CUMBERLAND
RESOURCES LTD.

MEADOWBANK GOLD PROJECT

NO-NET-LOSS OF HABITAT (NNL)

JANUARY 2005

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DESCRIPTION OF SUPPORTING DOCUMENTATION

Cumberland Resources Ltd. (Cumberland) is proposing to develop a mine on the Meadowbank property. The property is located in the Kivalliq region approximately 70 km north of the Hamlet of Baker Lake on Inuit-owned surface lands. Cumberland has been actively exploring the Meadowbank area since 1995. Engineering, environmental baseline studies, and community consultations have paralleled these exploration programs and have been integrated to form the basis of current project design.

The Meadowbank project is subject to the environmental review and related licensing and permitting processes established by Part 5 of the Nunavut Land Claims Agreement. To complete an environmental impact assessment (EIA) for the Meadowbank Gold project, Cumberland followed the steps listed below:

1. Determined the VECs (air quality, noise, water quality, surface water quantity and distribution, permafrost, fish populations, fish habitat, ungulates, predatory mammals, small mammals, raptors, waterbirds, and other breeding birds) and VSECs (employment, training and business opportunities; traditional ways of life; individual and community wellness; infrastructure and social services; and sites of heritage significance) based on discussions with stakeholders, public meetings, traditional knowledge, and the experience of other mines in the north.

2. Conducted baseline studies for each VEC and compared / contrasted the results with the information gained through traditional knowledge studies (see Column 1 on the following page for a list of baseline reports).

3. Used the baseline and traditional knowledge studies to determine the key potential project interactions and impacts for each VEC (see Column 2 for a list of EIA reports).

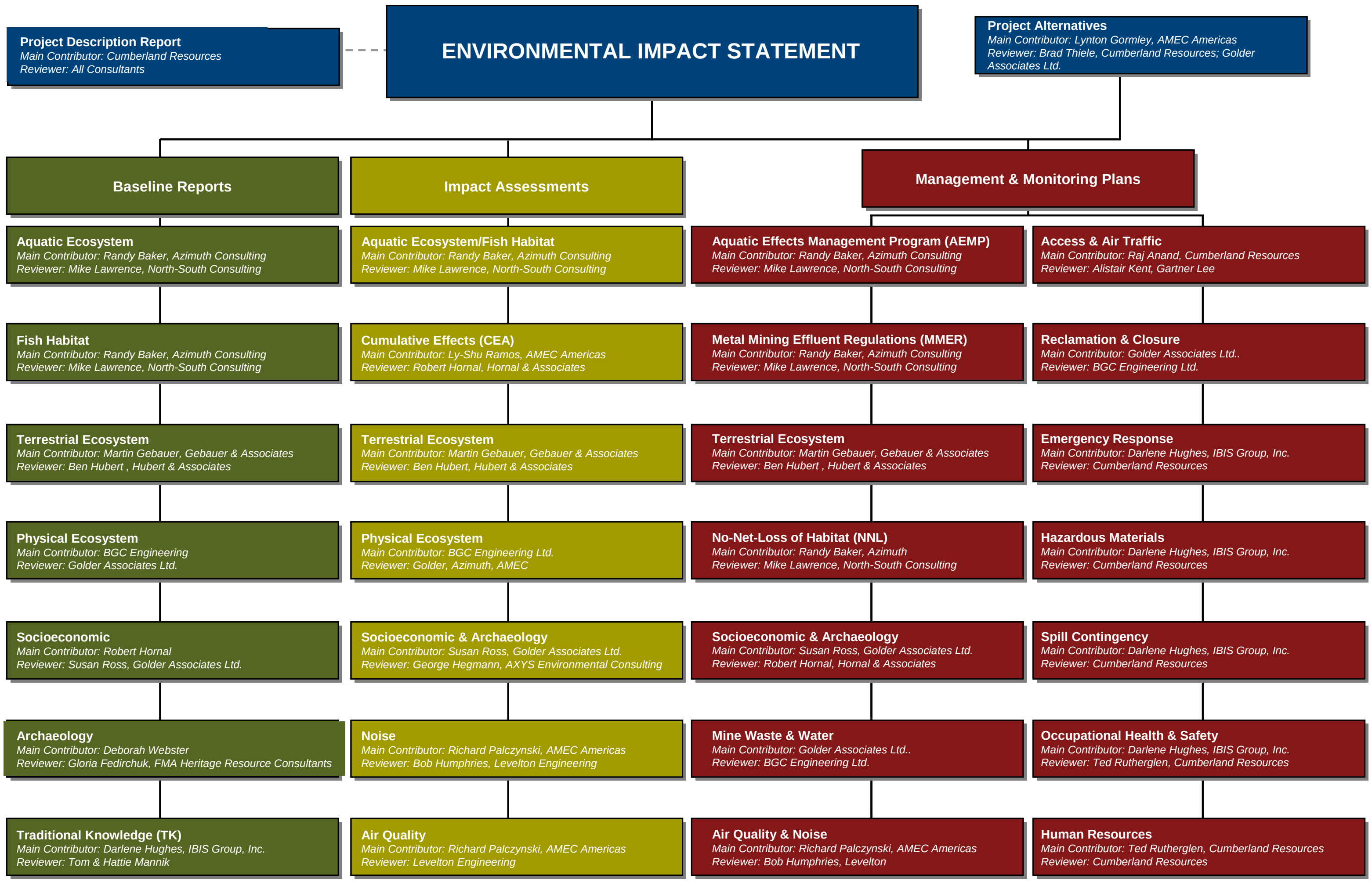
4. Developed preliminary mitigation strategies for key potential interactions and proposed contingency plans to mitigate unforeseen impacts by applying the precautionary principle (see Column 3 for a list of management plans).

5. Developed long-term monitoring programs to identify residual effects and areas in which mitigation measures are non-compliant and require further refinement. These mitigation and monitoring procedures will be integrated into all stages of project development and will assist in identifying how natural changes in the environment can be distinguished from project-related impacts (monitoring plans are also included in Column 3).

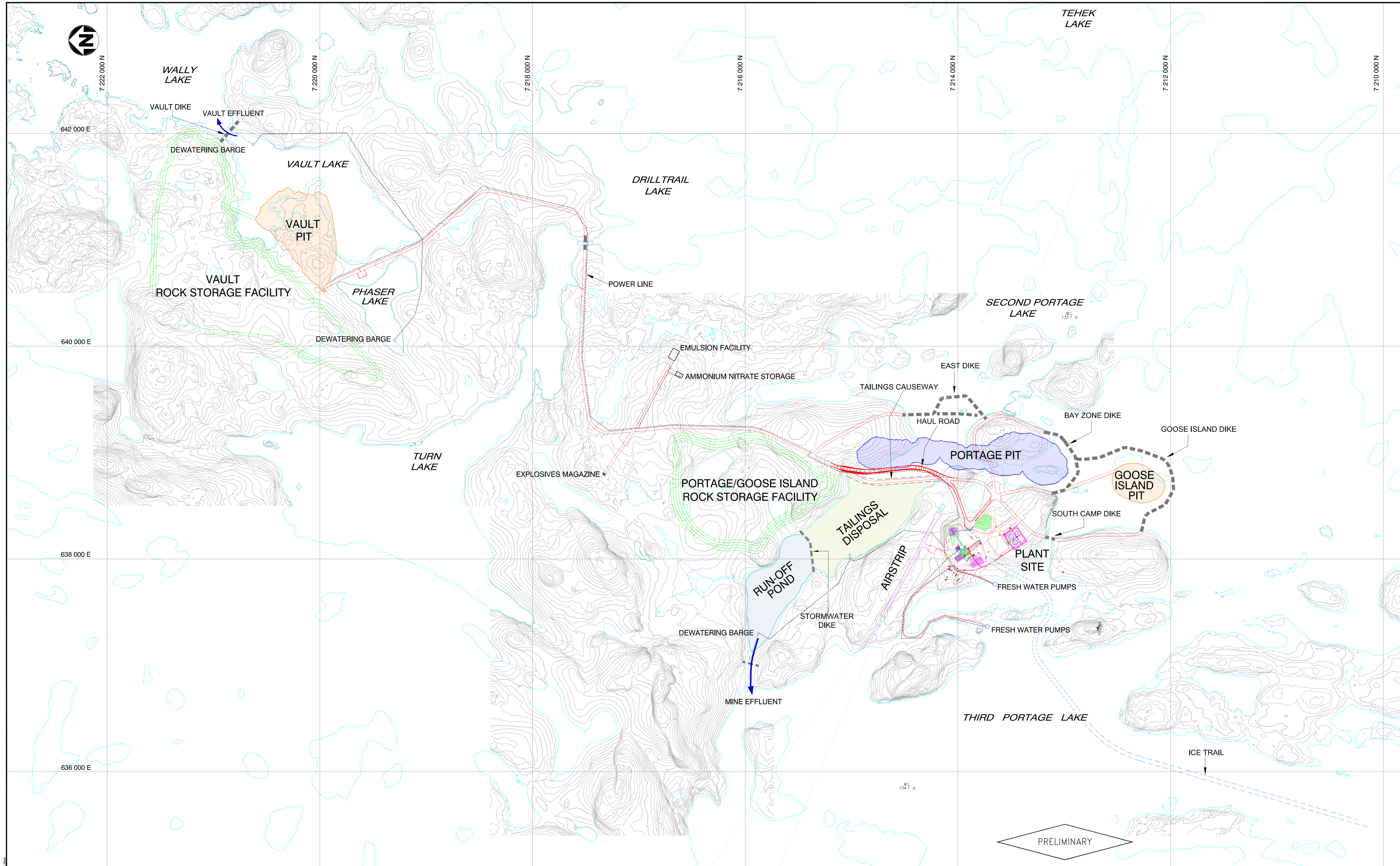
6. Produce and submit an EIS report to NIRB.

As shown on the following page, this report is part of the documentation series that has been produced during this six-stage EIA process.

EIA DOCUMENTATION ORGANIZATION CHART



PROJECT LOCATION MAP



Datum: UTM NAD83 Zone 14

Proposed Mine Site Layout

CUMBERLAND RESOURCES LTD.

Meadowbank Gold Project

SOURCE: AMEC drawing 100-c000c.dwg

SECTION 1 • INTRODUCTION

1.1 BACKGROUND

Cumberland Resources Ltd. (Cumberland) is evaluating the feasibility of establishing a gold mine at its Meadowbank property near Baker Lake, Nunavut. The Meadowbank project, about 75 km north of the Hamlet of Baker Lake, is situated on the headwaters of several oligotrophic, fish-bearing lakes. Second Portage, Third Portage, and Vault/Wally lakes are located directly within the boundaries of the mineral zones being explored on the Meadowbank property and drain into Tehek Lake. Tehek Lake is a large lake (455 km^2) that flows via the Quoich River system into the western end of Chesterfield Inlet and, eventually, into Hudson Bay. The surrounding terrain is typically barren-ground subarctic, dominated by many small lakes and ponds with indistinct and complex drainage patterns.

Supporting documents relating to the aquatic environment for an environmental impact assessment (EIA) of the Meadowbank project include the following:

- Baseline Aquatic Environment Assessment Report (BAEAR, 2005) – This report summarizes the baseline studies (1996 to 2003) of the physical, chemical, and aquatic ecological characteristics of the Meadowbank project lakes.
- Framework for the Application of Metal Mining Effluent Regulations report (MMER, 2005) – This report presents a study design framework to comply with and implement studies required under the Metal Mining Effluent Regulations (MMER) and Environmental Effects Monitoring (EEM) program.
- Aquatic Environmental Management Program (AEMP, 2005) report – This report presents a framework for environmental monitoring of the aquatic environment of project lakes during mine construction and operation.

These documents provide the background, or baseline, information necessary to determine the extent and magnitude of impacts to aquatic valued ecosystem components (VECs) as a result of mine development.

An initial interpretation of aquatic nearshore littoral and shoal habitat was performed from stereoscopic pairs of 1:10,000 colour air photos (1999 and 2002 series) of the project lakes. These features were used to distinguish identifiable polygons, which were described according to four different habitat attributes including: sediment grain size (e.g., boulder, cobble), morphology (e.g., platform, shoal, shelf), depth (shallow, moderate, deep, or very deep), and habitat complexity (low, moderate, or high). Representative habitat polygons identified from aerial photographs were groundtruthed in the field using underwater video photography. Using the photographs, empirical bathymetry data, and underwater video imagery, a habitat type was assigned to individual polygons.

Six different habitat types were described, ranging from very coarse boulder gardens at shallow depths to fine (silt/clay) sediments at deep depths. Habitat type of individual polygons was mapped and quantified using a Geographic Information System (GIS). Then, a valuation and ranking system was devised to score and assign a relative value to individual polygons. Based on score, polygons were ranked as having high, moderate, or low value based on their relative contribution and importance as spawning, nursery, shelter, foraging, and overwintering habitat for fish. High moderate and low value habitat were then quantified using GIS and mapped.

This assessment and mapping procedure will be described in greater detail in Section 2.3 and provides the basis for quantifying impacts to fish habitat as a result of each major and minor component of mine development (e.g., stream crossings, dike construction and operation, and tailings and waste rock disposal).

The purpose of this document is to assess and quantify impacts to fish habitat in the project lakes related to activities undertaken during construction, operation, and post-closure and present a range of options to compensate for loss of fish habitat. This is necessary to achieve the goal of no net loss (NNL) of fish habitat as stipulated under the Canada Fisheries and Oceans (FOC; previously known as Department of Fisheries and Oceans [DFO]) *Fisheries Act*.

1.2 REGULATORY CONTEXT

The federal *Fisheries Act* describes fish habitat as, “spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes.” Fish habitat is comprised of physical (e.g., substrate type and structure, water velocity), chemical (e.g., nutrients, temperature), and biological (e.g., plankton, insects) attributes that combine to create a variety of conditions affecting the productivity of fish populations in a lake or stream. The federal no net habitat loss principle described in the DFO Policy for the Management of Fish Habitat (DFO, 1986) strives to avoid a net loss of productive capacity of fish habitat as a result of a development project by following a set of guidelines or a hierarchy of options. In order of preference, these are:

- relocation or physically moving a project or part of the project to eliminate the potential for adverse effects

- redesign of a project to avoid adverse impacts

- mitigation of impacts in cases where relocation or redesign of a project is not possible—an example is installation of erosion control measures or materials to minimize effects of introduced sediments on habitats.

Compensation involves replacing harmfully altered, disrupted, or lost habitat with newly created habitat or enhancement of existing habitat. This is only considered when relocation, redesign, or mitigation measures fail to avoid harmful alteration, disruption, or destruction of fish habitat. There is also a hierarchy of compensation measures ranging from the creation of similar habitat at or near the development (i.e., like for like), to the least preferred option, increasing productive capacity of fish habitat of a different species (or stock) away from or off-site.

Major project activities (e.g., dike construction and operation) will result in the harmful alteration, disruption, or destruction (HADD) of fish habitat. DFO (1998) defines HADD as, “any meaningful change in one or more habitat components that can reasonably be expected to cause a real reduction in the capacity of the habitat to support the life requisites of fish.” A HADD occurs when the physical, chemical, or biological features of a water body are sufficiently altered such that habitat becomes less suitable for one or more life history processes (e.g., spawning, feeding) of fish. By definition, HADD can involve alteration (i.e., an indefinite change in capacity of habitat to support fish that does not eliminate habitat), disruption (i.e., temporary changes to habitat that cause a reduction in capacity to support fish), or destruction (i.e., permanent change in habitat that eliminates capacity to support fish).

Major project activities will alter or destroy fish habitat, despite reasonable attempts to avoid impacts, because of the nature of certain activities. Thus, this NNL framework document presents a range of possible options to mitigate and compensate, to the extent possible, impacts to fish habitat in the project lakes. If impacts cannot be fully mitigated and a HADD is likely to occur, it is within the discretion of FOC to issue an authorization under Section 35(2) of the *Fisheries Act*, allowing for habitat alteration, disruption, or destruction (DFO, 1998), provided that full compensation of the HADD can be achieved, either through on-site and/or off-site measures to create or improve existing habitat. A full explanation of the hierarchy and decision framework for the determination and authorization of HADD can be found in DFO (1986 and 1998).

A consideration of application of the NNL principle is that it only applies to habitats that directly or indirectly support fish species that sustain a sport, domestic, or commercial fishery, or have demonstrated ecological importance. Although the project lakes do not support a fishery of any kind, they have the potential to support a fishery and are therefore afforded the same level of protection as habitat that supports an active fishery.

Consideration is also given to the spatial and temporal context of impacts to habitat and the relative value of affected habitat. Project activities that affect large areas of low value habitat may have no impact or smaller impacts than activities that affect small areas of high value habitat. In addition, project activities that cause impacts of short duration will have less overall impact than activities that cause long-term or permanent HADD (DFO, 1998). Therefore, this NNL assessment will consider differences in temporal duration, spatial extent, and magnitude of impact relative to habitat value. That is, greater emphasis will be placed on impact assessment and compensation of medium and high value habitat (e.g., spawning shoals, complex platform, and apron habitat providing shelter and feeding) and less on low value habitat (e.g., deep-water, low-complexity habitat). Impacts with the potential to affect habitat for longer time periods (years) than brief time periods (months) will also be given greater emphasis.

Finally, lakes that do not contain fish and do not provide resources to sustain fish in adjacent lakes are not considered productive fish habitat (DFO, 1998) and will not be accounted for under the NNL framework presented here. For example, shallow (<3 m depth) lakes or ponds that are not connected to larger water bodies and have insufficient depth to support overwintering by fish have no potential to support a fishery and are not considered productive fish habitat.

1.3 UNDERSTANDING HABITAT FEATURES OF PROJECT LAKES

Fish habitat is generally classified according to five major categories: spawning/nursery; rearing; feeding; overwintering; and migratory. Migratory habitat is important in systems where stream habitat provides life history functions for particular species, such as spawning and feeding by Arctic grayling, or to connect lakes, acting as migratory corridors. Because of the headwater nature of the project lakes, there is negligible stream habitat as most lakes are connected to one another by small, ephemeral connecting channels that freeze during winter. Furthermore, there are no seasonally migratory movements by fish in the project lakes and the connecting channels are used opportunistically and only to a limited extent (BAEAR, 2005).

Fish habitat, as it pertains to importance and utilization by different fish species at particular life history stages (e.g., larvae, juvenile, adult) in the project lakes, is a complex mixture of physical, chemical, and biological features.

- Physical features include the type, size, shape, distribution, and slope of bottom sediment, ranging in size from fine material (clay, silt, and sand) to coarse material (gravel, cobble, and boulder). Water depth, exposure to wind forces, currents, ice scour, temperature, oxygen concentration, and proximity to sediment sources and tributary streams also affect physical habitat quality and utilization by fish. The project lakes are ice-bound for much of the year (October through June), which has a strong influence on fish species composition, distribution, and productivity.

- Chemical features include pH, nutrient concentration, organic carbon content of sediment, and contaminants (e.g., metals, hydrocarbons). The project lakes are very nutrient-poor (ultra-oligotrophic), with naturally low productivity.

- Biological features include abundance of food sources (algae, zooplankton, and benthic invertebrates), predators, and competing species. Project lakes are dominated by lake trout (*Salvelinus namaycush*), which exert a strong influence over other species present because of their piscivorous diet.

Understanding the relative abundance and spatial distribution of physical features and structure of habitat in lakes is important to determine the quality of habitat, which is reflected ultimately in the abundance (i.e., biomass), productivity, and diversity of fish. Abundance of fish differs between lakes as a result of a complex interaction between quality and abundance of available habitat, quantity of critical habitats such as spawning, availability and abundance of food resources (as dictated by lake productivity) and immigration or emigration by fish. Large-scale geographic or climatic effects also dictate distribution and abundance of fish, independent of habitat features.

For example, the project lakes are near the northern geographic extent of the range of Arctic grayling and this species has not been documented in the Quoich River watershed (Lawrence and Davies, 1977). Lake trout is the most abundant species found in the project lakes, which is typical of lakes at this latitude in this region of the Arctic.

1.4 OBJECTIVES

The ultimate objective of this NNL framework report is to quantitatively assess the distribution, abundance, and value of habitat types within Second and Third Portage lakes and Vault Lake that may potentially be adversely affected by mine development, relative to areas of these lakes that are unaffected, and to propose options to mitigate or compensate for HADD during mine life and beyond.

SECTION 2 • FISH HABITAT ASSESSMENT

2.1 LAKE AREA CLASSIFIED

A total of 383 ha was mapped in Second Portage Lake, over all habitat types combined (see Table 2.1). This included all habitats within the proposed Portage pit and Tailings pit (see Figure 2.1) extending from the north end of Second Portage Lake to the outlet into Tehek Lake. This does not include surface area of Drilltrail Lake, which is part of the Vault/Wally Lake system.

Table 2.1: Total Area of Project Area Lakes Relative to Area Classified for Fish Habitat

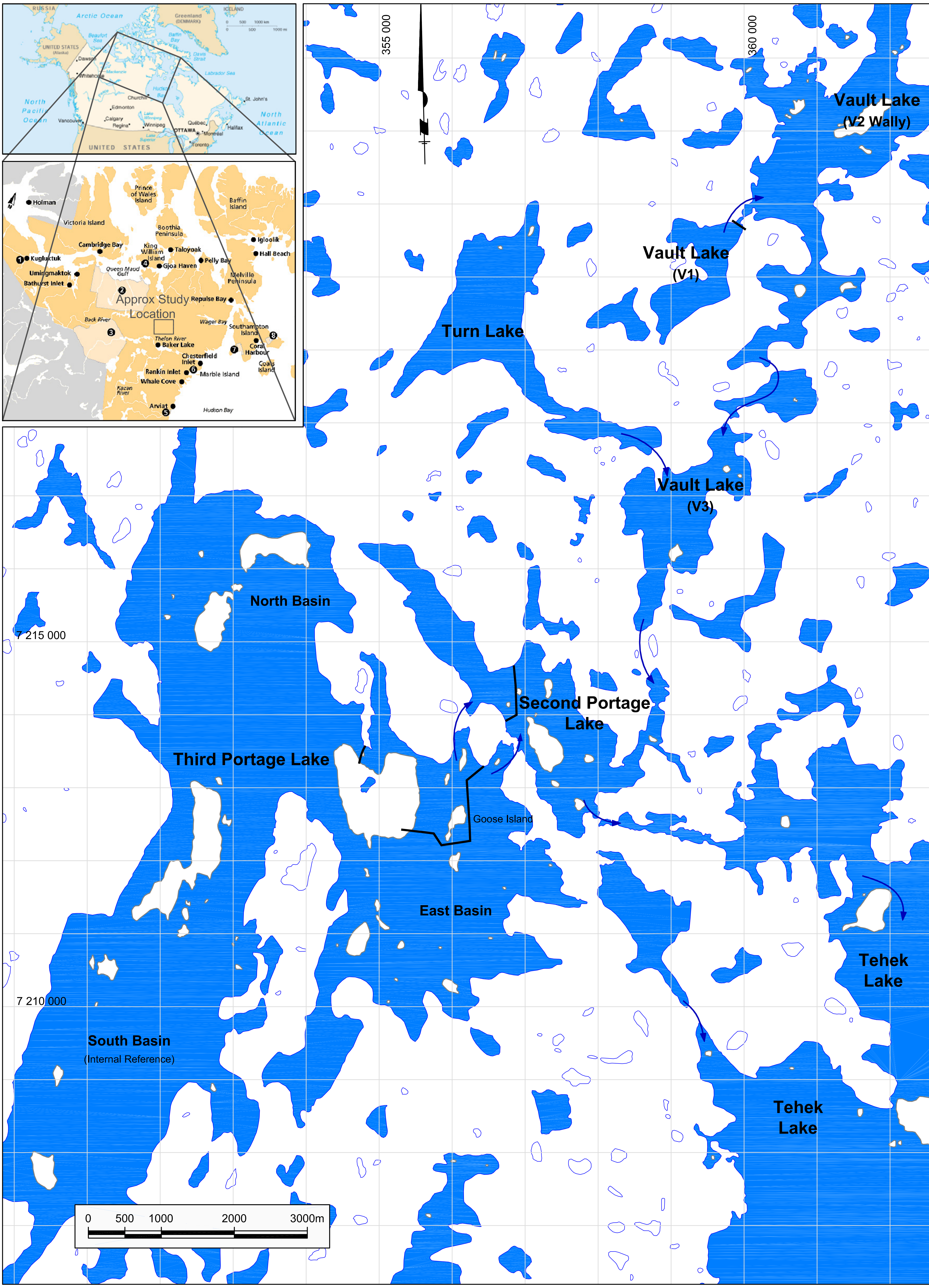
	Total Area (ha)	Total Classified Area (ha)	% Area Classified
Second Portage	383	383	100
Third Portage	3,600	2,593	72
Vault Lakes	732	697	95

Third Portage Lake is much larger than the other lakes, totalling about 3,600 ha. Approximately 2593 ha of Third Portage Lake habitat was quantified, which is nearly three quarters (72%) of the total area of Third Portage Lake (see Table 2.1). Because of its very large size, the entire lake was not mapped. Mapping focused on the northern basin (effluent discharge site and because of the existence of empirical bathymetry data), the southern basin (which serves as the internal reference area) and the east basin (where the majority of mine development is occurring) were mapped. Note that areas presented here are plan-view areas and do not incorporate the effect of slope on actual area. That is, the area of high quality habitat along shorelines may actually be slightly higher than estimated from air photos (two dimensions) because of the slope of lakebed; however, this difference is consistent for all of the lakes and represents only a small difference.

Vault, Wally, and Drilltrail lakes flow in a north-south direction, eventually connecting with Second Portage just upstream of its outlet to Tehek Lake (see Figure 2.1). Vault Lake is a small lake (98 ha) adjacent to the Vault deposit, while Wally Lake is a large (598 ha), convoluted lake that lies immediately adjacent to Vault Lake and is connected via a small (10 m) channel. Wally Lake connects to Second Portage Lake via a small connecting lake (Figure 2.1). Vault and Wally lakes have a combined surface area of 732 ha, of which 697 ha (95%) were mapped.

2.2 SPECIES REQUIREMENTS

The project lakes are dominated by only a few species, especially lake trout, round whitefish (*Prosopium cylindraceum*), and Arctic char (*S. alpinus*). All are fall spawners and all have similar habitat requirements for spawning/nursery and rearing. For example, ideal spawning/rearing and nursery habitat for trout, char, and whitefish occurs between 2 and 5 m depth over shoals and sloping platforms consisting of a complex mixture of boulder and cobble, that are typically exposed to wind-generated currents that minimize sediment accumulation (Scott and Crossman, 1979; Thibodeau and Kelso, 1990; Marsden et al. 1995; Sly and Evans, 1996; Diavik, 1999; Snap Lake, 2002; and others).



Legend

- Flow Direction
- Lake
- Approximate Dyke Location

Azimuth Consulting Group Inc.
218-2902 West Broadway
Vancouver BC, V6K 2G8

PROJECT: Meadowbank No Net Loss

TITLE: **Meadowbank Study Area Lakes and Dike Locations**

CLIENT: CUMBERLAND RESOURCES LTD.

Figure 2.1

This habitat also provides excellent shelter habitat for rearing of juveniles of all species. Because of the obvious importance of substrate type and complexity, greater relative value was assigned to these habitat attributes than morphology and depth.

Feeding habitat differs among the three major species in the project lakes. Lake trout are highly piscivorous, opportunistic feeders that prey mostly on each other, and on round whitefish (BAEAR, 2004). Juvenile trout also consume benthic invertebrates, especially chironomids, tadpole shrimp, and occasionally other fish (ninespine stickleback). Round whitefish are omnivorous, feeding on benthic invertebrates (insects, bivalves) from soft bottom and hard substrates, as well as zooplankton. Arctic char feed principally in open water exclusively on zooplankton (BAEAR, 2005). Arctic char in this system are non-anadromous because of an impassable falls on the Quoich River approximately 50 km upstream of Chesterfield Inlet. Although char grow to a relatively large size (>2 kg), analysis of strontium data from hard parts (fins, otoliths) confirms that none of the char in this system have been to sea (BAEAR, 2004).

Boulder apron, sediment apron, and mixed sediment apron habitat in shallow rocky areas and in transition areas from coarse to fine substrates provides the best habitat for feeding by all species, especially juvenile and adult round whitefish and lake trout.

Overwintering habitat requirements are similar for all species and consist of deep (>4 m), well-oxygenated areas of lakes. Because of the large size of the project lakes, there is a tremendous abundance of deep water, sediment basin habitat that is suitable for overwintering by all species. This habitat has the lowest relative value because it is suitable only as overwintering habitat and as feeding habitat for round whitefish.

2.3 HABITAT ATTRIBUTE CLASSIFICATION

Four major physical habitat attributes were used to delineate polygon boundaries and to describe visible features of each polygon. This was accomplished based on interpretation and GIS of 1:10,000 stereo aerial photographs. The four attributes were substrate type, morphology, water depth, and habitat complexity. Definitions of each are as follows:

- *morphology* – the general form of the polygon feature (shape, approximate slope, and dimensions)
- *substrate* – an estimate of the substrate composition and grain size (e.g., silt, gravel, cobble, boulder)
- *depth* – an estimate of depth (m) based on colour, position, and empirical bathymetry data
- *complexity* – a qualitative estimate about the composition and spatial heterogeneity of the habitat.

Aerial photograph interpretation revealed a total of 627 unique, identifiable polygons in Vault Lake (24 polygons), Wally Lake (112 polygons), Second Portage Lake (66 polygons, 14 of which were identified within the proposed Portage pit area and tailings disposal facility), and Third Portage Lake (425 polygons, 208 of which were identified within the Goose Island pit area).

The circumference (m) and area (m^2) of each individual polygon was measured using GIS and examined to define habitat features according to the four main attributes above. The relative contribution of each habitat attribute, as it contributes to overall quality of habitat for fish, is discussed in Section 2.6. Features of the four major habitat attribute categories are described below.

2.3.1 Morphology

Morphology of habitat is a term used to describe large, discrete units of substrate features (i.e., polygons) than can be delineated and quantified and are distinct from adjacent units. For example, a visible offshore shoal surrounded by deeper, indistinct sediment is captured and measured as a discrete unit and quantified with GIS.

The four morphology classes are:

- *Platform* – A continuous, low-slope polygon, usually adjacent to the shoreline. General characteristics of platform habitat are predominantly coarse, boulder substrate, but occasionally may include a discontinuous veneer of boulder cobble over bedrock. Complexity is moderate to high.
- *Apron* – Aprons occur lakeward of platforms or shoals and generally have a steeper slope than platforms. Substrate of aprons is finer than platforms or shoals and represent transitional habitat between shallow littoral areas and deep (>6 m) zones of the lake with fine (sand or silt/clay) sediments.
- *Shoal* – Shoals may or may not be associated with platforms; offshore width may be as wide as alongshore length. Shoals are most commonly not attached to land and are found at depths from 2 m and deeper. Substrate typically consists of a mixture of coarse material (boulder, cobble), but may have a veneer of fine sediment draped over the surface. Complexity is usually moderate.
- *Sediment basin* – Represented by large, low slope continuous polygons offshore of aprons, shoals, and platforms. Generally characterized by deep depths (>8 m) with predominantly fine substrates (silt/clay) with some occasional boulder or cobble patches in discrete areas. Complexity is low and uniform.

Morphology can influence habitat quality in terms of proximity to food sources such as periphyton and insects; these food sources are more commonly associated with platforms. Morphology is also an indicator of lakebed complexity. Greater complexity is associated with platforms while less complexity is associated with aprons and deep, sediment basin habitats.

2.3.2 Substrate

Lakebed substrate is a key habitat attribute that dictates habitat function (e.g., spawning, feeding) and extent to which fish utilize particular habitats.

Substrate is an important factor in determining habitat utilization and value. In general, coarse, heterogeneous sediment mixtures have a higher habitat value because of greater diversity and structure. Coarse sediment is required for spawning, nursery, and shelter habitat by fish. Sediment composed of an even mixture of fine substrates with little or no complexity is very common, but has lesser value than heterogeneous substrate. Fine substrate habitat is used for feeding by some species and does not provide good, direct habitat for other life history needs.

Substrate of each habitat polygon was classified according to one of four classes: boulder-dominated substrate; boulder/cobble; sediment-dominated with cobble/boulder; and fine-sediment-dominated. Lakebed imagery collected from drop-camera stations provided insight into grain size and depth when combined with colour gradations visible from the aerial photographs. General descriptions of the four substrate classes are as follows:

- *Boulder* – Predominantly boulder and cobble substrates. These may be ice-scoured in very shallow platforms and have light to heavy periphyton coverage. This substrate type was most common in shallow water.
- *Boulder/cobble* – A heterogeneous mixture of boulder-cobble substrate interspersed with some fine sediment patches. Boulders and cobbles are sometimes pressed into fines. This substrate type is also more common in shallow water and has a covering of periphyton.
- *Sediment with boulder/cobble* – A heterogeneous mixture of sediment (i.e., sands and silt-clay) with occasional boulder-cobble coverage (between 10% and 50%). Boulders and cobble may have a light veneer of fines draped over the surface. This substrate occurs primarily in the transition zone between shallow boulder cover and deeper fine sediments at depths of 2 to 6 m.
- *Sediment fines* (silt-clay) – Predominantly silt-clay sediment (90%) with some sand (<5%) and occasional patchy boulder/cobble (<10%). Most common in water depths >6 m.

2.3.3 Depth

Depth was assigned to lake areas from which depth polygons were derived and quantified using GIS. Depth was estimated from features that could be distinguished from air photos and empirical bathymetry data, and groundtruthed from depths measured in the field using underwater video photography.

Classifying depth is important in ranking habitat quality because of the influence of ice, wind-driven currents, and wave action on nearshore and shoal habitat features. For example, ice can scour shallow, littoral zones to a depth of 2 m, minimizing colonization by benthic invertebrates and attached algae. Fish do not spawn successfully within several metres of the water surface because of the risk of freezing of eggs. Wave action and exposure determines sediment grain size and sedimentation rate in shallower waters.

Four depth classes were identified.

- *Shallow* – Less than 3 m depth. Shallow areas were typically found adjacent to shoreline and were associated with platforms and sometimes, shoals. Boulders and/or cobbles may pierce the water's surface and are assumed to freeze to the lakebed in winter.

- *Moderate* – From 2 to 4 m depth. Moderate depth areas provide optimum depth for spawning because of favourable substrate size and distribution. Shoals and aprons typically have moderate depth. Recent studies (e.g., Diavik, Snap Lake) indicate that this depth is preferentially used by lake trout for spawning.

- *Deep* – From 4 to 6 m depth. Deep areas are found lakeward of platform habitat and are most often associated with aprons and shoals. The 6 m lower limit of this class frequently corresponded to the outer edge of platforms.

- *Very deep* – Greater than 6 m depth. Bottom substrate features at depths greater than 6 m could not be clearly distinguished from air photos. Based on underwater video survey results and sediment sampling from previous field studies (BAEAR, 2005), substrate at these depths and greater consist almost exclusively of fine (clay-silt) sediment.

2.3.4 Complexity

Complexity of substrate describes the relative diversity, roughness, and heterogeneity of bottom substrate. There is a positive correlation between substrate complexity and habitat quality. Complex, three-dimensional habitats have a large surface area, which provides for optimal conditions for spawning, nursery, rearing, and shelter habitat for fish because of the diversity of microhabitats. Soft sediment with uniform slope and grain size has low diversity and very little microhabitat diversity.

Three classes of habitat complexity were identified:

- *Complex* – Polygons shows considerable surface roughness (e.g., boulder veneer on bedrock) and a diversity of microhabitats. Complex habitats were more frequently observed at shallow to moderate depths (0 to 4 m) and were associated with platform and shoal habitats.

- *Moderately complex* – Polygon shows some (25% to 50% of area) surface roughness with moderate microhabitat diversity. Usually found at depths greater than 3 or 4 m, associated with shoal and apron habitat.

- *Uniform* – Polygons with little or no surface roughness and low diversity of microhabitats. Usually associated with fine sediment in deeper (>8 m) depths and shallow, sloping bedrock or bedrock controlled shorelines with little or no boulder veneer and low complexity habitat.

2.4 DETERMINATION OF HABITAT TYPE

Habitat attributes described above were grouped within identifiable units (i.e., polygons) based on unique combinations of habitat attribute (i.e., substrate, complexity, morphology, and depth) and class (within attribute features) that were mapped and quantified (ha) using GIS.

Six discrete, repeatable habitat types were identified in nearshore littoral zones, shoals, and offshore areas in the project lakes, as distinguished from aerial photograph interpretation and groundtruthed during field surveys (BAEAR, 2005) and with underwater video. The six habitat types are:

- *Boulder platform* – Situated adjacent to shorelines, substrate is typically very coarse, dominated by large boulders (<75%) and cobble, shallow depth (<2 m), and high complexity.
- *Boulder shoal* – Situated offshore of landforms, unconnected to shorelines. Substrate is very heterogeneous and comprised of boulders (75%) with mixed sediment, including cobble and coarse gravel. Depth ranges from shallow (2 m) to moderate depth (2 to 4 m) with high complexity.
- *Boulder apron* – Transition habitat between platforms or shoals and deep sediment basin habitat in deeper water. Substrate typically composed of a moderately complex mixture of boulder and cobble (>70%). Depth is usually shallow to moderate (2 to 4 m), although some polygons were deeper (6 m) with moderate to high complexity.
- *Mixed sediment apron* – Transition habitat consisting predominantly of fine sediments (sand, silt, clay >50%) with occasional boulder and cobble embedded in the sediment with moderate complexity and moderate depth (2 to 4 m).
- *Sediment apron* – Transition habitat with small amounts of coarse substrate (boulder/cobble <25%) and moderate to low complexity. Transition to higher amounts of fines (silt/clay) and reduced complexity with increased depth. Moderate to uniform complexity typically at depths of 4 to 6 m.
- *Sediment basin* – Inferred from field and video data where substrate is dominated by fines (>90%) with few, occasional boulders or small cobble patches. Morphology is flat with uniform complexity and depth is greater than 6 to 8 m.

Habitat type of each polygon was identified and mapped in the Portage lakes and Vault/Wally Lake as depicted in Figures 2.2 and 2.3, respectively. Surface area of each habitat was also quantified using GIS to determine total and relative abundance of each habitat type across project lakes (see Table 2.2).

Note that shallow sandy beach and boulder shoal habitat at deeper depths (6 to 8 m) do not exist in the project lakes. That is, there were no areas identified where fine sediments dominated grain size in shallow water, nor were there areas where very coarse sediments dominated grain size in deep (>6 m) areas. There was a consistent, inverse relationship between sediment grain size and increasing depth. Ice scouring, wind, and wave erosion cause very coarse materials to dominate along shorelines in shallow waters. Fine grain sediment (silt/clay) is found in transition and profundal (i.e., sediment basin habitat) areas. The headwater nature and absence of stream habitat and consequent inputs of sediment from upstream tributaries is a contributing factor to the six habitat types described here, which encompass the range of habitat types observed.

2.5 DISTRIBUTION & ABUNDANCE OF HABITAT TYPES

The spatial distribution of all six habitat types (i.e., boulder platform, boulder shoal, boulder apron, mixed sediment apron, sediment apron, and sediment basin) were quantified by area using GIS, mapped, and assigned a unique color to allow easy visual interpretation for Second and Third Portage lakes (see Figure 2.2) and for Vault/Wally Lake (see Figure 2.3). The same procedure was followed for habitat attributes: morphology (platform, shoal, apron, profundal basin), depth (shallow, moderate, deep), substrate (boulder, boulder-sediment, sediment-boulder, fine sediment), and complexity.

Figure 2.2: Distribution of Habitat Types in Second & Third Portage Lakes

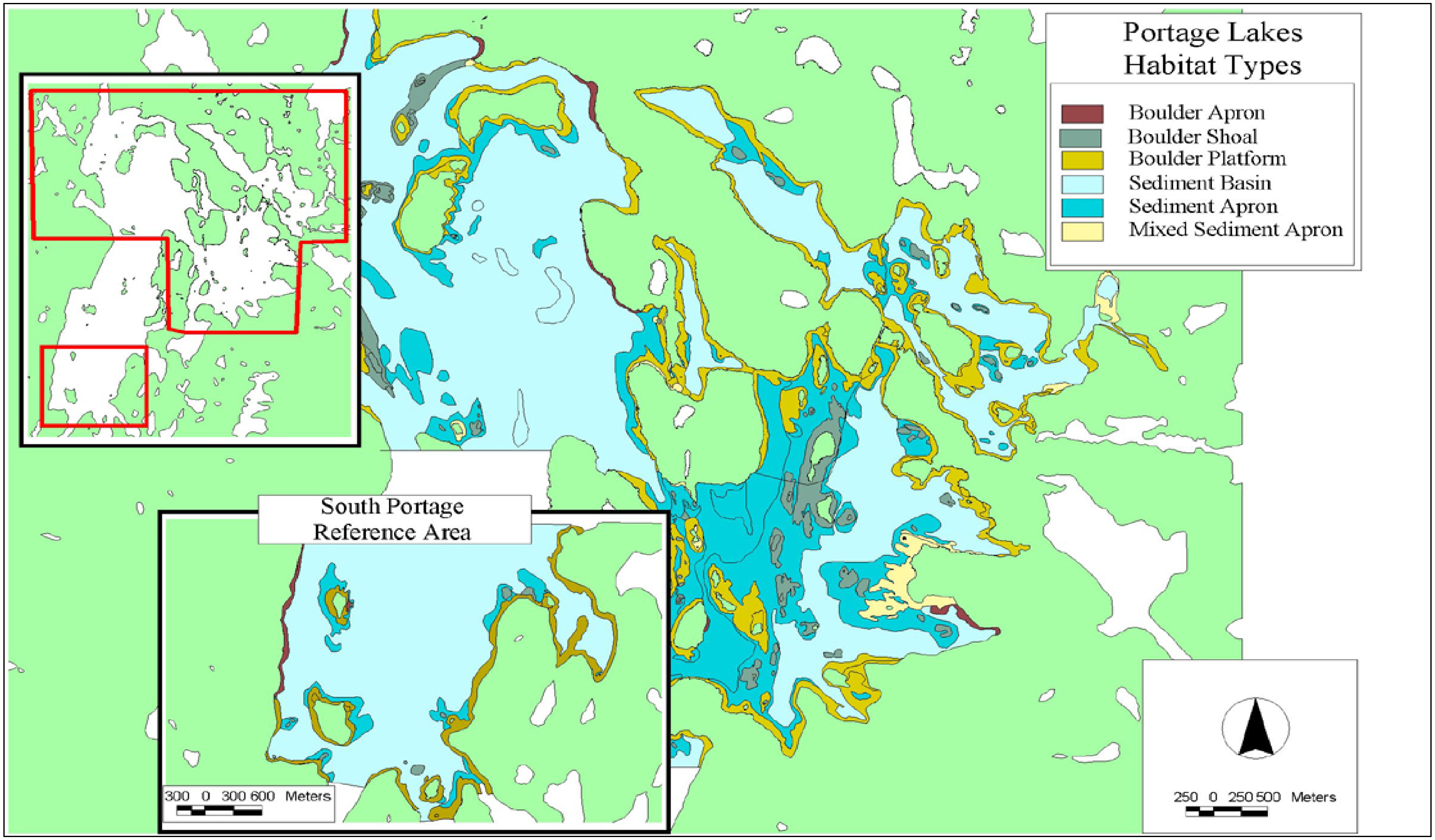


Figure 2.3: Distribution of Habitat Types in Vault & Wally Lakes

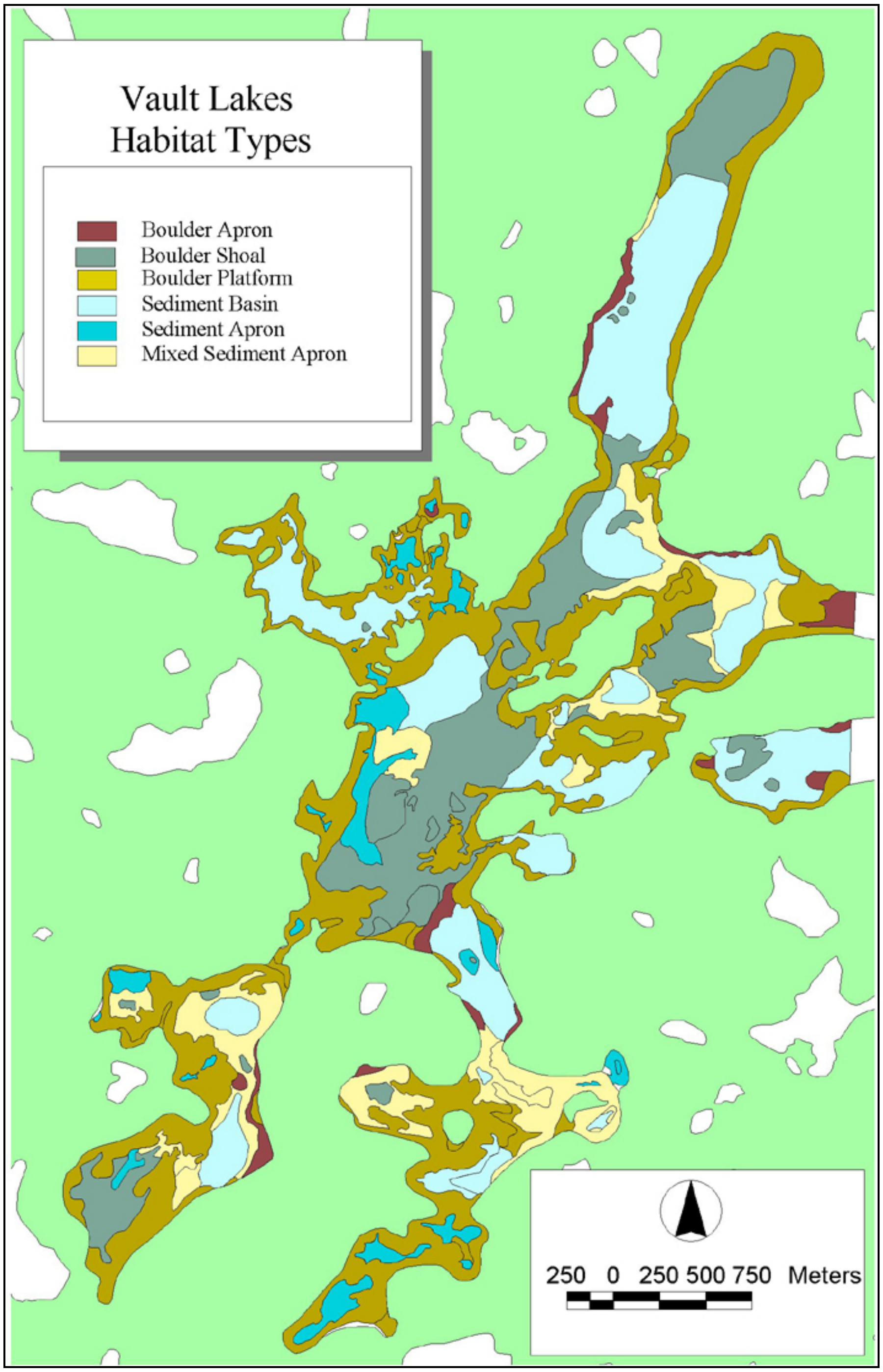


Table 2.2: Total Area & Relative Abundance of Habitat Types within Project Area Lakes

Sum of Hectares Habitat Type	Second Portage Lake		Third Portage Lake		Vault Lake		Wally Lake	
	Total Area (ha)	Percentage of Total	Total Area (ha)	Percentage of Total	Total Area (ha)	Percentage of Total	Total Area (ha)	Percentage of Total
Boulder Platform	103.4	27.0	316.1	12.2	47.4	48.3	217.0	36.2
Boulder Shoal	6.4	1.7	104.1	4.0	12.9	12.7	118.7	19.8
Boulder Apron	0.0	0.0	20.2	0.8	3.1	3.0	14.5	2.4
Mixed Sediment Apron	6.6	1.7	33.0	1.3	20.8	20.4	57.1	9.5
Sediment Apron	36.3	9.5	496.3	19.1	3.8	3.7	29.1	4.9
Sediment Basin	229.7	60.0	1,623.5	62.6	11.0	10.8	162.4	27.1
Grand Total	383.0	100.0	2,593.0	100.0	98.1	100.0	598.8	100.0

2.5.1 Second Portage Lake

The majority of lake area in Second Portage is deeper than 6 m, the visual limit of resolution of air photos. Maximum depth of the north arm is 38 m and the bottom slopes steeply away from the shoreline and is composed primarily of bedrock and or bedrock with heavy boulder veneer. Sixty percent of the total area of Second Portage Lake consists of profundal basin sediment, greater than 6 m deep. This habitat type dominates the area occupied by the Portage pit and tailings disposal area (see Figure 2.1).

South of the north arm, lake habitat complexity is more diverse, with many boulder platforms and shallow shoals, and submerged shoals and platforms extending from islands and shorelines. This habitat is preferred for spawning by lake trout, round whitefish, and Arctic char.

Sediment basin habitat, greater than 6 m deep, consisting of low complexity fine sediment habitat was the dominant feature in Second Portage Lake composing almost 230 ha or 60% of total lake area. Boulder platform habitat (103 ha) was the next most abundant habitat type in less than 4 m depth, composing 27% of the total lake area (see Table 2.2). Sediment apron (9.5%), mixed sediment apron (6.6%), and boulder shoal habitat (6.4%) composed the remainder of habitat in Second Portage Lake.

2.5.2 Third Portage Lake

The relative proportions of habitat in Third Portage Lake were similar to those of Second Portage Lake. There are several large, deep (>30 m) basins in Third Portage Lake, which composed 62.6% of the total area mapped (75% of total lake area). Sediment apron habitat composed 19% of the lake by surface area and was found predominantly in the east basin, west and south of Goose Island. This habitat is moderately deep (2 to 4 m), with abundant mixed boulder/cobble shoals interspersed with fine sediment. Boulder platform habitat was the next most abundant type (12.2%), with smaller amounts of boulder apron, boulder shoal (especially around Goose Island and in the North Basin), and mixed sediment apron habitats (see Table 2.2).

2.5.3 Vault/Wally Lake

Vault (98 ha) and Wally (598 ha) lakes are headwater lakes with very complex shorelines and great spatial diversity in depth, substrate type, and morphology. Within Vault Lake, deep sediment basin habitat is rare and composes a small area of the overall habitat (11%), but is proportionally more abundant in Wally Lake (27%; Table 2.2). Boulder platform habitat dominates nearshore habitat in both lakes, followed by boulder shoal habitat, contributing to the relatively high habitat value in these lakes. Boulder apron and sediment apron habitat each composed less than 5% of habitat by area in Vault and Wally lakes. The complex spatial distribution of habitat types, substrates, and depths contribute to the high overall spatial complexity and value of habitat within these lakes.

2.6 DETERMINING HABITAT VALUE

Habitat value is a relative concept based on the suitability of the physical, chemical, or biological attributes of the habitat to provide for one or more important life history functions, namely spawning/nursery, rearing, feeding, and overwintering. At a gross level, morphology, substrate, complexity, and depth contribute to habitat value. According to the combinations of each of these habitat attributes, the value of the habitat differs according to species and life history requirement. The following section describes how habitat value was determined for individual polygons based on rank and score of habitat attributes. Once this was accomplished, total area (ha) of high, moderate, and low value habitat in Second Portage, Third Portage, Vault, and Wally lakes were summed using GIS to determine the amount of available habitat, by value, in each project lake.

2.6.1 Scoring Habitat Attributes

Each of the 627 polygons identified from air photos assigned a habitat type was evaluated with respect to its value as spawning, nursery, rearing, feeding, and overwintering habitat for fish. To accomplish this, a scoring system was devised to score habitat attributes using a weighting and ranking system (see Table 2.3), whereby the relative contribution of each attribute to provide for basic fish life history requirements is assessed and assigned a score. The rationale for weighting and scoring of habitat attributes is based on our understanding of fish habitat requirements and local conditions, professional judgment and experience, and the scientific literature.

To determine habitat value, the relative importance of each of the major habitat attributes (substrate, morphology, depth, and complexity) were weighted and the features within attributes (classes) were ranked from one (low value) to three or four (high value), according to their relative importance for spawning/nursery, rearing, feeding, and overwintering. The rationale for scoring habitat features within each habitat attribute is described below and summarized in Table 2.3 below.

Table 2.3: Scores Assigned to Habitat Classes Described from Project Lakes

Habitat Attribute	Weighting[1]	Class	Rank[2]	Feature Score[3]
Substrate	2	Boulder	3	6
	2	Boulder/Cobble	4	8
	2	Boulder/Cobble/Fines	2	4
	2	>90% Fines	1	2
Complexity	2	Uniform	1	2
	2	Moderate	2	4
	2	Complex	3	6
Morphology	1	Apron	2	2
	1	Shoal	3	3
	1	Platform	4	4
	1	Sediment Basin	1	1
Depth	1	Shallow (0-2 m)	1	1
	1	Moderate (2-4 m)	4	4
	1	Deep (4-6 m)	3	3
	1	Very Deep (>6m)	2	2

Notes: 1. Weighting indicates the relative importance of each habitat attribute as a determinant of habitat value. **2.** Ranking indicates relative importance of features within habitat attributes. **3.** Feature score is the product of Weight x Rank, and indicates the relative importance of habitat attributes as they contribute to overall habitat value.

2.6.1.1 Morphology

The shape, topography, and slope of individual polygons determine the particular life history function that the polygon provides to fish, such as feeding, overwintering, or spawning. Shoals are particularly important as spawning areas while nearshore platforms are important as feeding and rearing areas. Platforms and shoals consisting of heterogeneous substrates were ranked higher (3 or 4) than aprons because of good light penetration, low ice scour and sediment deposition, and good water circulation. Aprons represent transitional habitats consisting of lesser periphyton growth, reduced circulation, and lower diversity substrates (boulder/cobble <50%; rank 2) or predominantly fines (rank 1). Platforms and shoals have a steeper slope, less accumulated sediment on the rock surfaces, and a greater abundance of periphyton growth than aprons and are therefore scored higher. Deep sediment basin polygons (aprons and profundal areas) consisting predominantly of fine sediments with low diversity, low slope, and no cover were ranked lowest (1).

2.6.1.2 Substrate

Substrate features largely dictate the function and contribute significantly to overall habitat function and quality. To recognize the contribution of substrate to habitat value, a range of scores was assigned depending on sediment composition. Heterogeneous mixtures of coarse sediment (boulder, cobble, and gravel) were assigned a maximum score of 4. Sediment dominated exclusively by boulders, generally found in shallow water (<2 m) was ranked lower (3) because of the lower diversity and surface area. As sediment grain size becomes increasingly smaller and more uniform in composition, overall value was diminished and assigned a score of 2 or 1, in the case of silt/clay sediment, found at deeper depths or bedrock-controlled shorelines at shallow depths.

2.6.1.3 *Depth*

Depth has a strong, direct influence on habitat value, primarily because of the relationship between ice scour, light penetration, biological productivity (e.g., periphyton growth and benthic community), water circulation, sedimentation, currents, and exposure. Habitat polygons in moderate depth (2 to 4 m) ranked higher (4) than habitats deeper than 4 m (rank 3) because of greater light penetration, periphyton growth, water mixing, and exposure to nutrients. Deep sediment basin habitats provide good foraging and overwintering habitat, but there is no cover habitat for spawning or nursery areas and thus received a lower rank (2). Shallow habitat at depths of 2 m or less is ice-scoured, exposed, subject to high wave energy, and ice-free only 8 to 9 months received the lowest rank (1).

2.6.1.4 Complexity

Polygons with complex habitat attributes characterized by high surface roughness, substrate heterogeneity, slope, and dimensionality due to variable depth received the highest rank (3). Polygons displaying intermediate complexity attributes were scored as moderate (2). Polygons displaying low spatial and vertical complexity and uniformity in sediment grain size, slope, and depth received the lowest rank (1).

2.6.2 Determining Habitat Value

Habitat value of individual polygons was determined by multiplying the numeric rank value within each habitat attribute by a weighting factor to achieve a feature score (see Table 2.3). Two of the habitat attributes, substrate and complexity, were assigned a weighting factor of 2, reflecting the greater relative importance of these attributes to overall habitat quality, compared to morphology and depth, which were assigned a weighting of 1. Feature scores were summed to derive a total score that is a reflection of habitat value.

Scores were calculated for all 627 identifiable polygons in Second Portage Lake (66 polygons), Third Portage Lake (425 polygons), Vault Lake (24 polygons), and Wally Lake (112 polygons). For example, the total score or value of a particular habitat polygon, such as a boulder shoal found at moderate depth was determined according to its unique composition of substrate type (e.g., boulder/cobble = 8), complexity (e.g., moderate = 4), morphology (e.g., shoal = 3), and depth (e.g., moderate = 4) to produce a total score of 19.

Based on the scoring system, the highest possible score was 22. To simplify the classification system, habitat types with a total score of 18 to 22 were assigned a value of "high," scores of 13 to 17 a value of "moderate," and a score of 12 or less, a value of "low." High (red), moderate (orange), and low (yellow) value habitats were classified, quantified, and mapped using GIS and are presented in Figures 2.4 and 2.5 for Second/Third Portage lakes and Vault/Wally Lake, respectively.

High value habitat is characterized by complex boulder or boulder/cobble substrate of moderate depth on shoals or platforms that are best suited for multiple life history requirements, including spawning, nursery, rearing, shelter, and feeding. Moderate value habitat also consists of a mixture of coarse substrates on shoals or aprons, of deep or shallow depth in transition areas, and is less important for spawning/nursery, but is more important as feeding habitat. Low value habitat consists primarily of uniform fine substrate, of low complexity in deep water, and provides feeding and overwintering habitat. This combination of habitat features is most common. Some low value habitat is also found very near shore in Second and Third Portage lakes (see Figure 2.4) and Vault/Wally Lake (see Figure 2.5) and is characterized as sloping bedrock or broken rock slabs extending from shore to depths of several metres. These shorelines are flat with low complexity and low diversity in structure and habitat value.

There is no established, widely recognized procedure or protocol for mapping and valuing fish habitat in Arctic lakes. Although the same basic principals are used, environmental assessments of northern mining projects (e.g., Diavik, BHP EKATI, Snap Lake) have used different approaches on a site-specific basis (e.g., use of aerial weighted habitat suitability indicators, HSI).

Some subjectivity is required to assess and assign scores to individual habitat attributes. Video data acquired from the 2003 field survey revealed that the composition and diversity of habitats was relatively simple and allowed some general assumptions to be made to simplify the assessment and increase robustness of data interpretation.

Figure 2.4: Relative Value of Fish Habitat in Second & Third Portage Lakes

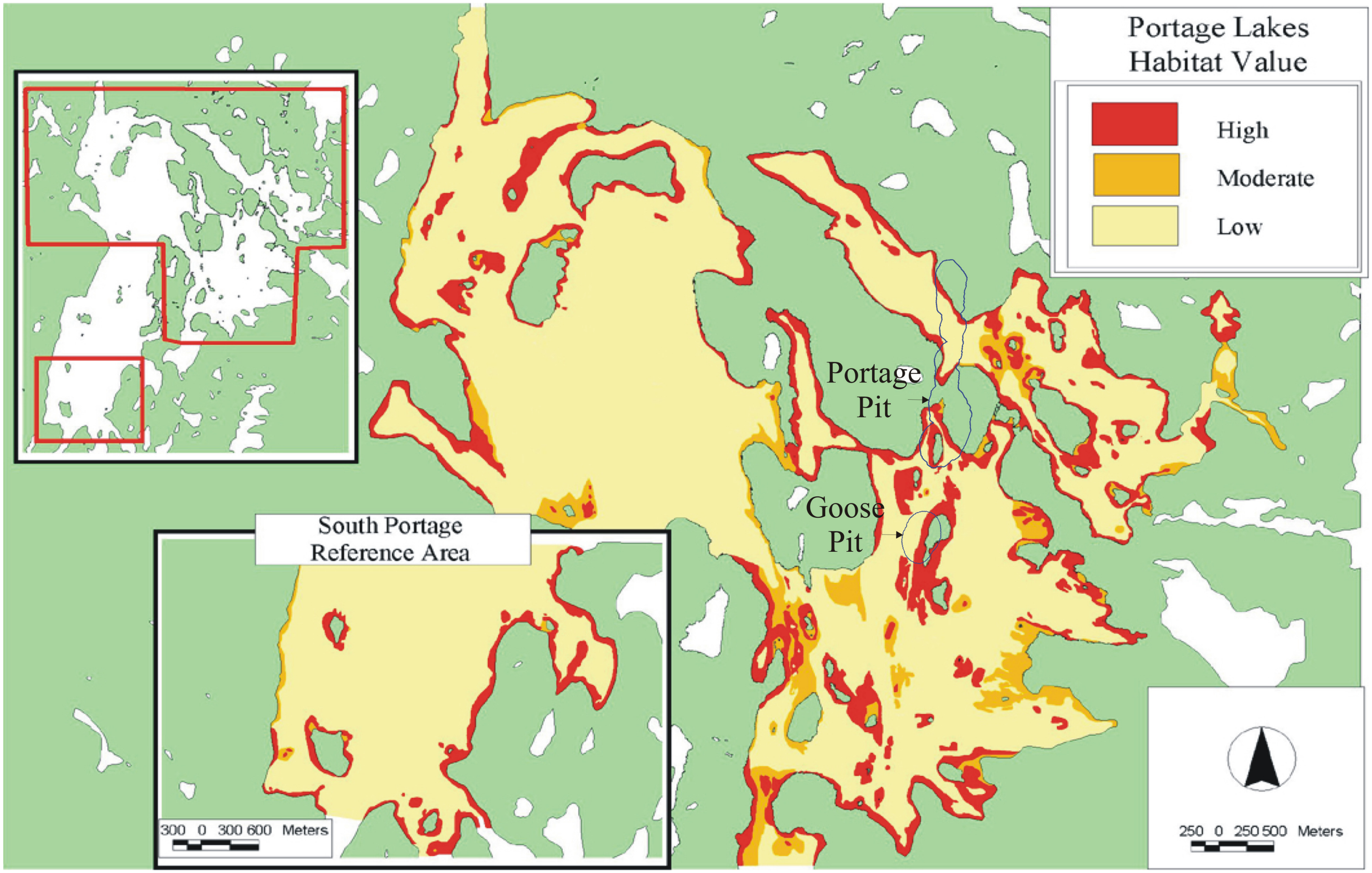
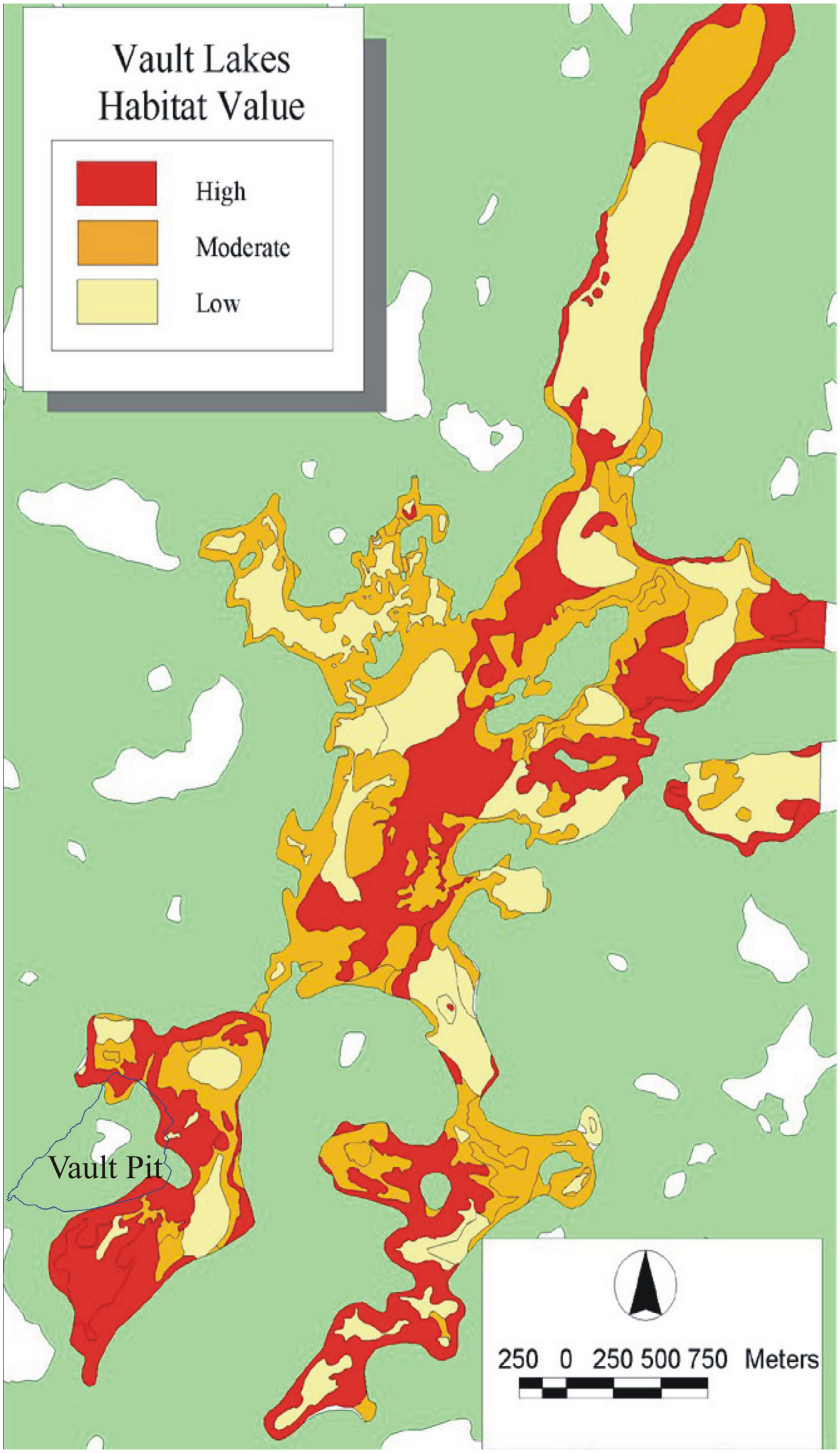


Figure 2.5: Relative Value of Fish Habitat in Vault Area Lakes



2.7 HABITAT VALUE OF PROJECT LAKES

The spatial distribution of high, moderate, and low habitat type in Second and Third Portage lakes and Vault/Wally Lake is depicted in Figures 2.4 and 2.5, respectively, and quantified in Table 2.4.

2.7.1 Third Portage Lake

High (376 ha) and moderate (152 ha) value habitat in Third Portage Lake is strongly associated with boulder platform and boulder shoal habitat because of ideal substrate, complexity, and depth for feeding and spawning/nursery and rearing habitat for lake trout, round whitefish, and Arctic char. The east basin contains proportionally more moderate and high value habitat than the north and south basins, which are dominated by large, deep basins with few islands and shallow shoals. Low value habitat composes nearly 80% of the lake surface area because of the deeper depth and predominance of low value, fine-sediment basin habitat. Fine sediments with little or no boulder/cobble and very low complexity characterize low value habitat, although areas of intermediate depth (4 to 12 m) provide good feeding habitat for round whitefish because of abundant benthic invertebrate populations (BAEAR, 2005). Note that the hectares in Table 2.4 for Third Portage Lake are uncorrected for total area of Third Portage Lake (3,600 ha).

2.7.2 Second Portage Lake

Second Portage Lake (383 ha) contained proportionately more high and moderate value habitat (34%) than low value habitat (66%) compared to Third Portage Lake, because of shallower depth and greater abundance of boulder platform and boulder shoal habitat of shallow to moderate depth and high complexity (see Table 2.4). The smaller lake area and large number of islands and submerged shoals contribute to greater complexity and diversity of habitat.

A relatively small area of moderate value habitat exists in Second Portage Lake, especially the north basin because of the steep sloping shorelines and deep depth of the basin, with the exception of a shallow (8 m) sill that separates the planned attenuation pond from the tailings disposal facility. South of this area, near the proposed location of the East dike, habitat complexity and value is high because of ideal depth and substrate characteristics. Abundant boulder/cobble substrate over platform and shoal habitat in moderate depth water contributes to this high value. High and moderate value habitat is strongly associated with islands, where platform and shoal habitat exists windward and in the lee of the strong prevailing northwest wind direction.

2.7.3 Vault/Wally Lake

A large proportion (75%) of the surface area of Vault Lake (98 ha) was classified as high (59 ha) and moderate value habitat (15 ha) (see Table 2.4). A similar proportion of Wally Lake (599 ha) was rated as high (31%) and moderate value (32%) habitat that is abundant and distributed evenly throughout the lake system, especially in the central region of Vault and Wally lakes (see Table 2.5). Again, high value habitat was typically associated with boulder platforms with heterogeneous substrates, shallow to moderate depth, and high complexity (see Table 2.5).

Table 2.4: Total Area & Relative Abundance of High, Moderate & Low Value Habitat in Project Lakes

	Second Portage		Third Portage		Vault Lake		Wally Lake	
Habitat Quality	**Total Area (ha)**	**Percentage of Total**	**Total Area (ha)**	**Percentage of Total**	**Total Area (ha)**	**Percentage of Total**	**Total Area (ha)**	**Percentage of Total**
High	100.7	26.3	376.8	14.5	59.4	60.5	186.8	31.2
Moderate	27.9	7.3	154.2	5.9	14.6	14.9	191.5	32.0
Low	254.0	66.4	2,062.3	79.6	24.1	24.6	220.5	36.8
Total Hectares	**383**	**100**	**2,593**	**100**	**98.1**	**100**	**598.8**	**100**

Note: Total area of Third Portage Lake refers to total area estimated, not actual total lake area (3,600 ha).

Table 2.5: Total Area of Habitat Type & Value in Project Lakes Altered or Destroyed as a Result of Minor Project Activities

Habitat Type	Phaser (ha)	NP-2 (ha)	NF-1 (ha)	Total HADD Area (ha)
Boulder Platform	12.7	5.5	0.4	18.6
Boulder Shoal	0.7	0.2	0	0.8
Boulder Apron	0.9	0.0	1.1	2.0
Mixed Sediment Apron	0.6	0.1	0.0	0.7
Sediment Apron	0.0	0.0	0.0	0.0
Sediment Basin	11.5	3.7	1.5	16.7
Habitat Value				
High	3.9	4.9	1.0	9.9
Moderate	22.4	0.9	0.4	23.7
Low	0.0	3.7	1.5	-
Total Hectares*	**26.3**	**5.8**	**1.4**	**33.6**

Note: * Total for moderate and high value habitat only.

The total area of moderate value habitat in Vault and Wally lakes was 206 ha, or 30% of mapped surface area, and is considerably more than the area and proportion of moderate value habitat than in the Portage lakes. Moderate value habitat is associated with boulder apron and mixed sediment apron, and is dominated by coarse substrates in water of shallow-to-moderate depth and moderate complexity. Similar to the Portage lakes, use of moderate habitat by fish for spawning is probably very site-specific. Given the abundance of high and moderate value habitat in the Vault lakes, this area is not limited by physical habitat attributes.

Low value overwintering and feeding habitat in Vault Lake (24 ha, 24%) and Wally Lake (220 ha, 37%) was relatively less abundant than low value habitat in the Portage lakes because of the generally shallow nature of the Vault/Wally lake basins.

SECTION 3 • HABITAT LOSS DURING MINE DEVELOPMENT

3.1 CONTEXT

The project lakes are situated in the extreme headwaters of the Quoich River system and are nutrient-poor with low productivity and low diversity of fall spawning fish species. Quantifying the value of habitat loss is complex and depends on a number of factors that influence how habitat, and ultimately, fish biomass, is affected during the course of mine life. The absolute and relative value of fish habitat potentially affected by mine development activities is based on the assessment of habitat as determined from aerial photographs, underwater video imagery, field studies, and professional experience. It is difficult to predict how the loss of habitat, especially high value habitat, in the project lakes will affect fish population abundance and species composition. Three major factors considered in this assessment include:

- The project lakes are isolated and have not been fished by community members from Baker Lake, except on very rare occasions. The project lakes do not support domestic or sport fisheries.
- High and moderate value habitat is abundant and widely distributed throughout the project lakes. There does not appear to be a disproportionate amount of high value habitat altered or destroyed within lake areas affected by the proposed mine development that does not exist elsewhere in the project lakes.
- The project lakes are ultra-oligotrophic and severely nutrient-limited. Consequently, production of fish biomass in project lakes is limited by lack of nutrients and not due to deficiencies, limitations, or distribution of physical habitat types.

Low value habitat is the most abundant habitat type in all of the project lakes and is not a factor limiting fish production or biomass. Therefore, for the purposes of this assessment, only moderate and high value habitat was quantified and would be compensated for. Because low value, deep water overwintering habitat is very abundant, replacing this habitat where it is altered or destroyed is not necessary, nor scientifically defensible. Furthermore, after mine closure, residual habitat created by pit development in Second and Third Portage lakes and Vault Lake will create larger areas of low value, deep water habitat than existed prior to development (see Section 4.3.4).

Estimating the significance of habitat loss, based on the relative amount (%) of habitat lost within an individual lake, is generally not meaningful. For example, although the number of hectares of high and moderate value habitat affected by mine development in Second Portage (39.4 ha) and Third Portage (62 ha) lakes is similar, these values represents 30% and 8% of high and moderate value habitat in Second and Third Portage lakes, respectively; however, because the lake systems are connected to each other, as well as to Tehek Lake, a very large lake (455 km^2), fish are able to move freely between the lakes and, unless there is a natural barrier, the project lakes should be considered as a unit. Therefore, percentages of lake areas affected are presented only to put this in context with residual habitat in unaffected areas within the project lakes.

Mine development will result in the unavoidable alteration, disruption, or destruction of fish habitat because certain activities cannot be relocated or mitigated. The creation of open pits within the bounds of Second Portage Lake, Third Portage Lake, and Vault Lake will permanently eliminate or alter habitat despite reasonable attempts to avoid impacts. This section of the NNL framework document quantifies the amount (ha) of moderate and high value habitat altered, disrupted, or destroyed from minor and major development activities, and will propose several candidate options to compensate for loss of fish habitat in the project lakes.

3.2 HABITAT LOSS FROM MINOR PROJECT ACTIVITIES

Minor project activities are those activities that have the potential to affect small amounts of habitat (<0.5 ha) and whose effects can be mitigated through proper construction practices or on-site habitat enhancement. Detailed descriptions of construction methods and mitigation during installation and operation of each of these activities is provided within the EIA and supporting documents. Furthermore, direct impacts on fish due to worker fishing, consumptive water use, blasting, noise and disturbance from dike construction, and effluent discharge are described in detail in the EIA and are not quantified here.

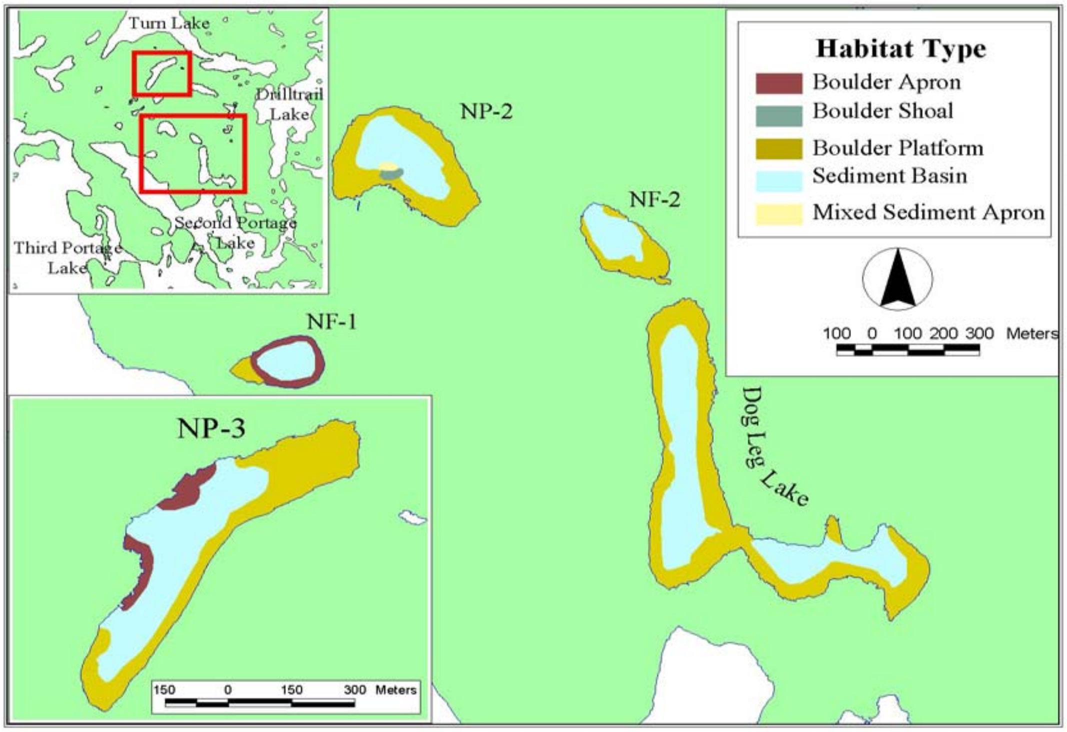
The following proposed minor project activities have the potential to alter, disrupt, or destroy fish habitat within project lakes:

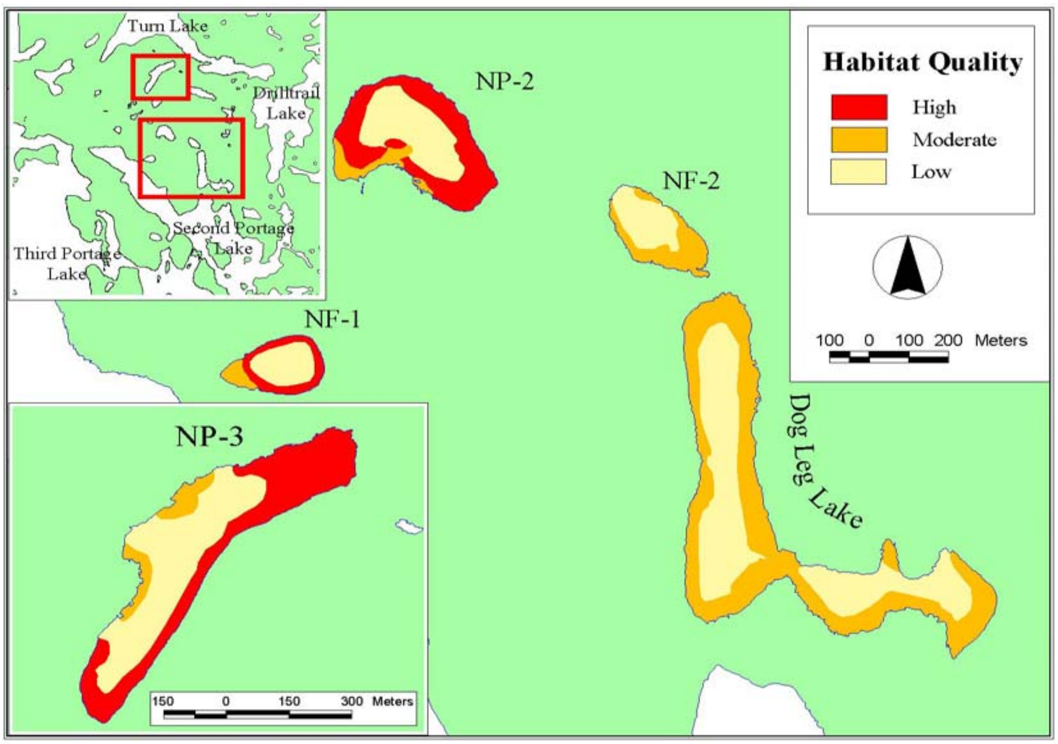
- elimination of one of three channels that connect Second Portage and Third Portage lakes as a result of construction of the East and Bay Zone dikes
- alteration of habitat from construction and installation of a water intake pipe and effluent discharge pipe in Third Portage Lake
- construction of the Portage waste rock storage facility will destroy fish habitat in one fishless lake (NF-1) and one fish-bearing lake (NP-1) (see Figure 3.1)
- isolation of Phaser Lake from Vault Lake. At this time, it is unknown if there is a hydraulic connection between the two lakes, or if Phaser Lake contains fish; this will be verified by a 2004 field investigation
- installation and operation of the Turn Lake Road crossing
- construction and operation of a marine barge landing facility at Baker Lake.

3.2.1 Portage Lakes Connecting Channel

Construction of the Bay Zone and East dikes will eliminate the westernmost of the three channels connecting Second and Third Portage lakes. Normally, fish passage via this channel is difficult or impossible during the open-water season except possibly during the peak of spring freshet. The channels are shallow and consist of boulder cobble with most water flow between or beneath the large substrate at all times except freshet. Movement by fish between the lakes is impossible during winter (October to June) because the channels are frozen. Monitoring of fish movement between Second and Portage lakes detected very small (<10 fish) movements of fish over the course freshet between the lakes (BAEAR, 2005). No fish movements were detected at base flows in August.

Figure 3.1: Habitat Type & Value of Small Project Lakes





The connecting channels are short and are not used as migratory routes, and spawning, nursery habitat, and rearing by juvenile fish do not occur here. Blackfly larvae have been observed and these may provide a minor, opportunistic food source for juvenile fish in Second Portage Lake.

To compensate for the loss of this connecting channel, the easternmost channel will be widened and deepened to facilitate greater flow that must now pass via two channels and not three. Of the two remaining channels, this easternmost channel is the furthest from mine operations and less likely to be affected by noise or disturbance, such as blasting (note: DFO's peak particle velocity (PPV) and overpressure (mm/s) criteria will not be exceeded beyond the dike exteriors (Wright and Hopky, 1998)). The channel is approximately 25 m in length and 10 m wide, consists of very coarse boulder/cobble substrate, and is not subject to erosion.

Improving fish passage between Second and Third Portage lakes may have considerable benefits to fish species composition in Third Portage Lake especially Arctic Char. Currently, the relative abundance and biomass of Arctic char in Third Portage Lake is low (7%) relative to abundance in Second Portage Lake (25%) and Tehek Lake (16%; BAEAR, 2005). Establishing a reliable hydraulic connection between Second and Third Portage lakes that will permit movement by fish throughout the open-water season could allow Arctic char to move into Third Portage Lake. This could be viewed as a viable means of compensating for habitat loss. This candidate option is discussed in greater detail in Section 4.3.

3.2.2 Intake & Effluent Pipe Installation & Operation

Three pipelines will be constructed in the project lakes:

- a water intake pipe situated west of the plant site on the western shore of the small, south-facing peninsula in Third Portage Lake
- a water effluent pipe extending from the north end of the Second Portage Lake attenuation pond into Third Portage Lake, discharging between the mainland and the most northerly island
- a water effluent pipe extending from the Vault Lake attenuation pond into Wally Lake.

The freshwater intake pipe will extend from shore and run along the lake bottom, extending from nearshore, rocky habitat to sediment basin habitat approximately 75 m offshore at a depth of 10 to 12 m. The intake will be fitted with an appropriately sized screen to minimize entrainment of small fish, calculated using the DFO (1995) guidance to minimize entrainment of fish in the intake, based on intake volume, screen size, intake velocity, and swimming ability of local fish species.

The intake pipe will be 1 m in diameter and constructed of a heavy-duty, insulated polyvinylchloride (PVC). During installation, care will be taken to minimize disturbance of coarse, nearshore substrate to seat the pipe along the bottom. Coarse material will be placed on either side of the pipe to anchor it to the bottom. At depths deeper than 4 to 6 m there is a transition to fine silt/clay sediment; therefore, the pipe will improve habitat complexity, especially in the sediment basin habitat by providing vertical structure and increasing available shelter habitat. Surface area occupied by the pipes during operation is small (0.007 ha), and the amount of benthic area lost will be more than compensated for by the riprap material used to anchor the pipe and by the dimensionality of the pipe itself.

Effluent will be discharged to each of the receiving environments (Wally and Third Portage lakes) via a 0.5 m HDPE pipe. The pipe will extend at least 50 m offshore of the nearest coarse substrate in at least 10 m of water. The end of the pipe will have a diffuser to maximize dilution of effluent into the receiving environment. Effluent will be directed away from any sensitive habitats. Similar mitigation measures will be implemented as for the intake pipes to minimize disturbance and increase habitat complexity near the effluent pipe.

3.2.3 Waste Rock Storage Facilities

Two areas are designated as rock storage facilities to contain overburden and waste rock materials: Portage/Goose (surface area ~150 ha) and Vault (surface area ~250 ha). To construct the Portage/Goose waste rock facility, two small lakes within the perimeter storage pile will be dewatered (NF-1 and NP-2; see Figure 3.1). There are no small lakes within the perimeter of the Vault storage facility. One of the ponds, Lake NP-2 at the Portage/Goose facility (9.5 ha) contains a small population of lake trout. This lake lies within a small depression, has no direct contact with Second Portage Lake, and is isolated.

Habitat is dominated by boulder platform and sediment apron (see Table 2.5). Habitat value of NP-2, determined from groundtruthed air photo interpretation, has 4.9, 0.9, and 3.7 ha of high, medium, and low value habitat, respectively. Although this lake is not connected to Second Portage Lake, it contains a small fish population that is limited by the small area of deep (>4 m) overwintering habitat. Despite the isolated nature of this lake, loss of high and moderate value habitat (5.8 ha) has been accounted for (Table 2.5) as part of the HADD assessment. Fish within NP-2 will be salvaged prior to draining and either placed in Second Portage Lake or sacrificed and provided to residents of Baker Lake.

The second pond, NF-1 (3 ha), is very shallow, with a maximum depth of about 3 m and does not contain fish. There is a small, ephemeral connection between this pond and Second Portage Lake that flows only in spring and has a very small surface connection. The habitat value of this pond was not accounted for as part of the HADD assessment because it has no fish population.

3.2.4 Turn Lake Road Crossing

The access road between the plant site and the Vault development will require that twin culverts be placed across a narrow constriction in the lake. The proposed crossing is 70 m wide and approximately 100 m upstream of the discharge point to Drilltrail Lake. The crossing will require two 75 m long, 2.5 m diameter round culverts with a sideslope ratio of 3H:1V for protection of habitat. Culverts will be installed in the dry during winter and embedded 0.8 m into the existing lake bottom to provide lateral structural stability.

Culverts are used regularly where roads cross water bodies and there are well-established mitigation measures to ensure that the crossing does not impair fish passage or pose a potential chronic source of sediment. The measures below will be implemented.

- Standard construction practices will be employed during culvert installation.
- Shorelines will be riprapped to prevent exposure of permafrost and prevent soil erosion.

- Coarse substrate will be placed inside the culverts and at the approaches to both ends to encourage fish movements and provide compensatory fish habitat with greater complexity than the uniform, fine sediment bottom where the culverts will be installed.
- Installation will be carried out during winter to avoid sensitive time periods for movements and feeding by fish.

Culvert diameter is sized to accommodate a 1:100 freshet. Under normal, freshet conditions, discharge velocity within the culvert will not exceed 0.6 m/s and will allow upstream movement by fish. There are no spring-spawning fish within the Quoich River watershed and there are no defined migrations by fish (BAEAR, 2005).

Riprap will be used to ensure the protection of shoreline banks from erosion and to provide complexity to habitat. In addition, a layer of coarse gravel and stone will be placed inside the entire length of the culverts to a depth of 0.5 m. This will provide sufficient cover habitat within the bottom of the culverts to reduce avoidance by fish passing through the culverts. A layer of very coarse material will also be placed at the approaches to the culverts to provide similar habitat as inside the culverts to facilitate fish movement. These coarse materials also will provide suitable habitat for periphyton and benthic colonizers. Approximately 0.52 ha of moderate and low value habitat will be affected by placement of the culverts; however, placement of riprap along the bottom and approaches to the culverts will increase habitat complexity and mitigate habitat alteration due to culvert operation.

3.2.5 Baker Lake Marine Barge Landing Facility

A marine barge facility will be constructed at Baker Lake to allow barges carrying mine supplies to access local roads and the winter ice road. A ramp will be constructed of a geotextile material, extending from the nearshore to 1 m depth about 10 m offshore. This ramp will allow shallow draft marine barges to land without causing disturbance and erosion of the nearshore environment. The approximate area of the barge landing facility is 0.02 ha. The geotextile material and ramp will alter a small amount of the shoreline that is normally ice-scoured or frozen in winter. Thus, a very small area of low value benthic habitat may be temporarily altered.

3.2.6 Summary

There is no net HADD of habitat as a result of construction and operation of most minor project activities. Adherence to proper construction practices and mitigation measures (e.g., winter culvert installation, sediment control, intake screen, etc.), and use of riprap to stabilize shorelines and anchor pipes will ensure that productive capacity of habitat is not diminished during mine life.

Creation of the waste rock facility at Portage/Goose will eliminate a small fish-bearing lake (NP-2) and a fishless lake (NF-1). Although NP-2 has no hydraulic connection with a larger adjacent project lake, total area of moderate and high value habitat has been quantified and is accounted for as part of the HADD exercise (see Table 2.5). Isolation of Phaser Lake from Vault Lake during mine operations composes the vast majority of temporary physical habitat loss (26 ha). Few fish move between Phaser and Vault lakes, however, applying the precautionary principal, given that movement between lakes is possible, it has been conservatively assumed that this habitat is affected.

3.3 HABITAT LOSS FROM MAJOR PROJECT ACTIVITIES

Major project activities are those activities that have the potential to affect larger amounts of habitat (>0.5 ha) and whose effects cannot be entirely mitigated through proper construction practices or on-site habitat enhancement. Major activities involve dike construction and operation of pits in project lakes. Development of Meadowbank mine will require construction of four dikes that will impound four discrete areas of the project lakes, which will be developed as pits. Pit size and depth will increase over the life of the mine as ore is extracted, for either processing or disposal in the tailings disposal area of Second Portage Lake or as waste rock. The net impact to the project lakes is directly related to the temporary loss of moderate and high value habitat within the pit areas. Following is an evaluation of the quantity and quality of habitat altered or destroyed within each project lake.

3.3.1 Second Portage Lake

The East dike will impound 138 ha of Second Portage Lake and is proposed for Year 1 of the development. Of this total, 91 ha will be situated behind the West dike, which isolates the north arm of Second Portage Lake and will contain the tailings disposal area and attenuation pond. The area behind the West dike containing these ponds will be gradually filled with tailings and will cause a permanent loss of fish habitat. The lake area east of the West dike, occupied by the Portage pit (41.5 ha), will be re-flooded upon mine closure and will be reoccupied by fish as part of Third Portage Lake. Pit development will also cause existing habitat to be significantly altered and diminish the value relative to current conditions. Furthermore, pit development in Second Portage Lake will cause water volume to increase by 15.8 Mm^3, nearly doubling the pre-mine development volume of the area of the Portage pit and tailings disposal area, which is estimated as 16.6 Mm^3.

Total area (ha) of habitat type affected by mine development in Second Portage Lake is depicted in Table 3.1. Because of the deep depth of the north basin, more low value sediment basin habitat (85.4 ha) will be destroyed than all other habitat types combined. The most abundant moderate or high value habitat destroyed is represented by boulder platform (31.9 ha) and transition sediment apron habitat (18.3 ha).

The total amount of moderate and high value habitat destroyed as a result of development of the tailings disposal area (21.1 ha) and Portage pit (18.3 ha) is 39.4 ha (see Table 2.5). The residual amount of moderate and high value habitat available to fish in Second Portage is 89.2 ha.

3.3.2 Third Portage Lake

In Year 1 construction of the Bay Zone dike will impound 19.9 ha of Third Portage Lake, which is 0.5% of the total surface area of Third Portage Lake. In Year 5, the Goose Island dike will expand the affected area to allow development of the Goose Island pit. The Goose pit occupies approximately 73 ha of Third Portage Lake. Combined with the Bay Zone pit area (93 ha), this is 2.6% of the total surface area of Third Portage Lake (~3,600 ha).

A relatively small portion of low value sediment basin habitat (22.5 ha; 17%) will be destroyed as a result of development of the Goose Island pit because of the shallow nature of the lake at this location.

Table 3.1: Total Area of Habitat Type & Value in Project Lakes Altered or Destroyed as a Result of Major Project Activities

Habitat Type	**Tailings Disposal Area (ha)**	**Second Portage Pit (ha)**	**Goose Island Pit (ha)**	**Vault Lake (ha)**	**Total HADD Area (ha)**
Boulder Platform	20.1	11.8	46.9	47.4	126.2
Boulder Shoal	1.0	1.0	14.1	12.7	28.8
Boulder Apron	0	0	0	3.0	3.0
Mixed Sediment Apron	0	0	0.7	20.4	21.4
Sediment Apron	11.7	6.6	50.1	3.7	72.1
Sediment Basin	58.0	27.4	22.5	10.9	118.8
Habitat Value					
High	21.1	12.2	59.6	59.4	152.3
Moderate	0.0	6.1	2.4	14.6	23.1
Low	69.7	28.6	72.3	24.1	
Total ha*	**21.1**	**18.3**	**62.0**	**74.0**	**175.4**

Note: * Total for moderate and high value habitat only

Similar to Second Portage Lake, boulder platform (46.9 ha) and sediment apron (50.1 ha) habitat are the most abundant habitat types that will be destroyed in nearshore and shallow water (see Table 3.1). A small amount of boulder shoal (14.1 ha) habitat will also be destroyed; however, these areas compose relatively small amounts (112 ha or 8%) of the total non-sediment basin habitat (1,348 ha, prorated to total surface area [3,600 ha] of Third Portage Lake) available to fish in Third Portage Lake (see Table 2.3).

In terms of habitat value, approximately 62 ha of moderate and high value habitat will be destroyed as a result of development of the Goose Island pit (see Table 2.5). The majority of the habitat affected by the pit development consists of mixed sediment apron habitat, followed by boulder platform and boulder shoal habitat. Virtually no deep, sediment basin habitat is affected. This habitat is moderate in depth (2 to 4 m) with very coarse, complex substrate features.

The residual amount of moderate and high value habitat available to fish in Third Portage Lake is 738 ha (prorated based on lake area surveyed (2,593 ha) to total lake area). At mine-closure the Goose Island dike will be breached and the Goose pit be allowed to gradually fill. After filling, water volume in Third Portage Lake will increase by 4.1 Mm^3 from the current volume contained within the Goose dike (approximately 2 Mm^3).

3.3.3 Vault Lake

The Vault dike will be constructed in Year 5 across the small channel that connects Vault to Wally Lake, isolating Vault and Phaser lakes from Wally Lake during the final seven years of mine life. The majority of Vault Lake will be drained and discharged to Wally Lake, except for two deep (>6 m) depressions that will serve as attenuation ponds. Development of the Vault Lake pit will alter or destroy 74 ha of moderate and high value habitat. This is a conservative estimate because not all of the original lake bottom may be adversely affected.

In addition, although fish have been captured within Vault Lake, much of the lake is quite shallow and overwintering habitat may be limiting. Therefore, there is some uncertainty as to the relative value of this lake to fish on a year-round basis.

Depending on final pit configuration, a portion of existing lake habitat will be destroyed. Phaser Lake is a small (26 ha), shallow lake connected to Vault Lake via a small rocky channel that is not passable by fish. Habitat type in Phaser Lake was dominated by boulder platform habitat (12.7 ha), followed by sediment basin habitat (11.5 ha), with small amounts (<1 ha) of boulder shoal, boulder apron, and mixed sediment apron habitat (see Table 2.5).

The entire area of Phaser Lake was assessed as moderate- or high-value habitat (see Figure 3.2), given the relatively shallow nature and favourable substrate conditions in the lake. Overwintering habitat for fish in Phaser Lake may be limited. Also, the ephemeral channel connecting Vault and Phaser lakes is used only to a limited extent by fish and movements by fish between the lakes are infrequent.

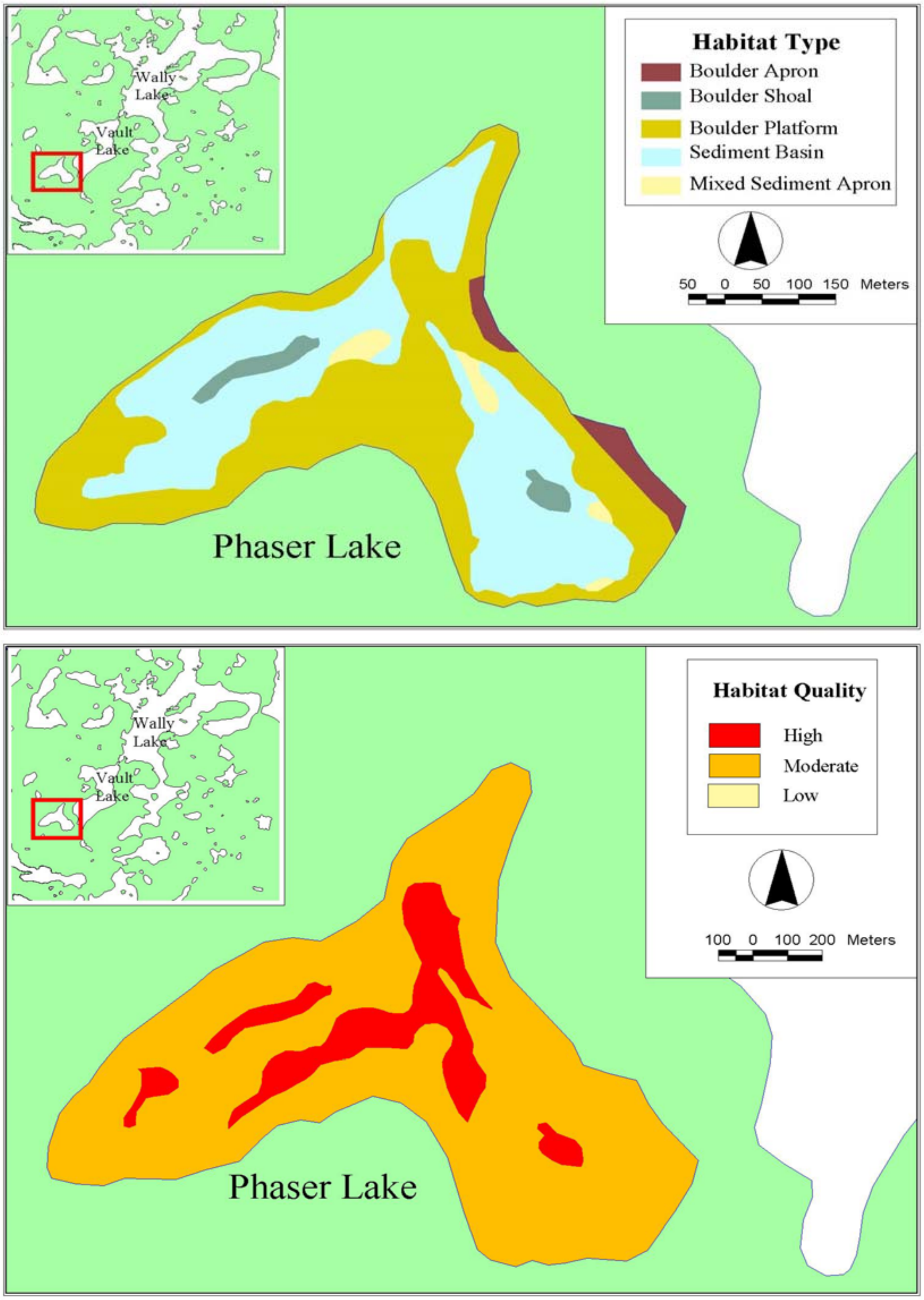
Wally Lake contains 379 ha of moderate and high value habitat that is widely distributed throughout the lake. The lake is relatively shallow and is dominated by boulder platform (217 ha) and boulder shoal habitat (119 ha; Table 2.2). Boulder apron, sediment apron, and mixed sediment apron habitat is also relatively abundant in Wally Lake. Deep, sediment basin habitat (162 ha) constitutes 27% of total available habitat and is considerably less abundant in Wally than in Second (60%) and Third Portage (63%) lakes (see Table 2.2). Wally Lake is also continuous with Drilltrail Lake and this lake system connects directly with Second Portage Lake, just upstream of its outlet to Tehek Lake via a wide, deep channel. Fish are able to easily move between Tehek Lake and the Vault/Wally Lake system because of the absence of velocity or elevation barriers (BAEAR, 2005).

At mine closure, the Vault dike will be breached and the Vault pit gradually flooded, increasing volume from approximately 2 to 19.6 Mm^3. Thus, the combined lake volume of Vault and Wally will be increased considerably from current conditions after mine closure.

3.3.4 Summary

Major project activities will result in a total HADD of 175.4 ha of moderate and high value habitat caused by diking, dewatering, and development of the Second Portage pit and tailings disposal facility (39.4 ha), Goose Island pit (62.0 ha) and the Vault pit (74 ha; Table 3.1). The majority of this habitat consists of boulder platform, boulder shoal, and mixed sediment apron. Total area of project lakes impounded by the East dike, Goose Island dike, and Vault dike are accounted for as part of the HADD exercise.

Figure 3.2: Habitat Type & Value of Phaser Lake



SECTION 4 • CANDIDATE HABITAT COMPENSATION OPTIONS

4.1 PHILOSOPHY

The NNL of habitat principle strives to avoid a net loss of productive capacity of fish habitat as a result of a development project. This NNL framework document has quantified the loss of productive habitat within the Meadowbank project lakes projected to occur for those activities that cannot be relocated, redesigned, or mitigated and will result in the HADD of fish habitat. The challenge is to try to compensate for this loss of habitat through on-site compensation, if possible; however, the options for effective on-site compensation are extremely limited. The DFO (1998) decision framework document recognizes this by stating, "on-site compensation is an option where site rehabilitation can be successfully undertaken. Compensation can also take place off-site and is normally the only option when there are long-term impacts to habitat or it is simply destroyed on site." Furthermore, this document goes on to state that, "the relationship between the quantity and quality of fish habitat and fish production is not well understood…and that compensation measures may not completely offset a HADD of fish habitat resulting from a project development." DFO managers are encouraged to, "seek compensation which is at least equivalent with respect to quantity and quality of habitat" and that "the goal of NNL of productive capacity is thus applied not as a rigid quantitative rule, but as a guiding principle."

This NNL framework document incorporates this philosophy by recognizing the natural limitations of on-site habitat compensation when such a relatively large area is altered or destroyed, and balances the significance of habitat loss from the perspective of the risk to the local and regional fish population and the local resource user.

In applying the NNL principle to a project, a number of factors must be considered when assessing whether an authorization for HADD of fish habitat should be issued. DFO (1998) lists these considerations, which are paraphrased below. The left-hand column lists the DFO considerations, while the right-hand column describes their specific application to the Meadowbank project, where appropriate (see Table 4.1).

The above assessment attempts to put local site conditions in perspective with the principle of application of NNL. Productive capacity of project lakes is limited by nutrient availability and not by physical habitat. There is considerably more physical habitat available in the project lakes than required by the current biomass of fish (BAEAR, 2005). For this reason, it is not proposed that large amounts of physical habitat in project lakes be constructed within lake areas where there is already an abundance of physical habitat. Furthermore, there is no precedent that in non-habitat limiting systems, creating new habitat will result in increased productivity of fish.

4.2 PRECEDENT

There have been three NNL plans recently developed as part of environmental impact assessments for Arctic mines: Diavik, Snap Lake, and Miramar. The Diavik NNL report (1998) proposed the following habitat compensation projects:

Table 4.1: Factors Considered by DFO when Issuing a HADD Authorization

DFO Considerations	Site-Specific Considerations
The acceptability of the HADD.	To be determined through consultation with DFO, and community members of Baker Lake.
Fisheries population or management objectives.	There are no specific management objectives, due to the remote nature of the area and the existence of large areas of similar habitat.
Does the habitat support an active fishery – if not, there is flexibility in timing and implementation of compensation.	The lakes do not support commercial, sport, or domestic fishing activities because they are remote.
Importance of the habitat – is the habitat in low supply or does it have high value to fish production?	High value habitat has been quantified, but is not in low supply and is not limiting to fish production.
Is the HADD temporary or permanent?	The HADD will be permanent in large areas of the pit areas.
Does the HADD cause a significant change in the capacity of the habitat to produce fish?	The HADD will cause a reduction in the capacity of the habitat to produce fish; however, the relative meaningfulness of this reduction is debatable.
The availability of technically feasible habitat compensation options, and evidence of past success in efforts to compensate for habitat loss of this type and magnitude.	Few technically feasible options are available. There is little, if any, evidence that on-site compensation to replace large areas of habitat lost is successful in restoring productive capacity.
Compatibility with the hierarchy of preference for compensation options.	Given that on-site opportunities for compensation are very limited, off-site compensation is proposed, which is the least-preferred option.
Does this authorization set a precedent that could lead to future cumulative impacts?	Unlikely. This is the only mine development within a very large area.

- modification of the external surface of containment dikes during operation and internal surfaces at closure
- creation of shallow reefs and other habitat features constructed on the shallow shelf between the dike interior and the open pit, after closure and breaching of the dike
- filling of deep areas of three small shallow lakes with coarse material to provide foraging habitat
- excavation of one shallow lake to provide overwintering habitat
- improvement of existing stream habitat to compensate for stream habitat loss.

None of the proposed NNL projects involved placing material into Lac de Gras as compensation for lost habitat within the impoundment area.

The Snap Lake project will affect only a very small area of Snap Lake due to installation and operation of water intake and mine water outlet structures. Proposed habitat mitigation consists of using a coarse boulder/cobble mixture to increase habitat diversity in the immediate area of the pipes (Snap Lake, 2002). No other habitat compensation outside of the immediate areas affected is proposed for Snap Lake.

The NNL plan for the proposed underground gold project (Doris North) by Miramar Hope Bay Ltd. proposed compensation measures for impoundment of a portion of a lake (Tails Lake), alteration of marine habitat from construction of a jetty, and other minor project activities (stream crossing, water intake, and floating dock). RL&L/Golder (2003) stated that, "the tailings containment area could not be relocated or redesigned to avoid impacts," and did not recommend habitat enhancement within Tails Lake. Instead, they proposed that enhancement of a stream channel of a nearby lake (Roberts Lake) to facilitate upstream and downstream movement by Arctic char for spawning purposes would provide the necessary compensation; however, DFO subsequently requested (FOC, 2004) that Miramar Hope Bay provide additional mitigation/compensation options to fully compensate for habitat loss in Tails Lake. RL&L/Golder (2004) responded by proposing that rearing habitat, which is purported to be limiting in Doris Lake just west of Tails Lake, be created in shallow, sandy areas at five locations. Placement of habitat in Tails Lake was not proposed.

In summary, no recent mine developments have proposed that new habitat be created within natural lakes where habitat does not appear to be limiting and there is no precedent for this. Given the abundance of habitat of all types in the project lakes, opportunities for on-site mitigation and compensation during mine operation are extremely limited. Consequently, off-site habitat compensation seems to be the most logical means of trying to achieve the principles of NNL and provide the greatest practical benefit to local resource users from Baker Lake; however, it should be noted that habitat loss is temporary and restricted to the period of mine operation. During post-closure, because of newly flooded land areas there is expected to be a net gain in productive capacity in the project lakes.

4.3 PROPOSED ON-SITE HABITAT COMPENSATION

This section describes several candidate options intended to compensate for habitat that is harmfully altered, disrupted, or lost, with newly created habitat or enhancement of existing habitat during operation and at post-closure. The following options compensate for lost habitat in project lakes by creating or allowing fish to access similar habitat that is lost at or near the development.

Operational Habitat Enhancement

Proposed on-site habitat compensation during operation involves a combination of the following:

- incorporating high value habitat features into dike exteriors during mine operation and on dike interiors (at post-closure)
- creating access for fish from Second Portage Lake to Dogleg Lake — this lake currently has a small, isolated fish population
- enhancing the connecting channel between Second Portage and Third Portage Lake to encourage Arctic char to access Third Portage Lake, increasing their abundance and fish biomass in Third Portage Lake.

Closure Habitat Enhancement

At post-closure, the south end of the Goose Island dike will be breached and the pits will be allowed to flood over a period of several years.

The entire contiguous area from the Goose pit north will become part of Third Portage Lake and will be 1 m in elevation higher than Second Portage Lake on the east side of the East dike. Prior to post-closure, habitat within the pits and setback areas (sills) between the pit crest and the toe of each dike will be contoured to provide optimal fish habitat.

Post-closure, on-site habitat compensation consists of the following:

- creation of spawning/nursery and rearing habitat within the upper 3 m of the Portage, Goose, and Vault pits for all habitat less than 6 m depth post-flooding
- creation of shoal and platform habitat on the sills or setback areas between the pit crests and dike interiors
- creation of spawning/rearing habitat on the dike interiors.

Habitat structures (reefs, boulder gardens, and shoals) will be constructed where appropriate prior to flooding, to create fish habitat on the sill areas and pit walls. The benefits of habitat enhancement and compensation measures undertaken during construction/operation will persist through post-closure into the foreseeable future. In particular, the benefit of improving access by Arctic char into Third Portage Lake is anticipated to increase relative abundance of this species

4.3.1 Pit Areas & Dikes

Dikes will be designed to provide habitat for periphyton and benthic communities, as well for spawning, nursery, and rearing habitat for the three key VEC species, lake trout, Arctic char, and round whitefish. The dike exteriors adjacent to project lakes will provide optimal habitat for fish during the life of the mine, as well as beyond mine life, as the vast majority of dike habitat will become a permanent feature of the lakes at post-closure.

In general, dike exteriors will be designed to emulate and incorporate optimal habitat features in terms of substrate size and heterogeneity, depth, slope, and complexity for spawning and rearing by VEC species. Habitat specifications have been gathered from various sources including published literature, grey literature, professional experience, local site conditions, and other recent EIAs.

At Meadowbank, spawning by lake trout, round whitefish, and char occurs in relatively shallow water, between 2 and 6 m depth. This is the depth range below the ice scour depth and above the depth where there is a transition to very fine grain sediment (BAEAR, 2005) and is consistent with generalized spawning habitat preferences for lake trout (Scott and Crossman, 1979).

Arctic char and round whitefish have similar spawning habitat requirements. Arctic char spawn over gravel and rocky shoals at depths to 4.5 m while round whitefish seek “gravelly shallows of lakes” or a “gravel and rock bottom” in reasonably shallow depths (Scott and Crossman, 1979). Other authors who have documented spawning habitat features for lake trout in the Great Lakes (Thibodeau and Kelso, 1990), northeastern USA and Ontario (Sly and Evans, 1996), in Northwest Territories and Nunavut lakes (Richardson et al., 2001), and at other mine sites, found similar preferences. In Lac de Gras, lake trout selected spawning characterized by either open water shoals or shorelines bordered by deep water with large substrates (boulders >256 mm in diameter), with many interstitial spaces, shallow water (2.5 to 7 m), steep slope, and wind-exposed areas to prevent accumulation of fine materials (Diavik EIA, 1999). Similarly, preferred spawning habitat for lake trout in Snap Lake occurred over exposed, rocky shoals 2 to 6 m depth with a boulder/bedrock substrate (Snap Lake EIA, 2002). Thus, dike design at Meadowbank will incorporate features to provide for spawning, egg incubation, and nursery habitat for lake trout, round whitefish, and Arctic char.

Side slopes of dike exteriors will depend on water depth and gradation of rockfill. In shallow lake areas less than about 5 m depth, side slopes will range between 1.4H:1V to 1.8H:1V. The slope of dike exteriors is sufficiently steep to ensure that wave action prevents fine sediments from accumulating, thus preventing potential impacts to incubating fish eggs. In lake areas greater than 5 m depth, side slopes will be slightly shallower, between 1.8H:1V and 2.5H:1V.

Capping material will consist of a mixture of boulder/cobble ranging from 0.2 to 0.8 m diameter rock. Slightly larger material will be used between 0 and 2 m depth to make the dike sufficiently durable to resist erosion from wave action and ice scouring. The size of material used to cap the dikes is similar in size to substrates found elsewhere in the project lakes. Ultramafic rock will be used as a surface capping cover because this material has relatively lower metals-leaching potential. Dike material below the water surface will consist of iron formation (IF) type rock that has lower submerged leaching potential than other rock types.

Portage Pit Area

Operation

Upon completion, the Portage East dike will be 1 km in length with an average depth of only 1.5 m. Maximum water depth along the East dike is 4 m. Because the East dike will be constructed across a relatively shallow area of Second Portage Lake, a relatively small area of the dike face will be underwater. The submerged surface area of the East dike is 3,800 m^2 (0.38 ha) and will consist of moderate value habitat (see Table 4.2). Because of the relatively shallow water depth west of the dike, this habitat will provide limited spawning habitat for fish, but will provide a medium for growth of periphyton and benthos as well as providing shelter habitat for juvenile VEC fish. Total moderate and high value habitat area created on the East dike during operations is 0.38 ha.

Post-Closure

At the end of mine life, the Portage pit will considerably larger in area than the original area and volume of impounded lake areas and will be connected to the Goose pit in Third Portage Lake. The two Portage pits will be long (2 km), rectangular (150 to 250 m), deep (100 to 120 m) pits connected by a 50 m wide sill. Flooded surface area is 57 ha with a projected volume of 29.8 Mm^3. Pre-impoundment volume of Second Portage is approximately 16.6 Mm^3.

At closure, the combined surface area of the Portage and Goose pits is predicted to be approximately 68 ha with a volume of 35.9 Mm^3. Much of this habitat will be recovered and enhanced to increase productive capacity after closure. Relative to the original area (3,600 ha) and volume of Third Portage Lake (228 Mm^3), this is <2% of lake area and 11% of pre-mine lake volume, most of which is additional volume (e.g., dewatered volumes of the Goose Island pit and Second Portage pit are both estimated at 2.6 Mm^3).

At closure, the interior of the Portage pits will be flooded and the dike interior, setback area or sills, and pit face (0 to 3 m) will be contoured to provide moderate and high value habitat. All new habitat will consist of moderate and high value habitat and have indicated as much in Table 4.2. Average water depth in the newly flooded Portage pit area is expected to be 3 m, not including the pit itself, which is quite deep (>100 m). The areas listed below will be targeted for habitat compensation.

- The East dike interior (0.47 ha) will incorporate the same habitat design features as the dike exterior to provide spawning/nursery and rearing areas for fish.

- The east face of the tailings dike, which now forms part of the shoreline of Third Portage Lake, will incorporate 2.55 ha of high value habitat.

Table 4.2: Total Area of Moderate & High Value Habitat of On-Site Habitat Compensation Projects

During Operations

Operation	East Dike Exterior (ha)	Goose Island Dike Exterior (ha)	Dogleg Lake (ha)	Portage Lakes Connection Channel	Total Operation Gain (ha)
High	0.38	1.49	0.00		1.87
Moderate	0.00	1.22	12.55		13.77
Total ha	**0.38**	**2.71**	**12.55**	**Unknown**	**15.64**

At Post-Closure

Post-Closure	Portage Pit				Goose Island Pit				Vault Pit		Total Post-Closure Gain
	East Dike (ha)	Tailings Dike (ha)	Portage Pit (ha)	Sill Area (ha)	Goose Dike (ha)	Goose Pit (ha)	Bay Zone Sill (ha)	Goose Sill (ha)	Vault Pit (ha)	Vault Lake (ha)	(ha)
High	0.47	1.03	1.18	13.5	1.13	4.5	4.0	25.5	0.65	47.5	99.46
Moderate	0.0	1.52	1.18	13.5	0.05	4.5	4.0	25.5	0.65	47.5	98.40
Total ha	**0.47**	**2.55**	**2.36**	**27.0**	**1.18**	**9.0**	**8.0**	**51.0**	**1.3**	**95.0**	**197.86**

- The sill area (measured from the crest of the pit to the toe of the dikes) east of the East dike (including the causeway area) and west of the tailings dike, not including Portage pit itself, is approximately 27 ha. Average water depth, not including the pit, is 3 m. This area will be contoured using coarse rock to provide boulder shoal and boulder platform habitat as spawning/nursery, rearing, and feeding habitat

- The upper 3 m of the pit wall around the entire Portage pit will incorporate the appropriate slope and boulder/cobble material to provide for spawning/nursery, rearing, and feeding habitat for fish. Total area of the Portage pit from 0 to 3 m depth is 2.36 ha, split between moderate and high value habitat. The pit area below 3 m depth is considerable because of its depth (>100 m); however, this habitat is considered low value and has not been counted as a credit towards compensation for HADD of fish habitat (see Table 4.2). Plan surface area of Vault, Portage, and

Goose Island pits is 41.7 ha, 55 ha and 21.9 ha respectively. Deep pit areas are considered to have relatively low habitat value.

At post-closure, moderate and high value habitat created within flooded dike interiors, sills, and pit walls is approximately 32.4 ha. This value may change depending on final configuration of the dike interior, pit dimension, and setback area.

4.3.1.1 Goose Island Pit Area

Operation

The Goose Island dike will be approximately 2 km in length with a surface area of 27,200 m^2 (2.7 ha) below the water surface. The mean water depth along the dike exterior is projected to be 5 m, with a maximum water depth of 15.5 m. Approximately 1.49 ha of the Goose Island dike lies between 0 and 5 m depth and will be engineered as high value habitat. The remaining surface area (1.22 ha) is deeper than 5 m and is considered moderate value habitat (see Table 4.2). Habitat created along the dike will provide a medium for growth of periphyton and benthos, as well as providing optimal habitat for spawning/nursery and rearing areas for VEC fish species. This is especially true along the entire eastern section of the dike that borders deep water, which is preferred for spawning by fish. During the life of the mine, the entire face of the dike is expected to provide potential spawning habitat.

Total moderate and high value habitat area created during operation is 2.71 ha (see Table 4.2).

Post-Closure

At closure, the Goose pit will be contiguous with the Portage pit. The Goose pit will be 500 m in length, 350 m wide, and 130 m deep with a surface area of 11 ha and volume of 6.1 Mm^3. The same three areas will be targeted for habitat compensation as the Portage pit (see Table 4.2):

- The surface area of the flooded dike interior (1.18 ha) will provide high value spawning/nursery and rearing areas. Note that part of the southern area of the dike will be breached to allow flooding of the pit.

- The setback between the pit crest and the toe of the Goose dike is 80 m, with a mean water depth of 3 m. There are two sill areas between the Goose dike and pit, not including the pit itself, which will be enhanced; the Bay Zone (between the Portage and Goose pits; 8.0 ha) and remaining area surrounding Goose pit (51.0 ha), split between moderate and high value habitat. These areas will be contoured using coarse rock to provide boulder shoal and boulder platform habitat as spawning/nursery, rearing, and feeding habitat.

- The upper 3 m of the Goose pit wall will be constructed to provide spawning/nursery, rearing, and feeding habitat for fish, will have a total area of 9.0 ha. Pit slopes greater than 3 m depth are considered low value and are not counted as a credit towards compensation for HADD of fish habitat (see Table 4.2).

During post-closure, moderate and high value habitat created within the Goose Island/Bay Zone area is approximately 69.18 ha. Again, this value may change depending on final configuration of the dike interior, pit dimension, water depth, and setback area.

4.3.1.2 Vault Area

Operation

The Vault dike separates Vault Lake from Wally Lake and will be constructed across the small, 10 m wide x 20 m long channel that connects the two lakes. The dike will be 250 m in length and the toe of the dike will extend into Wally Lake to a depth of about 1 to 2 m. Surface area of the dike beneath the water is small (230 m^2) and will provide moderate value feeding and shelter habitat during summer. Because of the shallow depth of water along the dike face, this will freeze during winter and will not provide suitable spawning habitat for fish.

Habitat area created on the Vault dike exterior contributes a very small amount (0.02 ha) during operation and has not been accounted in Table 4.2.

Post-Closure

At closure, the Vault dike will be breached and the Vault pit gradually be allowed to fill. Vault pit will cover a triangular area of 42 ha, and is projected to be 900 m long x 600 m wide, with a maximum depth of 160 m. When flooded, the pit volume is projected to be 19.6 Mm^3, which is several times the volume of Vault Lake (2.0 Mm^3) and more than half the volume of Wally Lake. It is uncertain how much of Vault Lake will be unaffected by pit development, thus there is some uncertainty as to the area and value of habitat area recovered at post-closure.

Habitat area within the upper 3 m of the Vault pit will be enhanced to provide spawning/nursery habitat for fish and constitutes 1.3 ha, split between moderate and high value habitat. Residual habitat within the rest of the pit itself has not been accounted for. The area of Vault Lake that is recovered exclusive of the pit (41 ha) is 95 ha, which has been split between moderate and high value habitat (see Table 4.2). Similar to the Portage and Goose areas, the recovered lake area will be contoured using coarse rock to provide boulder shoal and boulder platform habitat as spawning/nursery, rearing, and feeding habitat.

Total area of high and moderate value habitat recovered and enhanced in Vault Lake at post-closure is approximately 96.3 ha, which is just less than the pre-development surface area of the lake (98 ha).

4.3.2 Dogleg Lake

Dogleg Lake is a small (23 ha) lake that has a small lake trout population that is isolated from Second Portage Lake. The small, ephemeral drainage channel connecting Dogleg to Second Portage has very little flow and does not allow fish passage. Excavating a shallow (1 m), 120 m long channel between the two lakes will allow fish from Second Portage Lake to access Dogleg Lake and vice versa. Although not strictly considered additional habitat, the connection of the two lakes will allow VEC fish species from Second Portage Lake to access habitat that is currently unavailable and may optimize utilization by fish.

The total amount of moderate value habitat accessible by Second Portage Lake fish is estimated as 12.55 ha (see Figure 3.1; Table 4.2), consisting primarily of boulder platform habitat. This habitat will be available to Portage Lake fish, especially Arctic char, during operation and after post-closure.

4.3.3 Portage Lakes Connecting Channel

The westernmost of the three channels connecting Third Portage Lake to Second Portage Lake will be eliminated as a result of development of the Portage Goose pit. Fish passage between these two large headwater lakes via all of the channels is difficult or impossible during the open water season except possibly during spring freshet. Movement by fish between the lakes is impossible during winter because of blockage by ice.

To compensate for the loss of one connecting channel, the easternmost channel will be widened and deepened to facilitate greater flow from Third to Second Portage Lake; however, more importantly, this channel will also be designed to facilitate movement by fish, especially Arctic char, between Second and Third Portage lakes. This may have significant beneficial implications for the productivity of fish populations in Third Portage Lake and is intended to partially compensate for habitat loss in the Portage lakes.

Lake trout is by far the most abundant species present in the project lakes, including Third Portage (85%), Second Portage (65%), Tehek (80%), and Wally Lake (75%; BAEAR, 2005). The size distribution of lake trout in Third Portage, Second Portage, and Tehek lakes covered a wide range, up to 1.1 m, and size distribution of trout in all lakes was bimodal, which is typical for most Arctic lakes dominated by lake trout (Johnson, 1976).

During periodic fisheries surveys between 1997 and 2002, Arctic char were consistently less abundant in Third Portage Lake (8%) than in Second Portage Lake (28%). Primary and secondary production in Third Portage Lake was also lower, as was abundance of fish, as determined from catch-per-unit effort statistics. Furthermore, Arctic char from Second Portage Lake were larger (478 mm) and had a higher condition factor (K = 1.09) than char from Third Portage Lake (288 mm, K = 1.03; BAEAR, 2005). The smaller number of char in Third Portage Lake may be related to lower lake productivity, but may also to the difficulty in overcoming the barrier that exists between Second and Third Portage lakes. It is possible that char from Tehek Lake or lakes further south in the system migrate into Second and then Third Portage lakes seeking spawning grounds. If a char happens to gain access to Third Portage Lake to spawn, it likely remains in this lake because of the absence of reliable passage into Second Portage. Thus, offspring of char in Third Portage will tend to remain small because of the low productivity of Third Portage Lake.

Facilitating movement of fish, especially Arctic char, between the Portage lakes may result in an increase in the relative abundance of char over the long term because of improved access to spawning and rearing habitat and under-utilized planktonic food resources in Third Portage Lake, given the low abundance of round whitefish. Arctic char in this system exclusively consume zooplankton. Lake trout do not consume zooplankton beyond one or two years of age and round whitefish, which compose a small percentage of the fish population in Third Portage Lake, also consume zooplankton and may compete with char for this resource.

It is difficult to predict if facilitating movement of fish between the Portage lakes will result in increased productivity and biomass of fish in the system and, if so, by how much. Given that fish in Third Portage Lake cannot presently access downstream habitat and vice versa, this probably limits overall productivity and genetic diversity of the system. Arctic char have a greater intrinsic value to Inuit than lake trout because they are more commonly exploited for food. Therefore, increasing the biomass of char in the system, even at the expense of lake trout, is regarded as beneficial. The compensatory benefit of facilitating access by char to 708 ha of moderate and high value habitat in Third Portage Lake will be assessed pending discussions with Fisheries and Oceans Canada.

4.3.4 Summary

During the post-closure environment, overall gains in moderate- and high-value habitat from flooding of terrestrial environments and habitat enhancement of flooded aquatic habitat will, over the long-term, compensate for habitat loss during mine operations.

The total amount of moderate and high value habitat created on site during mine operations is limited to 15.64 ha, derived from high value habitat created on dike exteriors and by providing access by fish to Dogleg Lake (see Table 4.2). This total does not account for possible benefits to fish, particularly char, by facilitating access between Second and Third Portage lakes, which is difficult to quantify and will be determined pending discussions with DFO.

At post-closure, a considerable amount of habitat can be recovered from the original lake areas impounded as well as former land area between the Portage and Goose Island pits (see Table 4.2). With the exception of most of the pits themselves, this habitat can be enhanced such that its productive capacity is equal to or greater than its productive capacity prior to mine development. This can be achieved by creating reef, shoal, and platform habitat of ideal substrate type, slope, complexity, and depth to provide spawning/nursery, rearing, and feeding habitat.

Total moderate and high value habitat created at post-closure is approximately 197.86 ha. Combined with operational habitat area, which will continue through post-closure (15.64 ha), the total amount of residual moderate and high value habitat is 213.50 ha. This value is higher than the total HADD of 175.4 ha (see Table 3.1) resulting from major project activities caused by diking, dewatering, and development of the Second Portage pit and tailings disposal facility (39.4 ha), Goose Island pit (62.0 ha) and the Vault pit (74 ha). The main reason for the overall gain in habitat value is that formerly low value habitat in Second and Third Portage lakes, and terrestrial areas (Goose Island, other small islands, and the peninsula separating the Portage lakes) will become high value aquatic habitat.

4.4 OFF-SITE HABITAT COMPENSATION

The total area of moderate and high value habitat proposed for on-site compensation during operation (15.6 ha) is not sufficient to completely offset habitat loss of major mine development activities (174 ha). Note that this total does not include the compensatory value of enhancing fish passage between the Portage lakes to increase the abundance of Arctic char in Third Portage Lake.

This NNL framework document does not propose that large amounts of new, artificial habitat be created in remaining lake areas of affected project lakes during mine operation for the following reasons:

- The ultra-oligotrophic nature of the lakes means that lake productivity and biomass of fish is limited by nutrients and not by habitat. Creating new habitat does not necessarily mean that fisheries resources will be enhanced, because the food resources required to support additional fish are likely unavailable.

- Spawning/nursery, rearing, and overwintering habitat is abundant in all of the project lakes and no habitat type is limiting within the lake areas outside of the dikes.

McAughey and Gunn (1995) have shown that when lake trout have been deprived of traditional spawning sites, trout responded by seeking out alternative spawning locations within the lake, or utilizing other traditional spawning sites to a greater degree than before. The authors observed that there was no change in the timing of spawning and that trout adapted very quickly to the altered conditions and appeared readily and quickly to use alternate sites. This is particularly true in habitats where physical habitat is not limiting, such as in the project lakes. VEC species in general are adaptable and will seek out alternate spawning, foraging, and overwintering areas if certain traditional areas are altered or destroyed.

- There is no sport or domestic fishery in the project lakes. Creating new habitat would require a large capital investment that would not result in tangible benefits to local people.

- As discussed, there is no precedent for creating new habitat in large lakes that are not habitat-limited in any way.

Given that on-site candidate projects will not completely compensate for altered or destroyed habitat as a result of major project activities during mine operation, off-site compensation may be considered. This was recognized by Minns (1997) who, in proposing a NNL strategy, stated that lake habitat lost as a result of mining in northern lakes cannot be replaced as, “on-site mitigation or compensation actions are not possible,” and that, “attainment of NNL can be achieved through off-site compensation actions such as restoring comparable habitats degraded or destroyed in the past.” The most appropriate way to develop proposals for off-site compensation is to first hold discussions with DFO to identify a range of options that are acceptable to DFO in principle.

Options for off-site compensation will also require input from community members of Baker Lake. Ultimately, any proposed habitat compensation project should strive to satisfy requirements of the NNL guiding principle, but in doing so also provide tangible, long-term benefits to local resource users who are the ultimate beneficiaries of increased productivity capacity of local fisheries resources. Once an agreement in principle has been reached between the various parties, Cumberland will submit a NNL plan that details the final compensation agreement.

SECTION 5 • REFERENCES

Aquatic Environment Management Report. Framework for the application of aquatic environment management and monitoring of Meadowbank project area lakes. A report prepared for Cumberland Resources, Vancouver by Azimuth Consulting Group, Vancouver. March 2004.

Baseline Aquatic Environment Assessment Report. Baseline aquatic environmental assessment report, Meadowbank study area lakes, Nunavut. A report prepared for Cumberland Resources, Vancouver by Azimuth Consulting Group, Vancouver. October 2003.

Canada Department of Fisheries and Oceans. 2003. A federal perspective on fish habitat management. www.dfo-mpo.gc.ca/canwaters-eauxcan/infocentere/legislation-lois/policies.

Canada Department of Fisheries and Oceans. 1998. Decision framework for the determination and authorization of harmful alteration, disruption, or destruction of fish habitat. DFO Habitat Management and Environmental Science Habitat Management Branch. Communications Directorate, Ottawa, Ontario. 23 p.

Cumberland Resources Ltd. 2003. Meadowbank Gold Project Description Report. A report prepared by Cumberland Resources Ltd., Vancouver for the Nunavut Impact Review Board, Iqaluit, Nunavut.

Department of Fisheries and Oceans (DFO). 1986. Policy for the management of fish habitat. Fish Habitat Branch, Ottawa Ontario. October, 1987. 30 p.

Department of Fisheries and Oceans (DFO). 1995. Freshwater intake end-of-pipe fish screen guideline. Department of Fisheries and Oceans, Ottawa Report No. 5080. 27 p.

Department of Fisheries and Oceans (DFO). 1998. Decision framework for the determination and authorization of harmful alteration, disruption or destruction of fish habitat. DFO Habitat Management and Environmental Science, Habitat Management Branch, Ottawa Ontario. 12 July 1999.

Diavik. 1999. Diavik Diamond Mine Environmental Impact Assessment document. No Net Loss Plan, September, 1998.

Fisheries and Oceans Canada (DFO). 2004. Doris North pre-hearing conformity analysis and adequacy review, Miramar Hope Bay Ltd. Final EIS. Letter to Stephanie Briscoe, NIRB from M. Curtis, DFO Iqaluit, 30 January 2004.

Fitzsimmons, J.D. 1996. The significance of man-made structures for lake trout spawning in the Great Lakes: are they a viable alternative to natural reefs? Can. J. Fish. Aquat. Sci. 53: 142 – 151.

Johnson, L.L. 1976. Ecology of Arctic populations of lake trout, *Salvelinus namaycush*, lake whitefish, *Coregonus clupeaformis*, Arctic char, *S. alpinus* and associated species in unexploited lakes of the Northwest Territories. J. Fish. Aquat. Sci. Can. 33: 2459 – 2488.

Lawrence, M. and S. Davies. 1977. Aquatic resources survey of Keewatin and Franklin Districts. Environmental-Social Program Northern Pipelines ESCOM Report No. A1-31.

Marsden, J.E., J.M. Casselman, T.A. Edsal, R.F. Elliot, J.D. Fitzsimons, W.H. Horns, B.A. Manny, S.C. McAughey, P.G. Sly and B.L. Swanson. 1995. Lake trout spawning habitat in the Great Lakes – a review of current knowledge. J. Great Lakes Res. 21 (Supplement): 487 – 497.

McAughey, S.C. and J.M. Gunn. 1995. The behavioral response of lake trout to a loss of traditional spawning sites. J. Great Lakes Res. 21: 375 – 383.

Metal Mining Effluent Report. Framework for the application of metal mining effluent regulations (MMER) at Meadowbank. A report prepared for Cumberland Resources, Vancouver by Azimuth Consulting Group, Vancouver. March 2004.

Minns, C.K. 1997. Quantifying “no net loss” of productivity of fish habitats. Can. J. Fish. Aquat. Sci. 54: 2463 – 2473.

RL&L/Golder, 2003. Doris North Project “No Net Loss” Plan. Prepared by RL&L Environmental Services/Golder for Miramar Hope Bay Ltd, November 2003.

RL&L/Golder, 2004. Supplementary information on Doris North Project No Net Loss Plan. Prepared by RL&L Environmental Services/Golder for Miramar Hope Bay Ltd, March, 2004 in response to a request by DFO, January, 2004.

Scott, W.B. and E.J. Crossman. 1979. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. 966 p.

Snap Lake EIA. 2002. Snap Lake Environmental Impact Assessment. Prepared for DeBeers by Golder Associates, Calgary, AB. February, 2002.

Sly, P.U. and D.O. Evans. 1996. Suitability of spawning habitat for lake trout. J. Aquat. Eco. Health 5: 153 – 175.

Thibodeau, M.L. and J.R.M. Kelso. 1990. An evaluation of putative lake trout (Salvelinus namaycush) spawning sites in the Great Lakes. Can. Tech. Rep. Fish. Aquat. Sci. 1739. 20 p.

Wright, D. and G. Hopky. 1998. Guidelines for the use of explosives in or near Canadian fisheries waters. Can. Tech. Rep. Fish. Aquat. Sci. 2107. iv + 34 p.