversion channel is to be enhanced by incorporating natural channel features into design. • 21,000 m^2 of fish habitat is to be enhanced through the construction of 21 underwater shoals. • 182 m^2 of fish habitat is to be enhanced in a connecting channel (Stream O21) to improve fish passage between Lake O2 and Lake O3 (DFO 2005).
APPROVED BY DFO	An Authorization for the Harmful Alteration, Disruption, or Destruction of Fish Habitat was issued by DFO in April of 2005.

MONITORING CONDUCTED

A compensation monitoring program will be implemented and will include:
- A photographic record
- Details of the effectiveness of the compensation measures
- Preparing and submitting “as constructed” drawings
- Details of any contingency measures followed

REFERENCES

Department of Fisheries and Oceans. April 2005. Authorization for Works or Undertakings Affecting Fish Habitat #NU-00-0068 – Jericho Diamond Project.

Samis, S.C., Birtwell, I.K., and Khan, N.Y. 2005**.** Commentary on the management of fish habitat in northern Canada: information requirements and policy considerations regarding diamond, oil and placer mining. Appendix. Can. Tech. Rep. Fish. Aquat. Sci. 2608.

WHOLE LAKE CASE STUDY: SNAP LAKE, NORTHWEST TERRITORIES	
PROJECT	De Beers Snap Lake Diamond Mine Project
LOCATION	The project is located at Snap Lake, Northwest Territories, approximately 220 km northeast of Yellowknife.
TYPE OF PROJECT	The project includes installation and operation of two structures that will affect fish habitat within Snap Lake. One tributary stream on the northwest peninsula will also be affected by the project.
KEY COMPONENTS	• Construction and operation of a water intake facility in Snap Lake • Mine water outlet in Snap Lake • Operation of a treated final effluent diffuser in Snap Lake • Construction of a pile that will eliminate flow from Lake IL6 to stream S29 on the peninsula.
FISH SPECIES IMPLICATED	Lake trout Arctic grayling Round whitefish Longnose sucker Burbot Slimy sculpin Lake chub
HABITAT LOSS	
ESTIMATED LOSS	• The total amount of habitat lost due to the construction of the water intake structure was calculated to be 2,022 HUs, though through compensation measures there will be a net gain of 2,371 HUs (DFO 2004). • The total amount of HUs lost due to the construction of the mine water outlet was calculated to be 4,370 HUs, although through compensation measures there will be a net loss of only 1,477 HUs (DFO 2004). • The operation of a treated final effluent diffuser in Snap Lake will result in the loss of 2,377 HUs (DFO 2004). • The amount of habitat lost in stream S29 will be 6 HUs.

QUANTIFICATION METHOD	A modified Habitat Evaluation Procedure (HEP) (USFWS 1980) was used to quantify fish habitat lost or gained during construction and operation of the project. The method combines detailed habitat quality, defined by a Habitat Suitability Index (HSI) value for each fish species of concern, with habitat quantity to calculate HUs. Multiplying the HSI value for each species and habitat class by the area of each type of habitat provides the number of HUs available for each species during each project phase. Eight habitats were identified in Snap Lake, including seven shoreline habitats and one deepwater habitat. Once these habitat types were identified and quantified, the total area (m^2) of each habitat type in Snap Lake was calculated. HSI models previously developed for northern environments (i.e., Diavik) were used for each species of concern in four distinct classes of habitat (spawning, nursery, rearing, foraging) within Snap Lake. Stream S29 was evaluated for one class of habitat (seasonal foraging habitat). Once the HSIs were determined, HUs were calculated by multiplying the area of each habitat class by the appropriate HSI value for each species. The HUs were then used to predict potential habitat gains and losses for each species resulting from the development and operation of the structures.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	Habitat compensation will be created during the construction of the water intake and mine water outlet, by the physical presence of the associated rock-filled embankments along the shoreline of Snap Lake. As a result, the water intake will create a total of 1,097 m^2 of habitat. The total length of shoreline gained by the construction of the water intake will be 82.8 m. The mine water outlet will create 471 m^2 of shoreline habitat. The zone of turbulence produced by the diffuser does not create any habitat, although once it has been removed, the zone of turbulence associated with the diffuser will no longer exist, reclaiming this area (Golder 2004). Several options are proposed for the compensation of fish habitat within stream S29. The preferred option is the removal of a blockage in nearby stream S27, located on the peninsula, to

	compensate for the temporary loss of habitat. Other options include creation of pool and riffle habitat in stream S1, or compensation in an unidentified area off-site from the Snap Lake Diamond Project (Golder 2004). It is important to note that the fish habitat compensation plan for the De Beers Snap Lake Project is still undergoing significant revisions.
APPROVED BY DFO	This project has not yet been approved by DFO.
MONITORING CONDUCTED	
Compensation monitoring plans are yet to be developed (Golder 2004).	
REFERENCES	

Fisheries and Oceans Canada. June 2004. Letter to De Beers Canada Mining Inc. regarding the proposed Fish Habitat Compensation Plan.

Golder Associates. 2004. Fish Habitat Compensation Plan for the Northwest Peninsula of the De Beers Snap Lake Diamond Project. Submitted to: DeBeers Canada Mining Inc.

U.S. Fish and Wildlife Service (USFWS). 1980. Habitat Evaluation Procedures (HEP). Ecological Service Manual 102. U.S. Fish and Wildlife Services Division of Ecological Services. U.S. Government Printing Office. Washington D.C.

NORTHERN METAL MINES

WHOLE LAKE CASE STUDY: DORIS NORTH PROJECT, NUNAVUT	
PROJECT	Doris North Project, Nunavut
LOCATION	The Doris North Project is located in the West Kitikmeot Region of Nunavut, 685 km northeast of Yellowknife and 160 km southwest of Cambridge Bay. The nearest communities are Umingmaktok (65 km to the west) and Bathurst Inlet (110 km to the southwest).
TYPE OF PROJECT	An underground gold mine with plans to remove 500,000 tons of rock over two years.
KEY COMPONENTS	Key components of the Doris North Project that have the potential to result in a loss of habitat include construction of: • A tailings dam • Two water intake structure • A float plane and boat dock • Multiple watercourse crossings • A jetty in Roberts Bay
FISH SPECIES IMPLICATED	• Arctic char • Lake trout • Broad whitefish • Lake whitefish • Cisco • Fourhorn sculpin • Least cisco
HABITAT LOSS	
ESTIMATED LOSS	Estimated habitat loss for the Doris Lake Project includes: • Tail Lake will be taken out of biological production, as this lake will be the recipient water body for all process tailings and treated sewage. 34.8 Habitat Units (HUs) of fish habitat will be lost in Tail Lake. • The natural flow in Tail Outflow will be disrupted by the tailings dam altering 0.027 ha of fish habitat. • The float plane and boat dock will alter approximately 0.0004 ha of fish habitat in Doris Lake. • The proposed jetty in Roberts Bay will alter approximately 0.130 ha of marine fish habitat.

QUANTIFICATION METHOD	• A modified Habitat Evaluation Procedure (HEP) (USFWS 1981) was used to calculate the quantity and quality of fish habitats lost in Tail Lake. • HEP analysis combines the habitat quality, defined as Habitat Suitability Index (HSI), with habitat quantity to calculate HUs. • Multiplying the HSI value by the area (in hectares) of habitat affected provides the number of HU's available. • This model was developed for the Diavik Diamond Project and utilized in the Snap Lake Project. Tail Lake HUs • In order to determine the area affected by the project, bathymetric survey data of Tail Lake were used to produce a digital bathymetric chart displaying contour lines at 0.5m intervals. This survey resulted in Tail Lake being divided into three main habitat environments – two nearshore types and a deepwater type. • In order to calculate HU's, each type of habitat was assigned a numerical ranking of suitability based on the HSI. The area in hectares of each habitat type was multiplied by the appropriate HSI value to obtain HUs. Once the HUs were calculated, they were used to predict potential habitat losses cause by the gold mine. • Lake trout was the only species evaluated, since it was the only fish species captured in Tail Lake. The habitat evaluation involved utilizing HSI values for each of the four life stages of fish (spawning, nursery, rearing, and foraging). HSI values range from 0-1.0, with a rating of 1.0 being excellent and 0 being unsuitable. Once HSIs were defined for all life stages, they were applied to the specific habitat types present in Tail Lake and HUs were calculated. • Since the sum of the HUs lost represents the loss of habitat caused by the gold mine, it was determined that 38.65 HUs would be lost in Tail Lake. • Species weightings were also incorporated into the model through determination of the relative importance of fauna in terms of fish exploitation activities. Domestic/commercial species were given a weighting of exploitation importance of 0.4, sport species were given a weighting of 0.4, and forage species were given a weighting of 0.2. Since lake trout are considered both domestic/commercial and a sport species, a weighting of 0.8 was assigned. • Weightings were also developed to reflect the relative abundance of lake trout in Tail Lake. They were given

<table>
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an abundance rating of 1.0. The final rating for lake trout in Tail Lake was calculated as the mean of the exploitation and abundance weightings (0.9). This value was multiplied by the HUs calculated for each habitat type and life stage, giving a final value for habitat loss in Tail Lake of 34.78 HUs.
<u>Waterbodies other than Tail Lake</u>

Habitat losses caused by project specific activities (excluding Tail Lake) were quantified as total area, and not by the HEP analysis used for Tail Lake, since HSIs were not available for some of the affected species.
The habitat losses quantified in terms of area are as follows, according to activity:

Dewatering of Tail Lake Outflow and construction of tailings dam: 0.027 ha
Float plane and boat dock: 0.004 ha
Jetty: 0.130 ha
A net area of 0.161 ha of habitat will be negatively affected by the project.

Other activities included in the project, for which potential habitat loss would be mitigated include:

Water intake structure (mitigated using best practice such as intake screening, sediment control during construction and removal, etc.)
Watercourse crossings (mitigated using best practice such as avoiding instream activities whenever possible during construction, constructing outside of spawning/incubation periods, applying appropriate controls to surface runoff, etc.)

</td></tr>
<tr><th colspan="2">COMPENSATION MEASURES</th></tr>
<tr><td>APPROACH TO IDENTIFYING COMPENSATION</td><td>Compensation options for the loss of lake trout habitat productive capacity in Tail Lake were explored based on the Hierarchy of Preferences for HADD compensation. The preferred option is to create similar habitat or otherwise enhance the productive capacity of the habitat at or near the development site, within the same ecological unit. Habitat compensation within Tail Lake is not feasible because following construction of the Tails Dam, the lake would become a tailings containment area. Sites near the development were, therefore, considered for potential fish habitat compensation opportunities.</td></tr>
</table>

PROPOSED	The proposed compensation measures include: <u>Increasing accessibility to nearby Roberts Lake and stream enhancement in Roberts Outflow</u> The proposed habitat compensation plan involves the construction of a fishway through the dense boulder garden that hinders fish passage at the outflow of Robert's Lake. Presently, this natural boulder garden severely impedes fish passage during low discharge periods and some fish become stranded within the boulder garden where they often perish. This low discharge period typically occurs during the fall migrations for Arctic char. The addition of a fish passageway through the dense boulder garden would increase the accessibility of Roberts Lake for fish migrating to and from the ocean, resulting in increased availability of rearing, feeding, and spawning habitat, as well as critical overwintering habitat for species such as Arctic char. By allowing greater access into Roberts Lake, and the reduction in the high mortality of adult fish stranded within the boulder garden section, it is expected that the biomass of Arctic char as well as reproductive success in this lake will increase. The young Arctic char are expected to rear in Roberts Lake for 4 to 5 years before migrating to the ocean. This compensation could potentially provide an overall gain of 132.16 HUs for Arctic char. The general concept for the design of the compensation is to construct a fish passageway within the existing channel (Roberts Outflow) by rearranging the boulders to create a step-pool structure approximately 55 m long, containing 10 rock weirs. This structure would provide additional fish habitat and thus the HEP method was used to determine the number of HUs. Species evaluated include Arctic char, lake trout, and broad whitefish. An overall gain of 0.69 HU was predicted for the step-pool structure in Roberts Outflow thus totaling in a gain of 132.85 HUs for Roberts Lake and Outflow. <u>Rearing Habitat Enhancement</u> • Based on the bathymetry of Doris Lake, it is apparent that shallow in-shore rearing areas with large substrate are limited in abundance. • Creation of rearing habitat at three locations within Doris Lake is proposed as additional compensation for the loss of fish habitat in Tail Lake. • All three of the rearing areas are to be located at

the south end of Doris Lake in shallow, sandy bays.
  - Rearing habitat would be created by placing rock on the ice during winter and this material would settle into place during breakup.
  - Placement of large substrate would create a shallow area with interstices that would provide rearing and nursery habitat, thereby reducing predation on the juveniles by adult lake trout or other predators.
  - While this rearing habitat is targeted for lake trout, these enhancement areas would also benefit lake whitefish and cisco in Doris Lake.
  - This would provide an additional net gain of 0.188 ha of fish habitat, which would primarily benefit lake trout survival, the species being affected by loss of Tail Lake production.

<u>Stream Habitat Enhancement</u>

- To provide additional rearing habitat, and to promote survival of juvenile fish (primarily Arctic char) in Roberts Lake, it is proposed that additional pool habitat be created in the lower portion of a small tributary to Roberts Lake.
- The selected stream would either be one that allows fish passage at the lake confluence or a stream where a barrier could be removed.
- A minimum of 2 pool habitats would be created within the selected stream.

<u>Waterbodies other than Tail Lake</u>

- In total, 0.161 ha of habitat outside of Tail Lake would be negatively affected by the project.
- Creation of two additional rearing habitat areas within Doris Lake is proposed to compensate for the loss of 0.027 ha in fish habitat in Tail Outflow as a result of disrupting the natural water flow.
- The creation of rearing habitat to compensate for the loss of 0.004 ha in fish habitat at the proposed float plane and boat dock on Doris Lake is proposed in a bay to the south of the dock site.

<u>Roberts Bay Jetty</u>

- The jetty proposed in Roberts Bay will potentially affect 0.130 ha of fish habitat.
- Compensation measures will include rock spurs and riprap to further enhance the diversity of available habitat.
- The rock spurs will create a total of 0.120 ha of fish habitat, and the riprap located between each spur will create 0.018

	ha of fish habitat, for a total of 0.138 ha.
APPROVED BY DFO	The Doris North Project has not yet been approved by DFO for implementation.

MONITORING CONDUCTED

A monitoring program to determine the effectiveness of the compensation measures will be conducted. This includes: rearing habitat areas created in Doris Lake, pool habitat creation in a tributary to Roberts Lake, rock spurs and riprap constructed for rearing and foraging habitat along the jetty, and fish movements/accessibility through the dense boulder garden in Roberts Outflow.

Snorkel or SCUBA surveys will be undertaken in the rearing areas created in Doris Lake, to assess use of these areas by juvenile lake trout. Fish utilization of these areas will also be compared to that of natural shoreline areas. In the Roberts Lake tributary with the pool habitat creation, backpack electrofishing surveys will be conducted during the open water period to assess the effectiveness of the proposed structures. Fish fences will used to assess migrating anadromous char populations.

REFERENCES

RL&L Environmental Services Ltd., Golder Associates. 2004. Doris North Project No Net Loss Plan.

<table>
<tr><th colspan="2">WHOLE LAKE CASE STUDY:
KEMESS SOUTH GOLD-COPPER PROJECT</th></tr>
<tr><td>PROJECT</td><td>Kemess South Gold-Copper Project</td></tr>
<tr><td>LOCATION</td><td>Thutade Lake watershed of the Toodoggone region of north central British Columbia.</td></tr>
<tr><td>TYPE OF PROJECT</td><td>A 40,000 t/d open pit gold/copper mine-mill complex (Kemess South Mine) in the Thulade Lake watershed of the Toodoggone region of north central British Columbia.</td></tr>
<tr><td>KEY COMPONENTS</td><td>Construction of a dam on South Kemess Creek.
Construction of 3 water storage dams on upper tributaries of South Kemess Creek.
Construction of an open pit mine.
Development of a waste rock dump.</td></tr>
<tr><td>FISH SPECIES IMPLICATED</td><td>• Dolly Varden
• Bull trout</td></tr>
<tr><th colspan="2">HABITAT LOSS</th></tr>
<tr><td>QUANTIFICATION METHOD / ESTIMATED LOSS</td><td>Estimated habitat loss for the Kemess South Gold-Copper Project includes:
• 17.8 km of stream habitat (South Arm Creek, South Kemess Creek, and Waste Rock Creek).
• Potential alteration of 10.4 km of stream (i.e. flow reductions in South Kemess Creek, Kemess Creek and an unnamed creek draining the waste rock area (DFO, 1996).

The amount of bull trout habitat directly affected by the project is 4.1 km of stream length containing 146 m²of spawning area and 2,288 m² of fry rearing area and 3,206 m² of juvenile rearing area (Kemess Mines Inc., 1996). Fish population estimates indicated that a total of approximately 2,050 bull trout would be affected, consisting of 20 adults that spawn, and 2,030 fry and older juveniles.

Fish habitat losses by project component would be:
• Waste Rock Dump – Affected habitat provides for approximately 882 Dolly Varden of all age classes. Total surface area of impacted creek 4,876 m² (0.49 ha); an</td></tr>
</table>

	additional 17,000 m² (1.7 ha) of pond surface would be inundated by the waste rock storage area; length of affected creek normally used by bull trout is 5.2 km.; affected area estimated to contain approximately 60 m² of suitable spawning channel, 4,876 m² of juvenile rearing area and 1,132 m² of fry rearing area. • Tailings Impoundment Area – Affected area provides spawning habitat for approximately 20 migratory bull trout in the upper reaches of South Kemess and South Arm Creeks. This is estimated to represent approximately 2.3% of the bull trout spawning habitat area in the Thutade Lake tributaries. The affected area was considered to provide rearing areas for an estimated 2,050 fry and juvenile bull trout. The main spawning areas for a resident population of Dolly Varden in South Kemess and South Arm Creek would be permanently inundated by the tailings dam and impoundment area. This population predominantly spawned in several ground water seepage channels in the upper watershed. The total area of the creek affected and used by Dolly Varden is 22,485 m² (2.3 ha) and total length of creek is 8.1 km. The affected area is estimated to contain approximately 49 m² of suitable spawning channel, 3,202 m² of juvenile rearing area and 2,496 m² of fry rearing area. • The catchment area of Kemess Creek will be reduced and the tailings dam will attenuate peak flows. Mean monthly flows will not be affected and low flows may be enhanced (Kemess Mines Inc., 1996).
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	• Lengthy discussion between the proponent, DFO and the provincial agency led to agreement on a number of habitat compensation strategies set out independently for Dolly Varden and bull trout in a matrix. Compensation strategies were ranked using the following factors: o Suitability under DFO NNL Policy o Probability of long term success o Amount of ongoing maintenance required o Technical viability o Environmental impact of the strategy o Available findings (Kemess Mines Inc., 1996). • Due to the unavoidable uncertainty over the potential success of habitat replacement for Dolly Varden and bull trout, an adaptive management approach to habitat compensation was developed, supported by a comprehensive monitoring/applied research program

	(Kemess Mines Inc., 1996). The approach outlines projects that will be implemented, contingency projects and how those contingencies are to be triggered. The proponent committed, for the life of the mine, to undertake an annual scientific data collection and performance monitoring program as part of the Kemess Fisheries Management Compensation Plan, consisting of: biological and physical data collection and evaluation; a program to determine the effectiveness of the compensation; and scientific data collection to provide more basic information on char biology. The questions to be addressed include: micro- and macro-habitat selection and preferences; quantifying habitat availability and use; determining normal recruitment rates from one life-history stage to the next and how they vary in perturbed and unperturbed systems; basic information on growth and reproduction; timing and duration of fish movements; and relation between lacustrine and riverine environments with respect to bull trout in particular. • It was not known whether bull trout productivity in the relevant systems was limited by available spawning area or other factors such as available food or rearing area for juveniles (Kemess Mines Inc. 1996).
PROPOSED COMPENSATION	• Create Dolly Varden habitat in the waste rock storage area diversion ditches. • Transplant resident Dolly Varden from the tailings impoundment (South Kemess and South Arm Creeks) and the open pit and waste rock storage areas (Waste Rock Creek) to Tributary 14 and Diagonal Mountain Creek. • Construct one seepage channel in North Kemess Creek. • Construct riprap channels through the tailings pond area upon mine closure. • Mitigate the reduced flows to the Attichika Creek tributary below the waste dump. • Construct fishways around 3 waterfalls in Tributary 4 to provide passage for in-migrating (spawning) bull trout and out-migrating bull trout juveniles. • Construct 125 m^2 of bull trout spawning habitat at 10 sites upstream of the falls in Tributary 4 and create 4 appropriately designed and sited spawning structures in South Kemess Creek below the discharge of the tailings pond water diversion system. • Provide fish passage around/through beaver dams to Niven River tributaries; KMI agrees to consider the use of non-destructive techniques to allow fish passage past the beaver dams in Niven River. • Conduct an annual program of maintaining access to off

	channel inverts in Kemess Creek. • Subject to the limitations of available storage capacity of 350,000m^3 of water in the Kemess South tailings diversion system, maintain during a 1:2000 dry year, a minimum water flow of 0.23m^3/s at the mouth of Kemess Creek, 0.17 m^3/s below the confluence of North Kemess and South Kemess and 0.8 m^3/s in South Kemess Creek at all times, and develop a procedures manual to outline details of late winter water release. • Create bull trout spawning habitat in North Kemess Creek by installing stream complexing structures. (DFO, 1996)
COMPENSATION APPROVED BY DFO	A *Fisheries Act* Metal Mining Liquid Effluent Regulation Tailings Impoundment Area designation and an Authorization for Works or Undertakings Affecting Fish Habitat were issued by DFO for the Kemess South Gold-Copper Project in November 1996 (DFO, 1996). The Kemess South Habitat Compensation Agreement was approved by DFO in November 1998.

MONITORING CONDUCTED

Monitoring requirements:
- An annual survey of Dolly Varden spawning and juveniles to evaluate use by Dolly Varden and performance of the compensation measures.
- A survey of the number and location of Dolly Varden and bull trout spawners and redds in each stream. Information collected was to include: length of channel surveyed for each seepage or mainstem location, number of adult Dolly Varden observed, visual estimate of size range and number of redds, and an estimate of spawning stage (peak, prior to peak, or complete). Physical characteristics were to be measured for individual redds (i.e., depth and average velocity at each redd, redd dimensions, cover distance and types, discharge, stream temperature, channel width, wetted width, gradient and overall bed material composition. The presence of juvenile Dolly Varden was to be monitored at selected sites in each stream, utilizing electrofishing techniques consisting of two pass removal at sites that were closed off with stopnets. Information collected during these surveys was to include: location, stream length surveyed, number of fish collected, fish size and weight where appropriate, and branchiostegal ray counts to differentiate between Dolly Varden and bull trout where appropriate (Kemess Mines Inc. 1996).
- An annual survey to evaluate use and performance of bull trout compensation projects.
- The use of three fishways will be evaluated for a five year period and modifications made up to twice, and attempt various techniques to induce use by bull trout (Kemess Mines Inc. 1996).
- Success is defined as the creation of 10 redds through the combined implementation of bull trout related projects (Kemess Mines Inc. 1996).

- Biological and physical monitoring for the life of the project to identify the impacts of reduced flow in South Kemess Creek and the unnamed Attichika Creek tributary below the waste rock dump.
- A biological and physical monitoring program to identify the impacts of any reduced flows in both South Kemess and lower Kemess Creeks for the life of the mine. Monitoring would include: visual assessment of stream morphology each year in late summer to evaluate unanticipated problems affecting fry or juvenile rearing habitat; visual assessment and fish sampling in South Kemess, Kemess and North Kemess (control stream) each year in late summer to check for underutilization of bull trout fry and juvenile summer rearing habitat; visual assessment of South Kemess, Kemess and North Kemess (control stream) annually in late summer/early fall to monitor the continued utilization of existing bull trout redds and relate findings to the control stream; visual inspection every six years to monitor gravel suitability at bull trout redd sites in south Kemess and lower Kemess Creek; maintain stream flow and temperature monitoring at four locations; visual assessments annually every winter to monitor frazil ice formation downstream from the tailings impoundment spillway; survey representative cross-sections of South Kemess and mainstem Kemess creeks at 500 m intervals every five years along with visual assessments of the stream to check for infilling of pools, side channels and stream margins and any increase in stream embeddedness (related to rearing habitat) that could result from channel narrowing and sedimentation resulting from reduced flows; large scale aerial photographs every five years to evaluate effects of any reduced stream flow rates on side channel narrowing, infilling of pools; obstruction or loss of side channels and stream margins and the degree of riparian vegetation encroachment; pre-development gravel sampling at five existing bull trout redd sites to determine gravel composition and configuration; pre-development visual survey in South Kemess, Mill Creek, and the mainstem of Kemess Creek to identify existing and potential sources of gravel that are currently being used by natural forces to maintain bull trout spawning habitat or have the potential to be used for the creation and maintenance of new bull trout spawning habitat; and a visual assessment every six years in South Kemess and lower Kemess to monitor the condition and maintenance requirements of gravel for bull trout spawning habitat (Kemess Mines Inc. 1996).
- The collection of physical and biological data related to the maintenance and well being of a healthy, viable population of bull trout and Dolly Varden in Thutade watershed.
- Annual reports to the required regulatory bodies.

Success Criteria

The objective of the Compensation Plan is to ensure that overall Dolly Varden and bull trout productivity remain at pre-development levels within the Thutade Lake watershed. DFO, the province and proponent all recognized the difficulty inherent in measuring the success of the compensation projects by monitoring the overall productivity of the Thutade system. It was considered that measuring the overall productivity of the watershed would confuse the success or failure of each of the specific projects with any increases or reductions resulting from other factors (e.g. changes to fishing regulations) or natural population fluctuations resulting from disease, short term drought, flood cycles, or natural temporal barriers (Kemess Mines Inc. 1996).

It was decided that the success of each initiative would be measured on a project by project basis, with the measure being project specific. To be considered “successful”, a project should achieve its desired objective structurally, functionally and biologically for the intended species and life stage. A timeline needs to be established within which a project can be considered successful, partially successful or not successful, with this determination based on monitoring with pre-determined, measurable criteria (Kemess Mines Inc. 1996).

Dolly Varden compensation projects were to be considered successful if:

- It can be demonstrated that each of the two transplanted stocks has established a healthy population in the respective transplant watersheds. “Healthy” is considered to be a population where stocks of Dolly Varden are spawning in successive years and there is clear evidence that eggs, fry and juveniles are surviving to become adults and spawners. Target population numbers were established for the two identified transplant streams, with population size being measured by electrofishing, which is accepted as underestimating fish populations.

Bull Trout compensation projects were to be considered successful if:

- 10 bull trout redds are established in identified locations. A successful redd was defined as one that fish spawn in and eggs survive to hatching. This minimum number of redds was to be repeated over a minimum of four successive years.

REFERENCES

Dave Bustard and Associates and Hallam Knight Piésold Ltd.. 1995. Kemess South Gold-Copper Project – 1994 Fisheries Studies. Prepared for El Condor Resources Ltd. and St. Phillip’s Resources Inc.

Department of Fisheries and Oceans (DFO). 1996. Kemess South Habitat Compensation Agreement.

Kemess Mines Inc. 1996. Fisheries Impact Compensation Plan. Kemess South Project, British Columbia.

WHOLE LAKE CASE STUDY: VOISEY'S BAY, LABRADOR	
PROJECT	Voisey's Bay Nickel/Copper/Cobalt Mine and Mill
LOCATION	Voisey's Bay, Labrador, 35 km southwest of Nain, and 79 km northwest of Utshimassits.
TYPE OF PROJECT	Open pit and underground nickel/copper/cobalt mine and mill
KEY COMPONENTS	• Open pit mining facilities and operations. • Construction and operation of storage and deposition areas for waste rock and overburden. • Mine site roads. • Borrow pits and quarries, and their road access. • An airstrip. • A mill. • Tailings impoundment areas. • Accommodation and services complex. • Port site with a shipping dock. • Concentrate storage building. • Maintenance and storage areas. • Explosives storage and manufacturing facilities. • Sewage treatment system. • Power supply and distribution system. • Water supply and distribution system. • Water diversion and drainage systems. • Communication systems.
FISH SPECIES IMPLICATED	• Arctic char • Brook trout • Three-spine stickleback
HABITAT LOSS	
ESTIMATED LOSS	Loss of 88.83 ha of lacustrine habitat equivalent units in Headwater Pond, which will be used as a tailings impoundment area for the disposal of tailings and potentially acid-generating waste rock. Loss of 37.5 units (1 unit = 100 m^2) of riverine habitat from Camp Brook as a result of dams being constructed to ensure the tailings remain within the tailings impoundment area. A total of 1.30 ha of lacustrine habitat equivalent units will be altered in Camp Pond and 3.71 units of riverine habitat will be altered in Camp Brook as a result of reduced inflows into

	Camp Pond due to the removal of Headwater Pond from the Camp Brook watershed, as well as direct water extraction from Camp Pond for mining/milling operations. Loss/alteration of 16.6 units of riverine habitat in Pond 54 tributary due to diversion of a stream to facilitate construction of a waste rock storage area referred to as East Rock Stockpile, and open pit mining operations. A total of 0.38 units of riverine habitat will be altered along the main stem of Reid Brook as a result of reduced flows from Camp Brook. Any loss of flow from Pond 54 watershed to Reid Brook is considered negligible.
QUANTIFICATION METHOD	Streams • Detailed transects were established in each stream reach that had the potential to be affected. • Transects were located in habitat considered to be representative of reaches important for fish utilization with respect to water depth and wetted perimeter, taking into account sensitive biological time periods. • Each transect was used to calculate the relationship of flow to wetted perimeter graphs. These plots were used to assess whether flows could be reduced within the streams to meet the mill/mine water demands and still maintain suitable habitat for fish species in the river, specifically brook trout and Arctic char. • The information provided from each representative cross section, in terms of changes in wetted perimeter and water depth, was plotted and used to calculate the potential habitat loss in each stream section. • The loss in horizontal stream width at each location was multiplied by the habitat in each represented stream reach in order to get an estimate (in HUs) of potential habitat loss for each habitat type. Ponds Habitat loss/alteration in ponds was quantified in terms of a composite habitat equivalence which reflects the product of the habitat's composite suitability rating for all present salmonid life cycle stages (spawning, nursery, rearing, foraging) and the actual surface area of each HU (AMEC 2003a). The methodology was developed by AMEC and Voisey's Bay Nickel Company in consultation with DFO, and was based on DFO draft Guidelines for Habitat Classification/Quantification of Lacustrine Habitat (DFO 1998). These guidelines include the following instructions:

	Habitat Classification: 4. Bathymetry (m^2) in littoral and pelagic zones. The zones can be delimited using Secchi depth. 5. Map substrate type and any emergent or submergent vegetation in the littoral zone and provide area (m^2) of each distinct habitat type. 6. Collect several measures of the “condition index” for each lake under construction, including but not limited to, total phosphorus and nitrogen, seasonal rate of C_{14} uptake, index of water quality, chlorophyll ‘a’, and flushing rate. Habitat Quantification 4. Assign HSI value for each life stage of each species, for each habitat type. 5. Calculate HUs as Weighted Suitable Area (WSA). 6. Develop a consistent weighting scheme for combining species and life stage suitability ratings into a composite suitability for each habitat type. Habitat suitability matrices were calculated as per Minns et al. (1995) using the lacustrine habitat requirements supplied by DFO (Bradbury et al. 1999) for Arctic char and brook trout.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION **PROPOSED**	 In order to compensate for the loss of lacustrine habitat, a nearby fishless lake (Pond 61), located in a headwater system high on a plateau and draining with a cascade into Reid Pond, was to be repopulated, with nearby North Pond being used as a contingency. It is predicted that 116.4 ha of new habitat will be created. This was to be completed through the following steps: 1. Conducting fish and fish habitat baseline studies on Pond 61 and North Pond. 2. Conducting hydrological baseline studies of Pond 61 outlet and/or its associated tributaries. 3. Conducting baseline studies on Arctic char and brook trout within Headwater Pond to verify whether these two fish species are non-anadromous lake spawners. 4. Enhancing Pond 61 salmonid riverine habitat and/or its associated tributaries. 5. Constructing a control weir in a suitable location at the outflow of Pond 61, to restrict out-migration of any transferred fish.

	6. Capturing and relocating fish from Headwater Pond into Pond 61. 7. Measuring and marking Arctic char and brook trout transferred from Headwater Pond prior to release into Pond 61. Compensation for the fluvial habitat loss includes the enhancement of 58 units of relatively unproductive habitat within the Reid Brook watershed into 13 units of Type I habitat and 45 units of Type II habitat. This was to be achieved by placing substrate and altering flow patterns within stretches of existing unproductive habitat (AMEC 2003b). This was to be completed through the following steps: 1. Conducting baseline studies of the Reid Brook watershed. 2. Enhancing Reid Brook to provide a minimum of 58 units of spawning and rearing habitat.
APPROVED BY DFO	An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in June of 2003.

MONITORING CONDUCTED

Monthly monitoring reports must be submitted to DFO in addition to a summary report at the end of each construction/operating season. The reports are to describe the effectiveness of the environmental protection measures implemented during construction/operation, from a fish and fish habitat perspective. Required elements for inclusion are:

- Water and sediment quality monitoring;
- Monitoring of metals and other contaminants;
- Hydrological assessments, including flow and/or groundwater alterations; and
- Fish sampling (DFO 2003).

REFERENCES

AMEC Earth and Environmental. 2003a. Freshwater Aquatic Habitat Quantification. Voisey's Bay Mine/Mill Site. Voisey's Bay, Labrador. Prepared for: Voisey's Bay Nickel Company Ltd.

AMEC Earth and Environmental and Sikumiut Environmental Management Ltd. 2003b. Freshwater Voisey's Bay Mine/Mill Project Fish Habitat Compensation Plan. Voisey's Bay, Labrador. Prepared for: Voisey's Bay Nickel Company Ltd.

Department of Fisheries and Oceans. 2003. Authorization for Works or Undertakings Affecting Fish Habitat #03-004-001 – Voisey's Bay Nickel/Mine Project.

WHOLE LAKE CASE STUDY: SEABEE GOLD MINE, SASKATCHEWAN	
PROJECT	Seabee Gold Mine, Claude Resources Inc.
LOCATION	East Lake is located on the Seabee Gold Mine Surface Lease belonging to Claude Resources Inc.. The mine is approximately 120 km northeast of La Ronge, Saskatchewan at 55°41'N, 103°36'W.
TYPE OF PROJECT	Gold mine.
KEY COMPONENTS	Use of East Lake as a tailings disposal area.
FISH SPECIES IMPLICATED	• Walleye
HABITAT LOSS	
ESTIMATED LOSS	The total loss was calculated as 2,994 m^2 of walleye habitat.
QUANTIFICATION METHOD	A modified application of the HEP approach was used to quantify the potential walleye spawning grounds (Sentar 1991, USFWS 1981). Each distinct section of shoreline and shoal was ranked according to its suitability as walleye spawning habitat, with the following categories being assigned: Good Spawning Habitat, Fair Spawning Habitat, Poor Spawning Habitat, and Unsuitable Spawning Habitat. All areas for each habitat category were summed and then multiplied by the HSI value for walleye (Sentar 1991).
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	• An artificial spawning bed of no less than 2,994 m^2 in surface area was created for lake trout. • The selected areas were treated with clean, crushed rock, 100 to 300 mm in diameter, free of fine particulates. • Material was placed to a depth of 100 to 120cm (DFO 1992).

APPROVED BY DFO	• An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in 1992.

MONITORING CONDUCTED
• An assessment of the effectiveness of the habitat compensation program was required within the Habitat Compensation Agreement (DFO 1992).   • Samis, Birkwell, and Khan (2005) indicate that the constructed reef in Porky Lake was assessed in 1992 and 2001. No lake trout eggs were collected at the constructed reef.

REFERENCES

Department of Fisheries and Oceans. 1992. Fish Habitat Compensation Agreement. Seabee Mine – East Lake.

Samis, S.C., Birtwell, I.K., and Khan, N.Y. 2005. Commentary on the Management of Fish Habitat in Northern Canada: Information Requirements and Policy Considerations Regarding Diamond, Oil Sands, and Placer Mining – Appendix. Can. Tech. Rep. Fish. Aquat. Sci. 2608.

Sentar Consultants Ltd. 1991. Habitat Compensation Agreement Proposal – Seabee Mine – East Lake.

U.S. Fish and Wildlife Service (USFWS). 1981. Standards for the development of habitat suitability models. U.S. Fish and Wildlife Service. Washington D.C.

WHOLE LAKE CASE STUDY: LAC DORÉ VANADIUM PROJECT, QUÉBEC	
PROJECT	Lac Doré Vanadium Project (Proposed) Mackenzie Bay International Ltd.
LOCATION	The proposed project is located 27 km southeast of Chibougamau, in Québec, on the divide between the James Bay and Saint Lawrence River watersheds.
TYPE OF PROJECT	The proposed mine is expected to produce high purity vanadium-based electrolyte for vanadium redox battery technology over a period of 20 years, with possible expansion for another 20 years.
KEY COMPONENTS	• Two waste rock disposal sites (north and south) in natural depressions for a proposed 40 million $m^3$of tailings. • The south site would result in the destruction of an 8 ha headwater lake that drains toward Lac Jean. • The north site would cut off Lac Laugon and Lac Coil from Villefagnan Stream. • Tailings would be transported to the disposal sites by truck, requiring the construction of mine roads. • Process tailings from the mill would be deposited via pipeline into the Rivière Boisvert watershed. • The proposed Tailings Impoundment Area (TIA) would cover 350 ha and would be contained by 15 m high dyke • The mill operation requires the use of 400 m^3/h of water that would be extracted from Lac Brigon.
FISH SPECIES IMPLICATED	The principle fish species implicated by the project include: • Brook trout • Northern pike • Burbot • Lake whitefish • Walleye • Perch. • A limited Aboriginal fishery exists in the immediate area of the project. • Lac Chibougamau, approximately 10 km downstream from the TIA, supports a sport fishery.
HABITAT LOSS	
ESTIMATED LOSS	Construction of the TIA would result in the destruction of: • Lac Chauve-Souris (3.75 ha);

	• 3 unnamed lakes (total of 3.2 ha); • km of Sable Stream; and • Would cut off Lac Coco from the rest of the watershed. The 400 m^3/h of water required to feed the mill would be extracted from Lac Brigon, resulting in a significant reduction of water levels in that portion of the Rivière Boisvert watershed.
QUANTIFICATION METHOD	
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	• Proposed compensation involves blasting a waterfall in Villefagnan stream to allow walleye to access 5,875 m^2 of potential habitat.
APPROVED BY DFO	
MONITORING CONDUCTED	
REFERENCES	

Samis, S.C., Birtwell, I.K., and Khan, N.Y. 2005**.** Commentary on the management of fish habitat in northern Canada: information requirements and policy considerations regarding diamond, oil and placer mining. Appendix. Can. Tech. Rep. Fish. Aquat. Sci. 2608.

<table>
<tr><th colspan="2">WHOLE LAKE CASE STUDY:
WABUSH LAKE, NEWFOUNDLAND</th></tr>
<tr><td>PROJECT</td><td>Iron Ore Company of Canada – Wabush Lake</td></tr>
<tr><td>LOCATION</td><td>Labrador</td></tr>
<tr><td>TYPE OF PROJECT</td><td>Iron Ore Mine (IOC)</td></tr>
<tr><td>KEY COMPONENTS</td><td>Tailings discharge into Wabush Lake began in 1962. IOC is now required to confine its tailings within a dyke in order to ensure compliance with the Fisheries Act Metal Mining Effluent Regulations with regard to tailings confinement and maintenance of water quality in Wabush Lake. The dyke will also control “red water” in the unconfined area of Wabush Lake.

The tailings confinement dyke will be 15 km long within Wabush Lake and is to be completed by 2011.</td></tr>
<tr><td>FISH SPECIES IMPLICATED</td><td>• Lake whitefish
• Longnose sucker
• Lake trout
• Round whitefish
• White sucker
• Northern pike
• Burbot
• Ouananiche
• Brook trout
• Longnose dace
• Slimy sculpin
• Lake chub</td></tr>
<tr><th colspan="2">HABITAT LOSS</th></tr>
<tr><td>ESTIMATED LOSS</td><td>Areas of habitat loss are:
Dyke Footprint – 140 ha
Tailings Containment Area – 2,567 ha
Area of Channel Deepening – 0 ha
Area of Dredging – Nil
<u>Hydro Pole Base Pads (12) - 0.2 ha</u>
Total Composite Equivalent HUs – 2,707 ha

In terms of HUs the loss was estimated at:
Littoral Medium Substrate – 73 HUs
<u>Non-littoral Fine – 410 HUs</u></td></tr>
</table>

	Total – 483 HUs In considering the precautionary approach, the following measures were applied: • Depth of the littoral zone was overestimated; • When substrate grain size variation was noted, the more sensitive size was used; • All species in Wabush Lake and its tributaries were considered; and • Bradbury et al. (1999) and Power et al. (2000 Draft) are based upon conservative assumptions.
QUANTIFICATION METHOD	• The areas potentially affected were derived from existing and project related mapping: basemaps; lake bathymetry; and project drawings. • The littoral zone was defined on the basis of Secchi depths. • Substrate was described using a classification system based on Bradbury et al. (1999) and Power et el. (2000 Draft). • Species of fish identified in Wabush Lake were derived from Beak (1995) and augmented by (Jacques Whitford, 2000a). • Natural-lake HSI values were derived from Bradbury et al. (1999) and Power et al. (2000 Draft). Indices for Wabush Lake were adjusted to account for the current state of degradation of the habitat (Turbidity on Production, Turbidity on Feeding, Sedimentation, Sediment Chemistry) to provide corrected composite suitability indices.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	Quantification of projected habitat gain was considered difficult because it involved consideration of the fact that the project as a whole would result in changing a highly degraded habitat to a less degraded habitat (Jacques Whitford 2000b, 2001). To account for this, the following methods were used to quantify habitat compensation: • Existing habitat outside the containment dyke was quantified using the same methods as the HADD calculation; • The same amount of habitat was adjusted to account for the projected short- and long-term habitat conditions, to indicate the HUs that will be provided by the lake; and • The difference between HUs lost due to HADD and those gained due to improved conditions would be considered an

	HU equivalent gain. Calculations were based on the number of HUs post project, after application of a correction factor to reflect improved HSI scores. In addition, 10 ha of new habitat, created by flooding an island area after quarrying, and 74 ha. as a result of deepening the lake between the island and the eastern shore and the outside face of the dykes. New or improved habitat resulting from installation of the toe dyke and related lake dredging were not included.
PROPOSED	
APPROVED BY DFO	

MONITORING CONDUCTED

Monitoring Objective – To quantify regional improvement over time and to provide the basis for statistical comparisons within the length of Wabush Lake and downstream.

The program was designed to track progress and detect changes over an extended period of time, because construction of the dyke will take 10 years to complete.

Approach (Jacques Whitford 2001):

- Conceptually divide Wabush Lake into monitoring Areas 1-5 that correspond to the existing basins in the unconfined portion of the lake. Selection and designation of the basins provides each area with a full range of depths, and presumably habitats, which can be compared as single sites over time and between sites at the same time.
- Establishment of Area 6 as a control site in Julienne Lake.
- Parameters
  - Secchi depth to re-define the extent of littoral habitat over time
  - Primary productivity, and plankton biomass and composition – to track improvements as iron partitioning of phosphorus reduces over time and lake transparency improvements increase the photic zone
    - Sampling three times per year (ice-out, mid-season, late-growing season)
    - Incident Photosynthetically Available Radiation
    - Replicate water samples – alkalinity, total dissolved inorganic carbon, ^{14}C uptake, subsurface chlorophyll content, phytoplankton biomass and size distribution, zooplankton biomass and taxonomic categories.
    - Changes from baseline quantified spatially and temporally to index increased production in terms of chlorophyll and plankton biomass.
    - Summary statistics (Chi-square, *t*-test) to determine whether changes are statistically significant.
  - Benthic productivity
    - Periphyton as an indicator of primary productivity
    - Artificial substrates

    - Organic content, biomass, chlorophyll content
    - Benthic invertebrates to determine changes at depths in current and projected littoral zones, changes spatially and changes in monitoring areas over time. Includes: 5 stations per depth – no replicates. Hard substrates – artificial substrate. Soft Substrates – Eckmann grab. Analysis to Order and Family level with samples archived.
    - Summary statistics using standard tests (ANOVA, diversity indices, non-metric multidimensional scaling NMDS) to determine whether changes are statistically significant.
  - Fish Communities
    - CPUE to be used as an index of abundance
    - Focus on four numerically dominant species – lake trout, lake whitefish, round whitefish, longnose sucker – with all other catches recorded
    - Stomach analysis
    - 16 sample stations
    - Standardized methods to provide comparable results – gang of experimental gillnets using mesh sizes intended to reduce mortalities that could result from catching large lake trout by the teeth
    - Three times each year – spring, summer, fall
    - Shallow and deep sets – 12-16 hours
    - Use of a reference station in another lake
    - Record – species, length, weight, sex and maturity of mortalities, age for a representative sample
    - Analysis – total catch, catch frequency (ratio of occurrence in all sets), % of total catch, and CPUE for all species. Data to be used to determine: condition factor; weight at age; size at age; gonad weight; liver weight; egg size; and fecundity.
  - Previous studies had indicated that fish abundance in Wabush Lake was directly related to food availability and that use of habitat and spawning areas by fish was not limiting. This was taken to mean that an increase in benthic productivity would translate into increased fish abundance.

Fish Study Findings (Jacques Whitford 2002a)

- Due to differences in gear and methodology, limited comparison could be made with prior sampling results, preventing rigorous statistical comparisons.
- Confirmed prevalence of four species - lake trout, lake whitefish, round whitefish and longnose sucker. Brook trout and northern pike were taken in very low numbers and all other species were absent from the catches of the 52 sets.
- CPUE was highest in Area 1, declined progressively through Areas 2-5 and had a CPUE in the reference Area 7 similar to Areas 2 and 3.
- Deep sets (>5-m depth) had a higher CPUE than shallow sets (< 5-m depth).
- Distribution and metrics reported.
- Sampling mortality rates were considered unacceptable for a program designed to document improved population status. Losing >40% of the fish sampled would become an issue on a repeated basis. To be acceptable, the program would need to

have a loss rate of <10% and even this level may have an effect on long-lived large reproductive lake trout. The lake trout suffered mortalities of 53% and 15% in the two phases of the sampling, respectively.

- The program could not be continued using the current methods. Some alternatives considered included sampling with Fyke nets in the littoral zone or acoustic methods.

Productivity Study Findings (Jacques Whitford 2001b)

- Data permit a qualitative extrapolation of the effects to be expected once tailings confinement begins.
- It is difficult to characterize the seasonal averages at present based on only three sampling dates.

Benthos (Jacques Whitford 2002b)

- Concluded that the benthic community of Wabush Lake is significantly lower in species abundance, richness, and diversity compared to the upstream reference station on Little Wabush Lake. Significant differences were detected at most depths.

Plankton Study Findings (Jacques Whitford 2002c)

- Comparisons indicate that overall ecosystem production, as reflected by chlorophyll level, is dominated by the pelagic component. Areal measures of benthic chlorophyll (sand and tile) tend to be comparable to that of the open water at the northern-most stations; however, the littoral habitat occupies only a small fraction of the total lake area. Trophic efficiency of benthic food chains should be greater than that of pelagic food chains due to fewer trophic levels, so the benthic contribution to fish production is likely underestimated by areal comparison alone.

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URANIUM MINES

WHOLE LAKE CASE STUDY: RABBIT LAKE MINE	
PROJECT	Rabbit Lake Mine, Cameco Corporation
LOCATION	Wollaston Lake (Collins Bay), Saskatchewan 58°15'N, 103°38'W
TYPE OF PROJECT	Open pit mine.
KEY COMPONENTS	Two dykes were constructed in two areas (A-zone and D-zone) of Collins Bay on Wollaston Lake.
FIS SPECIES IMPLICATED	• Lake whitefish • Northern pike • Longnose sucker • White sucker • Arctic grayling
HABITAT LOSS	
ESTIMATED LOSS	D-Zone (DFO 1994a): Construction of a dyke in Collins Bay and subsequent dewatering of the area resulted in a loss of 4.9 ha of fish habitat. A-Zone (DFO 1995a): Construction of a dyke in Collins Bay and subsequent dewatering of the area resulted in a loss of 9.3 ha of fish habitat.
QUANTIFICATION METHOD	Two field surveys were conducted to assess the relative importance of fish habitat in the A-Zone and D-Zone pit areas to Collins Bay. The study area included all of Collins Bay, with specific emphasis on the A-zone and D-zone areas. The first field survey took place in the fall of 1993 and involved: • Identifying concentrations of lake whitefish in reproductive condition through the use of spawning nets; • Obtaining length, weight, and age of spawning individuals in Collins Bay; • Mapping shoreline habitat and determining the spawning suitability indices for fish present in Collins Bay; and • Obtaining general limnological measurements (dissolved oxygen profiles, temperature profiles, pH, specific conductance and secchi disk transparency). The second field survey took place in June 1994 and involved:

	• Identifying concentrations of spawning fish through the use of spawning nets and egg searches; • Obtaining length, weight, and age of spawning individuals in Collins Bay; • Completing shoreline habitat mapping for Collins Bay and the mouth of Collins Creek, and determining spawning suitability indices for fish present in the Collins Bay area; and • Obtaining additional general limnological measurements (dissolved oxygen profiles, temperature profiles, pH, specific conductance and secchi disk transparency). HEP procedures were used to determine the quality of fish habitat (USFWS 1981). This involved a process which included: 4. Delineating Habitat Units (HUs) based on physical characteristics. 5. Describing each HU including: depth 5 m offshore, substrate, aquatic vegetation, and shoreline characteristics. 6. Developing the HSI value. For this task, each habitat unit was rated for its suitability as spawning habitat for each of the species investigated (Arctic grayling, longnose suckers, white suckers, lake whitefish, and northern pike) and given a HSI value in one of four categories (not suitable, marginal, moderate, most suitable). This value was based on known spawning characteristics. The selection of fish species for which spawning habitat was evaluated was based on whether the species was known to occur or potentially occur in the study area. By combining HUs and HSI values with active spawning investigations, an understanding of the relative contribution of the impact areas to the populations of the various fish species was gained. (TAEM 1994).
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	Cameco proposed to implement the following fish habitat compensation measures. <u>D-Zone (DFO 1994b)</u> • Create a lake whitefish spawning shoal off the point of land

<table>
<tr><td></td><td>immediately north of the D-zone development (2,500 m^2).
• Create marsh habitat suitable as nursery and rearing habitat for various fish species, immediately north of the existing B-zone dyke (650 m^2).

<u>A-Zone (DFO 1995b)</u>
• Create a lake whitefish spawning shoal off the point of land immediately north of the A-zone development (3,000 m^2).
• Create a northern pike spawning and rearing habitat east of the A-Zone dyke (7,600 m^2).
• Create marsh habitat between the B-Zone and D-Zone dykes (2,000 m^2).</td></tr>
<tr><td>APPROVED BY DFO</td><td>An Authorization for Works or Undertakings Affecting Fish Habitat (SK-94-031) was issued by DFO in September 1994 for the HADD of fish habitat in D-Zone, Collins Bay, Wollaston Lake (DOF 1994a).

An Authorization for Works or Undertakings Affecting Fish Habitat (SK-90-005) was issued by DFO in August 1995 for the HADD of fish habitat in A-Zone, Collins Bay, Wollaston Lake (DFO 1995a).</td></tr>
<tr><td colspan="2">MONITORING CONDUCTED</td></tr>
<tr><td colspan="2"><u>D-Zone</u>
• The Habitat Compensation Agreement (DFO 1994b) indicated that a Monitoring Program would be set up that to assess the effectiveness of the Compensation Program including:
  • A survey of the whitefish spawning shoal during the summers of 1995 and 1996.
  • Assessing fish utilization of the created habitat by conducting biological and limnological surveys during the whitefish spawning season during the 3rd and 6th year following final placement of the substrate.
  • A survey of the created marsh habitat within one year of placement of the organic substrate.
  • Assessing the establishment and growth of aquatic vegetation in the created habitat by conducting biological surveys during the summer season during the 3rd and 6th year following the final placement of the substrate.
  • Reporting to the appropriate regulatory agencies.

<u>A-Zone</u>
• A monitoring program was set up that assesses the effectiveness of the Compensation Program. Components of this program include:
  • A survey of the whitefish spawning shoal during years 1, 3, 6 and 9 following deposition of the substrate.
  • A survey of the created pike habitat during years 1, 3, 6 and 9 following the deposition of the substrate.
  • Monitoring sediment transport from the created habitat during years 1, 3, 6 and 9</td></tr>
</table>

following deposition of organics.

- Assessing the establishment and growth of aquatic vegetation in the created habitat by conducting biological surveys during the summer season in years 3 and 6 following transplantation of the aquatic vegetation.
- Assessing fish utilization of the created habitat by conducting biological and limnological surveys during the whitefish spawning/post-spawning season during years 3, 6 and 9 following final placement of the substrate.
- A survey of the created marsh habitat during years 1, 3 and 6 following deposition of the substrate.
- Monitoring sediment transport from the created habitat during years 1, 3, 6 and 9 following the deposition of organics.
- Approval of methods by the appropriate regulatory agencies.
- Reporting to the appropriate regulatory agencies.

Samis, Birtwell, and Khan (In Prep.) indicate that the pike spawning marsh habitats have been utilized by pike for spawning though the utilization has been somewhat lower in comparison to reference sites. This may change as the constructed marsh habitats continue to develop. Monitoring results were confounded by low water levels during the sampling years. Utilization of the constructed whitefish spawning shoals has been limited but viable eggs have been collected at each of the shoals. Results have been confounded by failure to find a suitable reference site for comparison. The situation may be that the lake whitefish might be utilizing a large stream for the majority of spawning. The proponent has now presented a number of options for reconnecting one of the restored pits with the main part of Collins Bay.

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U.S. Fish and Wildlife Service (USFWS). 1981. Standards for the development of habitat suitability models. U.S. Fish and Wildlife Service. Washington D.C.

OIL SANDS

<table>
<tr><th colspan="2">WHOLE LAKE CASE STUDY:
JACKPINE MINE, ALBERTA</th></tr>
<tr><td>PROJECT</td><td>Shell Canada Limited
Jackpine Mine – Phase 1</td></tr>
<tr><td>LOCATION</td><td>Within the Muskeg River watershed, approximately 60 km north of Fort McMurray, Alberta.</td></tr>
<tr><td>TYPE OF PROJECT</td><td>• Stand-alone oilsands development that includes facilities for the generation of approximately 200,000 barrels per day of bitumen product.

• Open pit mining and bitumen extraction operation that uses truck and shovel type mining with semi-mobile crushers.

• Ancillary activities include alteration of the drainage and fish habitat.</td></tr>
<tr><td>KEY COMPONENTS</td><td>Key components of the development that affect fish habitat include the following:
• Khahago Creek transects the proposed external tailings disposal area and initial 10 year mining area, and requires diversion before pre-stripping and construction of tailings dykes. Khahago Creek diversion entails the diversion of run-off from Pemmican, Green Stockings and Blackfly Creeks to a surge pit. Runoff inflow to the pit is pumped through a pipeline to an operational ditch that conveys pit and Wesukimina flows to Muskeg Creek. On closure, the surge pit is to be filled with water from the Athabaska River to create a lake (Khahago Lake) that, on closure, will discharge through a channel to the East End Pit Lake.
• Construction of the surge pit at the Stage 1 diversion will alter the habitat areas within the lower watercourse areas of Pemmican, Green Stockings and Blackfly Creeks.
• Elimination of Unnamed Waterbody 7.
• Elimination of Shelley Creek.
• Wesukemina Creek is to be redirected around the active mine development area by the initial Khahago Creek diversion, for the period from 2007 to 2018. In 2019, flows in Wesukemina Creek will be directed to polishing ponds constructed as part of the muskeg drainage activities. At closure, Wesukemina Creek will flow into the East End Pit Lake.
• Redevelopment of Muskeg Creek in the section where it</td></tr>
</table>

	joins Muskeg River to accommodate construction and connection with the Compensation Lake, starting in 2007 to 2008. • A diversion of Muskeg Creek will constructed before mine development activities encroach on the creek in 2016. A new outlet from Kearl Lake will be established along the west shoreline by dyking off the existing outlet channel. The outlet channel required from the West End Pit Lake at closure also forms part of the initial diversion. This diversion will result in the lower reaches of the existing Muskeg Creek being abandoned. • Repositioning of Muskeg Creek along a designed channel that runs west along the northern edge of Lease 13, with inclusion of a fish ladder system for the period during the operational life of Jackpine Mine – Phase 1. The redesigned channel will connect with the existing downstream area of Muskeg Creek. • Redevelopment of Muskeg Creek from Kearl Lake as part of closure includes an exit channel designed to eliminate the requirement for the fish ladder along the creek. The closure configuration for Muskeg Creek is to be designed to integrate with the No Net Loss Compensation Lake developed in the downstream area of Muskeg Creek. • Connection of the West End Lake discharge stream to a channel that connects with the Muskeg River at a new discharge point.
FISH SPECIES IMPLICATED	• Northern pike • Arctic grayling • Walleye • Longnose sucker • White sucker • Lake chub • Brook stickleback • Fathead minnow • Pearl dace • Slimy sculpin • Spoonhead sculpin • Spottail shiner
HABITAT LOSS	
ESTIMATED LOSS	Total HUs Lost Including Upstream Tributaries 1,864,931 Excluding Upstream Tributaries 1,501,738 HUs Created as Compensatory Habitat

	Muskeg Creek 486,204 HUs Compensation Lake 3,358,300 HUs Total 3,864,931 HUs
QUANTIFICATION METHOD	Estimates of habitat loss required a thorough understanding of the fish communities present, as well as an accurate assessment of the available habitat. This required: • Determination of the total surface area of habitat disturbed, including information on component habitat types (e.g. run, riffle, pool); • Description of the physical characteristics of the area before and after the alterations, including: substrate composition (e.g., boulder, gravel, sand, vegetation); habitat features (e.g., instream woody debris, aquatic marcrophytes, and bank characteristics); and other variables such as water quality (e.g., turbidity, dissolved oxygen). • Consideration of the contribution of benthic invertebrate productivity and drift to the productive capacity of fish habitats; • Determination of the fish species that may use the habitat before and after the Alterations; • Knowledge of the habitat requirements of each fish species including specific requirements during various life stages (e.g., spawning, rearing, migration); and • Conducting fish inventories and benthic invertebrate drift surveys. Detailed habitat mapping and evaluation were also conducted. A HEP type of approach (U.S. FWS 1980) was used as an accounting system to document habitat quality and quantity. Habitat quality was defined by HSI values, which rank the importance of available habitat for specific species and life stages. Habitat quantity (stream area) was determined from measurements taken directly (i.e., channel width) during field programs and channel lengths estimated from digital maps using GIS. Stream area was calculated as the average channel width for a stream segment times the length of the stream segment. HUs were derived by multiplying the HSI value for habitat quality by the habitat quantity (surface area in m²). The number of HUs altered by the project was calculated and compared with the number of HUs to be created through habitat compensation

	measures. Habitat assessments included consideration of the contribution of benthic invertebrate productivity and drift to productive capacity. Fish species used to estimate current habitat availability in the watercourses were selected from among those identified as Key Indicator Resources (KIRs) identified by the proponent's consultant, in consultation with stakeholders and regulatory agencies. Identified KIR species included: northern pike; Arctic grayling; longnose sucker; and lake chub. Fish known or believed to reside in specific watercourses were also included in the habitat availability assessment. These species included: walleye; white sucker; brook stickleback; fathead minnow; pearl dace; slimy sculpin; spoonhead sculpin; and spottail shiner. Previously published HSI models were used to determine HSI values for northern pike, Arctic grayling, walleye, and white sucker. For species where previously published HSI models did not exist, (e.g., lake chub, brook stickleback, fathead minnow, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner), published information on species habitat preferences was used to develop HEP-type HSI models to derive suitability index ratings. For longnose sucker, a riverine model was derived using the published HSI model for white sucker as a template. Where published data were unavailable for individual fish species, HSI models were developed using the following assumptions: • Where criteria for dissolved oxygen requirements were unavailable, the HSI ratings of "excellent", "average", and "poor" were based on CCME Water Quality Guidelines For Aquatic Life (5.5 – 9.5 mg/L). • HUs for the developed models were based on the "Stream Habitat Classification and Rating System" from the consultants Technical Procedures for watercourse mapping. • Where fish were captured from areas known to be of low habitat suitability, dissolved oxygen concentrations were assumed to be 1.0 mg/L in the absence of site-specific data. • Where the recorded presence of species had spatial gaps in distribution, the species distribution was assumed to cover all of the watercourses between the points. • The HUs generated for species with spatial gaps in

	distribution accounted for all watercourse areas between the sites at which the species was recorded. • For the Muskeg Creek Diversion Channel, a replacement ratio was calculated at 0.8:1; however, the re-designed channel was to be based on a natural analogue of greater length and convolution, to provide a greater amount of habitat than apparent from the calculated values. • Lake whitefish expected to use the inlet and outlet of Compensation Lake, and a section of Muskeg River Diversion Channel, were not included in the calculation of total HUs created. • HUs for yellow perch on Compensation Lake were not included in the calculation of total HUs created. • Where values were not available from the published literature, estimates of habitat potential were made based on regional fish species capture data, professional judgment and knowledge of the area. Shell Canada Ltd. (2003) indicates that, while the HEP-type models that were used to estimate HUs provide a useful tool for quantifying anticipated habitat losses and gains, they are relatively simple representations of habitat suitability and there are some inherent limitations and uncertainties in their application.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	
PROPOSED	The proposed compensation plan includes the development of a new lake in the lower reach of the existing Muskeg Creek, near its confluence with the Muskeg River, as well as the reconstruction of Muskeg Creek. The inlet for the lake is to be constructed from the existing Muskeg Creek channel and will be located at the southeastern end of the proposed lake basin. The outlet will be constructed at the northwestern end of the proposed lake basin, and will be connected to the Muskeg River. *Reconstruction of Muskeg Creek* It was proposed that Muskeg Creek would be re-positioned along a designed channel (Muskeg Creek Diversion Channel). The re-positioned and re-constructed Muskeg Creek would flow into the proposed compensation lake constructed near the creek

<table>
<tr><td></td><td>mouth. The Muskeg Creek Diversion Channel is a meandering channel that includes habitat features designed to provide a quality and quantity of fish habitat comparable to that in the natural Muskeg Creek. The channel was designed to provide 525,910 HUs of compensatory habitat.

Lake Development Near the Mouth of Muskeg Creek
The proposed compensation lake, 473,000 m² in area, is to be created by excavating a low-lying area in the Muskeg River floodplain. Lake outflows are to be routed to the Muskeg River through a new 100 m outlet channel and a 150 m downstream reach of the existing Muskeg Creek. The lake is to include habitat features to support northern pike, longnose sucker, white sucker, lake chub, brook stickleback, fathead minnow, pearl dace, slimy sculpin, spoonhead sculpin, and spottail shiner. If efforts to maintain a sustainable population of lake whitefish are not successful, then yellow perch are to be introduced, following consultation and with the support of stakeholders.

Habitat features proposed for inclusion in the lake include: an extensive littoral zone (2 m); deep overwintering holes (7 m); and rock reefs. The shoreline is to be constructed in an irregular pattern, with numerous indentations or small embayments, to maximize shoreline length, littoral zone area and shoreline habitat diversity.

HUs Budget
Total HUs Lost
Including Upstream Tributaries 1,864,931
Excluding Upstream Tributaries 1,501,738

HUs Created as Compensatory Habitat

Muskeg Creek 486,204 HUs
<u>Compensation Lake 3,358,300 HUs</u>
Total 3,864,931 HUs</td></tr>
<tr><td>APPROVED BY DFO</td><td>An Authorization for Works or Undertakings Affecting Fish Habitat was issued by DFO in 2004.</td></tr>
<tr><td colspan="2">MONITORING CONDUCTED</td></tr>
<tr><td colspan="2">Shell Canada proposed to conduct monitoring as part of its overall commitment to environmental management, to provide feedback on the suitability of the mitigation/compensation. Monitoring plans included:
• Streamflows, water levels and discharge rates;</td></tr>
</table>

- Channel stability and morphology;
- Water and sediment quality;
- Littoral zone development;
- Growth of aquatic vegetation;
- Riparian zone vegetation;
- Benthic macroinvertebrate communities; and
- Fish populations.

REFERENCES

Shell Canada Limited. 2003. Revised No Net Loss Plan for Jackpine Mine – Phase 1. Second Draft Report prepared by Golder Associates for Shell Canada Limited.

<table>
<tr><th colspan="2">WHOLE LAKE CASE STUDY:
HORIZON OIL SANDS MINE, CANADIAN NATURAL RESOURCES LTD.</th></tr>
<tr><td>PROJECT</td><td>Horizon Oil Sands Mine, Canadian Natural Resources Ltd.</td></tr>
<tr><td>LOCATION</td><td>The Horizon Oil Sands Mine is located approximately 70 km northwest of Fort McMurray in Alberta in Township 96 and 97, Ranges 11 to 13, West of the 4^{th} meridian.</td></tr>
<tr><td>TYPE OF PROJECT</td><td>Oil Sands Mine</td></tr>
<tr><td>KEY COMPONENTS</td><td>Construction of the Horizon Oil Sands Project is planned in two phases. Key components of the Project that affect fish habitat include the following:

<u>Phase 1</u>
Construction of a dam across the mainstem of Tar River to create Compensation Lake. Compensation Lake will outlet to the External Tailings Area via a fish exclusion outlet culvert, or to the Compensation Lake spillway.
Construction of Tar Watershed Diversion A to divert flows of several Tar River tributaries away from the external tailings area and to the Compensation Lake.
Construction of Tar Watershed Diversion B from the Compensation lake spillway and along a Tar River tributary channel in order to direct flows from the Compensation Lake to the Tar River mainstem.
Construction of the mine pit southern limit diversion to direct flows of a Tar River tributary, as well as muskeg and overburden drainage waters, away from the south mine pit.
Re-construction of the Compensation Lake spillway and of Tar Watershed Diversion B to provide a permanent channel designed to provide fish habitat and connectivity to the Calumet watershed.
<u>Phase 2</u>
Construction of a waste overburden area to block the existing lake outlets, direct Calumet Lake outflows north to the Calumet Watershed Diversion Channel A, and allow development of the north mine pits in the lower Calumet watershed.
Construction of the Calumet Watershed Diversion A to convey flows from the Calumet Lake Inlet to the Calumet Watershed Diversion B and eventually to the Athabasca River.</td></tr>
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	• Construction of Calumet Watershed Diversion B to convey diverted flows from Calumet Watershed Diversion A to the Athabasca River. • Construction of a drop structure and fish passage structure at the outlet of Calumet Watershed Diversion B to reduce excavation requirements. • Construction of Calumet Watershed Diversion C to convey flows from an unnamed Calumet River tributary and the Calumet Lake Inlet to Calumet Watershed Diversion A, bypassing Calumet Lake and reducing flows into the lake. • Construction of Calumet Watershed Diversion D across several southern Calumet River tributaries to the junction with Calumet Watershed Diversion E. • Construction, at mine closure, of permanent Calumet Watershed Diversion E to provide fish habitat. • Construction of Calumet Watershed Diversion F in order to connect Calumet Watershed Diversion A to the Athabasca River along a gradual gradient that will provide permanent fish passage and fish habitat. • Decommissioning of Calumet Watershed Diversion B, the drop structure and the fish passage structure once Calumet Watershed Diversion F is constructed. • Reconstruction of Calumet Watershed Diversion A, Calumet Watershed Diversion, C, Calumet Watershed Diversion D as final channels, all designed to provide fish habitat.
FISH SPECIES IMPLICATED	• Arctic grayling • Northern pike • Walleye • Yellow perch • Mountain whitefish • Burbot • Longnose sucker • White sucker • Brook stickleback • Lake chub • Flathead chub • Pearl dace • Longnose dace • Trout-perch • Fathead minnow • Slimy sculpin
HABITAT LOSS	
ESTIMATED LOSS	<u>Phase 1</u> Fish habitat in portions of the Tar Watershed (~213 ha). <u>Phase 2</u> Fish habitat in portions of the Calumet Watershed (~89 ha). Authorization # AB01-477-3 lists the project permanent HADD as: • 44 ha for the Tar River mainstem reaches;

	• 169 ha for Tar River tributaries; • 15 ha for the Calumet River mainstem reaches; • 72 ha for Calumet River tributaries; • 1 ha for an unnamed tributary to the Pierre River; and • 1 ha for an unnamed tributary to the Athabasca River Authorization # AB01-477-3 lists temporary losses of: • 70 ha for Calumet Lake • 5 ha for Waterbody
QUANTIFICATION METHOD	• Fish habitat losses were calculated as surface areas of fish habitat, in hectares, multiplied by expected annual biomass production. • Fish habitat gains were calculated as surface areas of constructed compensation habitat multiplied by the expected biomass production.
COMPENSATION MEASURES	
APPROACH TO IDENTIFYING COMPENSATION	A Compensation Ratio of 2:1 was required, based on fish biomass productivity.
PROPOSED	Compensation measures for the project will include habitat compensation for fish species listed above, and specifically include: • Construction of an ecological and physically functional 76.7 ha Compensation Lake that meets the required 2:1 Compensation Ratio, before commencement of Phase 2; • Construction of an ecological and physically functional 46.7 ha permanent diversion channel comprised of Calumet Watershed Diversion A, C, D, E, and F that meets the required 2:1 Compensation Ratio. • If the Compensation Ratio is not met for the Compensation Lake and diversion channel, other ecologically and physical functional measures are to be implemented until the 2:1 Compensation Ratio is met.
APPROVED BY DFO	An Authorization # AB01-477-3 for Works or Undertakings Affecting Fish Habitat was issued by DFO in 2004.
MONITORING CONDUCTED	
A monitoring plan will be implemented that is aimed at monitoring fish and fish habitat effects including: • Monitoring fish habitat use, habitat productivity and self-sustaining fish populations (including successful spawning and recruitment). • Assessment of fish utilization of compensation structures in all seasons.	

- Monitoring of water quality, sediment quality, thermal regime, aquatic vegetation and benthic invertebrates.
- Monitoring the discharge from the Compensation Lake outlet to verify the modeling upon which the hydrological feasibility assessment was based.
- Monitoring of fishing pressure in the Compensation Lake and the effects of fish harvest on the sustainability of the populations.
- Assessment of fish habitat productivity, baseline and effects monitoring of all potentially affected waterbodies.
- Deployment and monitoring of spring counting fences to assess habitat use by fish.
- Assessment of lost fish habitat productive capacity versus constructed compensation fish habitat productive capacity is required. This is to include:
    - Average annual fish biomass production per unit area for all species in the waterbodies being sampled;
    - All mesohabitat types in both compensation and natural habitats; and
    - Monitoring in both compensation habitat and natural controls areas.

REFERENCES

Department of Fisheries and Oceans. Date Unknown. Authorization for Works or Undertakings Affecting Fish Habitat #AB01-477-3 - Horizon Oil Sands Mine.

APPENDIX 2: WORKSHOP REPORT

1.0 INTRODUCTION

The Habitat Management Program of the Fisheries and Oceans Canada has undertaken a review of the approaches being applied nationally to quantifying losses and gains associated with approving projects involving whole lake/stream destruction. A Discussion Paper on "Methodologies for Estimating Changes in Productive Capacity from Whole-lake / Stream Destruction and Related Compensation Projects" was prepared in July 2005. The Discussion Paper is comprised of: a series of case studies involving whole-lake/stream destruction that examine the approaches used to quantify the loss, calculate the required amount of compensation and monitor the effectiveness of the compensation in replacing lost fish habitat productive capacity. The Discussion Paper also looks at: approaches from the literature for quantifying productive capacity; alternative approaches to habitat compensation; and options for consideration by the Habitat Management Program.

A workshop was convened on July 26, 2005, in Ottawa, Ontario, to review the Discussion Paper, gather information to enhance the paper, and build consensus around next steps.

The purpose of the workshop was to:

- Review findings in the Discussion Paper:
  - Case studies on application of No Net Loss to projects involving whole lake destruction;
  - Approaches for measuring change in productive capacity from whole lake destruction; and
  - Alternate approaches.
- Build consensus on:
  - Pros and Cons;
  - Gaps; and
  - Next Steps.

DFO staff in attendance represented Habitat Management and Science, from both Headquarters and Regions. A list of workshop attendees is presented in Appendix 1. The workshop format was facilitated discussions held in plenary. This document presents an overview of the discussions and key areas of consensus, as building blocks for moving the initiative forward.

2.0 BACKGROUND

Subsection 35(1) of the *Fisheries Act* stipulates that the "harmful alteration, disruption or destruction of fish habitat" (HADD) is prohibited, unless authorized under s.s. 35(2) or carried out in accordance with a *Fisheries Act* regulation. This section of the

Fisheries Act came into effect in 1977. In 1986, the Department of Fisheries and Oceans (DFO) promulgated the "Policy for the Management of Fish Habitat" (Habitat Policy) to provide policy direction and guidance for decisions to issue s.s. 35(2) Authorizations. S.s. 35(2) provides broad discretionary powers. No Net Loss (NNL) in fish habitat productive capacity is the guiding principle under the Habitat Policy for the issuance of s.s. 35(2) Authorizations by the Department. To ensure NNL, the Habitat Policy requires that compensation measures must be implemented to replace any fish habitat productive capacity lost as a result of issuing a s.s. 35(2) Authorization.

The DFO Habitat Management Program has not established standardized protocols for estimating losses in habitat productive capacity as a result of whole-lake/stream destruction. As a result, quantifying the amount of compensation required for any given project can become an involved process that may be subject to differences in interpretation between the department and a proponent. Moreover, projects involving whole-lake/stream destruction are often located in relatively pristine northern areas where there may be limited available information concerning the biology and life-history habitat requirements certain fish species. The experience base relating to measures for compensating for productive capacity losses through habitat creation or restoration can also be limited. Efforts to compensate for whole-lake/stream destruction can also be confounded in some areas by reluctance on the part of local people to consider habitat compensation options that involve enhancement of pristine habitats. When fish habitat compensation is implemented, the Habitat Management Program does not have a standardized approach or methodology for quantifying or monitoring gains in productive capacity achieved to confirm whether NNL was achieved.

To date, several approaches and methodologies have been used for: estimating productive capacity losses from whole-lake/stream destruction; selecting appropriate habitat compensation; and measuring/monitoring the effectiveness of compensatory habitat. By using different approaches and methodologies for different projects, without rationalizing the difference, the Habitat Management Program leaves itself vulnerable to criticism from proponents and the public regarding transparency and the degree to which regulatory decision making is consistent. In addition, there is a requirement, particularly in the case of northern environments, to gather new scientific information concerning the biology and life-history habitat requirements of resident species, and to validate methodologies being used for quantifying changes in habitat productive capacity.

In recognition of these challenges, a Discussion Paper was prepared to support consideration of standardized approaches for quantifying losses and gains in productive capacity resulting from whole-lake/stream destruction and associated habitat compensation projects.

The Discussion Paper is entitled "*Methodologies for Estimating Changes in Productive Capacity from Whole-lake / Stream Destruction and Related Compensation Projects*". The discussion paper presents an analysis and evaluation of available assessment methodologies for estimating the loss of productive capacity from whole-lake destruction, and approaches to monitoring the effectiveness of the compensatory habitat in achieving NNL. This Discussion Paper was circulated in advance of the July 26, 2005 workshop and served as the basis for workshop discussions.

In introducing the Discussion Paper, it was suggested that the challenges associated with addressing whole lake / stream destruction from a No Net Loss perspective have elements that fall into the following categories:

- Policy
- Science; and
- Operations.

Participants agreed with this observation and came back to this structure in analyzing issues and identifying next steps for the initiative.

3.0 OVERVIEW OF WORKSHOP PRESENTATIONS SUMMARY

The workshop was introduced by M. P. LeBlanc, Director, Habitat Protection and Sustainable Development. The context for the workshop was set in terms of discussions around the effectiveness of various methodologies used for quantifying losses and gains in productive capacity relating to whole lake/stream destruction. Mr. G. Packman was introduced as the consultant who has been working with the Habitat Management Program on this project and would be presenting the findings outlined in that paper.

It was confirmed that outcomes from the workshop will help guide the development of policy decisions, strategic approaches and guidance regarding approaches for habitat evaluation and productive capacity quantification for use upfront as well as for monitoring the effectiveness of habitat compensation measures.

3.1 APPROACHES FOR MEASURING CHANGES IN PRODUCTIVE CAPACITY

The presentations began with an introduction to the four main approaches being used in Canada to evaluate and compensate for change in productive capacity. The approaches are listed below. The approach in Category 1 represents a relatively unofficial but commonly used approach whereby compensation requirements are developed on the basis of professional experience and address production limiting habitat features in developing compensation measures. Approaches in categories 2 to 4 were derived from Minns (1995).

Category 1	Establishing compensation requirements and measuring effectiveness against specific compensation objectives.
Category 2	Use of surrogate habitat indicators.
Category 3	Use of biological indicators.
Category 4	Direct measurement and summation of production.

Application of each of these four approaches was elaborated upon further through reference to case study examples. It was noted that, while each case study had been categorized into one of the four approaches, most projects incorporate elements of several approaches in the methodologies used for quantifying losses and gains in productive capacity.

3.1.1 Kemess South Gold-Copper Mine

- Kemess South Mine represents an example of the application of the Category 1 approach (i.e. establishing compensation measures based on evaluation of production limiting habitat features and measuring effectiveness against specific pre-defined habitat compensation/production objectives).
- The approach was applied by:
  - Calculating the total area of habitat lost for spawning, fry rearing and juvenile rearing for Dolly Varden and bull trout.
  - The objective of the habitat compensation was established as: To ensure that overall Dolly Varden and bull trout productivity would remain at pre-development levels within the Thutade Lake watershed.
  - Compensation strategies were ranked collaboratively by DFO, the province and the proponent.
  - Compensation measures were developed to replace the categories of habitat lost.
  - Monitoring activities have included annual surveys of habitat use with success being determined by the presence of fish. This monitoring is currently ongoing.
  - Pre-determined response triggers were established based on monitoring information documenting habitat quality and adaptive management.
- Key features of this project included adaptive management to address uncertainty and the incorporation of users into decision-making.
- More details on this case study are provided in the Discussion Paper.

3.1.2 Jericho Diamond Project

- The Jericho Diamond Project represents an example of the application of the Category 1 approach (establishing compensation measures based on evaluation of production limiting habitat features and measuring effectiveness against specific pre-defined habitat compensation/production objectives).
- Specifically:
  - The total area of habitat lost was calculated (in m^2).
  - Compensation targeted construction of high quality spawning, rearing, foraging and overwintering habitat.
  - Annual monitoring reports are to be submitted to DFO.
- More details on this case study are provided in the Discussion Paper.

3.1.3 Yukon Placer Mining

- A new integrated regulatory regime for Yukon Placer Mining was announced in April 2005 for implementation in 2007.

- The new process uses watershed sensitivity classification, incorporating the use of Traditional Knowledge.
- Under the approach, watershed s.s. 35(2) Authorizations are issued (two types, depending on the sensitivity of the watershed).
- Adaptive management is used in implementing habitat compensation, which is primarily accomplished through habitat rehabilitation projects.
- DFO, in partnership with the Yukon Territorial Government, is responsible for monitoring watersheds annually.
- The approach adopted fits best into Category 1 (establishing compensation and measuring effectiveness against specific compensation objectives); however, the fit is not a perfect one.
- More details on this case study are provided in the discussion paper.

A **key issue** identified during the workshop, associated with the new regulatory regime, is that the parameters that are being monitored annually are focused on chinook salmon habitat, a decision which was based on the socio-economic aspects of chinook salmon harvesting in the Yukon, rather than the overall health and productive capacity of the watershed. In addition, it was pointed out that proponents do not have monitoring obligations (financial or otherwise).

3.1.4 Diavik Diamond Mine

- Diavik Diamond Mine represents an example of the application of the Category 2 approach (surrogate habitat indicators) to estimating productive capacity losses and developing compensation.
- Specifically:
  - A modified HEP approach was used to calculate the quantity and quality of fish habitats being altered, lost or created during all three phases (construction, operation, closure) of the Project.
  - The choice of HSI model used for each species was determined by their availability in the literature.
  - Published HSI models (developed for more southern environments) were available for lake trout, Arctic grayling, longnose sucker, and northern pike.
  - The Arctic grayling and longnose sucker models were adapted to northern environments by the proponent’s consultant.
  - Models for lake trout, round whitefish, cisco, burbot, slimy sculpin, lake chub, and lake whitefish were developed using a Delphi process. Participation in the Delphi process was limited; however, the proponent’s consultant indicated that the outcomes were valid.
  - Habitat compensation included the creation of:
    - Habitat in several inland lakes;
    - Migration corridor habitat; and
    - Rearing habitat on the external edges of dykes.
- **Recent Development:** It was pointed out by workshop participants that local Aboriginal people have recently raised objections to the proposed habitat compensation measures due to the fact that they involve altering a pristine environment that is presumably operating at optimal natural productive capacity.

- More details on this case study are provided in the Discussion Paper.

Key issues identified through discussion around the Diavik Diamond Mine case study include:

- Effectiveness: In developing compensation measures, it is necessary for DFO and the proponent to agree that the compensation measures proposed (i.e., artificial shoals) have the capacity to be effective. DFO cannot hold the proponent liable if the structures do not prove to be effective after they are built.
- Long term monitoring: Participants indicated that long term monitoring is required to determine the effectiveness of habitat compensation measures. If an artificial shoal is not being used within two years of being constructed, this does not necessarily mean that it would not be used after a longer period of time, such as five years. As a result of this consideration, a suggestion was brought forward that a departmental policy should be developed requiring long term monitoring in association with habitat compensation projects.
- Questions were raised over the use of physical and biological parameters as surrogates for quantifying productivity.

3.1.5 Ekati Diamond Mine

- Ekati Diamond Mine represents an example of the application of the Category 2 approach (surrogate habitat indicators) for estimating productive capacity losses and developing compensation.
- Specifically:
  - Compensation for the replacement of lake habitat was quantified at $1.5 million, the estimated cost of constructing replacement habitat.
  - Stream compensation measures (fish habitat creation and enhancement) were also developed.
- Several studies have been conducted by the proponent and DFO illustrating that the use of fish presence alone as a success criterion can be misleading. Independent studies by DFO, using the Before-After-Control-Impact (BACI) approach to study design, indicated that although fish were present in the artificial Panda Diversion Channel, the supply of nutrients and food is not sufficient to support growth rates and condition factors that are similar to control sites. The difference was accounted for by the lack of riparian vegetation and corresponding allochthonous food source in the artificially created habitat.
- More details on this case study are provided in the Discussion Paper.

Key issues identified through discussion around this case study include:

- There is a need to define how the success of compensation measures is to be established.
- The use of a multi-metric BACI study design provides more in-depth understanding of the success of habitat compensation measures in replacing habitat productive capacity and should be encouraged or even adopted as DFO policy.

3.1.6 Voisey's Bay Nickel Mine

- Voisey's Bay Nickel Mine represents an example of the application of the Category 2 approach (surrogate habitat indicators) to estimating productive capacity losses and developing compensation.
- The approach used was based on DFO's Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador (Bradbury et al. 2001).
- Compensation was developed for lacustrine and fluvial habitats.
- Lacustrine Compensation: Fish were transferred from the affected lake to a fishless lake that had demonstrated capability to support fish populations. The lake had been fishless due to a lack of post-glacial period access connecting it to fish-bearing waters.
- Fluvial Compensation: Workshop participants pointed out the fact that, while the documents available for preparation of the Voisey's Bay case study had referred to habitat compensation in Reid Brook, two Aboriginal organizations had subsequently opposed that compensation option. They had raised objections to any proposal that would involve changes to pristine habitat. As a solution, within five years the Aboriginal organizations are to identify fluvial habitat within their traditional territory that would be appropriate for restoration, in order to ensure that compensation obligations in the *Fisheries Act* Authorization are met. The proponent provided a Letter of Credit to ensure that the restoration (habitat compensation) would be completed. The Aboriginal organizations have reportedly recently come forward with four proposed areas.
- A monitoring program was developed to evaluate the effectiveness of the compensation measures and provide information on fish species/life cycle stage utilization of the created habitat.
- More details on this case study are provided in the Discussion Paper.

3.1.7 Iron Ore Company – Wabush Lake

- The work at Wabush Lake, undertaken by the Iron Ore Company of Canada, represents an example of the application of a combination of the Category 2 (surrogate habitat indicators) and Category 3 (biological indicators) approaches to estimating productive capacity losses and developing compensation.
- A modified version of the approach set out in the DFO Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador (Bradbury et al. 2001) was used to quantify lost productive capacity.
- The existing habitat was quite degraded from past mine tailings deposits and it was necessary to adjust the HSI models accordingly.
- The project involves construction of a 15 km dyke, between 2006 and 2011, in order to comply with the *Fisheries Act* Metal Mining Effluent Regulations. .
- A multi-metric approach was implemented to monitor improvements in habitat productivity, which included enumeration of fish abundance.
- Concerns were raised over the fish abundance sampling using gillnets, due to the number of mortalities incurred. Fish abundance monitoring has therefore been adjusted to use hydroacoustic methods.

- A precautionary approach was used in quantifying the compensation measures for this project in that: the productivity of the littoral zone to be compensated for was overestimated; the most sensitive grain size was used; and all species were considered.
- More details on this case study are provided in the Discussion Paper.

3.1.8 Large-scale Hydroelectric Projects

- Large-scale hydroelectric projects pose a different challenge in terms of assessing losses and quantifying gains to achieve No Net Loss.
- These projects can involve:
  - Several dams and dykes;
  - Conversion of river basins to create large reservoirs that may have a considerable drawdown;
  - Diversions between watersheds;
  - Reduced flows in downstream reaches; and
  - The potential release of naturally occurring mercury for an extended period of time following inundation.
- Given these types of fish habitat implications, the achievement of No Net Loss poses several important questions and challenges:
  - How to account for the loss of riverine and wetland habitat in light of the creation of a great deal of additional habitat in the hydro reservoir, while recognizing that fish productivity in the reservoir may also be impaired by drawdown and egg stranding/freezing, and fish may be subject to mercury contamination;
  - How to account for widely fluctuating productivity in a reservoir, and the possibility that more fish, but different species, may be produced;
  - How to account to inter-watershed diversions; and
  - How to account for the effects of reduced flows in downstream reaches.
- It was recognized that large hydroelectric projects do pose a series of questions and challenges that are different from whole lake/stream destruction and may warrant specific and separate attention.

It was noted that while time was short, several more case studies were available for review within the Discussion Paper.

3.2 KEY LITERATURE

Following the case study overview, an overview of key relevant literature was presented. From a Canadian perspective, the following papers were reviewed:

Minns, C.K. 1995. Calculating net change of productivity of fish habitats. Can. MS Rep. Fish. Aquat. Sci. 2282.

Minns, C.K. 1997. Quantifying "No Net Loss" of productivity of fish habitats. Can. J. Fish. Aquat. Sci. 54: 2463-2473.

Bradbury, C., A.S. Power and M.M. Roberge. 2001. Standard methods guide for the classification/quantification of lacustrine habitat in Newfoundland and Labrador. Fisheries and Oceans, St. John's, Newfoundland.

Pearson, M.P., J.T. Quigley, D.J. Harper and R.V. Galbraith. 2005. Monitoring and assessment of fish habitat compensation and stewardship projects: Study design, methodology, and example case studies. Canadian Manuscript Report of Fisheries and Aquatic Sciences.

Jacques, J.-G. 2004. Assessment of fish habitat productive capacity for projects causing impacts to large surface areas. A comparative analysis of two approaches. Fish Habitat Management Branch, Fisheries and Oceans Canada.

More details on these papers are provided in the Discussion Paper.

From an international perspective, work in England, Wales and Finland was briefly touched on; however, participants confirmed that to their knowledge essentially Canada and the U.S. are leaders in this type of work. Research on measuring changes in productive capacity in Europe varies considerably from research being conducted in Canada in that the Canadian focus is on pristine systems while the European focus tends to be on systems that have been previously disturbed

3.3 PROS AND CONS OF EACH APPROACH

Participants engaged in a facilitated discussion of the pros and cons associated with each of the four approaches identified in the introduction to the workshop. This discussion built upon the lists of Pros and Cons presented in the Discussion Paper. An overview of key discussion points is presented below.

3.3.1 Approach 1: Establishing Compensation Measures and Measuring Effectiveness Against Specific Compensation Objectives

Pros

- This is a practical approach that generally focuses on addressing what are perceived to be fish production limiting habitat components.
- Relatively inexpensive to identify solutions and quantify compensation objectives.
- Amenable to a risk management approach in that for relatively small projects, or habitat that is not particularly sensitive, compensation measures can be established without a great deal of upfront study and follow-up monitoring.

Cons

- There may be no real verification that fish habitat productive capacity has been effectively compensated if there is no upfront or follow-up quantification of losses and gains.
- This lack of quantitative information can lead to:
  - Inconsistent application between staff/offices that cannot be rationalized; and

    - A perception by proponents of inconsistent application.
- It is difficult to defend against proponent claims that excessive compensation is being demanded.
- Adaptive management to address non-performance requires an ongoing and active commitment to the involvement of DFO staff that may not always be possible.

Comments

- Participants agreed that this approach is probably least defensible of the four approaches brought forward in the Discussion Paper.

3.3.2 Approach 2 – Use of Surrogate Habitat Indicators (HEP/HSI)

Pros

- The HEP/HSI approach provides a systematic, analytical, rationalized approach to reflecting the relative contribution of various habitat types and quality to fish production.
- Provides a focus and vehicle for identifying gaps in scientific knowledge regarding the biology and habitat requirements of fish species and their life history stages.
- May be particularly applicable in northern, highly oligotrophic environments where food webs are simplified. Knowledge of the biology for northern aquatic ecosystems is not, however, currently adequate to take advantage of this.
- Rationalized method allows for focus on effectiveness monitoring.

Cons

- The HSI models have been developed in U.S., based on species and habitats that are different from the Canadian north.
- The HSI models are based to a large degree on literature reviews and professional opinion, and have not been extensively based upon field testing.
- The HSI models have not been ground-truthed for Canadian species in a northern/Arctic climate.
    - e.g. The standard lake trout HSI model is based upon the suitability of conditions in the hypolimnion of a lake; however, lakes in the Canadian north do not stratify, which negates the applicability of the model without adaptation.
- Application of the HEP/HSI approach can be costly because the models have to be adapted to Canadian northern conditions and there is a need to evaluate and quantify all habitat areas affected by a project.
- Broad application of the HEP/HSI approach would require considerable new science in Canada to understand the biology of fish species in extreme northern conditions.
- The HEP/HSI approach may provide a false sense of confidence given the underlying subjectivity of the models.
- The HEP/HSI approach looks at each species in isolation. It does not account for interrelationships between species (e.g., predator/prey relationships).
- Proponents use the HSI models but on occasion do not collect the right information to allow the models to run properly.

Comments

- The HEP/HSI method for using surrogate habitat indicators is a tool and should not be used without the required professional, scientific judgment.
- This method may supplemented by the Delphi approach to gather and factor in the required professional, scientific judgment in an unbiased manner. In the case of a tar sands project, multi-stakeholder groups used this approach to develop HSI models; however, the accuracy of models will not be known until monitoring has been completed.
- The question was raised as to whether the HEP/HSI approach, when it is used, should also be supported by information obtained through one of the other three approaches, in order to make the quantification of productivity losses and gains more defensible.
- Adopting this approach would require a departmental policy decision to abide by surrogate habitat indicators rather than specific measurements of productivity. Adoption of this approach would also necessitate the expenditure of funds on research to develop or fine tune HSI models to be applicable in northern/Arctic aquatic environments.

3.3.3 Approach 3 - Biological Indicators

Pros

- Application of a multi-metric approach to measure biological indicators, using a BACI study design, is considered to be the most comprehensive and scientifically defensible approach. There is, however, a need to exercise caution in choosing this approach.
- This approach measures changes in a suite of indicators chosen to be the most appropriate on a site specific basis. This provides a robust analysis of factors contributing to the overall productive capacity of the system.
- The approach also provides for extended time series data at both impact and control sites which helps to focus on the changes caused by a project and filters out natural variability to a certain degree.
- In each case, the approach and study design must be carefully analysed and rationalized for the specific system being studied and the anticipated effects of the project on that system.
- While considerable scientific judgement and experience is normally involved in study design (e.g., parameter selection, number of replicates needed, risk management considerations), a lesser degree of judgement is involved in making measurements and data interpretation.

Cons

- The multi-metric approach along with a BACI study design can be labour intensive and is likely the most complex and costly approach.
- Obtaining baseline data over a period of two years may be a challenge.
- Obtaining, managing and evaluating follow-up information over an extended period of time such as ten years can be a challenge for both the proponent and DFO.
- This approach is subject to constraints around the use of biological data (e.g., inter-annual variability, sampling variability, limits of sampling methods, etc.)

- The approach may not be applicable in certain circumstances. It was noted that the multi-metric biological indicator approach cannot be applied in all cases due to the level of effort and expense involved.
- Participants noted that the longer a multi-metric study continues, there is increased risk that the changes being monitored may derive from other projects or influences (i.e., area-wide and/or cumulative effects).

Comments

- It was agreed that this is the "Cadillac approach" and has considerable merit but its application needs to take into account the degree of risk posed by a project and the proposed habitat compensation measures, as well as the potential for outside influences to render the studies redundant.
- While this approach may be scientifically rigorous, there would be a need to take some key policy and operational decisions concurrent with any decision to adopt it on a program-wide basis.

3.3.4 Approach 4 - Direct Measurement and Summation of Production

Pros

- This approach provides direct and accurate measures of fish production by measuring the population levels.
- Application of this approach in the case of fish out programs has yielded higher and more diverse fish population numbers than had been estimated by other methods.

Cons

- Implementation of the sampling methodologies can be expensive, labour intensive and involve considerable destructive sampling (e.g., counting fences, mark re-capture studies, Catch Per Unit Effort (CPUE) programs).
- It may be difficult, although it is possible, to apply this approach on a large scale. The approach has been successful in the case of total fish out programs associated with lake destruction for diamond mines.
- The application of Maximum Sustained Yield (MSY) models to estimating fish habitat productive capacity needs to take into account the fact that these models are intended to underestimate fish populations, as a safety factor for setting harvest levels.
- Use of harvest data from fishers is not always completely reliable

Comments

- Other methodologies for application of the direct measurement approach include:
  - European gill net approach (i.e., Nordic Netting) may be used in Canada.
  - Fish capture and recapture.
  - Underwater visual survey (i.e., observing various types of fish in different areas/ counting the number of fish seen in different areas).
  - Defensible fish out protocols have been developed by the University of Alberta.

- o Using visual methods along defined transects.
- o It is important to note that information collected in this manner is a snapshot in time and may not be representative of annual productivity on a recurring basis.
- o Hydroacoustic methods can be useful; however, they do not necessarily provide a direct measure because they do not necessarily quantify bottom dwelling fish species.

3.3.5 General Comments

Participants made some general comments with regard to application of the four approaches that were discussed. These comments included:

- Participants raised a question regarding whether DFO has the authority to specify the type of data that proponents must collect before a project is assessed. In the case of the Snap Lake diamond project, baseline data were collected but the proponent did not collect benthic data. Benthic productivity was therefore not factored into the proponent's estimates of losses and calculations regarding compensation. This is an issue that may require national policy guidance.
- Decisions to use various approaches are often made by the consultant and without DFO input. This may also require national policy guidance and communication with proponents.
- Data collected by the proponent have not always been guided by an appropriate study design, collected rigorously, or subject to appropriate QA/QC procedures.

3.4 IS IT POSSIBLE / DESIRABLE TO SELECT ONE APPROACH FOR APPLICATION NATIONALLY?

The following general comments were made with regard to selecting one approach for adoption nationally:

- One method should be used predominantly, while the other three are used as support tools.
- One participant suggested that approach #1 should not be recommended by the department because it is too subjective. An in-depth understanding of the ecosystem (which is rarely possible) is required in order to effectively apply this method.
- It was suggested that, at a macro level, it is more important to focus on ensuring that rigorous study designs are in place, than selecting a preferred approach.
  - o For each project there is a need to identify the principle objective of the compensation and then it may be possible to use various approaches for quantifying losses and gains in productive capacity.

4.0 ISSUES IDENTIFICATION

Participants engaged in a facilitated discussion to provide feedback on the four approaches identified. It was decided that the discussion should be focused around the three principle categories of issues and challenges that were introduced in the workshop introduction, namely: Policy; Science; and Operations. Key points from this discussion have been summarized according these three main categories.

4.1 POLICY

Participants recognized that there are a number of fundamental policy implications associated with selecting methods for quantifying losses and gains in fish habitat productive capacity. Addressing these implications will be essential to advance the agenda and must occur concurrently with progress made in addressing Science and Operations issues.

Key policy issues that were identified for attention as part of any initiative related to deciding on a departmental approach to quantifying losses and gains in fish habitat productive capacity are discussed below.

4.1.1 Compensation in Pristine Areas

Habitat compensation in pristine areas is a challenge. Aboriginal people have raised concerns over attempts to enhance natural aquatic ecosystem productive capacity in areas where the fish habitat is essentially pristine. This effectively removes key options for habitat compensation to achieve No Net Loss in some cases. In such cases, other options may include: restoration of previously degraded habitats, although these may be geographically removed and benefit other fisheries resource users; restoration and compensation after the project is abandoned; or acceptance of financial compensation to be used by DFO or a third party to implement compensation measures elsewhere. Broad acceptance of the validity of the quantification of losses and gains in productive capacity is essential to support any of these approaches.

4.1.2 Proponent Pays Principle

Clarification of the “proponent pays” principle is needed, in terms of roles and responsibilities for quantifying losses and gains in fish habitat productive capacity. The issue here is to provide for DFO early involvement in selection of the quantification approach and methods, without DFO incurring undue costs and liabilities. One option that was discussed was the development of guidance materials by DFO for study design, methodologies, and data acceptability for various types of projects.

4.1.3 Stakeholder Engagement

Whether and how to engage stakeholders in quantifying losses and gains in fish habitat productive capacity, and in designing habitat compensation measures, was identified as a policy issue. This issue is particularly relevant with respect to the gathering and inclusion of Traditional Knowledge.

4.1.4 Holistic Approach

Participants agreed that, regardless of the approach used to quantify losses and gains in productive capacity, a holistic approach should be taken to begin managing fish habitat more comprehensively at the watershed level. Implementation using a nationwide GIS network would be preferable. Implementing a holistic approach has important policy dimensions that include: inter-governmental affairs; jurisdiction; funding; roles and responsibilities; and the commitment of DFO to support the approach on a watershed by watershed basis, as the need/opportunity arises.

4.1.5 Roles and Responsibilities

Policy direction is needed in terms of the quantification of losses and gains, and development of habitat compensation measures. Clarification is needed in terms of available options and roles and responsibilities in a wide range of areas. Areas for roles and responsibilities clarification include: quantification of the implications of gains and losses from a specific project in the context of for an overall watershed; identification of critical and production limiting habitats in a watershed; quantification of gains or losses in productive capacity on a watershed basis; and watershed monitoring.

4.1.6 Long Term Research

Building consistent and defensible approaches to quantification of losses and gains in fish habitat productive capacity will require a policy commitment to engage in long term research. Research focus and priorities will be driven by policy decisions on the quantification approaches to be pursued; however, initially research may be required to inform those policy decisions.

4.1.7 Acceptable Compensation

The Hierarchy of Preferences in the Habitat Policy provides guidance on the selection of compensation options. There is, however, a need for policy guidance for moving through the Hierarchy of Preferences. For example, key areas where guidance is required would include: decisions to compensate in a different area with, potentially, different resource users receiving the benefits; decisions to provide compensatory productivity that benefits a different suite of species (e.g. forage fish); decisions to accept financial compensation based upon Habitat Equivalency Analysis to support habitat improvement initiatives in other areas; etc. Policy decisions in these areas will have direct effects on Operations and the extent of Science support required.

4.1.8 Acceptable Timescales for Baseline and Follow-up Studies

Baseline data and follow-up studies are needed to quantify the productive capacity losses from a project and confirm that the capacity has been effectively replaced. Natural systems are subject to natural variability and cycles (e.g., climate variables including temperature; precipitation; hydrology; predator/prey relationships; etc.). Some approaches for quantifying losses are influenced to a greater degree by these cycles (e.g., multi-metric biological indicator approach; direct measurement approach), creating the need for longer time series baseline and follow-up studies.

Pearson et al. (2005) recommends, at a minimum, that two years of baseline studies and ten years follow-up studies (pulsed) are required to effectively implement a multi-metric biological indicator approach. Instituting a requirement for two years of baseline studies and 10 years of follow-up monitoring would have certain practical, financial, and policy implications for DFO and proponents. This illustrates the reality that, to enable decisions to be taken on the approaches for quantifying productive capacity, there is a need for concurrent DFO policy analysis and decisions to confirm what is possible/ feasible for implementation.

4.1.9 Adaptive Management

For any approach taken, there will need to be a commitment to use scientific research findings and advice from DFO Science to continually improve management decisions and practices through adaptive management.

Adaptive management is important due to the lack of existing research in the north. There are no proven techniques for compensation in northern/Arctic systems, and therefore each project is effectively an experiment both in terms of quantifying the loss and developing and implementing the compensation measures.

4.2 OPERATIONS

Participants recognized that there are a number of fundamental operational implications associated with selecting approaches for quantifying gains and losses in fish habitat productive capacity. Addressing these implications will be essential and must occur concurrently with progress made in Policy and Science.

Key operational issues that were identified and should be addressed as part of any initiative related to selecting an approach for quantifying fish habitat losses and gains included those set out below.

4.2.1 Workload

It is expected that implementation of any of the evaluated approaches in a rigorous manner would result in an increased workload for operational staff. The multi-metric biological indicator approach would likely have the greatest impact on workload, even if proponents do the information gathering and analysis. The DFO workload would relate to reviewing reports submitted by proponents, obtaining scientific input to report reviews, and perhaps site visits and audit studies. In adopting the more rigorous approaches, DFO would need to be prepared to accommodate an increased workload in this area of the Habitat Management Program.

4.2.2 Available Expertise

Not all of the Regions would necessarily have the required expertise within the Habitat Management Program or Science, to operationalize the approaches under consideration. Some referral officers in regions may not have the required scientific training. As an example, Science in Québec Region does not have expertise in freshwater. The availability of expertise and associated organizational implications are relevant considerations in deciding on approaches.

4.2.3 Links Between Operations and Science in the Field

To operationalize the approaches under consideration, there would be a need to establish effective links between Operations and Science in the field. Operations staff would require ongoing input in terms of the study designs proposed by proponents, sampling methods, data reliability, data interpretation, etc. Correspondingly, Science staff may need support from Operations staff in terms of identifying opportunities for research, project orientation, liaison with proponents, forwarding monitoring data provided by proponents to researchers, etc.

4.2.4 Variance in Approaches to Compensation

It is likely that there will continue to be variation in the approaches taken to providing habitat compensation, depending on project specific and site specific considerations. DFO has a responsibility to track this variance, evaluate the nature of the variance and correct any that cannot be rationalized.

4.2.5 Holistic Approach

Participants agreed that, regardless of the approach used to quantify losses and gains in productive capacity, a holistic approach should be taken to manage fish habitat at the watershed level. This should be implemented using a nationwide GIS network. This could have operational implications in terms of developing the approach for a watershed, building partnerships and tracking progress.

4.2.6 Protocols and Guides

Participants agreed that, once decisions are taken on approaches, there will be a need to prepare and circulate various documents to facilitate cohesive program delivery. These documents will likely include: methods manuals; protocols; practitioners guides; etc. and may be targeted at DFO staff, proponents, consultants, and/or stakeholders. It is likely that training in the use and application of these materials will also be required. Input from Science will likely be needed to support drafting and review of these materials.

4.3 SCIENCE

Participants recognized that there are a number of fundamental science implications to selecting approaches for quantifying gains and losses in fish habitat productive capacity. Addressing these implications will be essential and must occur concurrently with progress made in Policy and Operations.

Key science issues that were identified and should be addressed as part of any initiative related to habitat compensation included the following.

4.3.1 Long Term Research

Application of each of the approaches reviewed in the workshop requires long term research support, in the following areas:

- Research in northern/Arctic aquatic environments to build and/or refine HSI models for use in quantifying losses and designing compensation.
- Specific research to identify the most cost effective parameters for estimating losses and gains in productive capacity.
- Research into long term trends in aquatic ecosystem productivity in northern/Arctic climates, to put into context the effects observed from individual projects.
- Long term case studies to determine whether the compensation measures being implemented are effective in replacing habitat productivity.
- Long term research may involve targeted cooperative research.
- Long-term research is required across the country in all ecozones. It is impossible to restore or rehabilitate without an understanding of the system. The U.S. has established a fund to do research that meets the criteria of long term ecosystem research and doing something similar in Canada warrants consideration.

4.3.2 Holistic Approach

Participants agreed that, regardless of the approach used to quantify losses and gains in productive capacity, a holistic approach should be taken to manage fish habitat at the watershed level. This should be implemented using a nationwide GIS network. This approach would have implications in terms of Science input and opportunities.

4.3.3 Scientific Rigour

Implementing each of the approaches reviewed in the workshop requires a commitment to scientific rigour within DFO Operations and Science, as well as a commitment to require scientific rigour from proponents. Reviews of proponent generated data, by DFO Science will be needed. In addition, DFO Science input to the generation of study design protocols, standard methods, data QA/QC measures, etc. will be required.

4.3.4 Defensible Criteria

Regardless of the approach adopted, in order to review project and habitat compensation proposals, and audit/verify the effectiveness of implemented habitat compensation measures, it will be necessary to develop defensible habitat compensation success criteria. The Kemess South Mine provides an example of success criteria that seem valid and workable. DFO Science would be expected to play a significant role in the development of such criteria, or in reviewing and advising on the validity of criteria proposed by proponents and their consultants. A suggestion was made that monitoring reports should be published by DFO so that they can be used in developing other programs.

4.4 ISSUES INTEGRATION AND STRATEGIC APPROACH

Participants clearly agreed and recognized that, for progress to be made, there is a need to advance the Policy, Science and Operations agendas concurrently. It was suggested that one way to organize to address the challenge would be to develop a matrix identifying issues/task and that this would demonstrate and facilitate management of the inter-connections.

5.0 NEXT STEPS

Participants discussed next steps and the consensus was summarized as follows:

- The Discussion Paper should be linked to the Northern Report (Samis et al. 2005) and the Monitoring Report (Pearson et al., 2005).
- Workshop participants should review Discussion Paper and submit their detailed comments to NHQ.
- The discussion paper and the workshop report will be revised in accordance with the comments and finalized for publication as a DFO Manuscript Report.
- A gap analysis should be completed to identify outstanding Policy, Operations and Science issues that need to be addressed.
- Create a national intranet site for the dissemination of information related to the Habitat Monitoring Framework, effectiveness monitoring protocols and methodologies, and recent reports (e.g. National Monitoring Framework and Whole Lake Destruction workshop reports, the Northern Report, and Pearson et al., 2005)
- Establish a monitoring working group that reports to the Habitat Sub-committee of the Senior Habitat Management Committee to work on aspects of monitoring, including the development of methodologies, tools, protocols, training, and data management and reporting standards.
- Develop a Practitioners Guide to effectiveness monitoring that emphasizes a holistic approach to monitoring compensation projects (combining HADD assessment and compensation effectiveness evaluations into a single process) and strong scientific designs (i.e., BACI study designs).

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Whole Lake / Stream Compensation Workshop – List of Participants

July 26, 2005 Ottawa, ON

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