SECTION 1
INTRODUCTION

Hydropower Limited Partnership

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1.0 INTRODUCTION

1.1 PURPOSE AND CONTENT OF VOLUME

This Aquatic Environment Supporting Volume (AE SV) is one of six volumes produced in support of the Response to EIS Guidelines for the Keeyask Generation **Project** Environmental Impact Statement (EIS). The EIS has been developed by the Keeyask Hydropower Limited Partnership (the Partnership) as part of the regulatory review of the Project under the *Canadian Environmental Assessment Act* and *The Environment Act* (Manitoba).

The EIS consists of the following:

- A video, *Keeyask: Our Story*, which presents the Keeyask Cree Nations' history and perspectives related to hydroelectric development. Presented through the lens of their holistic Cree worldview, it explains the journey taken by the Keeyask Cree Nations (KCNs) as they evaluated their concerns about the Project, the nature of their participation as Partners, and the decisions they ultimately made to support the Project;
- An executive summary;
- A Response to EIS Guidelines issued in response to an application by the Partnership for environmental approvals under the government regulatory environmental assessment process. This response includes findings and conclusions, with charts, diagrams, and maps to clarify information in the text, and a concordance table to cross reference requirements of the EIS Guidelines with information in the EIS; and
- The KCNs' Environmental Evaluation Reports providing each of the KCNs' own evaluation of the effects of the Project on their community and Members and including Aboriginal traditional knowledge relevant to the Partnership's response to the EIS Guidelines.

The six supporting volumes were developed by the Manitoba Hydro environmental team in consultation with the Members of the KCNs. These volumes provide details about the Project Description and about the research and analysis of the following topics: Public Involvement Program, Physical Environment, Aquatic Environment, Terrestrial Environment, Socio-economic Environment, Resource Use, and Heritage Resources (the latter three topics are included in one volume). The supporting volumes have been reviewed, commented on, and, as appropriate, finalized in a manner consistent with the arrangements of the Partnership.

This AE SV describes the environmental setting and assesses impacts of the construction and operation of the Project on the aquatic environment. The following topics are included:

Section 2: Water and sediment quality;

Section 3: Aquatic habitat;

Section 4: Lower trophic levels;

Section 5: Fish community;

Section 6: Lake sturgeon;

Section 7: Fish quality; and

Section 8: Sensitivity of effects assessment to climate change.

Each of Section 2 to Section 7 provides information pertaining to the environmental setting, including past conditions, current conditions and trends to the future, and assessment of the Project effects, including a description of required mitigation. A summary of residual effects and proposed monitoring and follow-up is provided in each section. Section 8 of this document considers whether predicted effects of the Project are sensitive to climate change.

This introduction section provides the following information with respect to the aquatic assessment:

- An overview of the ecosystem-based assessment approach, including scoping of the assessment and basic assessment methods (Section 1.2);
- A description of the study area (Section 1.3);
- A summary of the pathways of effect evaluated to examine potential interactions between Project construction and operation and the aquatic ecosystem, and the process to identify mitigation measures (Section 1.4); and
- Sources of information used for the assessment (Section 1.5).

Aquatic resources support commercial and recreational fisheries in the region and are an important domestic food for KCNs Members. These and other resource use activities are documented in the Socio-economic, Resource Use, and Heritage Resources Supporting Volume (SE SV), Resource Use Chapter.

1.2 OVERVIEW OF THE ECOSYSTEM-BASED ASSESSMENT APPROACH

This section describes the overall approach to the design and conduct of the ecosystem-based assessment on the aquatic environment.

An ecosystem is a functional unit comprised of the living and the non-living things in a geographic area, as well as the relationships between all of these things (Aber and Melillo 1991). An ecosystem has patterns (*e.g.*, habitat patches), structures (*e.g.*, food web, trophic structure), dynamics (*e.g.*, cycling of energy, nutrients and matter) and performs functions (*e.g.*, converts carbon dioxide into plant material, provides fish habitat).

An ecosystem-based approach was used to understand the aquatic environment and to evaluate the potential effects of the Project on it. This approach recognizes that the aquatic environment is a complex system in which changes to one component directly and/or indirectly affect many other components.

Key elements of the ecosystem-based approach that were applied to the aquatic assessment are listed below:

- The environmental components selected for the assessment included representation from different levels of the ecosystem;
- Scoping of the assessment considered both direct and indirect effects of the Project on the environmental components of interest;
- The spatial scale of the assessment considered both the scale(s) at which the Project can affect the environment and the scale(s) at which components within the ecosystem use the environment;
- The temporal scale of the assessment considered annual and between-year variations in the environment, including long-term changes;
- Given the complexity of potential interactions between the Project and the ecosystem, and within the ecosystem itself, models were used for (i) understanding processes relevant to the assessment; and (ii) predicting changes caused by the Project;
- The description of effects considered relevant benchmarks, including the degree of difference from undisturbed states, degree of change from the existing environment, and comparison to established thresholds and guidelines; and
- Uncertainties associated with the predicted effects were described, as were potential measures for addressing these uncertainties. Monitoring, including adaptive management, is one measure used to address uncertainty.

The following provides a brief overview of the aquatic ecosystem, followed by a description of the scoping and methods applied to the assessment.

1.2.1 The Aquatic Ecosystem

The biota of the aquatic ecosystem described in this volume are typical of Canada's northern boreal region. The ecosystem consists of fast-flowing large river habitat interspersed by shallow lakes and man-made reservoirs. The main channels of the lakes and reservoirs retain many of the characteristics of the river mainstem, and **residence times** of the mainstem sections are typically in the order of days. Small rivers and streams drain the generally low gradient boggy areas adjacent to the main waterways.

As is typical of all northern boreal systems, the area experiences distinct seasons. Winter is characterized by a prolonged period of ice cover, during which low temperatures and lack of sunlight to support primary production result in minimal biological activity. Rising temperatures and increasing daylight in spring create a burst in productivity throughout the ecosystem; this is also the time of the onset of reproduction and growth in many of the biota. Growth continues through summer, but by fall, most biological components are entering a period of relative inactivity for winter. Interannual variations in weather (*i.e.*, sunlight and timing of spring temperature increase and fall temperature decrease) and stream flow result in marked differences in the ecosystem between years.

The aquatic ecosystem includes primary producers (aquatic plants and attached and planktonic algae) and consumers (benthic invertebrates, zooplankton and over 30 fish species). Energy enters the system from the sun, where it is trapped by the primary producers, which in turn are eaten by the consumers or die and settle to the bottom to become part of the detrital system. As a riverine environment, energy also enters and leaves in the flow of the river, in the form of drifting and planktonic plants, animals and detritus (dead organic material). The fish resident within this reach also move to both upstream and downstream waters. There are also linkages to the land environment: riparian vegetation affects nearshore habitat, runoff from the adjoining land enters the water bringing nutrients and other substances, and birds and mammals may consume fish and aquatic invertebrates. Nutrients, in particular nitrogen and phosphorus, enter the food web primarily via inflowing water, in the form of detritus and as dissolved and particulate inorganic forms that are taken up by plants and algae and then become available to higher level consumers.

The area that will be directly altered by the Project supports a diverse array of aquatic habitats, including off-current bays, sandy channels, rapids, swift flowing river segments, and a lake. Some of the biological components of the ecosystem are restricted to only one or a few habitat types (*e.g.*, plants require shallow, standing water habitat), while others range widely and may require several distinct habitat types (*e.g.*, many fish species require distinct habitat types for spawning, rearing, feeding and overwintering).

Periodic natural disturbances play an important role in determining the structure of the ecosystem. In particular, shoreline areas are disrupted by changes in water level seasonally and between years (including extremely low levels associated with droughts), wave and ice action, and periodic floods that scour river channels and littoral areas.

The area that will be affected by the Project has been subject to subsistence harvest over the millennia and recreational and commercial harvest over the last decades. More recently, the water regime was greatly altered due to hydroelectric development (LWR/CRD and five individual generating stations on the Nelson River), and inflowing waters have become more nutrient-rich. The reach immediately downstream of Gull Rapids was impounded in the early 1970s by the Kettle Generating Station (GS), which flooded a large area to form Stephens Lake. This development may have affected fish usage of the Nelson River upstream of Gull Rapids. More recently, rainbow smelt, an invasive species, has become established in this reach, and is now a substantial component of the fish fauna. Rising temperature due to climate change is a concern in this region, as in all northern areas.

Linkages between the aquatic ecosystem and the Project are discussed in Section 1.2.2.2.

1.2.2 Scope of the Environmental Assessment

The environmental assessment was scoped through a multi-step process, as follows:

- The Project components to be considered in the assessment were identified. This included not only the physical structures of the Project, but effects of the construction and operation of the Project itself and mitigation measures;
- Potential linkages or pathways of effect between the Project and the aquatic ecosystem were identified. Both direct and indirect effects were considered;

- Components of the ecosystem to be included in the environmental studies were identified based on the potential for the Project to cause a substantial change in their function within the ecosystem, and for their importance to the overall ecosystem and their potential for use as an indicator of change;
- Certain ecosystem components/attributes (**Valued Environmental Components**, VECs) were selected as the focus of assessment;
- The spatial scope of the assessment was determined based on the spatial scales relevant to the environmental component in question and the scale at which it will interact with the Project. Multiple spatial scales were considered; and
- The temporal scope of the assessment was determined based on temporal scales relevant to the environmental component in question and the scale at which it will interact with the Project. Effects of past and on-going change were considered when determining the temporal scope.

Although described as a linear process, scoping of the assessment was iterative because on-going assessment work modified the understanding of the nature and extent of Project effects to some components of the ecosystem, and this modified understanding required re-evaluation of potential linkages to other ecosystem components.

1.2.2.1 Project Components Included in the Assessment of the Aquatic Environment

The scope of the assessment covered the effects of the Project, as follows:

- Construction of the GS, including temporary alteration of habitat as a result of instream construction, inputs of materials to surface waters, and specific activities such as blasting. Changes due to flooding that commence during construction are considered within the operation period of the assessment;
- Construction of the south access road and operation of the north and south access roads during construction and operation of the Project;
- Effects of accidents and malfunctions (*e.g.*, fuel spills);
- The structure of the GS, including loss of habitat under the structure and dewatering of the river channel, and changes to movements of the biota;
- Flooding of upstream aquatic and terrestrial areas, including release of material from flooded terrestrial areas and its fate in the aquatic environment;
- Effects of station operation on the open water and ice regimes;
- Effects of various mitigation works; and
- Changes to resource harvest in the area directly affected by the Project.

Effects to the fisheries resource that may arise from the Adverse Effects Agreements (AEA; Keeyask Generation Project: Response to EIS Guidelines Section 4.8) are discussed in the SE SV Resource Use Chapter.

1.2.2.2 Linkages to the Project

The second stage of scoping considered linkages between the Project components listed above and the aquatic ecosystem to identify potential direct and indirect effects.

Changes in the physical environment caused by the construction and operation of the GS will be manifested through the aquatic ecosystem by various pathways of effect or linkages. Figure 1-1A and Figure 1-1B represent some of the major habitat types and linkages involving transfers of energy and nutrients that will be altered. These diagrams provide a conceptual illustration of the rationale for identifying potential direct and indirect effects of the Project on the aquatic ecosystem. The primary change that will occur as a result of the construction and operation of the GS are an increase in water levels upstream of the GS, resulting in the flooding of existing aquatic habitat and terrestrial areas. Existing habitat in rapids and littoral areas in the mainstem and portions of small tributaries will be lost, and the reservoir will be larger, deeper and slower moving than the current aquatic environment. The open water and ice regimes in the new reservoir will be different from the existing environment in that the overall range of water level variation will be smaller, but water level changes will occur more frequently. Aquatic habitat will be lost under the structure of the GS itself and in the dewatered riverbed immediately downstream of the dam. Upstream movements of fish will be blocked and downstream movements of all aquatic biota will be altered.

These changes in aquatic habitat will affect water quality, the presence of specific habitat types (*e.g.*, rapids habitat), and productivity in the trophic system. As indicated in Figure 1-1B, this creation of new habitat and alteration of existing habitat will create cascading effects through the food web, altering growing conditions for primary producers, including plants and algae, and habitat for invertebrates, including zooplankton and benthos. Detrital pathways, via bacteria, protozoans and micro- and macroinvertebrates, will also be affected. As indicated in Figure 1-1B, the newly flooded terrestrial areas will initially release both mineral and peat materials to the aquatic environment. Habitat in these areas will gradually evolve as shorelines stabilize, new bottom types form, and the littoral zone is re-established. The condition of the new littoral zone is somewhat uncertain, given the altered condition of the substrate and water regime. The fish community will be affected both through direct habitat alterations (*e.g.*, flooding of spawning habitat) and indirect effects through the food web. Overall structure of the aquatic ecosystem will be affected by a change in existing patterns of energy transfer because organic material will enter from flooded areas and be trapped in the reservoir. A reduction in the diversity of biota may also occur because the reservoir habitat is more homogenous than the existing lake, river and small streams.

As illustrated in Figure 1-1B, species dependent on certain habitat types (*e.g.*, rapids habitat, littoral habitat) are directly affected by the Project. An assessment focussing on effects to selected higher trophic level components that are sensitive to environmental changes caused by the Project (*e.g.*, selected fish species) could also act as indicators of effects to other parts of the ecosystem. For example, walleye feed on planktonic organisms as fry and then shift to invertebrates and forage fish production as they grow in size. Therefore, an assessment of potential trophic effects will include all of these food groups as well as the environmental components that support them (e.g., forage fish provide food to walleye but in turn rely on benthic invertebrates and plankton). In terms of habitat, the assessment will need to consider effects to water quality, and the presence of areas of moving water over coarse substratum (spawning habitat), shallow protected bays (rearing habitat), and open water habitat (adult foraging habitat).

Figures 1-1A and 1-1B indicate that humans are linked to the aquatic ecosystem via harvest of fish.

1.2.2.3 Ecosystem Components Included in the Assessment

Ecosystems are hierarchical systems that can be described at various levels of organization from individual species (*e.g.*, walleye), to assemblages (*e.g.*, benthic invertebrates), trophic levels (*e.g.*, predators) and major functional groups (*e.g.*, primary producers). Table 1-1 provides a list of ecosystem components that will be affected by the Project, incorporating components at various organizational levels within the ecosystem. As indicated in Table 1-1, certain components were selected for inclusion in the environmental assessment studies, and a few were selected for detailed study (described in discussion of VECs below). Components selected for study were those that will be affected by the Project, were amenable to measurement within the level of effort typical for an environmental assessment, and could provide useful information about Project effects to the aquatic environment. The following components were selected:

- Water quality is of fundamental importance to the aquatic ecosystem, as it determines the suitability of the environment for aquatic biota. Variables measured as part of water quality include dissolved oxygen, organic carbon and inorganic nutrients, which are measures of the major cycles within the ecosystem. Direct effects to water quality are an important pathway by which hydroelectric development affects the aquatic environment.
- Aquatic habitat provides the environment in which aquatic organisms live. For aquatic organisms, the structure of the habitat is provided by water depth and velocity, substratum type, and the presence or absence of cover (*e.g.*, aquatic vegetation, terrestrial debris, and riparian vegetation). Alteration of aquatic habitat is the major pathway by which hydroelectric development affects the aquatic environment.
- Lower trophic levels include all organisms, apart from fish, that occupy the aquatic environment, including algae, rooted plants, zooplankton, and benthic invertebrates. Algae and rooted aquatic plants are primary producers, which provide one of the major sources of energy to higher trophic levels in the ecosystem. Primary producers are affected both by changes in water quality and habitat. Zooplankton and benthic invertebrates are an important link in the aquatic ecosystem between primary producers and fish. Particular emphasis was placed on benthic invertebrates as they are affected by alterations in aquatic habitat caused by the Project, are an important food source for most fish species at some point in their life cycle, and are a useful indicator of environmental conditions. Microscopic invertebrates and single-celled organisms are important in overall ecosystem function, but changes to the larger invertebrates are expected to reflect changes to these groups and the smaller forms are extremely difficult to study directly.

- Fish community contains most of the middle and top trophic levels in the aquatic ecosystem. Certain species are also of direct interest to humans for consumption. The fish community integrates effects to the aquatic ecosystem as a whole, since various fish species require different habitat types and are dependent on production from lower trophic levels. As described below, certain fish species were selected as VECs.
- Mercury in fish is listed in Table 1-1 because it is of particular interest due to its importance in determining the suitability of fish for consumption by humans and represents the end effect of a complex pathway by which flooding mobilizes mercury in the food web.

1.2.2.4 Selection of Valued Environmental Components

It is not practical nor necessarily instructive to decision-making to investigate and describe all aquatic components of the ecosystem in all places at all times or to predict and assess the possible effects of the Project on each component of the aquatic environment. Therefore, certain VECs were selected to focus the assessment. To be considered as a VEC, an environmental component had to be likely to be affected by the Project, amenable to scientific study in terms of the analysis of both existing and post-Project conditions, important to local stakeholders and regulatory requirements and, preferably, indicate conditions of other components of the ecosystem or be important to ecosystem function.

Five VECs were selected:

- Water quality – is a major pathway by which Project effects are linked to other portions of the aquatic ecosystem. Water is important to all living things, and changes to water quality are subject to regulatory guidelines and restrictions. Water quality affects the suitability of the aquatic environment to support life, and variables are indicative of many of the major pathways of energy and nutrient transfer within the ecosystem;
- Lake whitefish – are negatively affected by hydroelectric development as they are adversely affected by sedimentation in spawning areas and overwinter drawdowns in reservoirs. This species is important to the KCNs for domestic use, is harvested commercially and, due to its sensitivity to adverse environmental conditions (*e.g.*, water quality), position in the mid-level of the food web, and use of open water lacustrine habitats, provides a good indicator of conditions in this portion of the ecosystem. As with other fish species, lake whitefish and their habitat are protected under the federal *Fisheries Act*;
- Northern pike (locally known as jackfish) – are sensitive to changes in littoral habitats and small tributary streams, which are the environments most vulnerable to effects of hydroelectric operations (*e.g.*, water level fluctuations). This species is harvested in domestic and recreational fisheries. As a top level predator utilizing nearshore, vegetated habitats, changes to northern pike can be indicative of productivity of the littoral environment;
- Walleye (locally known as pickerel) – use a variety of habitats that will be substantially altered by the Project. This species is harvested in domestic, commercial and recreational fisheries. As a top-level predator using both nearshore and offshore habitats, it provides a general indication of the condition of the aquatic ecosystem; and

- Lake sturgeon – are particularly vulnerable to effects of hydroelectric development as a result of their low population numbers and specific habitat requirements. They are culturally and spiritually important to the KCNs and are harvested. They have special status as a heritage species in Manitoba, are assessed as endangered by the Committee on the Status of Endangered Wildlife in Canada and are being considered for protection under the federal *Species at Risk Act*. Lake sturgeon is one of the species of greatest concern for the Project and, as such, has been the focus of considerable study and mitigation planning. Effects to lake sturgeon may also be indicative of effects to other species dependent on riverine environments.

1.2.2.5 Spatial Scope

The spatial extent of the assessment was determined through (i) identifying where the Project could directly affect environmental components of interest; and (ii) identifying where the Project could result in indirect effects (*e.g.*, downstream transport of sediment in water; movement of fish). Map 1-1 provides an overview of the region discussed below (detailed maps are in Section 1.3).

The open water **hydraulic zone of influence** (*i.e.*, the zone of direct Project effects) includes the footprint of the Project itself and the area that will experience substantial changes in water levels and flows. It includes the following:

- Gull Rapids, the site of the proposed GS;
- The reach immediately upstream of the GS where water levels will increase due to impoundment and backwater effects. This reach extends from approximately 3 kilometres (km) downstream of the outlet of Clark Lake to Gull Rapids, including Gull Lake, and the flooded reaches of small tributary streams; and
- The approximately 3 km long reach of the Nelson River immediately downstream of the GS where water levels and flows will be altered by diversion of flow through the tailrace of the GS and by the dewatering of the south channel of Gull Rapids.

Apart from the mainstem, the Project will also affect several streams crossed by the north and south access roads.

The zone of influence of indirect Project effects includes waterbodies that may be affected due to the movement of fish from the direct zone of influence and/or be affected by changes in inputs carried in the river from upstream. The following are included:

- Split Lake and adjoining waters where effects may occur due to the movement of fish from the reservoir;
- The upstream sections of flooded tributaries where fish usage may be affected by changes at the mouth;
- Stephens Lake where effects will occur because fish no longer will have access to Gull Rapids as habitat and the mainstem section will be affected by inputs from the construction and operation of the GS; and

- The Nelson River downstream of the Kettle GS, which may be affected by the downstream transport of substances in the water.

To provide context for existing and post-Project conditions in the waterbodies described above, comparisons were made to areas of northern Manitoba traversed by the Nelson River from Lake Winnipeg to its outlet at Hudson Bay and the Churchill/Rat/Burntwood system from the Manitoba border to its confluence with the Nelson River at Split Lake. The aquatic community of these areas has examples of both natural and regulated waters.

1.2.2.6 Temporal Scope

The temporal extent of the assessment (within the annual cycle and over multiple years) was determined based on:

- Seasonal differences that will affect the Project's effects on the environmental component of interest. For example, the analysis of effects to walleye considered changes to spawning habitat in spring, feeding habitat in summer and overwintering habitat under ice cover;
- Interannual differences were considered in terms of the variation in flow conditions between years, which are important in determining the amount and type of aquatic habitat;
- The period over which the Project could directly affect the environmental components of interest. In general, the assessment considered effects during the construction and operation phases. The operation phase was divided into an initial period (up to the first five years after impoundment to full supply level when the magnitude of on-going environmental change is the greatest), a transitional period (5–25 years as conditions stabilize), and long-term period (after 25 years when the reservoir environment has become established). As the Project life span is 100 years, long-term Project-related changes were considered permanent; and
- The environmental setting includes past conditions, in particular as they relate to the current condition of the environmental component of interest. Current conditions are generally described for the period 1997–2006, based on work done under various technical programs, in particular field studies for this assessment that were initiated in 1999. Additional information was collected after 2006 where analysis indicated data gaps, in particular in relation to lake sturgeon. An analysis of on-going change has also been conducted to determine whether there are clear trends that could continue into the future and markedly change baseline conditions, as they exist today. Conditions prior to 1997 were also considered to the extent that these were important to the current condition of the environmental component of interest.

1.2.3 Assessment Methods

The assessment was based on the concept of comparing the status of environmental components, including the VECs, without the Project in place and with the Project in place. Key elements of the assessment methods are described below.

1.2.3.1 Use of Indicators

As described in Section 2.0 to Section 7.0, the environmental components were described using indicators, which were selected based on their suitability for quantitative measurement and prediction, and relevance to the status of the component. In general, the number and quantitative nature of indicators for VECs were greater than for supporting environmental components. For example, the fish community is described generally in terms of abundance and relative species composition, while walleye, a VEC, are described in terms of the presence of habitat availability for specific life history stages (*i.e.*, spawning, rearing, feeding and overwintering), abundance, condition, and movements.

1.2.3.1.1 Use of Models

Given the complexity of the aquatic ecosystem, models were used for predicting effects of the Project. Within the aquatic assessment, the complexity of models employed depended on: the importance of the issue; availability of information or suitable models; and utility of modelling approaches.

Basic model types were:

- Simple conceptual models (*e.g.*, alteration in habitat leads to effect on fish population);
- Quantitative models based on changes in habitat area (*e.g.*, calculation of fish relative abundance based on specific areas of habitat types that had been sampled in the existing environment);
- Qualitative empirical models based on observed changes in the environment following similar developments in other Manitoba settings and in northern environments (*e.g.*, use of Stephens Lake as a **proxy** for post-Project conditions in the Keeyask reservoir);
- Quantitative empirical models based on Manitoba and similar environments (*e.g.*, predictive mercury model); and
- **Habitat suitability index** models using observed relationships between habitat type and fish use based on data observed in Manitoba and elsewhere (*e.g.*, lake sturgeon spawning, rearing and feeding).

1.2.3.2 Identification of Appropriate "Benchmarks" for Assessment

The assessment considered a variety of benchmarks, both to describe the existing environment as well as to describe the predicted Project effects.

These benchmarks included:

- Published guidelines (*e.g.*, the Manitoba Water Quality Standards, Objectives and Guidelines) which provide levels of various parameters for water of specified uses;
- Comparisons to areas unaffected by hydroelectric development (*i.e.*, "undeveloped" state); and
- Degree of relative change (*e.g.*, proportional change in amounts of various habitats).

1.2.3.3 Addressing Uncertainty

The complexity of the aquatic ecosystem results in uncertainty when trying to understand existing processes and responses to the Project. More specifically, uncertainty in environmental assessments arises due to:

- An incomplete understanding of the processes controlling the existing environment;
- An incomplete understanding of changes that will occur in the future environment;
- Field studies cannot address the full range of temporal and spatial variability;
- Uncertainty of ecosystem responses to Project effects where these lie outside of past experience within similar systems;
- Reliance on untested mitigation measures to reduce anticipated effects; and
- Unanticipated effects.

With respect to the Project, these uncertainties were addressed as follows:

- The incomplete understanding of processes controlling the local environment was addressed through field studies of key processes to the extent that credible predictions of environmental effects can be made. However, these processes will never be completely understood, regardless of the degree of study;
- Uncertainty with respect to future conditions was addressed through both an analysis of current trends to determine whether marked changes are currently occurring, and an analysis of whether future anticipated changes (*e.g.*, on-going effects of climate change) will be expected to affect conclusions with respect to Project effects;
- Variability over space and time was addressed to the extent feasible with the design of field programs that included collection of replicate samples in different areas and included several years of sampling under a range of flow conditions to account for inter annual variability;
- Uncertainty with respect to ecosystem responses to novel stresses was addressed through the use of proxies where similar changes have occurred (*e.g.*, for several components, Stephens Lake provides a reasonable indication of the response of the Keeyask system to impoundment), as well as the use of models to help assess pathways by which environmental components may be affected in unanticipated ways;
- Previously untested mitigation measures may or may not function as intended. This uncertainty will be addressed through monitoring to determine whether the measures do work, and provision of an adaptive management plan to develop alternate effective mitigation methods if the originally proposed measures do not function as intended; and
- Unanticipated effects that may arise will be addressed through provisions for monitoring and follow-up, if and as required.

1.2.4 Description of Residual Effects

The residual effects of the Project (*i.e.*, effects after mitigation was taken into consideration) were described for environmental components based on magnitude (*i.e.*, how large is the effect?), spatial extent (*i.e.*, how large an area is affected?), and duration (*i.e.*, how long will the effect last?). The frequency of the effect (*i.e.*, how often will it occur) and reversibility (*i.e.*, the potential for recovery from the effect) were also described. The ecological context (*i.e.*, whether an environmental component is particularly sensitive to disturbance and has the capacity to adapt to change) was considered where relevant. Finally, the certainty of the assessment was described.

Terms used in describing residual effects are listed below:

- Magnitude describes the predicted severity or degree of disturbance to the environmental component. Magnitude is described as:
    - Small – no definable, detectable or measurable effect; or below established thresholds of acceptable change; or within the range of natural variability; or minimum impairment of an ecosystem component's function;
    - Moderate – effects that could be measured and could be determined by a well-designed monitoring program; or are generally below or only marginally beyond guidelines or established thresholds of acceptable change; or are marginally beyond the range of natural variability or marginally beyond minimal impairment of an ecosystem component's function; or
    - Large – effects that are easily observable, measured and described (*i.e.*, readily detectable without a monitoring program), or well beyond guidelines or established thresholds of acceptable change; or well beyond the range of natural variability; or well beyond minimal impairment of an ecosystem component's functions.
- Geographic extent describes the spatial boundary within which the effect is expected to occur. Geographic extent is described as:
    - Small extent – effects that are confined to a small portion of one or more small areas where direct effects will occur;
    - Medium extent – effects that extend into local surrounding areas where direct and indirect effects can occur; or
    - Large extent – effects that extend into the wider regional area where indirect effects can occur.
- Duration describes the length of time that the predicted effect will last. Duration is described as:
    - Short-term – effects that generally occur within the construction period or initial period of impoundment, or that occur within only one generation or recovery cycle of the environmental component;
    - Medium-term – effects that extend through a transition period during the operation phase, or that occur within one or two generations or recovery cycles; or

  - Long-term – effects that extend for much or all of the operation phase, or that are permanent, or that extend for two or more generations or recovery cycles.
- Frequency describes how often the predicted effect will occur. Frequency is described as:
  - Infrequent – effects that occur only once or seldom during the life of the Project;
  - Sporadic/Intermittent – effects that occur only occasionally and without any predictable pattern during the life of the Project; or
  - Regular/Continuous – effects that occur continuously or at regular intervals during the life of the Project.
- Reversibility describes the component's potential for recovery from an adverse effect. Reversibility is described as:
  - Reversible – effect that is reversible during the life of the Project; or
  - Irreversible – a permanent effect.
- Ecological context describes whether the environmental component is particularly sensitive to disturbance or has the capacity to adapt to change. Ecological context includes consideration of the rarity, uniqueness and fragility of the component within the ecosystem. Ecological context is described as:
  - Low – the component is not rare or unique, or is resilient to imposed change, or is not important to ecosystem function;
  - Moderate –the component has some capacity to adapt to imposed change, is moderately/seasonally fragile, or is somewhat important to ecosystem function; or
  - High – the component is a protected/designated species, or fragile with low resilience to imposed change, or is very important to ecosystem function.

The results of the assessment were also described in terms of certainty, as follows:

- Low certainty – the effect is not certain. The effect may or may not occur or the magnitude/extent cannot be estimated with confidence. The environmental component requires monitoring and contingency plans for mitigation.
- Moderate certainty – the predicted effect is somewhat certain but the magnitude cannot be estimated with confidence. Monitoring is required to confirm magnitude/spatial extent/temporal duration of effect.
- High certainty – the estimate of the effect is quite certain because predictive methods (models, proxy systems) are well established and closely resemble the area to be affected by Project.

1.3 STUDY AREA

The Aquatic Environment **Study Area** includes the reach of the Nelson River from downstream of the Kelsey GS to the Kettle GS, as well as waterbodies immediately adjacent to the Nelson River (Map 1-2). Environmental studies were focused on the reach of the river from approximately 3 km downstream of the outlet of Clark Lake to the inlet of Stephens Lake approximately 3 km downstream of Gull Rapids, within which direct changes to water levels and flows are expected (Map 1-3). Studies were also conducted upstream of this reach in Split Lake and adjacent waterbodies because fish may move between this area and the area directly altered by the Project. Additionally, Stephens Lake was studied because fish in Stephens Lake use aquatic habitat within the river reach up to Gull Rapids, and a few move upstream into the habitat above Gull Rapids.

The Split Lake, Clark Lake to Stephens Lake (referred to as the Keeyask area), and Stephens Lake reaches each comprise individual local study areas, and together form the regional study area. Specific waterbodies included in each of the local study areas are as follows:

- Split Lake area: Split, Clark, and Assean lakes and tributaries to Split Lake (Nelson, Burntwood, and Aiken rivers);
- Keeyask area: the Nelson River from the outlet of Clark Lake to the inlet of Stephens Lake, including small tributaries. In discussing Project effects, this area is divided into upstream and downstream of the GS; and
- Stephens Lake area: Stephens Lake and associated tributaries, including the North and South Moswakot rivers and Looking Back Creek.

Sample collection for the water quality component extended downstream to the Nelson River at the estuary to address concerns that inputs to the water at the Project site could be carried downstream (Map 1-1).

Infrastructure associated with the Project, such as the north and south access roads, will affect several small streams and ponds and sampling was conducted at identified stream crossings (Map 1-4).

Ecoregions are shown in relation to the Aquatic Environment Study Area in Map 1-5 (Manitoba Conservation Data Centre, 2012a, 2012b).

1.4 OVERVIEW OF PATHWAYS OF EFFECT

This section describes the direct Project effects, as well as major changes to the physical and socio-economic environments that were considered in the assessment of effects to the aquatic environment. Information on the planned construction and operation of the Project was obtained from the Project Description Supporting Volume (PD SV). Effects related to other environmental components that are relevant to the aquatic assessment were obtained from the Physical Environment Supporting Volume (PE SV), the Terrestrial Supporting Volume (TE SV) and the Socio-economic Supporting Volume: Resource Use Chapter. Additional details used in the assessment for specific aquatic components are provided with the impact assessment of those components. The description of effects considered for the operation period also lists the major mitigation measures that will be implemented to reduce adverse effects of the Project on the aquatic environment

1.4.1 Construction Period

The assessment of construction effects considered temporary alteration of habitat as a result of instream construction, inputs of materials to surface waters, and specific activities such as blasting. The PD SV provides a description of construction activities, and effects to water regime and sedimentation are discussed in the PE SV, Section 4 and Section 7, respectively. Permanent changes to habitat that commence during construction are considered within the operation period.

The effects of the following instream construction activities were considered:

- Installation of an ice boom – the ice boom will be installed at the start of construction and will alter the ice regime by reducing the formation of an ice dam below Gull Rapids and by accelerating the development of an ice cover on Gull Lake. The structure of the ice boom has a minimal instream footprint.
- Stage I Diversion – construction of a rock groin and Stage I cofferdams will block flow in the north and middle channels of Gull Rapids over a three year period. Flows in the south channel will increase and open water levels on Gull Lake will increase by 0.8 metres (m) if inflows to the area are at flood stage. The Stage 1 cofferdams will permit construction of the powerhouse, central dam and spillway.
- Stage II Diversion – construction of Stage II cofferdams and removal of the Stage I cofferdams at the spillway will dewater portions of the south channel as flow is diverted through the spillway. Stage II diversion will last two years, after which cofferdams that are not part of the permanent dams will be removed, the reservoir will be impounded to full supply level (FSL), and water will flow through the powerhouse and spillway.

Other instream work includes:

- Construction of three stream crossing and widening of the Butnau weir on the south access road;
- Construction of two causeways for temporary haul roads across off-current channels to the north of the Nelson River. Access for fish to habitat on the other side of the causeways will be provided by culverts and an excavated channel.
- Construction of a boat launch and barge landing upstream and downstream of the Project along the north shore of the Nelson River.

The assessment of construction effects also considered:

- Effects of accidents and malfunctions (*e.g.*, fuel spills). The Environmental Protection Plans (EnvPPs) for the GS and south access road provide measures to prevent and manage spills, if they occur;
- Inputs of materials, both through controlled discharges and instream construction, surface runoff, *etc*. The principal effluents will be treated sewage and discharge from the concrete wastewater treatment

ponds. Other discharges include water from cofferdam dewatering and surface runoff. Effluent sources are described in the Project description and management measures are provided in the EnvPPs;

- Blasting will occur primarily within the confines of the Stage I cofferdam and continue through much of the construction period. Use of ammonium nitrate-fuel oils will be restricted to areas that will not be exposed to water; and
- Increased access and potential harvest are described in the SE SV Resource Use Chapter. During the construction period, use of the north and south access roads will be limited to construction workers and others requiring access to the construction site, as well as resource users with special permission. Construction workers will not be allowed to bring boats to the site, but fishing from shore will be allowed.

1.4.2 Operation Period

The primary impacts to the aquatic ecosystem during the operating phase of the Project are linked to changes in water levels and flows (which initiate changes in processes such as sedimentation) and the Project footprint, which includes both the GS and access roads (Figure 1-2). Operation effects to water regime and sedimentation (including both suspended sediment and deposition) are described in detail in the PE SV Section 4.4.2 and Section 7.4.2, respectively.

The following is an overview of the pathways of effect that arise from changes to water levels and flows:

- Terrestrial flooding — when the reservoir is first impounded to full supply level, approximately 45 km^2 of terrestrial area will be flooded. The majority of this area consists of sparsely to densely treed peatland. As discussed in the PD SV, the reservoir will be cleared of trees prior to flooding. Over time, an initial 7–8 km^2 will be flooded due to mineral bank erosion and shore peat breakdown.
- Increased depth — open water depth will increase along a 40 km stretch of the Nelson River, from the GS to approximately 3 km downstream of Clark Lake. Depth increases will be greatest at the downstream end of the reservoir and decline upstream: 10–15 m within Gull Rapids; 6–7 m at Gull Lake; 3–5 m from Birthday Rapids to Portage Creek; and less than 1 m upstream of Birthday Rapids. Above Birthday Rapids, effects to water levels will decline rapidly and will not be measurable at Long Rapids. For open water conditions, there will be no effects to water levels on Split and Clark lakes, although under low flow conditions in winter there might be a slight effect due to ice dam formation at Birthday Rapids.
- Decreased velocity — water velocity in the reservoir will decrease due to increased depth, with the largest decreases occurring in Gull Rapids, where velocities will decline by 2–6 m/s. Water velocity in upstream river section between Birthday Rapids and Gull Lake will decline by approximately 1 m/s; however, detectable flow will be present along the main channel of much of the reservoir. Downstream of the GS, within the first 3 km of river channel, there will be a shift in the distribution of velocity.

- Change in water level fluctuations — in the existing environment, water levels upstream of Gull Rapids typically vary by several metres annually or between years. After the project is in operation, the station may be operated in a base-loaded mode, resulting in stable water levels, or in a cycling mode, resulting in fluctuating water levels. During cycling, water levels in the reservoir will vary up to 1 m, but the frequency of water level changes will be greater than under existing conditions. Water level fluctuations in the tailrace due to cycling of flows will typically range from 0.1 to 0.2 m, and fall within the range of the existing water levels on Stephens Lake.
- Change in ice cover and timing — in the existing environment, the reach between Clark Lake and Gull Rapids and immediately downstream is subject to the formation of a thick ice cover, frequently with extensive ice dams that cause flooding during winter. Following Project construction, the formation of ice dams both upstream and downstream of the GS will be diminished and a thinner ice cover will form. Ice will also form somewhat earlier than at present.
- Change in suspended sediment levels — erosion and flooding will increase the input of mineral and organic sediments into the aquatic environment. Total releases of mineral and organic sediments are expected to decline quickly during the first five years following impoundment. The majority of mineral and organic sediments will deposit near eroding shorelines. Analysis of sediment transport indicates that total suspended sediment concentrations in the mainstem of the reservoir and immediately downstream in Stephens Lake will be lower than under existing conditions.
- Increased sediment deposition — fine sediments will deposit upstream of the GS over areas in Gull Lake and Gull Rapids that currently have coarse sediments. Deposition rates will be highest immediately post impoundment, and decline thereafter. Rates are higher in nearshore areas and lower in the mainstem (0-1 centimetres per year, depending on location).

The following is an overview of effects due to the Project footprint, including the GS and access roads:

- GS structure — the generating station will block the upstream movement of fish and alter the downstream movements of larval, juvenile and adult fish.
- Dewatering — approximately 100 ha of the south channel of Gull Rapids will be dewatered.
- Effects of effluents, runoff, accidental spills and releases — the Environmental Protection Plans (EnvPPs) for the GS and south access road provide measures to manage effects related to these effects.
- Access to fisheries — the access roads to the Project will become part of the provincial highway system, increasing access to areas both upstream and downstream of the Project.

As shown in Figure 1-2, the interactions between the Project effects listed above and components of the aquatic environment were assessed. In addition, the assessment considered interactions among aquatic environment components (*e.g.*, effects to fish arise primarily due to changes in the diversity and quantity of aquatic habitat).

During the environmental assessment, changes to the environment were identified that required mitigation to reduce adverse effects. Emphasis was placed on mitigating effects that were predicted to have marked effects on VECs. Mitigation concepts were evaluated through an iterative process involving evaluation of likely success based on biophysical considerations, including input from both technical studies and members of the KCNs, and technical feasibility and costs. As the assessment progressed, a subset of measures was selected for further development. Measures were discussed with the multilateral Aquatic Working Group, a technical working group comprised of KCNs community members and technical advisors, Manitoba Hydro representatives, and environmental consultants working on the technical aquatic studies. Measures were also presented to representatives of Fisheries and Oceans Canada (DFO) and Manitoba Conservation and Water Stewardship (MCWS). A description of mitigation measures identified and evaluated for the aquatic environment, as well as the rationale and design details for the selected measures, are provided in Appendix 1A. Mitigation measures described in Appendix 1A are also discussed in relation to relevant environmental components in Section 2 to Section 7.

The following is a list of the mitigation measures identified for the operating period of the Project:

- Spawning habitat will be constructed in the GS tailrace and near Stephens Lake, to replace lost spawning habitat in Gull Rapids for species such as lake sturgeon, walleye, and lake whitefish;
- Spawning habitat will be constructed in the lower reservoir to replace lost walleye and lake whitefish spawning habitat in Gull Lake;
- Access to small tributaries in the reservoir will be maintained by removing accumulations of debris;
- Channels in the reservoir at Little Gull Lake will be constructed to allow fish to escape and avoid mortality due to overwinter oxygen depletion;
- Channels will be constructed below the spillway to enable fish to move into Stephens Lake, rather than being stranded in isolated pools after the spillway is operated;
- A comprehensive stocking plan will be implemented to maintain/enhance lake sturgeon populations in the Project area and the broader region;
- Turbines were designed to minimize mortality and injury of fish passing through the powerhouse; and
- A trap and transport program for upstream fish passage will be implemented for key fish species, including lake sturgeon. The Project will be designed and constructed in a manner that would allow it to be retrofitted to accommodate other upstream and/or downstream fish passage options if required in the future.

Implementation of the following mitigation measures will be subject to post-construction monitoring:

- If monitoring demonstrates that lake sturgeon no longer spawn at Birthday Rapids, modification of the riverbank upstream of Birthday Rapids will create hydraulic features that will be attractive to spawning sturgeon; and
- If monitoring demonstrates that newly hatched young-of-the-year sturgeon are not able to use habitat in the reservoir, then sand/fine gravel will be placed at the upper end of present-day Gull Lake to create habitat known to be suitable for young-of-year sturgeon.

In addition to the measures listed above, the Partnership, DFO, and MCWS are continuing to discuss Project effects and mitigation, and additional measures may be identified that will be implemented prior to or during Project operation.

1.5 SOURCES OF INFORMATION

The environmental setting and impact assessment sections of this document are based primarily on information from technical studies, including work conducted before the environmental studies for the Project were initiated (1999) and during the course of these environmental studies. A brief summary of these information sources is provided below. In addition, information was obtained from local resource users and key person interviews with local resource managers. This information was particularly important with respect to providing a record of conditions in the area prior to the commencement of the environmental studies, and providing insights into observed changes in relation to other human activities, including previous hydroelectric development and resource harvest. In addition to local knowledge from KCNs Members, Aboriginal traditional knowledge had an integral role in the overall assessment, as presented in the Keeyask Generation Project: Response to Guidelines.

Environmental studies conducted in the area prior to 1999 were largely related to work conducted prior to and after the Churchill River Diversion/Lake Winnipeg Regulation (CRD/LWR) Project and construction of the Kettle, Long Spruce and Limestone generating stations on the lower Nelson River. References to specific studies are provided in subsequent sections of this volume; however, in general, the majority of studies were conducted under the following:

- The Lake Winnipeg Churchill River Study Board conducted work from the mid-1960s to the mid-1970s. No detailed studies were conducted in the area directly affected by the Keeyask Project; however, sampling was conducted in nearby waterbodies and also formed part of the record of the effects of hydroelectric development in similar environments in northern Manitoba;
- The Federal Ecological Monitoring Program (FEMP) was conducted as follow-up monitoring to determine the effects of CRD/LWR. Most work was conducted in the late 1970s to the mid-1980s. Although sampling was not conducted in the area directly affected by the Keeyask Project, work on nearby waterbodies provides a record of general conditions in the area and the effects of hydroelectric development;
- The Ecological Monitoring Program was conducted by Manitoba Fisheries Branch in conjunction with the FEMP and included sampling on Split and Stephens lakes in the mid-1980s;
- The Limestone Generating Station Monitoring Program was conducted by Manitoba Hydro from the late 1980s to the late 1990s. Sampling under this program also included work in the lower portion of Stephens Lake (referred to as the Kettle forebay) and provides a record of the evolution of conditions in reservoirs on the lower Nelson River; and
- Various long-term programs measuring mercury concentrations in fish flesh along the CRD, beginning with the FEMP programs and continuing under other programs to 2005.

Other shorter-term studies provide periodic information on conditions in the area. For example, the Tataskweyak Environmental Monitoring Agency conducted studies in 1997 and 1998 on Split Lake, and Manitoba Fisheries Branch carried out a lake sturgeon sampling program on Gull Lake in 1996.

Manitoba Conservation and Water Stewardship maintains a long-term water quality sampling station at the community of Split Lake, which provides long-term record of water quality conditions in the area.

Environmental baseline studies for the Keeyask Project were initiated in 1999 and continued from 2001 to 2006. The majority of the field studies were completed from 2001 to 2004; additional data were collected in 2005 to 2006 to address information needs and data gaps identified through the course of the baseline studies. Additional studies, in particular in relation to lake sturgeon, were conducted after 2006 and are reported in this EIS. The primary study components were water quality, lower trophic levels (including plants, algae, zooplankton and benthic invertebrates), fish community, and fish quality (primarily mercury). Several study programs targeted lake sturgeon in particular. A complete list of all aquatic data reports produced for the environmental studies program is provided in Appendix 1B.

The environmental impact assessment also used information from a wide range of scientific studies conducted in similar environments to assist in predicting Project-related effects. Work conducted previously in northern Manitoba at other hydroelectric developments and the studies of conditions in both historic and newly formed reservoirs in northern Quebec were particularly relevant. Research studies, for example, the Experimental Lake and Reservoir Program conducted at the Fisheries and Oceans Canada Experimental Lakes Area, also provided key information.

1.6 REFERENCES

1.6.1 Literature Cited

Aber, J. D., and Melillo, J. M.. 1991. Terrestrial Ecosystems. Saunders College Publishing. Philadelphia. 429 pp.

Manitoba Conservation Data Centre. 2012a. Ecoregion Search: Hayes River Upland. http://www.gov.mb.ca/conservation/cdc/ecoreg/hayesriver.html [accessed May 17, 2012].

Manitoba Conservation Data Centre. 2012b. Ecoregion Search: Churchill River Upland. http://www.gov.mb.ca/conservation/cdc/ecoreg/churchill.html [accessed May 17, 2012].

Table 1-1: Criteria used to select aquatic ecosystem supporting and valued ecosystem components.

	Potential Effects[1]	Data Collection Feasible[2]	Local Importance[3]	Regulatory Requirement[4]	Indicator[5]	Ecosystem Function[6]	Supporting Component	VEC
Biodiversity	✓	✓				✓	✓[7]	
Water quality	✓	✓	✓	✓	✓	✓		✓
Detrital pathways	✓					✓		
Aquatic habitat	✓	✓		✓	✓	✓	✓	
Primary productivity	✓					✓		
Phytoplankton	✓	✓			✓		✓	
Rooted plants	✓	✓			✓		✓	
Secondary productivity	✓					✓		
Zooplankton	✓	✓					✓	
Benthic invertebrates	✓	✓			✓	✓	✓	
Fish community	✓	✓		✓		✓	✓	
Lake whitefish	✓	✓	✓	✓	✓			✓
Lake sturgeon	✓	✓	✓	✓	✓			✓
Walleye	✓	✓	✓	✓	✓			✓
Northern pike	✓	✓	✓	✓	✓			✓
Rainbow smelt	✓	✓		✓	✓	✓	✓[8]	
White sucker	✓	✓		✓	✓		✓[8]	
Mercury in fish	✓	✓	✓	✓			✓	

1. Component will be markedly affected by the Project.
2. Data collection is feasible within scope of typical environmental assessment.
3. Of particular importance to resource use by local people.
4. Specifically required by legislation (*e.g.*, rare or endangered species) or guidelines (*e.g.*, water quality).
5. Indicator of other changes in ecosystem (*e.g.*, top level predator).
6. Important to overall function of ecosystem or measure of overall ecosystem function.
7. Included with specific groups of biota.
8. Included in fish community.

TABLES, FIGURES, MAPS

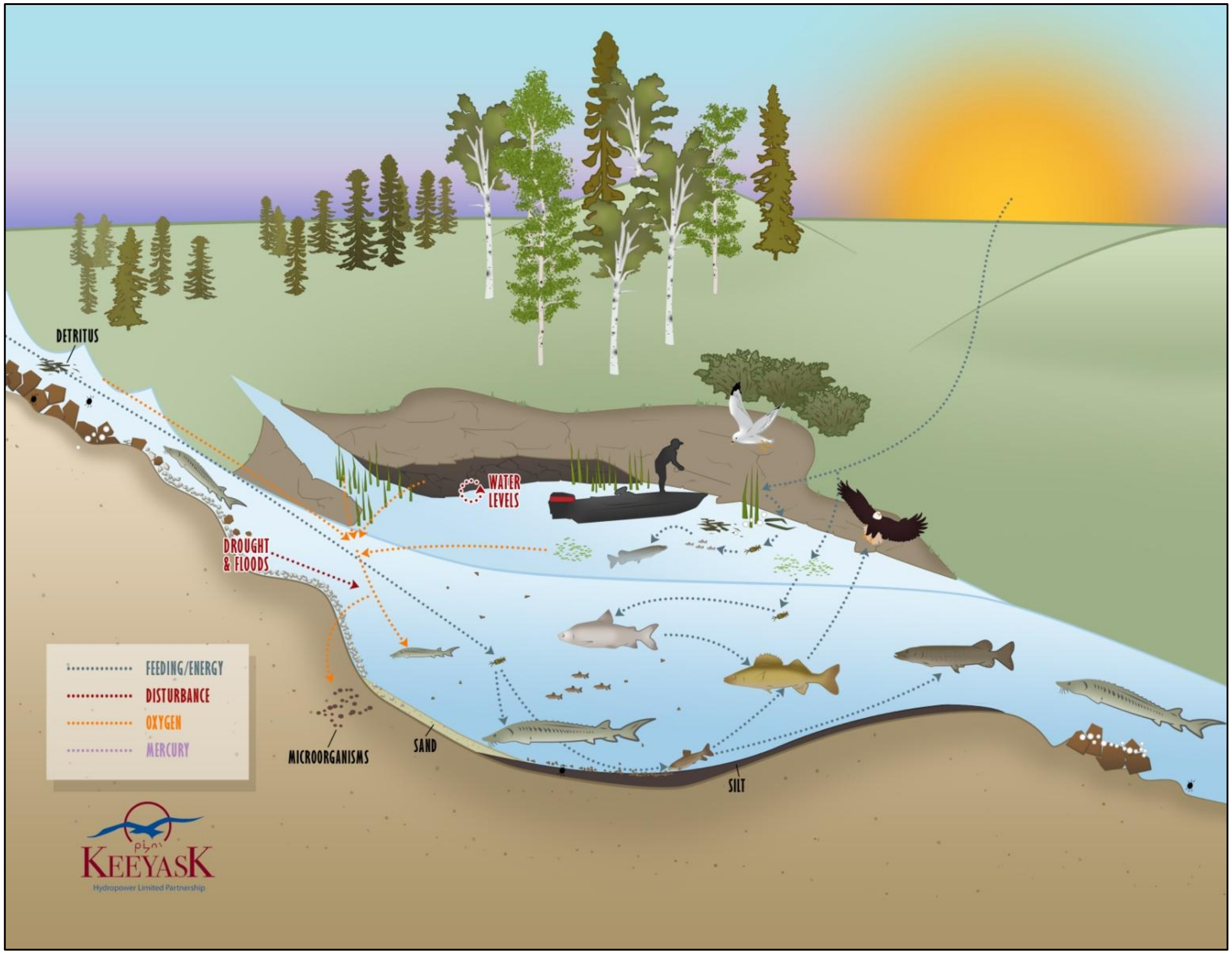


Figure 1-1A: Conceptual diagram of ecosystem in Keeyask area showing major pathways of energy and material transfer among components and major habitat types.

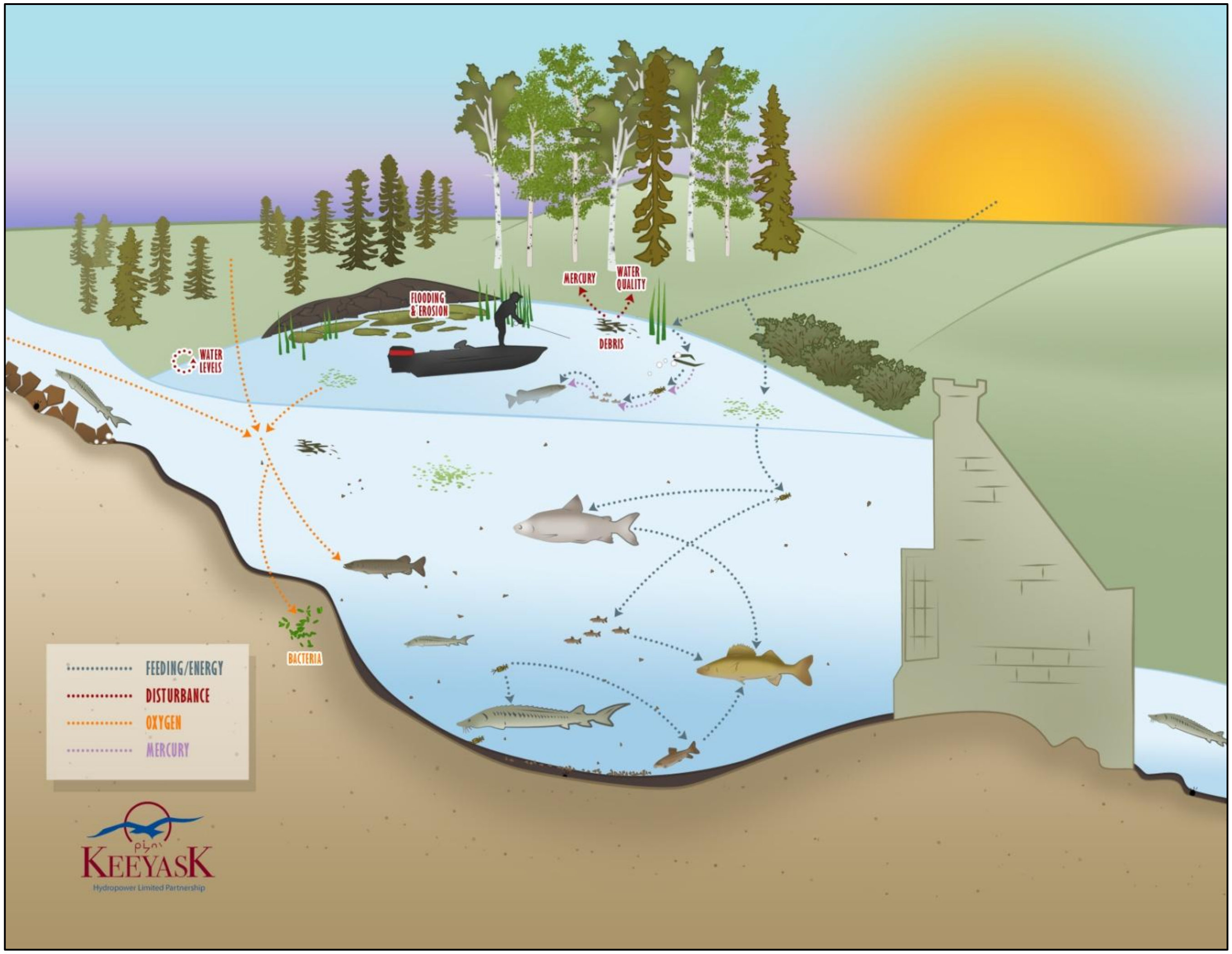


Figure 1-1B: Conceptual diagram of ecosystem in Keeyask area following construction of the Project, showing major pathways of energy and material transfer among components and major habitat types.

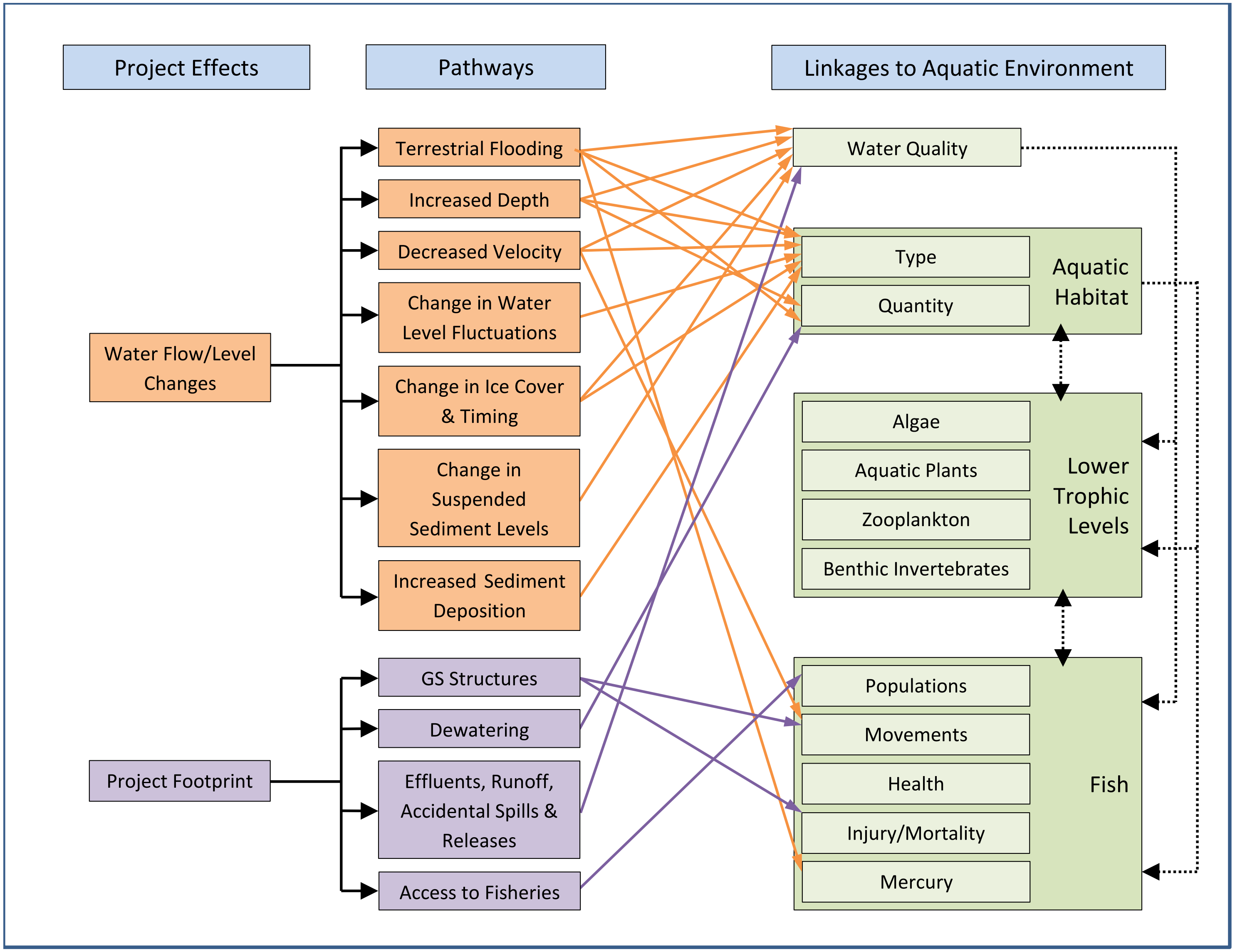
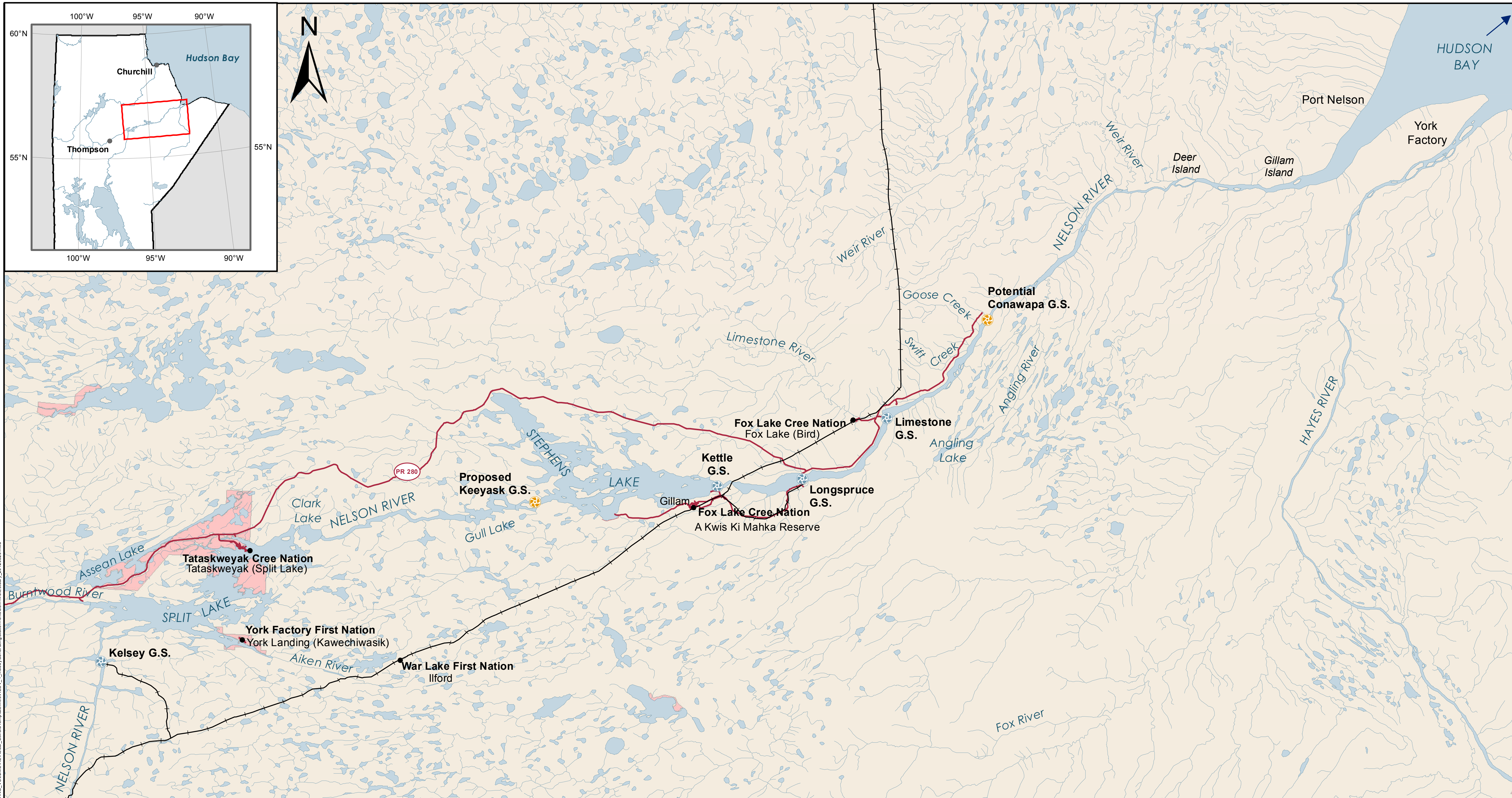


Figure 1-2: Summary of pathways of effect during the operation period



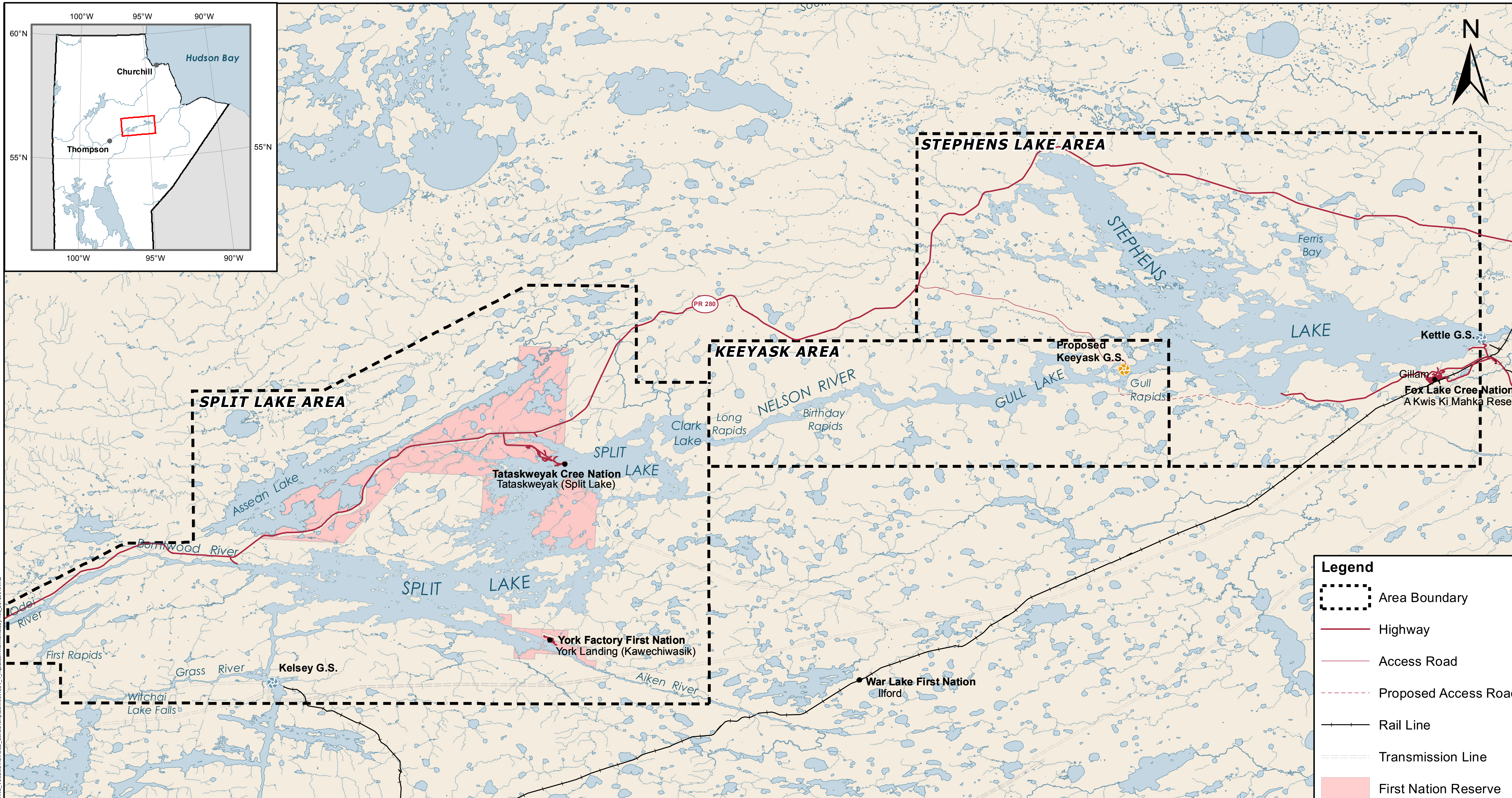
KEEYASK Hydropower Limited Partnership

0 25 50 Kilometres

0 10 20 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:500 000

Kelsey Generating Station to Nelson River Estuary



KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Aquatic Environment Study Area

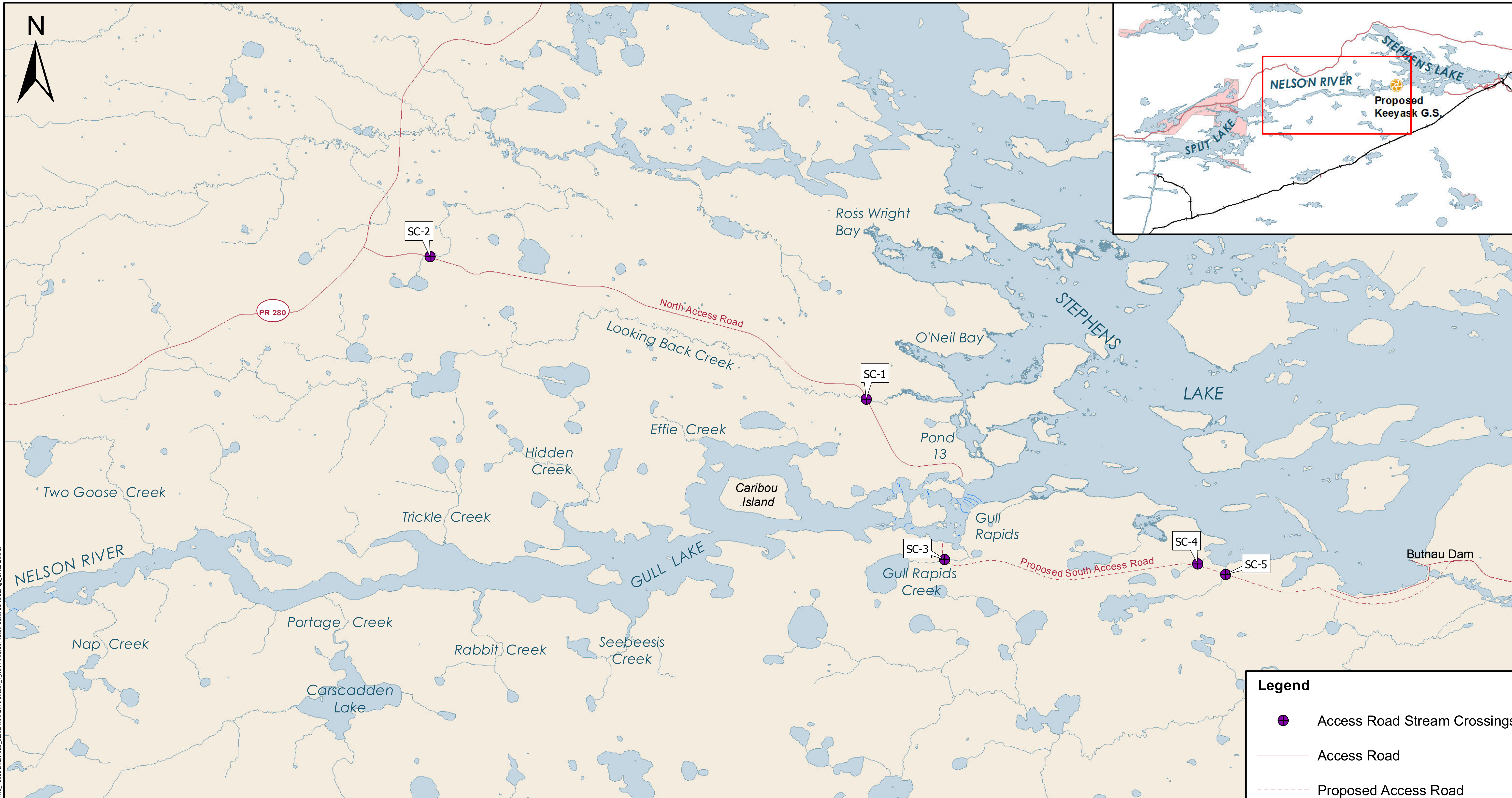
KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Shows 95th percentile inflow.

Clark Lake to Stephens Lake

Existing Environment



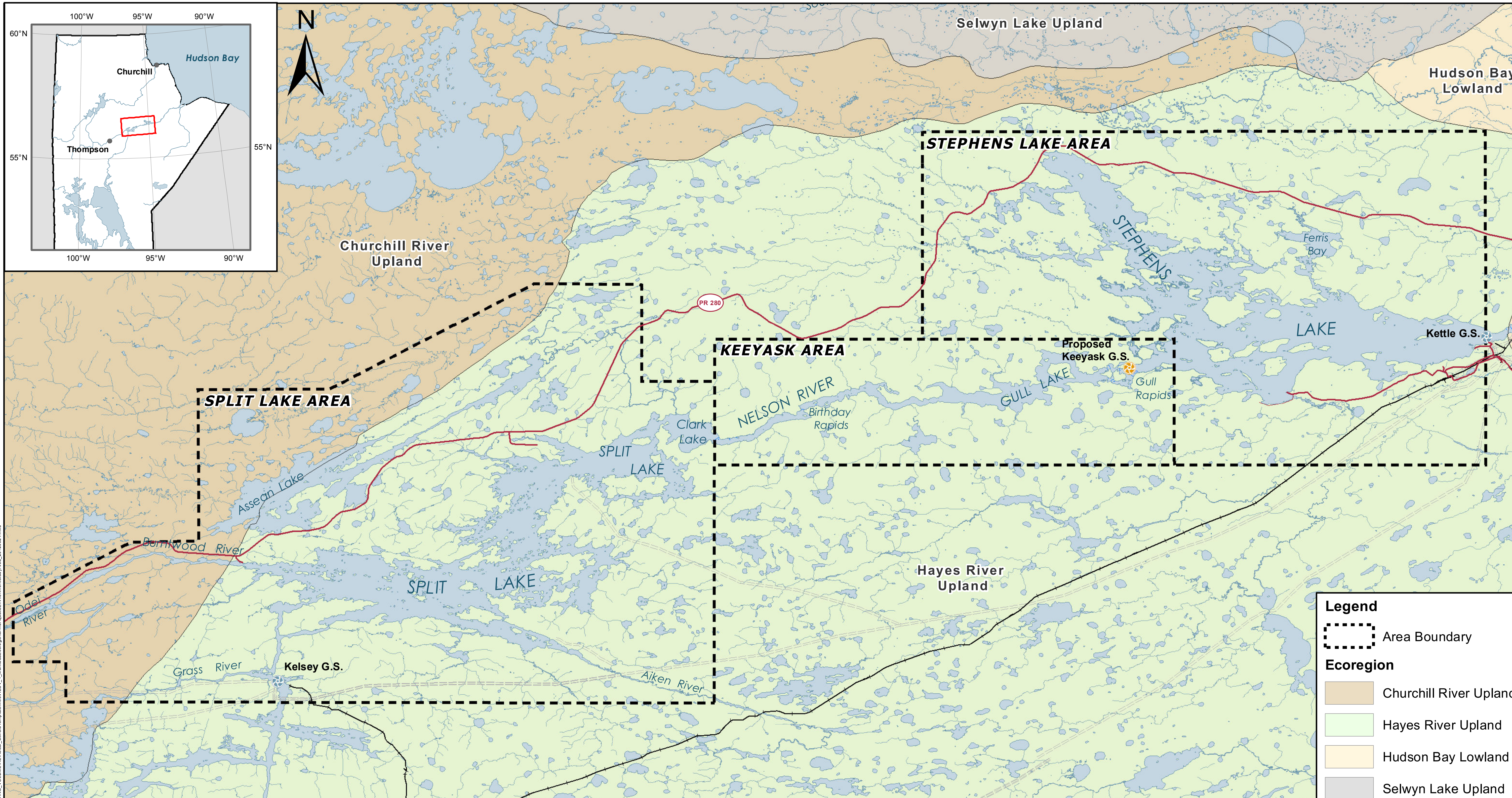
KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

North and South Access Road Stream Crossings

Map 1-4



KEEYASK Hydropower Limited Partnership

0 10 20 30 Kilometres

0 8 16 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000, Ecoregions - Province of Manitoba, Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006 Nelson River Shoreline modelled by Manitoba Hydro

Manitoba Ecoregions and Aquatic Environment Study Area

Map 1-5

APPENDICES

APPENDIX 1A
AQUATIC MITIGATION AND COMPENSATION MEASURES: EVALUATION OF ALTERNATIVES AND RATIONALE FOR SELECTED MEASURES

APPENDIX 1A – PART 1
EVALUATION OF ALTERNATIVES AND RATIONALE FOR SELECTED MEASURES

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1A.1 INTRODUCTION

During the environmental assessment for the aquatic environment, a range of options for mitigating effects to the aquatic environment was investigated. Emphasis was placed on mitigating effects that were predicted to have marked effects on environmental components of particular importance (*i.e.*, water quality, lake whitefish, northern pike, walleye and lake sturgeon) with a focus on the area that will be directly affected by the Project (Map 1A-1).

Aquatic mitigation measures were developed by the environmental team in consultation with the Project engineers and the KCNs. Mitigation concepts were evaluated through an iterative process involving evaluation of likely success based on biophysical considerations, including input from both technical studies and Aboriginal traditional knowledge (ATK), and technical feasibility and costs, based on input by Project engineers. As the assessment progressed, a subset of measures was selected for further development. Measures were discussed with the multilateral Aquatic Working Group, a technical working group comprised of KCNs members and technical advisors, Manitoba Hydro representatives, and environmental consultants working on the technical aquatic studies for the Project. Measures were also presented to representatives of Fisheries and Oceans Canada (DFO, formerly known as Department of Fisheries and Oceans) and Manitoba Conservation and Water Stewardship (MCWS).

The purpose of this document is to describe mitigation measures that were considered to reduce potential effects of the Project on the aquatic environment. Promising alternatives were taken forward to the design stage and were included in the suite of mitigation measures identified in the EIS. This document also provides a record of the mitigation measures considered and either the rationale for acceptance or rejection of each concept, or the status of the concept being considered (*e.g.*, some measures are contingencies that were identified because of uncertainty with respect to the need of a specific mitigation action). Potential mitigation measures were identified as project planning and environmental effects assessments were ongoing and were subject to an ongoing and iterative evaluation of their environmental merit and technical feasibility. Cost is not explicitly identified in the evaluations, however cost considerations did factor into recommended alternatives. Where and when appropriate, designs were assessed using appropriate hydraulic and habitat modelling techniques to verify that design criteria are satisfied and that the mitigation objectives are achievable. Overview designs and plans for those measures selected for implementation are provided.

The overall objectives of mitigation and compensation plans described in the following sections are:

- To avoid or minimize the potential construction-related impacts that were identified during project planning and environmental impact assessment studies and investigations;
- To provide habitat for all fish life history stages both upstream and downstream of the generating station (GS);
- To increase productivity of lake sturgeon in the region; and
- To ensure compliance with the Policy for the Management of Fish Habitat (DFO 1986).

The information presented in this appendix describes the different components of the Project based on the current status and assumptions of the engineering design studies and reflects input from the KCNs into the planning process. The engineering design and construction methods described are preliminary and will be refined during the final design stage, which will extend into the construction phase. In addition, on-going discussions with MCWS and DFO may identify modifications to the design of recommended measures or determine additional mitigation measures that will be implemented as part of the Project.

Stocking of lake sturgeon is a major component of the mitigation program, and is described in detail in Part 2 of this appendix.

1A.2 KEEYASK CONSTRUCTION MITIGATION OPTIONS

Construction plans and proposed construction methods (Project Description Supporting Volume [PD SV]) were developed and selected to, as much as possible, avoid or minimally impact the aquatic environment. Construction effects assessments (Aquatic Environment Supporting Volume [AE SV]) identified that alternative scheduling arrangements for in-water construction could further reduce the potential for adverse effects on fish and fish habitat (Section 1A. 2.1). In addition, alternative solutions for the placement of unclassified excavated materials within the reservoir were evaluated towards reducing potential aquatic impacts (Section 1A. 2.2).

1A.2.1 STRUCTURES IN WATER – CONSTRUCTION SCHEDULING

Restricted activity timing windows (DFO 2010) have been identified for Manitoba lakes, rivers and streams to protect fish during spawning and incubation periods when spawning fish, eggs and fry are vulnerable to disturbance or sediment. In northern Manitoba, no in-water or shoreline work is allowed during the 15 April - 30 June, 15 May - 15 July, and 1 September - 15 May periods where spring, summer, and fall spawning fish respectively are present, except under site- or project-specific review and with the implementation of protective measures.

Fish community studies conducted in the Keeyask area provide site-specific information concerning the timing of spawning activities and times when eggs and fry would be vulnerable to disturbance. Based on data from Keeyask field investigations (Table 1A-1), proposed area-specific timing windows for restricted in-water construction activities are as follows: 15 May - 15 July for spring and summer spawning fish and 15 September - 15 May for fall spawning fish. Consequently, the scheduling of construction activities that require working in water have been developed and modified to the extent practicable to avoid or minimize the potential for disturbance to fish in the Keeyask area during spawning, and egg and fry development periods.

Adjustments to scheduling so as to restrict construction and removal of structures to times of the year when sensitive life stages of fish are least likely to be present are summarized in Table 1A-2. These activities include:

- Quarry cofferdam construction;
- North channel rock groin construction;
- North channel Stage I cofferdam construction;
- Powerhouse Stage I cofferdam construction;
- Spillway Stage I cofferdam construction;
- Spillway Stage I cofferdam removal of portions;
- Central Dam cofferdam construction;
- ;
- South Dam Stage II upstream and downstream coffer dams construction;
- Tailrace summer level cofferdam construction;
- Tailrace summer level cofferdam repairs; and
- Tailrace summer level cofferdam removal.

To the extent possible, work in water has been scheduled to avoid interaction with fish and fish habitat during the spring and fall spawning periods. When avoidance of both spring and fall spawning periods was not possible due to critical construction sequences, avoidance of spring spawning periods was given priority over avoidance of the fall spawning period.

Additional mitigation of potential disturbances to fish and fish habitat will be gained by constructing each cofferdam in a sequence that minimizes the exposure of readily-transported fines to flowing water.

1A.2.2 PLACEMENT OF UNCLASSIFIED EXCAVATED MATERIALS WITHIN THE RESERVOIR

Surplus unclassified excavated materials will generally consist of silty clays, sandy silts, silty sands and peat; some cobbles and boulders may also be present in these materials. Some of the materials will be produced from unclassified excavations along the principal structures and dykes, while others will be produced from channel excavations and from reservoir improvement areas (PD SV).

The principal aquatic objectives with regards to the selection of placement areas inside the dykes of the reservoir are to prevent mobilization and release of unclassified materials (as suspended sediments) to the aquatic environment and prevent dissolved oxygen (DO) depletion through increased oxygen demand associated with organic (peaty) soils. Some of the key general criteria developed to guide the selection of placement areas inside the dykes of the reservoir include the following:

- Location – consider locations that would not be exposed to high water velocities that could mobilize sediments. Maximum velocity for the initial selection of placement areas for further investigation is 0.3 m/s (assumes minimum particle diameter of 0.02 mm). Internal placement areas should be located where they are sheltered from wave action;
- Peat resurfacing – spread mineral material over peatland types that once inundated have a high probability of resurfacing. This would reduce peat re-surfacing and associated high organic sediment release;
- Maximum elevation of a placement site, after receiving unclassified excavated material, including any protective caps must be at an elevation that allows for the formation of stable ice cover or be 0.5 m or more above the maximum reservoir level;
- Timing – unclassified excavation material will be put in place "in the dry" prior to reservoir flooding;
- Armouring – where there is potential for placed material to mobilize due to waves and currents, armouring with a minimum thickness of 1 m of unclassified mineral materials is required;
- DO depletion – peaty/organic materials should not be placed in areas where DO depletion will be exacerbated, unless they can be capped with a minimum of 1 m of mineral material. Otherwise it is preferable to create terrestrial habitat;
- Minimum depth below water – where material placements will be entirely submerged below water, a minimum depth of 1.5 m of water is required over the site at minimum reservoir elevation (158 m above sea level [ASL]) to prevent ice scour; and
- Maximum velocity over the final grade of the placement areas for stable ice cover formation is 0.7 m/s.

The foregoing criteria for the selection of placement areas were used to identify potential placement sites within the post-Project aquatic environment of the reservoir, as well as areas outside the dykes that have the potential to affect existing surface water bodies. It should be noted that there was a simultaneous evaluation of the effects of material placement in the terrestrial environment (PD SV) and the final siting of areas reflected both aquatic and terrestrial effects concerns. Final locations are provided in the PD SV, Section 6.11.2.3.

1A.3 KEEYASK OPERATION – MITIGATION AND COMPENSATION OPTIONS

Measures to mitigate the adverse effects arising from the creation and operation of the reservoir have been considered and have been incorporated into the design and plans for station operation. These include: selection of a maximum normal reservoir level (full supply level [FSL]) that would reduce flooded area; construction of dykes to minimize the area flooded; and selection of an operating regime that generally limits reservoir water level fluctuation to one metre or less above the minimum operating level (MOL).

In addition to these major project design features, objectives of planned mitigation and compensation activities are to:

- Create the most diverse and productive habitat economically feasible within the reservoir proper (recognizing that this will be a degraded environment in the early years);
- To the extent practicable, maintain or improve conditions that provide productive fish habitat within the backwatered river channel (Birthday Rapids to Gull Lake inlet);
- Provide for the continued productivity of fish populations in Stephens Lake; and
- Identify off-site works that could increase the productive capacity of habitat in the area, in particular for riverine species.

1A.3.1 RESERVOIR CREATION

Predicted impacts of reservoir creation and the means proposed to mitigate adverse effects or compensate for harmful effects on fish and fish habitat upstream of the generating station are listed in Table 1A-3, and described in the sections that follow.

1A.3.1.1 Loss of Walleye and Lake Whitefish Spawning Habitat

Habitat that is suitable for walleye and lake whitefish spawning currently exists within the reach of the Nelson River between Birthday and Gull rapids (Section 5.3.2.3). Walleye typically spawn over gravel, boulder or cobble substrate in water that is less than 2 m deep, while lake whitefish generally spawn over substrates ranging from large boulders to gravel and sand in water that is less than 5 m deep. Impoundment of the Keeyask reservoir will result in a loss of walleye and lake whitefish habitat due to increased water depth over existing spawning sites. Mitigation measures that were evaluated to create additional walleye and lake whitefish spawning habitat are discussed in Section 1A.3.1.1.1 and Section 1A.3.1.1.2.

1A.3.1.1.1 Rocky Shoal Construction

The construction of rocky shoals within lacustrine portions of the reservoir would ensure that spawning habitat is available early in the development of the reservoir environment. The creation of boulder/cobble/gravel habitat would, in addition to providing spawning habitat, also provide rearing and foraging habitat, thereby improving habitat diversity within the newly-formed reservoir.

Biological design criteria for the construction of rocky shoals are provided in Table 1A-4. Potential sites were selected at locations where post-project bottom depths ranged between 3–4 m ("shallow sites"). Additional "deeper" sites were identified at locations where post-project water depths would be greater than 4 m. These deep locations would not provide optimal lake whitefish spawning habitat, but could provide feeding areas.

Twenty sites (Table 1A-5, Map 1A-2) were identified for the potential development of shoals (minimum surface area of 1,000 m^2). Site selection was subsequently refined according to the following criteria:

- Whether its location is adjacent to known or suspected present-day spawning habitats;
- How likely it is to be exposed to fine particulate sedimentation post-impoundment (Map 1A-3); and
- Whether it is a minimum distance of 3 km upstream of the proposed locations of the GS and spillway intake structures so as to minimize entrainment and downstream transport of newly hatched fish.

Thirteen sites met these criteria (seven 3–4 m depth sites and six greater than 4 m depth (Table 1A-5, Map 1A-4). It is currently planned to develop the seven shallow areas to provide spawning habitat for walleye and lake whitefish.

1A.3.1.1.2 Dyke Surface and Structure Modifications

Walleye and lake whitefish spawning habitat might also be created through the enhancement of fish habitat features at selected locations along dykes in the Keeyask reservoir. This would be done through either the placement of gravel and cobble on the surface of the dykes, or the construction of rock groins that would project from the dykes at locations that would not compromise dyke function.

The north and south dykes will provide a linear length of approximately 10 km of sloped shoreline. Protective shells of crushed rock and riprap will be applied where required. Typical slopes along the face of the dykes range between 1:2 and 1:4. The maximum height of the north and south dykes will be 20 m and 13 m respectively.

Portions of these dykes, preferably where slopes are less steep, could receive a surface treatment of gravel or cobble-sized rocks instead of (or in addition to) boulders. This treatment would be designed to encourage and sustain spawning, particularly by fall spawners such as lake whitefish and lake cisco. Considerations for spawning habitat would include:

- Level to gradually sloping surface; and
- Minimum water depth of 3 m below FSL.

The latter point takes into consideration an anticipated operating reservoir water level fluctuation range of 1 m, and allows for at least 1 m of water under ice at full drawdown under winter conditions (assuming a 1 m maximum ice thickness and a 1 m drawdown). It should be noted that few locations along the dykes meet these depth criteria and most are within 3 km immediately upstream of the GS.

The vulnerability of locations to sediment deposition was taken into consideration during identification of the areas where surface treatments could be applied. Exposure to wave energy and moderate currents were additional criteria considered.

Construction of rock groins extending from the dykes required considerations similar to those for the rocky shoals (*i.e.*, built from boulder and cobble interspersed with coarse gravels; slope less than or equal to 10%; avoid habitat placement in ice scour zone; and variable hydraulic regime — therefore, build based on MOL; see Table 1A-6).

1A.3.1.1.3 Recommendation

Evaluation of the mitigation options concluded that the objective of creating replacement spawning habitat for both walleye and lake whitefish is more likely to be successfully achieved through the construction of up to seven shoals described in Section 1A.3.1.1.1. The creation of spawning shoals at these locations within the newly-formed reservoir is recommended as a priority habitat mitigation measure. The spawning shoals would be constructed at, or near to, known and suspected spawning locations, thereby improving the likelihood of success.

Spawning habitat development through dyke surface modifications and construction of rock groins along dykes is not recommended, largely because of sedimentation concerns, and the proximity of potential development sites with adequate depth and velocity characteristics to the powerhouse or spillway.

1A.3.1.2 Reduction in Quality of Shallow Water Foraging Habitat

Impoundment of the Keeyask reservoir will result in a large increase in the amount of available shallow water habitat, largely consisting of flooded terrestrial vegetation (small trees, bushes and peat; Section 3.4.2.2). Measures to increase diversity in this shallow-water habitat and to offset the effects of reduced aquatic plant cover were examined and evaluated. These mitigation measures included instream placement of mineral soils to promote growth of aquatic plants (Section 1A.3.1.2.1), the provision of cover through shoreline planting of willows (Section 1A.3.1.2.2) and instream placement of log bundles (Section 1A.3.1.2.3).

1A.3.1.2.1 Development of Shallow-Water Mineral Material Shelves

The amount of fish rearing and foraging habitat in the newly-formed shallow water areas could be increased through the development of mineral material shelves that would promote the growth of aquatic plants and increase benthic invertebrate populations. Locations for the development of these mineral shelves were identified as shown in Map 1A-2. Selection of locations for potential development took into consideration the potential for ice scour, the potential for added benefit in terms of downstream proximity to potential spawning shoal sites (Section 1A.3.1.1.1), and existing surface conditions (*e.g.*, presence and thickness of peat, existence of bedrock).

1A.3.1.2.2 Planting of Shoreline Willows

Rearing and foraging habitat could also be created within the newly-formed shallow water areas by planting willow and other native riparian shrub species along new shorelines to increase cover. Potential sites were identified as shown in Map 1A-2. Shoreline areas bordering dykes were excluded as they are lined with riprap. However, planting willows along the toe of the dyke alignment at some locations could be considered, provided the grade is suitable.

1A.3.1.2.3 Placement of Log and Brush Bundles

Bundles of cut trees could be cabled together and anchored in both deep and shallow areas to provide additional cover for fish species. Potential locations are along new shorelines where the bundles will not be disrupted by peat uplift, and dissolved oxygen conditions would be suitable for fish. Trees used for this purpose would be stockpiled during reservoir clearing.

1A.3.1.2.4 Recommendations

Measures to increase shallow water habitat diversity were deemed not necessary based on assessors' conclusions (Section 3.4.2.2) that early post-impoundment conditions will be sufficient to support the forage fish community, and habitat will evolve in the absence of measures. Specifically, shallow water mineral material shelf development is not necessary because shallow flooded areas will develop beds of rooted aquatic macrophytes over time. The planting of shoreline willows and the placement of anchored log and brush bundles is not necessary because flooded shrubs and patchy uplift of peat will create sufficient cover to support foraging fish.

1A.3.1.3 Loss of Small Tributary Foraging and Spawning Habitat

Several fish-bearing streams which flow into the upper riverine portion of the reservoir will be subject to flooding of their lower reaches (Portage, Two Goose, and Nap creeks), and the tributary mouths will experience minor daily and weekly fluctuations in water level. The upper reaches of these tributaries will be largely unaffected by the hydraulic changes of the Project. The measures that were considered to enhance habitat development within the lower portions of these tributaries are outlined in Section 1A.3.1.3.1.

1A.3.1.3.1 Enhancement of Habitat at Flooded Tributary Mouths

Inundated creek mouths will provide relatively sheltered and shallow habitats, with at least some influence from inflowing tributary water. Over time, portions of some of these areas are likely to be colonized by aquatic macrophyte communities, thereby creating suitable spawning/rearing habitat for select species. Removal of overlying peat veneers at post-impoundment tributary mouth locations prior to flooding could promote aquatic plant growth in the post-impoundment environment.

1A.3.1.3.2 Recommendations

The stripping-away of peat veneers at tributary mouths was examined and was deemed impractical due to the logistical difficulty of stripping away and appropriately disposing of the peat. It is expected that this habitat will evolve over time as peat disintegration and uplift expose substrate that permits macrophyte growth (Section 3.4.2.2).

1A.3.1.4 Loss of Access to Tributary Streams

As mentioned in Section 1A.3.1.3, impoundment will result in increased water levels at the downstream end of tributary streams in the Keeyask reservoir. At locations where gradient barriers to fish movement currently exist in the lower reaches of tributaries, inundation may improve fish access to the upper reaches of those tributaries. However, debris created by flooding of the reservoir may accumulate and obstruct fish movement into the tributaries. Debris management measures would mitigate this potential loss of habitat.

1A.3.1.4.1 Debris Management at Tributary Mouths

In order to ensure that fish are able to access upstream habitat in tributary streams, obstructions would be selectively and routinely removed from the mouths and lower reaches of creeks that are expected to support fish.

1A.3.1.4.2 Recommendations

The potential post-impoundment loss of fish access to tributary streams due to debris accumulation will be mitigated through the monitoring and removal of debris as described in the Response to EIS Guidelines Appendix 4A and Appendix 4B.

1A.3.1.5 Winter Entrapment of Fish at Little Gull Lake

Dissolved oxygen (DO) levels in Little Gull Lake currently decrease to near zero over winter, limiting its ability to support fish (Section 2.5.2.2, Map 2-18 to Map 2-21). Post-impoundment, large-bodied fish are expected to move into this area, as it will be connected to the reservoir. Fish that remain in the area following freeze-up would be susceptible to winterkill when the shallow connecting waterways between former Little Gull Lake and the main body of the reservoir freeze to the bottom and DO levels in the lake decline to near zero. Measures to minimize or avoid the potential winterkill of fish in this portion of the reservoir were examined and evaluated.

1A.3.1.5.1 Channel Construction at Little Gull Lake for DO Maintenance

Channels of sufficient size (150 m wide) to provide Little Gull Lake with adequate year-round flow to maintain sufficient DO concentration to support fish could be excavated from the flooded back-bay areas that will separate Little Gull Lake from the reservoir. The increased flow would elevate the winter DO concentration in Little Gull Lake to levels that permit the survival of overwintering fish.

Initial engineering evaluations found that the excavation of the channels of sufficient dimensions to provide flow to Little Gull Lake that would ensure fish survival would be a significant construction project in which about 1,340,000 m^3 of unclassified materials would be excavated from the reservoir. The disposal areas needed for these excavated materials would be very large. As well, the need for erosion protection along the excavated channels for flows and wave action in the reservoir would require assessment.

1A.3.1.5.2 Channel Construction at Little Gull Lake for Fish Egress

The excavation of smaller (approximately 5 m base width) and less costly channels that would allow fish to escape to areas with more suitable DO levels was examined as a means of mitigating potential winterkill of fish. Evidence concerning the behavioural response of fishes in a northern Wisconsin winterkill lake showed that fish species that are intolerant of low DO will move to locations with higher DO levels (Magnuson *et al*. 1985). The excavation of egress channels at the Little Gull lake area (Map 1A-5) is expected to result in an oxygen gradient that fish would detect, thus enabling avoidance of lower than desirable or tolerable DO levels. Channel design was based on the need to maintain connectivity for fish between the Little Gull Lake impounded area and the reservoir throughout the winter ice-cover period.

A channel with a base width of 4–6 m and a bottom elevation of 156 m ASL would provide a water depth of between 1–2 m below the ice surface depending on reservoir water surface elevation and ice thickness. It was concluded that a channel of these dimensions (similar to Looking Back Creek which supports winter-season fish movements) would be adequate to support year-round movements of fish to and from the Little Gull Lake area.

Current concepts are preliminary; however, studies conducted to date suggest that construction of the channels is feasible. 1A.3.1.5.3 Recommendations

It was concluded that the cost to excavate channels large enough to maintain adequate year-round DO for fish in flooded Little Gull Lake would be excessive, especially given that the area currently does not support overwintering fish. Consequently, the excavation of smaller and less costly channels that will allow fish to escape to areas with more suitable DO levels is recommended as the preferred means to mitigate the potential winterkill of fish.

1A.3.1.6 Alteration of Lake Sturgeon Spawning Habitat at Birthday Rapids

Lake sturgeon prefer to spawn at sites where white water is present. Impoundment of the Keeyask reservoir will lead to increased water levels at Birthday Rapids (Physical Environment Supporting Volume [PE SV]) which will convert the rapids into fast-flowing habitat; it is unknown whether lake sturgeon will continue to spawn at this site post-impoundment. Spawning habitat currently present at Long Rapids (upstream of Birthday Rapids) will continue to be available post-impoundment and it is expected that lake sturgeon will continue to use this area (Section 6.4.2.2.2)). The mitigation and compensation options that have been considered for Birthday Rapids are described below.

1A.3.1.6.1 Creation of Spawning Structures

Monitoring will be implemented to determine the success of lake sturgeon spawning in the reach of the Nelson River between Long Rapids and Birthday Rapids. Should monitoring indicate poor or no spawning success, contingency works to create suitable spawning habitat for the maintenance of lake sturgeon in the reservoir would be implemented. One option currently being considered is the addition of large boulders/structures at locations slightly upstream of the current spawning site at Birthday Rapids to create white water to attract spawning fish. Placement of large boulders in this area would be difficult during the construction phase due to lack of access. However, access would be improved during the operation period. The design would be such that the structures could not be removed by ice.

1A.3.1.6.2 Stocking Program

Concerns have been raised regarding the sustainability of lake sturgeon populations in the Keeyask area given current abundance estimates, and it is thought that the Project could add further stress to populations that may already be declining (Section 6.3.2.1). As monitoring will be required before determining whether lake sturgeon continue to spawn at Birthday Rapids post-impoundment (Section 1A.3.1.6.1), there is the potential for a temporary reduction in lake sturgeon spawning rates in the reservoir during the initial operation of the Keeyask GS. Stocking the Keeyask reservoir with young-of-the-year (YOY) and juvenile lake sturgeon would help to compensate for any such decrease.

Stocking rates for three lake sturgeon life history stages (early fry, fall fingerlings and yearlings) were developed as described in the Lake Sturgeon Stocking Strategy (Part 2 of this appendix). Plans for the Keeyask Reservoir include the stocking of both fall fingerlings and spring yearlings. Monitoring will be undertaken to evaluate the relative success of each life stage stocked and to modify stocking rates to maximize recruitment. Lake sturgeon fry would also be stocked in years where hatchery fry production exceeds rearing capacity.

1A.3.1.6.3 Recommendation

Implement monitoring at Birthday Rapids to determine whether lake sturgeon continue to spawn at this site. If spawning no longer occurs there, or rates are significantly reduced, spawning habitat enhancement measures will be implemented to provide new spawning habitat, if practicable and feasible.

Implement the lake sturgeon stocking strategy. Stocking is viewed as a necessary and viable component of the overall mitigation strategy for lake sturgeon in the Keeyask reservoir (Section 6.4.2.2), and one of the impacts it will help to mitigate is the temporary reduction or elimination of spawning at Birthday Rapids.

1A.3.1.7 Alteration of Young-of-the-Year Lake Sturgeon Habitat in Gull Lake

Suitable young-of-the-year lake sturgeon rearing habitat is characterized by sandy/gravel substrate with generally planar topography, a low to moderate slope, and slower water velocities. Such habitat currently exists upstream of Gull Rapids, north of Caribou Island (44 ha; Appendix 6D), but the water velocity changes resulting from impoundment of the Keeyask reservoir is predicted to render this area unavailable to YOY lake sturgeon. Measures that were examined and evaluated as a means of mitigating this loss of habitat are presented in Sections 3.1.7.1 and 3.1.7.2.

1A.3.1.7.1 Creation of YOY Lake Sturgeon Sandy Rearing Habitat

Predictions of post-impoundment changes to water velocity and related sediment transport conditions (Section 3.4.2.2; Map 3-34) suggest there will be a requirement to create compensatory YOY habitat. The initial selection of the preferred location for the construction of a sand blanket (Map 1A-6) was based on the most likely area where, in the post-impoundment setting, YOY lake sturgeon that emerge from spawning locations upstream (*i.e.*, in the Birthday Rapids to Long Rapids reach) would settle to the bottom (*i.e.*, in the transition zone of the river and the reservoir [Section 6.4.2.2; Map 3-31 and Map 3-32]). The selected areas are, as well, located in areas of minimal sediment deposition (PE SV) to maximize the success of the sand blanket as lake sturgeon YOY habitat.

Phased Approach

Prior to constructing the sand blanket, a monitoring program would be undertaken to determine with greater certainty whether or not YOY lake sturgeon find sufficient and suitable rearing conditions in the near-term post-impoundment environment. Monitoring would include determination of YOY and juvenile lake sturgeon distribution and abundance in conjunction with key parameters of substrate depth, and velocity. It should be noted that although sand is widely believed to be an important substrate for YOY lake sturgeon, other substrates might also be suitable. Monitoring would also provide more precise post-impoundment substrate and velocity data to supplement the modelled results. This information would be used to refine locations where sand should be placed, if required. A three-year monitoring program would provide sufficient information to determine whether sand placement should be implemented.

If monitoring indicates that sand placement is necessary to create YOY lake sturgeon habitat, then placement of a sand blanket as a Phase I pilot program would provide an area of sandy habitat covering a 20 ha area. This area represents approximately one-half of the existing high suitability area north of Caribou Island (Appendix 6D). Subsequent monitoring over one or more years to determine the success of the Phase I pilot placement would be necessary before implementing a Phase II sand placement (up to an additional 20 ha), which may or may not be adjacent to the pilot placement (Map 1A-6).

Sand Blanket Material

Modelling of the erosion potential of sand particles placed at the placement sites suggest that sand particles greater than 1.0 mm and less than 2.0 mm in diameter sizes can be used.

Sand Blanket Thickness

In order to cover any boulders or cobbles present on the bed of the Nelson River, a sand blanket thickness of approximately 0.20 m would be used.

1A.3.1.7.2 Stocking of Lake Sturgeon in the Keeyask Reservoir

It is predicted that YOY rearing habitat may be limiting within the reservoir during the initial operation of the Keeyask GS (Section 1A.3.1.7.1). Monitoring will need to occur before it can be determined whether YOY lake sturgeon can effectively use other types of available reservoir habitat for rearing purposes, so there is the potential for temporary disruptions to early life history stages.

Stocking effectively improves natural recruitment by ensuring survival through the very young life history stages, thereby bypassing a significant portion of mortality that occurs in wild fish populations. In the case of the Project, this will be particularly important as suitable habitat for the rearing of YOY lake sturgeon may not exist initially in the reservoir. See Section 1A.3.1.6.2 and Part 2 of this appendix for a more detailed description of stocking strategies.

1A.3.1.7.3 Recommendations

Monitoring would be undertaken post-impoundment to determine suitability and abundance of YOY lake sturgeon habitat in the reservoir. Based on results of monitoring, a decision would be made to implement construction of up to 40 ha of sandy habitat suitable for YOY rearing.

Stocking will be implemented to mitigate the temporary disruption to early life history stages that may result from YOY habitat loss.

1A.3.1.8 Reduction in Fish Access to Stephens Lake

Currently, a low level of incidental movement of adult fish occurs in the downstream direction over Gull Rapids (Section 5.3.2.6). Once the Keeyask GS is built, it will alter these movements, as fish moving downstream will need to pass via the turbines or the spillway when it is in operation. In the absence of upstream passage, fish that move downstream will not be able to return. Options for upstream and downstream passage are discussed in Section 1A.3.2.1 and Section 1A.3.2.2.

1A.3.1.9 Emigration of Sub-adult and Adult Lake Sturgeon from the New Reservoir

Habitat changes that result from the impoundment of the Keeyask reservoir may cause lake sturgeon (and other fish species) to leave the area in favour of finding undisturbed habitat (Section 5.4.2.1). Fish will be able to swim freely between the reservoir and areas on the Nelson River that are further upstream, but in the absence of upstream fish passage, fish that go downstream through the powerhouse (or over the spillway during periods of spill) will be unable to return to the upstream reservoir environment. Means examined to mitigate this loss of lake sturgeon from the Keeyask reservoir are described in Section 1A.3.1.9.1 and Section 1A.3.1.9.2. Upstream fish passage would provide a means for fish that have emigrated to return; however, it is not known how many migrants would move to Stephens Lake and, if so, whether they would return upstream. This mitigation measure is discussed in Section 1A.3.2.1.

1A.3.1.9.1 Design of Trash Racks to Exclude Fish

The potential to decrease the trash rack spacing and reduce losses of fish to the downstream environment was assessed and results are summarized below and provided in detail in Attachment 2 of this appendix.

The currently proposed 16.75 cm clear bar spacing of the Keeyask trash racks will likely not prevent or interfere with the downstream movement of the vast majority of fish approaching the racks. Depending on their approach trajectory and orientation, some of the largest fish may initially become impinged on the racks. Most of these fish should have the capacity to swim off the racks and move upstream. Some of the impinged fish, particularly if their swimming capacity is compromised, may be pushed through the bar spaces by the current when trying to move off the rack. A few fish may not be able to swim off the racks and, consequently, could suffer severe injuries resulting in death. As a large proportion of the fish that may become impinged on the trash racks are expected to be mature individuals actively moving downstream, these fish will likely make repeated attempts at passing the Keeyask GS.

A reduction in the currently proposed bar spacing may result in a reduction in the numbers of fish closely approaching the bar racks (increased behavioural exclusion) and an increase in both the number/proportion of fish being unable to swim off the rack after initial impingement and becoming permanently impinged on the racks or forced through the racks (increased mechanical exclusion, potential increase in approach velocities). Overall, fewer fish will likely be entrained into the turbine flow than under the currently planned bar spacing. Due to the lack of baseline data, suspected non-linear relationships between, for example, bar spacing and impingement rate, the relative frequencies of the different outcomes of trash rack encounter are difficult to predict. For example, there is evidence that trash rack spacing close to the mean body width of individuals of a target species/population results in high impingement mortality (Calles *et al.* 2010).

When trying to evaluate design options for a hydroelectric GS to minimize fish mortality, individual passage routes should not be considered in isolation; potential rates of injury and mortality have to be compared for each passage, to guide decisions on which option(s) will provide the best solution for a specific location. Given that over 90% of fish up to 500 mm are expected to survive passage through the turbines of the GS (Section 1A.3.2.2), the risk of fish mortality due to impingement as a result of narrower trash rack spacing appears greater than the risk of passage through turbines. In addition, passage past the trash racks and the turbines is one of the major forms of downstream passage planned for the Keeyask GS; therefore, excluding fish through reduced trash rack spacing is not appropriate unless other forms of downstream passage are included in the GS design.

1A.3.1.9.2 Stocking of Lake Sturgeon in the Keeyask Reservoir

To help mitigate lake sturgeon losses associated with downstream movements through the GS or spillway, fall fingerlings and spring yearlings could be stocked into the reservoir. See Section 1A.3.1.6.2 and Part 2 of this appendix (Lake Sturgeon Stocking Strategy) for the details of this mitigation measure.

1A.3.1.9.3 Recommendations

Stocking will be used to mitigate losses to the Keeyask reservoir lake sturgeon population that may result from out-migration in response to habitat changes. A reduction in trash rack spacing is not recommended due to: (i) risk of increased mortality due to impingement; and (ii) prevention of downstream passage (see Section 1A.3.2.2 for a discussion of downstream passage).

1A.3.1.10 Increased Lake Sturgeon Harvest

The construction of access roads and the increased navigability of Birthday Rapids that will result from the Project will make it easier to access this reach of the Nelson River, and may result in an increased lake sturgeon harvest in the area both upstream and downstream of the GS (Section 6.4.2.2 and Section 6.4.2.3). The existing small populations, additional stresses imposed by Project construction and operation, and increase in road and boat access will require careful management to avoid over-harvest.

1A.3.1.10.1 Conservation Awareness Program Development

A lake sturgeon conservation awareness program developed in consultation with the KCNs would reduce the potential for increased harvest due to improved access. Ideally, the program would include Elder involvement in its development and implementation.

1A.3.1.10.2 Recommendation

A conservation awareness program will be developed to help prevent an increased harvest that would be detrimental to the recovery of the lake sturgeon populations in the immediate area of the Project.

1A.3.2 DOWNSTREAM OF THE KEEYASK GENERATING STATION

The predicted effects of the Project on fish and fish habitat downstream of the GS are described in the Section 5.4 and Section 6.4. Potential mitigation measures to address these effects are discussed below and the rationale for the selected measures is provided. Measures are summarized in Table 1A-7 and described in the sections that follow.

1A.3.2.1 Loss of Fish Access to Gull Lake

With the construction of the Keeyask GS, fish in Stephens Lake will lose access to potential spawning and foraging habitat upstream of Gull Rapids (Section 5.4.2.3.4). Based on biological and life history evaluations of fish species (lake sturgeon, lake whitefish, northern pike and walleye) that do incidentally move upstream over Gull Rapids, the provision of access between Stephens Lake and Gull Lake does not appear important to maintaining either upstream or downstream populations, provided that sufficient suitable habitat exists or will be created in the post-Project up- and downstream environments (Section 5.4.2.3 and Section 6.4.2.3). Nevertheless, fish passage has been the subject of ongoing evaluation during the development of Project mitigation. Lake sturgeon has been the primary focus of the evaluation, given that this is the only species where individual fish were documented to move up- and downstream over the rapids.

1A.3.2.1.1 Preliminary Evaluation – Upstream Fish Passage for Lake Sturgeon

Early in the design of mitigation, the need for a better understanding of the potential to successfully provide upstream passage to lake sturgeon was identified. To that end, the feasibility, conceptual design, and likelihood of success associated with engineered and natural structures for upstream and downstream passage of lake sturgeon were the subjects of a preliminary evaluation (Peake 2004). The evaluation concluded that:

- Engineered fish ladders would have a low to moderate chance of passing lake sturgeon. Documented accounts of lake sturgeon passage in fish ladders were scarce and were only associated with low head (less than 4 m) structures;
- Fish locks would have a moderate to high probability of success. Several cases were documented where fish locks have successfully passed lake sturgeon and other species of fish. It was noted that fish locks are expensive to construct and maintain, and would require attraction flow;
- Fish lifts would have a moderate probability of success, would be expensive to maintain, and would require attraction flow;
- A "nature-like" bypass channel would have a moderate probability of success. Additionally , a "nature-like" bypass channel could also provide compensatory fish habitat;
- A trap and transport system would have a moderate to high chance of success in passing lake sturgeon upstream. A trap and transport system would require attraction flow and a challenge test to ensure only those fish motivated to move upstream were transported; and
- A capture and transport program would be relatively inexpensive to implement and operate, and would be expected to have a high chance of success at moving lake sturgeon upstream of the powerhouse. However, capture methods could result in injury and stress, and there would be high uncertainty whether or not fish were motivated to move upstream.

Based on this preliminary evaluation and an interest in evaluating methods of creating productive fish habitat, options for a nature-like bypass channel were developed (Section 1A.3.2.1.2). It should be noted that provision of fish passage for sturgeon is an area of on-going research, and the understanding of the suitability of various methods of fish passage for lake sturgeon has advanced since the review done by Peake (2004).

1A.3.2.1.2 "Nature-Like" Bypass Channel Options

Based on work conducted by Peake (2004), further consideration was given to the design and feasibility of constructing a "nature-like" bypass channel at Keeyask because of its potential to provide compensatory fish habitat in addition to providing potential passage for lake sturgeon and other fish species.

Biological criteria for the design of a "nature-like" bypass channel for lake sturgeon (in addition to other fish species) are summarized in Table 1A-8. Six potential options, three on the north bank and three on the south bank, were identified. The six alternatives had different entrance and exit locations and consequently different alignments, but overall used the same design criteria. The six alternatives were subsequently evaluated (Peake 2008) and the North Bank Alternative 1 was selected as the best option for providing passage via a "nature-like" channel and creating fish habitat. This option is discussed below. Details of the remaining alternatives can be found in Peake (2008).

The North Bank Alternative 1 is 5.47 km in length with the upstream exit located at a Freeboard Dyke section approximately 3.25 km upstream of the powerhouse and the downstream outflow/entrance located near powerhouse releases that could provide an attraction flow. It would traverse 2.60 km of land, 2.76 km of an existing creek, and 0.11 km of a small pond. The entrance is located near the constructed lake sturgeon spawning habitat, and would need to be constructed in such a way as to not interfere with the function of the spawning structure. It is suggested that the over-land section be constructed of natural materials. The presence of a small pond within the bypass would increase habitat diversity and potentially improve productivity in the reach. The upstream exit is located well above the dam, and fish exiting the channel are unlikely to immediately move back downstream past the GS in large numbers.

As discussed in the following section, this option was the subject of further evaluation related to the provision of compensatory fish habitat and the requirement for year-round connectivity (Section 1A.3.2.1.2.1).

1A.3.2.1.2.1 Nature-Like Bypass Channel with Compensatory Habitat

To compensate for habitat loss at Gull Rapids, the North Bank Alternative 1 option would be constructed to mimic a natural channel as much as possible, and constructed of natural materials wherever possible. The dimensions of the channels and pools, water velocities and the permissible vertical-drop-per-riffle would be selected to ensure that target species (lake sturgeon, walleye, lake whitefish and northern pike) would utilize the created habitat. As discussed above, fish in Stephens Lake do not appear to require access to habitat upstream of Gull Rapids to fulfill their life history requirements; therefore, the main function of the channel could be to replace lost riverine habitat, although providing support to incidental movements would also be desirable.

Worldwide, there are many examples of "nature-like" channels that provide both habitat and passage. However, these systems have not been constructed in locations that experience the severe winters that exist in the boreal regions of Canada. In large systems, ice flows can completely destroy a well-designed channel and small bypasses may freeze to the bottom if there is insufficient flow or depth.

Four possible options of the North Bank Alternative 1 "nature-like" channel, each of which included some form of compensation for habitat loss, were considered:

- **Option 1** – requirement for open-water fish passage and provision of open-water habitat, including spawning habitat, for fish. Criteria for this option would be based on fish passage and spawning requirements plus consideration of additional shoreline work (riparian vegetation planting, instream structures) to create habitat diversity. This option appears to be feasible;

- **Option 2** – requirement for provision of open water habitat for fish (as above) but provides no requirement for fish access to the upstream reservoir. This option appears to be feasible. However, there may be more cost-effective ways of achieving habitat creation;
- **Option 3** – requirement for fish passage and provision of year-round habitat for fish. Similar to Option 1 but would provide sufficient flow in winter to prevent ponds from freezing out. This option appears unfeasible (see below); and
- **Option 4** – requirement for provision of year-round habitat for fish (as in Option 3) but provides no requirement for fish access to the upstream reservoir. This option appears unfeasible (see below).

The design and maintenance of a channel to provide both open-water and winter habitat, combined with the uncertainty of its success, rendered Options 3 and 4 unfeasible. Such a channel would require enough depth and flow during the winter to allow for the formation of a stable ice-cover, and these conditions would render the channel less suitable for summer habitat. The creation of a deeper channel could also result in the loss of attraction flow in summer. Moreover, there is a high degree of uncertainty as to whether such a channel would succeed, as winter habitat criteria have not yet been met anywhere else in the world.

The use of a nature-like channel as fish habitat has raised concerns due to challenges associated with managing channel shut down to avoid significant mortality of resident fish. As a result, the option of a bypass channel designed to also provide foraging/spawning habitat for a variety of fish species was not pursued further as a method of providing fish passage.

The next phase of the fish passage evaluation focussed on the development of a method of fish passage that was guaranteed to move fish, in particular lake sturgeon, upstream. As described below, a phased approach is being implemented, with trap/catch and transport program selected as the initial option, given the high probability of successfully moving fish upstream.

1A.3.2.1.3 Trap/Catch and Transport Fish Pass System for Lake Sturgeon and Other Species

Based on several meetings and discussions with DFO, the Partnership has made a commitment to implement fish passage for the Project. The intent of fish passage would be to maintain existing connections between upstream and downstream populations in order to mitigate the uncertainty with respect to the function and importance of these movements. As identified in the review by Peake (2004) and re-iterated by more recent (2011) studies administered by Manitoba Hydro, there are many uncertainties in designing passage for non-migratory species, in particular lake sturgeon. It was noted during discussions with DFO that providing fish passage may be counter-productive because: a) fish moving upstream will encounter a reservoir rather than a riverine environment and may decide to move back downstream through the turbines, resulting in some fish mortality; and b) that moving lake sturgeon upstream may further deplete the small stock of lake sturgeon in Stephens Lake. Therefore, a precautionary, phased approach is being implemented, with the initial phase consisting of a manual trap/catch and transport program. In advance of the second phase, an evaluation of other methods of fish passage will be conducted as described in Section 1A.3.2.1.4.

The following will be conducted in the initial phase:

- Undertaking a trap/catch and transport program for upstream fish passage for key fish species, including lake sturgeon, coincident with the in-service date of the Project. Fish will be captured using a trap or other method, and transported to an upstream location(s) by truck and boat;
- Monitoring the results of the trap/catch and transport program, fish movements, and fish populations to determine the need for adjustments to the program to provide the greatest benefit to fish populations. Monitoring results will be reviewed with DFO and MCWS and decisions with respect to the species and number of animals to be transported, as well as the timing of transport, would be made jointly; and
- Designing and constructing the GS in a manner that would allow it to be retrofitted to accommodate other upstream and/or downstream fish passage options, if required, in the future.

Trap/catch and transport was selected as the preferred method of fish passage to be implemented at the Project in-service date for the following reasons:

- The selected method had to move lake sturgeon and other species upstream past the GS. Lake sturgeon are not know to have moved up any structural fishways of the size that would be required at the Keeyask GS, therefore a method that does not rely on fish swimming for a prolonged period was required;
- Given the uncertainties regarding the locations where sturgeon and other species of interest would congregate below the station, monitoring of fish movements will contribute to the design of the location of the long-term fish passage facility;
- Trap/catch and transport will allow operators to determine which individual fish to pass. In particular for lake sturgeon, the Stephens Lake population is very small and vulnerable to the loss of adults and sub-adults. A targeted approach (*e.g.*, only moving sturgeon upstream if they were originally tagged in upstream waters) could be applied;
- The capture system could be employed in a manner to avoid disrupting life history functions. For example, it is expected that lake sturgeon and other fish species would congregate downstream of the GS in spring to spawn in available habitat. Successful spawning will be required to maintain fish populations in Stephens Lake and, therefore, a decision could be made not to transport mature adults upstream during the spring spawning period;
- Fish that are transported upstream could be moved to suitable habitat. For example, the deep reservoir environment immediately upstream of the GS may not be highly suitable for many of the fish found at the tailrace of the GS, and a trap/catch and transport system could be used to move them into more suitable parts of the reservoir; and
- Fish that are collected and transported would be at less risk of harm than those in a fish pass that requires them to swim a considerable distance.

The trap/catch and transport program will be implemented when the first units of the station begin to operate. The method that will be used to capture fish is currently being evaluated and a variety of methods may be tested. Fish that are transported will be tagged and movements will be monitored to provide information that will be used in the evaluation of fish passage alternatives described in Section 1A.3.2.1.4.

1A.3.2.1.4 Evaluation of Alternatives to Identify a Long-term Method of Fish Passage

As discussed in the PD SV, to assist in the long-term assessment of fish passage options, an analysis of alternatives will be undertaken. The Partnership will work closely with DFO and MCWS during this process.

There are three main components to fish passage including the collection of fish moving upstream, upstream passage and downstream passage. Upstream collection defines the ability to attract and collect fish from the Nelson River downstream of the GS. Upstream passage defines the means to move fish from a fish collection facility to a release site upstream of the dam. As discussed in Section 1A.3.2.2, the selected option for downstream passage for the Keeyask GS is via the turbines and spillway. The implementation of other downstream passage alternatives will be considered if monitoring indicates that the selected passage method is impeding downstream movements or is associated with unacceptable rates of injury and mortality.

Alternatives that will be evaluated for long-term upstream fish passage include trap/catch and transport, fish lock/lift, nature-like bypass channel, and fish ladder. These are being designed and evaluated based on criteria such as fish biology, engineering, operation and maintenance requirements, ATK, stakeholder and regulatory input, cost, and benefit.

Biological information pertaining to Nelson River fish species will be an important input to the evaluation of fish passage alternatives for the Project. Biological information pertinent to the type, location, timing, and sizing of fishway components includes target species and life stages, timing of fish movements, fish size and abundance, movement behaviour and patterns, and fishway hydraulic design criteria.

As discussed above, lake sturgeon is the primary target species when designing and evaluating the long-term fish passage alternatives. The physical and hydraulic characteristics of the Project site and lake sturgeon swimming capabilities and behaviour will be evaluated to develop alternatives that provide the highest likelihood of passing lake sturgeon. Other species such as walleye, northern pike, and lake whitefish will also be considered through discussions with DFO and MCWS Fisheries Branch. Modifications to fish passage alternatives for species other than lake sturgeon will be considered insofar that these modifications do not significantly impact expected passage performance for lake sturgeon.

1A.3.2.1.4 Recommendations

A trap/catch and transport system will be implemented at the in-service of the Project. The details of the design and operation of this facility will be determined in discussions with DFO and MCWS over the next number of years.

Numerous long-term fish passage alternatives will be evaluated using a multi-criteria decision-making process that applies various social, economic, environmental and engineering criteria to break down alternatives into discrete elements for comparison, evaluation and organization. Review of the evaluation of alternatives will take place with the fish passage expert consultants and input from the KCNs, stakeholders and regulatory agencies.

It is anticipated that a decision on long-term fish passage will be made five years after the Project in-service date in consultation with DFO and MCWS.

1A.3.2.2 Reduction in the Number of Fish Entering Stephens Lake from Upstream

In the absence of a dedicated downstream fish passage structure in the Keeyask reservoir, fish would still be able to move downstream through the turbines and over the spillway (when in operation). This route past the GS can lead to fish injury and mortality (Section 6.4.2.2), but this can be mitigated through specific design modifications. The measures that were considered in order to reduce the instance of fish injury and mortality as a result of passage through turbines include the provision of a downstream fish pass system (Section 1A.3.2.2.1) and the use of a modified turbine design to reduce mortality and injury (Section 1A.3.2.2.2).

1A.3.2.2.1 Provide Downstream Fish Passage

Considerable effort and cost has gone into optimizing the turbine design to reduce fish mortality and allow some fish to move downstream (Section 1A.3.2.2.2). The concept of downstream fish passage will be investigated if long-term monitoring results demonstrate installation is warranted.

1A.3.2.2.2 Modified Turbine Design

Due to the potential for injury and mortality of fish as they pass downstream through turbines, a number of variables were considered in the selection and development of turbines for the Keeyask GS to minimize the risk of injury and mortality. These variables include the number, alignment, and shape of stay vanes and wicket gates, clearance at the wicket gates and runners, wicket gate overhang, number of blades, blade leading edge thickness, blade trailing edge (related to turbulence), rotation rate, runner diameter, blade speed, and absolute lowest pressure.

The use of a fixed blade vertical shaft turbine design for the Keeyask GS results in several advantages for fish passage survivability compared to other turbine styles. The fixed blade pitch of the vertical shaft units allows for the gap between the runner blades and the discharge ring to be minimized, reducing the likelihood of fish impingement and injury. The low rotational speeds associated with large diameter vertical shaft turbines also result in greater fish survivability. To reduce the risk of striking or impingement injuries, runner blades incorporated a thicker rounder leading edge, the gaps between wicket gates and both the bottom ring and head cover were minimized, and the wicket gate overhang was minimized. To reduce turbulence levels experienced by fish passing through the turbines; the runner blades incorporate a thinner trailing edge, units will operate at best gate whenever possible, and the shape of the draft tubes incorporate large sweeping radii. These are all known to improve the probability of a fish passing through a turbine without incurring significant injury or mortality.

This is the first time that Manitoba Hydro has included these variables relevant to fish survival as part of the evaluation in the initial turbine design selection process, and as a priority for further turbine design development. Although there are many variables to consider beyond those relevant for fish survival (particularly efficiency and cost), the objective for the Keeyask GS turbines is to achieve a minimum survival rate of 90%. Based on the Franke formula (Franke *et al.* 1997) for estimating the probability of survival of fish passed through turbines, fish up to 500 mm passing through the Keeyask turbines will have a survival rate of over 90%. Additional information on turbine selection and estimation of injury/mortality is provided in Attachment 1.

1A.3.2.2.3 Lake Sturgeon Stocking in Stephens Lake

Concerns have been raised regarding the sustainability of lake sturgeon populations in Stephens Lake given current abundance estimates, and it is thought that the development at Keeyask may add further stress to this population (Section 6.4.2.3). It is known that lake sturgeon currently move downstream from Gull Lake into Stephens Lake over Gull Rapids at a low frequency, and these individuals may currently be supplementing the Stephens Lake population (Section 6.3.2.7). In addition, it is possible that some larvae and YOY from the eggs that are laid at Birthday Rapids currently wash down through Gull Lake and Gull Rapids into Stephens Lake, where they develop into mature fish. After the Keeyask GS is built, fish from Gull Lake will no longer be able to freely swim downstream into Stephens Lake, and reduced velocities in Gull Lake as a result of reservoir impoundment will decrease the likelihood that larvae hatched at Birthday Rapids will wash downstream into Stephens Lake. In an effort to increase the size of the overall lake sturgeon population in Stephens Lake, and to mitigate the reduced number of lake sturgeon additions from Gull Lake, fall fingerlings and spring yearlings could be stocked into Stephens Lake. Lake sturgeon fry would be stocked in years where hatchery incubation success exceeds rearing capacity.

Stocking rates for three lake sturgeon life history stages (early fry, fall-fingerlings and spring yearlings) were developed as described in the Lake Sturgeon Stocking Program (Part 2 of this appendix). Monitoring would be undertaken to evaluate the relative success of each life stage stocked and to modify stocking rates to maximize stocking returns.

1A.3.2.2.4 Recommendations

Downstream passage will be provided via the turbines and spillway (when it is in operation). Post-Project monitoring may indicate the need for another form of downstream passage.

Stocking is viewed as a necessary and viable component of the overall mitigation strategy for lake sturgeon in Stephens Lake and the Lower Nelson River in general. It will serve to increase the current population levels in Stephens Lake, and post-impoundment it will help to mitigate the decreased input of lake sturgeon from Gull Lake.

1A.3.2.3 Loss of Spawning Habitat at Gull Rapids

Gull Rapids currently provides important spawning habitat for a number of fish species that live in Stephens Lake, including walleye, lake whitefish, and lake sturgeon (Section 5.3.2.4 and Section 6.3.2.4). Currently, Gull Rapids provides the only known spawning habitat for lake sturgeon in Stephens Lake. Once the Keeyask GS is built, Gull Rapids will cease to exist and there are no additional sets of rapids within the reach of the Nelson River between the proposed Keeyask GS and the Kettle GS. Alternate spawning locations are available for other species in Stephens Lake (lake whitefish and walleye); however, loss of Gull Rapids habitat will reduce spawning potential in the lake for these species as well.

1A.3.2.3.1 Creation of Artificial Spawning Habitat Downstream of the Powerhouse

The creation of artificial spawning habitat downstream of the powerhouse would ensure that lake sturgeon spawning habitat is available following development of the Project. Currently, the creation of spawning habitat in proximity to where it exists today appears to have the greatest probability of success. This spawning habitat would be designed specifically to attract lake sturgeon, but it could also be used by other species that spawn under similar conditions.

In addition, the spawning structures would provide habitat suitable for colonization by benthic invertebrates that inhabit high velocity rocky habitats, and will thereby partially compensate for the loss of foraging habitat in Gull Rapids.

Design Criteria

Criteria for the construction of lake sturgeon spawning habitat (Table 1A-9) are based on successful spawning structures that have been constructed for lake sturgeon in Québec and Russia (Verdon and Gendron 1991; DuMont *et al.* 2009 in LeHaye *et al.* 1992; Kerr *et al.* 2011). HSI modelling indicates that existing suitable spawning habitat within and below Gull Rapids tends to be found along the edges of the main channel (Section 6.3.2.3). The spawning structure is proposed to be built on the north shore of the river below the powerhouse tailrace in order to ensure adequate and reliable flow and to be situated where lake sturgeon moving upstream in low velocity habitat along the river's edge would locate it.

Final Design Plans/Considerations

Design and evaluation of the spawning structure required detailed hydraulic modelling, and was conducted using a stepwise process.

The initial concept that was evaluated involved the creation of 3 ha of sturgeon spawning habitat along the north shore, north and east of the powerhouse tailrace for base loaded operation of four to seven units. Spawning habitat location, details and configuration of the boulder cluster microhabitats are shown in Figure 1A-1 and Map 1A-7. Key features to this spawning habitat are a minimum substrate thickness of 0.6 m (with 0.1 m to 0.6 m diameter rock) and water depths of 1 m to 10 m. Under this initiative, micro spawning sites will be created by placing three (1 m to 2 m) boulders in V-shape (upstream chevron) clusters as shown in Figure 1A-1.

Depending on Stephens Lake elevation and the Keeyask GS unit discharges, results of hydraulic modelling indicate that the area of spawning habitat, as defined by the criteria, ranged from 1.4 to 3.0 ha for discharges of 2,200 m^3/s (four units) to 4,000 m^3/s for (seven units). These areas overlap with each other (*i.e.*, the 1.4 ha area is contained within the 3.0 ha area), suggesting that under operational conditions of four to seven units there will be a constant 1.4 ha that meet the prescribed suitability criteria. The amount and location of spawning habitat area that meets the aquatic habitat criteria are also dependent on the elevation of Stephens Lake. Sturgeon eggs that are distributed over areas that are inconsistently exposed to optimal velocities may experience lower incubation success owing to reduced water circulation in the interstices of the spawning substrate, and hence reduced oxygenation. The changes in water depth that accompany these sub-optimal velocities would be unlikely to affect incubation success.

The second concept expanded the evaluation to consider peaking operation of two units to seven units, and a phased approach to the placement of spawning habitat (Map 1A-8A and Map 1A-8). The design identified during the first concept was modified to include refinements to the north wall of the powerhouse tailrace channel to incorporate a slope in the channel and a bench along the north end of the tailrace channel near the powerhouse parking lot as shown in Figure 1A-2. These design modifications were included as studies at the Pointe du Bois GS have found that, under some flow conditions, sturgeon move into the tailrace channel and that quiet waters next to turbulent fast flow create preferred microhabitats. The changes to the vertical wall of the tailrace channel are meant to guide sturgeon that move upstream past the constructed spawning structure to an area of suitable substrate for spawning. In addition, the potential to create more suitable substrate for spawning by leaving remnants of the cofferdam, or side-casting, was evaluated (Map 1A-8A). Due to the hydraulic effects of the cofferdam remnants, leaving a substantial amount of material is not feasible. However, where practical, coarse materials from the remnants of the tailrace summer level cofferdam may be spread to create conditions attractive to spawning fish in areas where interference with the outflow from the GS will not be a concern.

At the project in-service date, spawning habitat available to sturgeon downstream of the GS will consist of the modified north bank of the tailrace channel, the first phase of the constructed spawning habitat (up to 5.3 ha), and areas where coarse material remains from cofferdam removal/side-casting (see Map 1A-8A). Use of these areas by spawning sturgeon will be monitored and, if a requirement for other spawning habitat is identified (*e.g.*, if conditions in the initially created habitat are not suitable), then additional habitat will be constructed in a phased approach. Potential areas downstream of the GS adjacent to the initially created habitat have been identified based on hydraulic modelling (creating up to 15.9 ha of spawning habitat); however, actual locations would be adjusted depending on site-specific conditions and responses of sturgeon to the flows downstream of the GS.

The area of spawning habitat that meets the design criteria is dependent on the discharge through the powerhouse and the water elevation of Stephens Lake. For example, the first phase provides 0.4–4.7 ha for discharges of 1,100 m^3/s (two units, 1 and 2) to 4,000 m^3/s (seven units) respectively, while the third phase provides approximately 3.0–7.9 ha for these same discharges.

During the spawning period, the operation of the Keeyask GS will be modified such that flow from the two northernmost units is continuous to maintain appropriate hydraulic conditions over the spawning structure. In addition, monitoring will be required to determine if the cycling mode of operation adversely affects the behaviour of spawning fish. As long as drawdowns on Stephens Lake do not cause spawning habitat velocity and depth criteria to be violated, it is unlikely that the operation of the Kettle GS would have to be modified.

1A.3.2.3.2 Spawning Habitat Within and Downstream of the Spillway

In addition to artificial spawning habitat downstream of the powerhouse, consideration was given to wetting existing spawning habitat at the lower end of Gull Rapids through operation of the spillway. There is considerable uncertainty in the bathymetry for the area downstream of the spillway. Consequently, the amount of flow required to create functional spawning habitat in this area will remain poorly understood until the GS is operational.

When total river discharge exceeds powerhouse discharge capacity the provision of spawning habitat below the spillway would have no operational cost. However, when total river discharge is less than the powerhouse discharge capacity this measure may be quite costly depending on the amount of water that would be discharged through the spillway, the duration of spill and the frequency of (*e.g.*, annual) spill.

1A.3.2.3.3 Construction of a Lake Whitefish Spawning Reef Downstream Towards Stephens Lake

Lake whitefish currently spawn in the South Moswakot River, Gull Rapids (Section 5.3.2.3 and Section 5.3.2.4) and Ferris Bay (Michaluk *et al.* 2011). The creation of a lake whitefish spawning reef at a location along the south shore of Stephens Lake (Map 1A-9) is being evaluated to mitigate the effects of the loss of lake whitefish spawning habitat at Gull Rapids. Design criteria for the spawning reef (Table 1A-10) suggest a minimum 1,000 m^2 area of spawning habitat be created, with depths of 1.5–2.5 m below the Stephens Lake minimum operating level and depth-averaged velocities between 0.2–1.0 m/s.

Alternative methods have been identified regarding accessibility to the spawning shoal location and construction methods. Due to the dynamic nature of the shoreline and bathymetry along the south side of this reach, the depths will need to be confirmed during the final design phase and possibly post-Project just before installation. Collection of velocity measurements near the proposed lake whitefish spawning habitat area in the post-Project environment will be needed to determine the optimum location for the spawning shoals.

1A.3.2.3.4 Provide Upstream Fish Passage

Provision of upstream fish passage may provide additional opportunities for spawning fish to access spawning habitat upstream of the generating station (Section 1A.3.2.1). However, it appears unlikely that fish produced at spawning sites in the Keeyask reservoir (*e.g.*, Birthday Rapids) would provide a substantial contribution to the population in Stephens Lake, given the presence of the large and deep lower section of the Keeyask reservoir. Therefore, this is not considered a useful approach to mitigating the effects of lost spawning habitat.

1A.3.2.3.5 Recommendations

It is recommended:

- To construct artificial lake sturgeon spawning habitat downstream of the powerhouse. This habitat constructed close to existing spawning habitat has a greater probability of success than more distant locations; and
- To construct additional spawning habitat for lake whitefish in Stephens Lake.

Operation of the spillway annually to wet spawning habitat in Gull Rapids is not recommended; however, such habitat may be used in years that the spillway is operating.

1A.3.2.4 Loss of Fish Habitat at Gull Rapids and Loss of Access to Gull Rapids Creek

When the Keeyask GS is constructed, the south channel of Gull Rapids will be dewatered resulting in the loss of foraging habitat and the likely elimination of northern pike and white sucker access to both foraging habitat and possible spawning habitat in Gull Rapids Creek (Section 5.4.2.3). Access up into the creek currently appears variable from year to year depending on water levels in Stephens Lake and the creek itself, Nelson River flow, and the presence or absence of ice at the mouth of the creek during the upstream migratory period in spring.

Conceptual plans to mitigate effects of the potential loss of access to the creek, as well as maintain some of the dewatered riverbed as wetted habitat, were developed and evaluated. The first concept was the construction of a channel that would maintain connectivity between the creek and Stephens Lake (Section 1A.3.2.4.1). The second concept provided more wetted habitat in the dewatered riverbed, as well as providing access to the creek and improving habitat in the creek itself (Section 1A.3.2.4.2).

1A.3.2.4.1 Construction of an Artificial Stream along the South Shore of Gull Rapids

The constructed channel would be designed to provide fish access from Stephens Lake to Gull Rapids Creek and to provide productive fish habitat over the approximate 1.5 km distance from the creek mouth to the permanently wetted area downstream of the dam and tailrace (Map 1A-10). It would mimic natural conditions as much as possible and would provide spawning habitat in the spring, and nursery and rearing/foraging habitat during the remainder of the open-water season.

Design Considerations

The elevation change across the reach is estimated to be up to 8 m and existing substrate is likely bedrock, possibly with some boulders and other coarse material in lower-velocity areas.

Design objectives for the construction of the connecting channel are as follows:

- Create rapids habitat to support fish spawning/feeding (including invertebrate production) to help offset the loss of Gull Rapids;
- Provide access to Gull Rapids Creek for spring spawning fish such as northern pike and sucker (currently the creek is not accessible in many years due to ice/water level conditions; providing access will serve to offset losses of creek habitat within the reservoir); and
- Create lake sturgeon spawning habitat at the base of the channel to supplement proposed spawning habitat creation associated with the generating station structures (Section 1A.3.2.3.1 and Section 1A.3.2.3.5).

Conceptual design considerations were based on the following requirements:

- Create a small river environment with a channel approximately 10 m wide with a series of riffles, glides and pools;
- Riffles should be at least 0.75 m deep with a peak velocity of approximately 1 m/s and areas of lower velocity;
- Riffles should be interspersed with deeper glides and pools. To avoid producing extensive low velocity areas, consider use of alternating groins for glide sections;
- Some portion of the habitat should have suitable spawning conditions for walleye (see examples in Newbury and Gaboury [1993]). In Manitoba, riffles for walleye generally have a 0.3 m height in the center and 0.6 m height at the banks, with a 4:1 front slope and a back slope ranging from 20:1 to 40:1;
- Some portion of the habitat (as far downstream as possible) should have suitable conditions for lake sturgeon spawning. Suggested criteria based on estimates for the Landing River are:
    - Channel width of 8–10 m;
    - Depth of 0.75–1.5 m; and
    - Spawning riffles 30–40 m long with velocities of 0.5–1.0 m/s.

The channel would be designed to support upstream and downstream fish movements in the spring. The following criteria were considered:

- Stream hydraulics below the designated lake sturgeon spawning area should meet criteria for sturgeon passage, and upstream of this point stream hydraulics should meet criteria for other species;
- Minimum depth of 1 m for lake sturgeon, 0.6–0.8 m for other species;
- Average slope of less than 1:30 for the whole channel;

- Average velocity of 0.4–0.6 m/s is suitable for large-bodied fish. Include low-velocity refugia that would be suitable for juvenile and small-bodied fish;
- Water velocity should not exceed 1 m/s, and 1 m/s flow should not occur for more than 20 m at a stretch;
- Attraction velocity of 0.6–0.9 m/s; and
- Entrance with a slope of less than 1:8 and continuous with the river-bottom.

Final designs would only be possible when the area is dewatered and site conditions can be assessed.

1A.3.2.4.2 South Side Enhancement Project

The South Side Enhancement (SSE) concept is an alternative approach to compensating for the loss of fish habitat below the south dam and for providing fish access to Gull Rapids Creek. The SSE concept would maintain foraging habitat at Gull Rapids, provide access to Gull Rapids Creek, and enhance habitat within the creek itself.

Concept Description

The SSE concept would involve construction of six low head dams and weirs to maintain wetted habitat over a large portion of Gull Rapids south channel that would be dewatered by the generation project (Map 1A-11). Shorelines would be enhanced with mineral soils and plantings to create riparian habitat and provide cover for fish. Four rocky ramp fishways would be constructed to provide upstream and downstream access for species such as northern pike and sucker to both Stephens Lake and Gull Rapids Creek to increase the range of fish species and life stages that could access this habitat. There is a risk that the passage structures could freeze up during the winter. This will need to be addressed during the final design stage. Excavation of three over-wintering pools for fish would also be required.

A discharge control structure built into the south dyke would typically maintain a flow of1 m^3/s to Gull Rapids Creek, which would flow to the SSE area. The discharge would be required year round for the mitigation measure to be effective.

The mitigation measures also include enhancements to Gull Rapids Creek, which would entail removing floating peat to open up the waterway and improve the quality of fish habitat. .

Adding flow to Gull Rapids Creek would improve the quality of the fish habitat, which is currently marginal.

1A.3.2.4.3 Recommendations

The creation of an artificial stream along the south channel of Gull Rapids to provide additional spawning habitat and mitigate the loss of access to Gull Rapids Creek by large-bodied fish as described in Section 1A.3.2.4.1, is not recommended. This concept was not recommended because other more promising opportunities to provide spawning habitat have been evaluated and recommended and the benefit of providing access to Gull Rapids Creek is marginal due to extremely low flows in the creek.

Construction of a stream/pool system along south channel of Gull Rapids, including the provision of flow year-round from the reservoir through Gull Rapids Creek would provide greater benefit to fish production, as areas in Gull Rapids Creek as well as the dewatered riverbed will be available (Section 1A.3.2.4.2). Final design and construction would only be possible once the area is dewatered and site conditions can be assessed. Whether or not this measure is implemented will depend on discussions with DFO and MCWS in terms of the suitability of this project for meeting fish habitat compensation objectives.

1A.3.2.5 Deposition of Silts over Lake Sturgeon Rearing Habitat in Stephens Lake

A lack of sufficient YOY and early juvenile lake sturgeon habitat downstream of the Keeyask GS would limit the success of constructed spawning habitat (Section 1A.3.2.3.1) and potentially the success of the proposed stocking program (Section 1A.3.2.2.3).

Current assessment indicates that sediments will not deposit in the area thought to provide YOY rearing habitat in Stephens Lake. Nevertheless, measures to mitigate potential alteration or loss of lake sturgeon rearing habitat due to siltation effects will be evaluated following construction of the Keeyask GS.

1A.3.2.5.1 Creation of YOY and Early Juvenile Lake Sturgeon Habitat in Stephens Lake

Post-project monitoring will be conducted to determine whether sufficient lake sturgeon rearing habitat exists downstream of the lake sturgeon spawning structures, and if it does not, new suitable habitat will be created.

1A.3.2.5.2 Stocking Yearling Lake Sturgeon in Stephens Lake

If post-Project monitoring indicates that there is a lack of YOY and early juvenile lake sturgeon rearing habitat in Stephens Lake, then stocking of lake sturgeon spring yearlings (see Section 1A.3.2.2.3 and Part 2 of this appendix for more details) would help to make up for any potential disruption before new habitat is constructed and proven effective.

1A.3.2.5.3 Recommendations

Post- Project monitoring will be undertaken to determine the requirement for creating suitable rearing habitat for YOY and juvenile lake sturgeon in the reservoir.

Stocking of spring yearling lake sturgeon will be used to help mitigate potential temporary loss of the potentially limiting existing YOY habitat in Stephens Lake.

1A.3.2.6 Potential for Fish Stranding

Changes to water levels downstream of the powerhouse or spillway following cessation of a spill have the potential to strand fish in isolated pools (Section 3.4.2.3). These fish are at risk of mortality due to increased water temperatures and depletion of dissolved oxygen. Measures being considered in order to prevent this stranding are discussed below.

1A.3.2.6.1 Measures to Allow for Escape from Pools

The collection of bathymetric data in the south channel of Gull Rapids has been limited due to high velocities in this area. As a result, the location of any potential isolated pools and the alignment of the proposed excavated channel to allow fish egress will need to be determined once the Powerhouse is operational and the Spillway is closed, thus allowing bathymetric data to be obtained. Construction is most likely to occur during the operation period in late fall or early winter when low flow is expected to occur and the spillway is most likely not operating. The rock will be excavated by drilling and blasting using dynamite and will be side cast into adjacent low-lying areas on the river bottom outside the zone of influence of the Spillway discharge.

Regular inspections of the channel will be carried out to ensure that debris that may come from spillway release, or from Stephens Lake, does not block fish movements.

Initial design concepts include approximately 1,000 m of channels that are of 2 m wide by 2 m deep to permit fish access to Stephens Lake.

1A.3.2.6.2 Recommendations

Plans will be further developed post-Project to design connectivity between the spillway discharge channel, pools and Stephens Lake.

1A.4 REFERENCES

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Table 1A-1: Timing and temperatures associated with fish species spawning and fry presence in the Keeyask area

Biological and Environmental Parameter	Northern Pike	Walleye	White Sucker	Lake Whitefish
Spawning temperature from literature	4.4–11°C[1]	4–11°C[1]	10°C[1]	5–10°C[2]
When these temperatures occur in study area[3]	Late May – early June	Late May – early June	Early June	Mid-September – early October
Water temperature when ripe fish captured in study area	9–17°C	9–17°C	7–17°C	3–8°C
Time of year ripe fish captured in study area	25 May – 28 Jun	25 May – 27 Jun	27 May – 15 Jun	25 Sep – 14 Oct
Water temperature when larvae captured in study area	15–18°C	15–21°C	13–21°C	3–19°C
Time of year when larvae captured in study area	18 Jun – 19-Jul	13-Jun – 19 Jul	12 Jun – 23 Jul	24 May – 17 Jul

1. Scott and Crossman (1998)
2. Stewart and Watkinson (2004)
3. Includes both the Nelson River mainstem between Birthday Rapids and Gull Rapids and Stephens Lake.

Table 1A-2: Timing of in-water work to avoid or minimize potential for interactions with sensitive spawning periods. Estimated month(s) of work is shown and subject to change

Structure	Early Planning	Adjusted Scheduling	Likelihood of Spawning Disturbance		Comments
			Spring	Fall	
Quarry Cofferdam Construction	April	Mid- to late July	No	No	Later start to avoid spring spawning.
North Channel Rock Groin Construction	Early May	Late July to mid-August	No	No	Later start to avoid spring spawning.
North Channel Stage I Cofferdam Construction	Late May	Mid-August to early September	No	No	Later start to avoid spring spawning.
Powerhouse Cofferdam Construction	June to September	Late July to mid-October	No	Minimal	Later start to avoid spring spawning. No flow through the North Channel so minimal interaction with fall spawning activity is expected.
Spillway Stage I Cofferdam Construction	June to September	Mid-July to mid-October	No	Yes	Later start to avoid spring spawning. Not possible to avoid potential disturbance to fall spawning fish without construction delays.
Spillway Stage I Cofferdam Removal of Portions	May to July	Early August to early September	No	No	Later start to avoid spring spawning.
Central Dam Cofferdam Construction	July to August	Mid-August to early October	No	Yes	Later start to avoid spring spawning. Possible interaction with lake whitefish spawning activity.

Table 1A-2: Timing of in-water work to avoid or minimize potential for interactions with sensitive spawning periods. Estimated month(s) of work is shown and subject to change

Structure	Early Planning	Adjusted Scheduling	Likelihood of Spawning Disturbance		Comments
			Spring	Fall	
South Dam Stage II Upstream Rockfill Section Construction	July to October	Early September to mid-October	No	Yes	Later start to avoid spring spawning. Likely interaction with lake whitefish spawning activity.
South Dam Stage II Upstream and Downstream Cofferdams Construction	July to October	Mid-May to mid-July	Yes	No	River flow is now through the spillway. Reduces potential for spring spawning activity adjacent to the South Dam Upstream Rockfill Section constructed the year previous.
Tailrace Summer Level Cofferdam Construction	June to July	Mid-July to mid-September	No	No	Later start to avoid spring spawning.
Tailrace Summer Level Cofferdam Repairs Year 2	April to May	Early to late June	Minimal	No	Repair work is expected to be above water. The absence of flow at this location minimizes the likelihood of spring spawning activity at this location.
Tailrace Summer Level Cofferdam Removal	No date	Early September to early October	No	Yes	Possible interaction with lake whitefish spawning activity.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Walleye and Lake Whitefish Spawning Habitat (3.1.1)	Construction of rocky shoals within the reservoir.	Would provide spawning habitat early in the development of the reservoir environment.	*3.1.1.1*	Recommended - proximity to existing spawning areas increases the chance of success.
	Gravel or cobble-sized rocks would be placed on dykes to encourage spawning in the reservoir (particularly for fall spawning fish like lake whitefish and cisco). Construction of rock groins adjacent to dykes to increase habitat diversity and provide surfaces for spawning.	Fish seeking spawning habitat may not approach dykes, many of which are situated in shallow, flooded areas. The construction of rock groins at select locations along the dykes would enhance fish habitat in the Keeyask reservoir but, as above, may not be situated in the best place within the reservoir for spawning habitat. Further, sediment deposition on dyke surfaces is expected in the Keeyask reservoir, which would cover the rocky materials within a few years of construction.	*3.1.1.2*	Not recommended - successful spawning habitat for walleye and lake whitefish is more likely to be created through the construction of shoals described above.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Reduction in Quality of Shallow Water Feeding Habitat (3.1.2)	Addition of mineral soils into the reservoir to promote growth of aquatic plants.	Mineral material shelves in the reservoir could increase the amount of fish rearing and foraging habitats by promoting plant growth and increasing aquatic invertebrate populations.	*3.1.2.1*	Not recommended - after the reservoir is flooded, conditions will be sufficient to support the forage fish community present at impoundment, and suitable habitat will evolve in the flooded areas over time.
	Provide cover for fish and accelerate shoreline stabilization by planting willows along shorelines.	Willows on the shoreline would provide cover for rearing and foraging habitat in nearshore shallow water areas.	*3.1.2.2*	Not recommended - after the reservoir is flooded, conditions will be sufficient to support the forage fish community present at impoundment, and suitable habitat will evolve in the flooded areas over time.
	Provide cover for fish by placing log bundles in the reservoir.	Cut trees could be cabled together and anchored in both deep and shallow areas to provide cover for fish.	*3.1.2.3*	Not recommended - after the reservoir is flooded, conditions will be sufficient to support the forage fish community present at impoundment, and suitable habitat will evolve in the flooded areas over time.
Loss of Small Tributary Foraging and Spawning Habitat (3.1.3)	Create foraging and spawning habitat by removing peat in shallow water areas and then undertake other measures such as planting vegetation.	Removal of peat at tributary mouths prior to flooding could promote aquatic plant growth in the reservoir.	*3.1.3.1*	Not recommended – removal and disposal of peat from tributary mouths would be a difficult and complicated process as access by machinery is very limited and poses risks to other components (*e.g.*, creation of access trails).

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Access to Tributary Streams (3.1.4)	Remove debris from the mouths and lower reaches of tributaries.	Removal of debris would permit fish access to upstream habitat in tributary streams.	3.1.4.1	Recommended – removal of debris will allow fish access to tributary streams.
Winter Entrapment of Fish in the Area of Present-day Little Gull Lake Resulting in Winterkill (3.1.5)	Excavation of large channels to maintain suitable dissolved oxygen levels in Little Gull Lake.	Large channels would permit year round flow through Little Gull Lake. This would elevate winter dissolved oxygen concentrations and allow fish to survive the winter.	*3.1.5.1*	Not recommended – an extremely large amount of material would need to be excavated and there are some technical challenges that may limit the probability of success. For these reasons, it is preferred to proceed with smaller access and egress channels discussed below.
	Excavation of small channels will allow fish to escape from Little Gull Lake, where dissolved oxygen levels are expected to drop to near zero.	Potential winterkill of fish will be reduced by digging channels that will allow fish to escape from Little Gull Lake into areas with higher flow (and therefore higher concentrations of dissolved oxygen).	*3.1.5.2*	Recommended - channels that allow fish to access areas with more suitable dissolved oxygen levels will be used to mitigate the potential winterkill of fish.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Alteration of Lake Sturgeon Spawning Habitat at Birthday Rapids (3.1.6)	Monitoring to determine whether sturgeon continue to spawn at Birthday Rapids and, if not, place large boulder/structures along the shorelines to create white water to attract spawning fish.	If monitoring indicates that lake sturgeon spawning is reduced, large boulders or structures would be added into the river near the Birthday Rapids spawning site to create turbulent flow. A survey of the shoreline indicates that suitable substrate is already present in areas where water levels would increase immediately upstream of the rapids. The structures would be designed in such a manner as to prevent removal by ice action.	*3.1.6.1*	Recommended – will create additional spawning habitat in the reservoir if Birthday Rapids is not used post- Project.
	Stocking of lake sturgeon.	Stocking would offset reduced year-class strength if spawning habitat at Birthday Rapids is no longer suitable.	*3.1.6.2*	Recommended - stocking is viewed as a necessary component of the overall mitigation strategy for lake sturgeon in the Keeyask reservoir.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Alteration of Lake Sturgeon Young-of-the-Year (YOY) Rearing Habitat in Gull Lake (3.1.7)	Monitoring and, if necessary, creation of habitat suitable for YOY rearing in the reservoir.	Impoundment is expected to alter existing YOY habitat in northern Gull Lake making it less suitable; however, conditions in the upstream portion of Gull Lake will have suitable depth and velocity. Monitoring will indicate whether substrate is suitable; if not, implement a contingency plan to create habitat suitable for YOY rearing in the reservoir by placement of a blanket of sand/fine gravel over 40 ha in a two-phased process (20 ha each phase).	*3.1.7.1*	Recommended - YOY habitat in the reservoir will be required to maintain a self-sustaining population.
	Stocking to offset potential effects of reduced YOY habitat.	Stocking will help mitigate reduced year classes until sufficient YOY habitat is available.	*3.1.7.2*	Recommended - stocking is a proven method for the recovery of lake sturgeon populations where habitat is available. Stocking will be used to help increase the number of young lake sturgeon if survival rates decline as a result of YOY habitat loss.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Reduction in Fish Access to Stephens Lake (3.1.8)	Provide downstream and upstream fish passage.	Information on fish movements and habitat availability indicates that access to Stephens Lake will not be required to maintain fish populations in the reservoir. For further discussion on fish passage, see Table 1A-7.	3.1.8	Recommended – see discussion of upstream and downstream fish passage in Table 1A-7.
Emigration of Sub-adult and Adult Lake Sturgeon (in particular at impoundment) (3.1.9)	Design of trash racks to reduce loss of fish from the reservoir.	Current spacing of trash racks excludes the largest fish; analysis of hydraulic conditions indicates that reducing spacing to exclude smaller fish could result in increased mortality due to impingement on the trash racks. Given that downstream fish passage will be via trash racks/turbines and spillway, excluding all fish from passage via turbines would not be beneficial.	*3.1.9.1*	Not recommended – risk to fish of passage past turbines is less than risk of impingement if trash rack spacing is reduced. In addition, passage past the trash racks and turbines is a method of downstream fish passage.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Emigration of Sub-adult and Adult Lake Sturgeon (in particular at impoundment) (3.1.9) (Continued)	A stocking plan will be implemented to offset potential emigration of lake sturgeon.	Fall fingerlings and spring yearlings could be stocked in the reservoir to help mitigate potential lake sturgeon losses due to movement out of the reservoir.	*3.1.9.2*	Recommended – stocking is a proven method for the recovery of lake sturgeon populations where habitat is available.
	Provide upstream fish passage	Would provide the opportunity for migrants that move downstream to Stephens Lake to return to reservoir. Not known to how many fish this would affect as (i) fish may move upstream or further downstream; and (ii) fish may not exhibit behaviour to move back upstream.	3.1.9	Recommended – see discussion of upstream and downstream fish passage in Table 1A-7.

Table 1A-3: Predicted impacts to fish habitat upstream of the Keeyask Generating Station, and proposed measures to mitigate and compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Increased Lake Sturgeon Harvest at the Keeyask Site (3.1.10)	A conservation awareness program will be implemented to reduce the potential for increased harvest due to improved access at the Keeyask site, in particular to the spawning areas.	A lake sturgeon conservation awareness program would be developed in consultation with the KCNs to reduce the potential for increased harvest due to improved access. Ideally, the program would include Elder involvement in its development and implementation.	*3.1.10*	Recommended – the existing small populations, additional stresses imposed by Project construction, and increases in road and boat access will require careful management to avoid over-harvest.

Table 1A-4: Biological design criteria for the construction of rocky shoals

Parameter	Design Criteria	Additional Considerations
Substrate	A mix of coarse materials as follows: 25% boulder (750–500 mm); 35% cobble (256–64 mm); 25% large gravel (64–32 mm); and 15% small gravel (32–8 mm).	Substrate layer should have minimum thickness of 0.75 m, and substrate material should be free of silt and clay. Important that there be ample interstitial space for egg incubation and larval development.
Velocity and/or Exposure	At sites with flowing water, the velocity should be between 0.2 and 1.0 m/s. If water velocity is less than 0.2 m/s, then location requires wave-generated circulation (*i.e.*, exposure to northeast – northwest winds).	
Depth	Crest of spawning shoal: Walleye = 0.3–0.8 m below minimum operating level (MOL); and Lake whitefish = 2.0–2.5 m below MOL.	Lake whitefish eggs incubate over winter; eggs deposited at depths less than 1.5 m below MOL will be vulnerable to freezing at maximum ice thickness.
Size of Spawning Area	Minimum crest area at preferred depth should not be less than 1000 m^2.	Shape of shoal should maximize surface area (longer and rectangular as opposed to round or square).
Slope	Slope of spawning area should not exceed 10%.	
Location	Select areas where mineral soil is present, areas adjacent to bedrock, or where organic soil is thin (*i.e.*, peat veneer). Where placement occurs over organic soils, gabion basket wire should be laid over the soil prior to placement.	At standing water sites, orient shoals to maximize exposure to wave action. Locations that meet depth, velocity/exposure, and soils criteria are provided in Map 1A-2.
Critical Annual Period	Walleye - Early May to mid-June. Lake whitefish - Late October to late April.	

Note: Rocky shoal design criteria were based on spawning shoal development criteria described in Kerr *et al.* 1997 and Geiling *et al.* 1996 and based on species ecology descriptions provided in Appendix 5A.

Table 1A-5: Potential and preferred (green) spawning shoal development zones

Development Site	Post-impoundment Location Characteristics	Comment
< 4 m Bottom Depth at Shoal Development Site		
1A	Low velocity, does not possess above-average exposure attribute, and potential for conflict with proposed channel excavation at Little Gull Lake (Section 3.1.5).	May not be a suitable location
1B	Low velocity, does not possess above-average exposure attribute and is in an area predicted to be exposed to higher than average sediment deposition (see Map 1A-2).	May not be a suitable location
1C-1 and 1C-2	Low velocity may negatively affect the value of this location. Low predicted sediment deposition (Map 1A-2) and adjacent to potential mineral shelf development zone.	More attractive than either 1A or 1B
1D	Good velocity and exposure attributes and adjacent to a potential mineral shelf development zone.	Suitable for shoal development
1E	Northeastern portion possesses suitable attributes for development. However, this location is closer to the generating station (GS) and spillway than other options.	Less attractive
	The southwestern portion (along the dyke) is exposed to above-average predicted sediment deposition over a sizeable portion of the selected area (Map 1A-2), and low water velocity.	Not recommended
1F	Possesses good velocity and exposure attributes, and is adjacent to existing known or suspected walleye spawning habitat and a deep water shoal development site (2D). The more downstream area may be subject to mineral sediment deposition (see Map 1A-4) suggesting that the focus should be on the upstream portion.	Above-average suitability
1G	Possesses good velocity and exposure attributes and is adjacent to existing known or suspected walleye spawning habitat. No concerns regarding sediment deposition are apparent.	Above-average suitability
1H	Possesses good velocity and exposure attributes. The downstream portion is adjacent to potential mineral shelf development area and the upstream to a deep water shoal development site (2E). It is also adjacent to existing known or suspected walleye spawning habitat. No concerns regarding sediment deposition are apparent.	Above-average suitability

Table 1A-5: Potential and preferred (green) spawning shoal development zones

Development Site	Post-impoundment Location Characteristics	Comment
1J	This site is in a location with good velocity and exposure attributes and adjacent to existing known or suspected walleye spawning habitat. However, post-Project sediment deposition may be at an unacceptably high level (see Map 1A-4).	Suitable for shoal development
1K	This site is in a location with good velocity and exposure attributes and adjacent to existing known or suspected walleye spawning habitat. However, post-Project sediment deposition may be at an unacceptably high level (see Map 1A-4).	Suitable for shoal development
1L	Possesses good velocity and exposure attributes, and is adjacent to a deep water shoal development site (2F). No concerns regarding sediment deposition are apparent.	Suitable for shoal development
> 4 m Bottom Depth at Shoal Development Site		
2A-1 and 2A-2	The sites possess good velocity attributes. However, there is a possible sedimentation concern at this location (See Map 1A-2).	Suitable location
2B	Close to spillway and GS intakes. The site is located well within the 3 km exclusion zone thus exposing post-larval fish to downstream transport out of the reservoir.	Not suitable
2C-1	Located at the 3 km exclusion zone boundary, thus potentially exposing post-larval fish to downstream transport out of the reservoir. No concerns regarding sediment deposition are apparent.	Suitable for shoal development
2C-2	Close to the spillway and GS. The site is located well within the 3 km exclusion zone thus exposing post-larval fish to downstream transport out of the reservoir.	Not suitable
2D	Possesses good velocity and exposure attributes, and is adjacent to an existing lake whitefish spawning area and a proposed site for shallow-water shoal construction (1F). No concerns regarding sediment deposition are apparent.	Above-average suitability
2E	Possesses good velocity and exposure attributes and is adjacent to an existing lake whitefish spawning area and a shallow-water shoal construction site (1H). No concerns regarding sediment deposition are apparent.	Above-average suitability
2F	Possesses good velocity and exposure attributes and is adjacent to shallow-water shoal construction site (1L). No concerns regarding sediment deposition are apparent.	Above-average suitability

Table 1A-6: Biological design criteria for rock groin construction

Parameter	Design Criteria	Additional Considerations
Substrate	A mix of coarse materials as follows: 25% boulder (750–500 mm); 35% cobble (256–64 mm); 25% large gravel (64–32 mm); and 15% small gravel (32–8 mm).	The distribution of material size would depend on likely exposure to ice, currents, and wave action at candidate sites.
Dimensions	Groin width (top) – 1–2 m Groin length – 10–15 m Side slope – 1vertical:1.5–2horizontal Groin spacing – 4–6 times groin length Minimum of 3 m below MOL	Dimensions will be influenced by site location and need for protection from ice forces.
Depth	Depends on location selected.	
Location	Select areas along permanent dykes where groin construction will not interfere with dyke integrity.	

Note: Substrate criteria are the same as rocky shoal substrate criteria (Table 1A-4); groin dimension criteria are based on information from US Army Corps of Engineers (2007).

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Fish Access to Gull Lake (Keeyask reservoir) (3.2.1)	Trap/catch and Transport - trapping or catching fish by some other means and moving them by truck and boat from downstream of the generating station (GS) to upstream of the GS.	Information on fish movements and habitat availability indicates that access to the Keeyask reservoir will not be required to maintain fish populations in Stephens Lake. However, given the uncertainty with respect to the importance of maintaining connections among populations, upstream fish passage will be provided. A trap/catch and transport program allows selection of individual fish to move upstream to avoid depleting fish populations in Stephens Lake. This method allows monitoring of the behaviour of fish that are transported upstream to assist in determining the best long-term approach to fish passage.	*3.2.1.3*	Recommended - address uncertainty with respect to maintaining connections among fish populations. Trap/catch and transport is a good option for initial testing of upstream fish passage.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Fish Access to Gull Lake (Keeyask reservoir) (3.2.1) (Continued)	Provide a nature-like channel through which fish could move to the reservoir.	Six alignments/designs for a nature-like channel were developed at a conceptual level. The best option was along the north bank of the Nelson River. This channel would provide habitat but there is difficulty in avoiding winterkills when flow is shut down.	*3.2.1.2*	Not recommended – issues with avoiding killing fish when flows in the channel are shut down for winter.
	Other method of upstream fish passage (*e.g.*, fish lift, fish ladder).	Experience with the trap/catch and transport program may indicate that other options for upstream passage are more suitable. An evaluation of other fish passage options will be conducted.	*3.2.1.4*	Recommended - address uncertainty with respect to the best option for upstream fish passage.
Reduction in Number of Fish Entering Stephens Lake from Upstream (3.2.2)	Incorporate measures to pass fish downstream safely via the turbines and spillway.	Design parameters for the turbines were selected in consideration of criteria that would reduce the incidence of injury and mortality. The spillway does not include features that are associated with increased fish mortality (*e.g.*, baffle blocks).	*3.2.2.2*	Recommended – will reduce mortality of fish moving past the GS and provide a means of downstream fish passage.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Reduction in Number of Fish Entering Stephens Lake from Upstream (3.2.2) (Continued)	Designed method of downstream fish passage.	Monitoring during the assessment of upstream passage may indicate that downstream passage is required.	*3.2.2.1*	Not recommended – post-Project monitoring may indicate that another form of downstream passage (in addition to via the turbines and spillway) is required.
	Stocking sturgeon in Stephens Lake to help increase the size of the overall population, which is currently low, and to compensate for reduced number of sturgeon that may emigrate from Gull Lake.	Stocking will increase the current small population in Stephens Lake and offset potential losses from a decrease in the number of sturgeon entering from upstream.	*3.2.2.3*	Recommended - stocking is viewed as a necessary component of the overall mitigation strategy for lake sturgeon downstream of the generating station.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Spawning Habitat at Gull Rapids (3.2.3)	The creation of spawning habitat downstream of the powerhouse.	This would provide lake sturgeon spawning habitat following development of the Project. The spawning structures would also provide habitat suitable for other fish species that spawn under similar conditions and habitat suitable for colonization by benthic invertebrates that inhabit high velocity, rocky habitats. This could then partially compensate for the loss of foraging habitat in Gull Rapids.	*3.2.3.1*	Recommended – the creation of spawning habitat downstream of the powerhouse in proximity to where it exists today has a high probability of success for lake sturgeon and could potentially be used by other species.
	The creation of spawning habitat downstream of the spillway by releasing flow through the spillway.	Lake sturgeon could use this habitat during years when spill operations satisfy flow requirements for successful spawning. Two options are available: providing a designated amount of spill annually; or, continuing to spill if spillway operation is initiated.	*3.2.3.2*	Not Recommended – due to high cost associated with required frequency and volume of flow except in instances where a spill is occurring anyway.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Spawning Habitat at Gull Rapids (3.2.3) (Continued)	The creation of a lake whitefish spawning reef further downstream towards Stephens Lake.	Lake whitefish spawn in Gull Rapids and in other locations of Stephens Lake. The creation of spawning reefs would replace habitat lost at Gull Rapids.	*3.2.3.5*	Recommended – this would compensate for habitat lost in Gull Rapids.
	Provide upstream fish passage.	Fish could be moved to suitable spawning habitat at the upper end of the reservoir, but given the size and depth of the lower Keeyask reservoir, it is unlikely that the progeny of these fish would contribute markedly to the Stephens Lake population.	*3.2.3.6*	Not recommended – upstream fish passage would not replace lost spawning habitat in Stephens Lake in terms of supporting the Stephens Lake population.
Loss of Fish Foraging Habitat at Gull Rapids and Loss of Fish Access to Gull Rapids Creek (3.2.4)	Construction of a stream/pool system along the south channel of Gull Rapids, including the provision of flow year-round from the reservoir.	Provides fish access from Stephens Lake to Gull Rapids Creek and also provide productive fish habitat over the approximate 1.5 km distance from the creek mouth to the permanently wetted area downstream of the dam and tailrace.	*3.2.4.1*	Not Recommended – other more promising opportunities are being evaluated.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Loss of Fish Foraging Habitat at Gull Rapids and Loss of Fish Access to Gull Rapids Creek (3.2.4) (Continued)	Construction of dams and weirs to maintain wetted habitat over a large portion of dewatered Gull Rapids. Year-round discharge from reservoir to Gull Rapids Creek would flow to the south side enhancement (SSE) area.	Provides fish foraging habitat at the south side of Gull Rapids and fish access to Gull Rapids Creek. The SSE would maintain forage habitat at Gull Rapids, would provide access to Gull Rapids Creek, and would enhance habitat within the creek itself.	*3.2.4.2*	Under review - whether or not this measure is implemented will depend on discussions with Fisheries and Oceans Canada and Manitoba Conservation and Water Stewardship in terms of the suitability for meeting compensation objectives.

Table 1A-7: Predicted impacts to fish habitat downstream of the Keeyask Generating Station, and proposed measures to mitigate or compensate for those impacts

Potential Effect (Report Section)	Mitigation Options	Biophysical and Socio-economic Considerations	Report Section	Probability of Inclusion after Biological Assessment
Silt Deposition over Lake Sturgeon Young-of-the-Year (YOY) Habitat in Stephens Lake (3.2.5)	Monitoring to determine habitat use post-Project and, if required, create suitable habitat.	Current assessment indicates that sediments will not deposit in the area thought to provide YOY rearing habitat in Stephens Lake.	*3.2.5.1*	Recommended
	Stocking of yearling sturgeon in Stephens Lake to help offset potential effects of a temporary reduction in rearing habitat.	See above.	*3.2.5.2*	Recommended – stocking is viewed as a necessary component of the overall mitigation strategy for lake sturgeon downstream of the generating station. Stocking will help mitigate losses to the Stephens Lake population.
Potential for Fish Stranding after Spillway Use (3.2.6)	Review how and where the water is flowing after the spillway is in use. Connect different channels so that fish can escape into Stephens Lake.	Necessary to avoid fish mortality.	*3.2.6*	Recommended – required to avoid death of fish due to stranding.

Table 1A-8: Biological design criteria for nature-like bypass channel for lake sturgeon

Parameter	Design Criteria
Width	Min = 5 m Max = 10 m
Depth	Min = 1 m The greater the depth, the more willing sturgeon will be to use it. A longer channel may require greater depth for cover to be effective.
Slope	Max = 1:30 Many existing channels are between 1:50 and 1:75.
Average Velocity	Min = 0.4 m/s Max = 0.6 m/s May be a problem for juvenile sturgeon if there are no refugia.
Maximum Length of Localized Areas of Increased Velocity	Min = 5 m at 1.5 m/s Max = 20 m at 1 m/s Water velocity should not exceed 1.5 m/s
Discharge	Will be a function of the area, depth, and velocity.
Attraction Flow	2% of river flow
Attraction Velocity	Min = 0.6 m/s Max = 0.9 m/s
Entrance	Max = 7.5° slope Continuous with bottom of river.

Table 1A-9: Biological design criteria for lake sturgeon spawning habitat creation below the Keeyask tailrace

Parameter	Design Criteria	Additional Considerations
Velocity	Min = 0.5 m/s Max = 1.5 m/s Velocities referenced to 0.6 of depth from surface.	A range of velocities should be available over the constructed habitat.
Flow	Flow should remain relatively constant during the spawning and incubation period. Flows should be less turbulent on the spawning area.	Flow should be less turbulent downstream of the site, transitioning to more turbulent at the site.
Depth	Min = 1 m Max = 10 m Pre-construction depth of 2 m–11 m required for materials placement.	A range of depths should be available over the constructed habitat.
Substrate	Minimum 10 cm diameter Maximum 60 cm diameter Size distribution: 100% <0.6 m, 75% <0.4m, 50% <0.2 m and 25% <0.15m.	Important that there be ample interstitial space for egg incubation and larval development. Minimum thickness of 0.6 m.
Micro-habitats	65 boulder clusters (three boulders >0.9 m) will be interspersed over the spawning habitat.	Provide refuge and create turbulence.
Size of Spawning Area	A total area of 3.0 ha is recommended.	Could be made up of several areas of no less than 0.5 ha that meet hydraulic criteria.
Location	As close as possible to the north shore of the river while satisfying hydraulic criteria.	
Critical Annual Period	Mid-May to mid-July.	Discharge would be managed during this period to satisfy velocity and depth criteria.

Table 1A-10: Biological design criteria for the construction of lake whitefish spawning habitat in Stephens Lake

Parameter	Design Criteria	Additional Considerations
Substrate	A mix of coarse materials as follows: 25% boulder (750–500 mm); 35% cobble (256–64 mm); 25% large gravel (64–32 mm); and 15% small gravel (32–8 mm).	Substrate layer should have minimum thickness of 0.75 m, and substrate material should be free of silt and clay. Important that there be ample interstitial space for egg incubation and larval development.
Velocity over Spawning Habitat	Minimum = 0.2 m/s Maximum = 1.0 m/s at 0.6 of depth (depth averaged) If water velocity is less than 0.2 m/s, then location requires wave generated circulation (*i.e.*, exposure to northeast – northwest winds).	
Depth	Crest of spawning shoal: 1.5–2.5 m below minimum operating level (MOL).	Lake whitefish eggs incubate over winter; eggs deposited at depths less than 1.5 m below MOL will be vulnerable to freezing at maximum ice thickness.
Size of Spawning Area	Minimum crest area at preferred depth should not be less than 1000 m^2.	Shape of shoal should maximize surface area (longer and rectangular as opposed to round or square).
Slope	Slope of spawning area should not exceed 10%.	
Location	Select areas where mineral substrate is present or areas adjacent to bedrock, Where placement occurs over organic substrates, gabion basket wire should be laid over the bottom prior to placement.	At standing water sites orient shoals to maximize exposure to wave action.
Critical Annual Period	Late October to late April.	

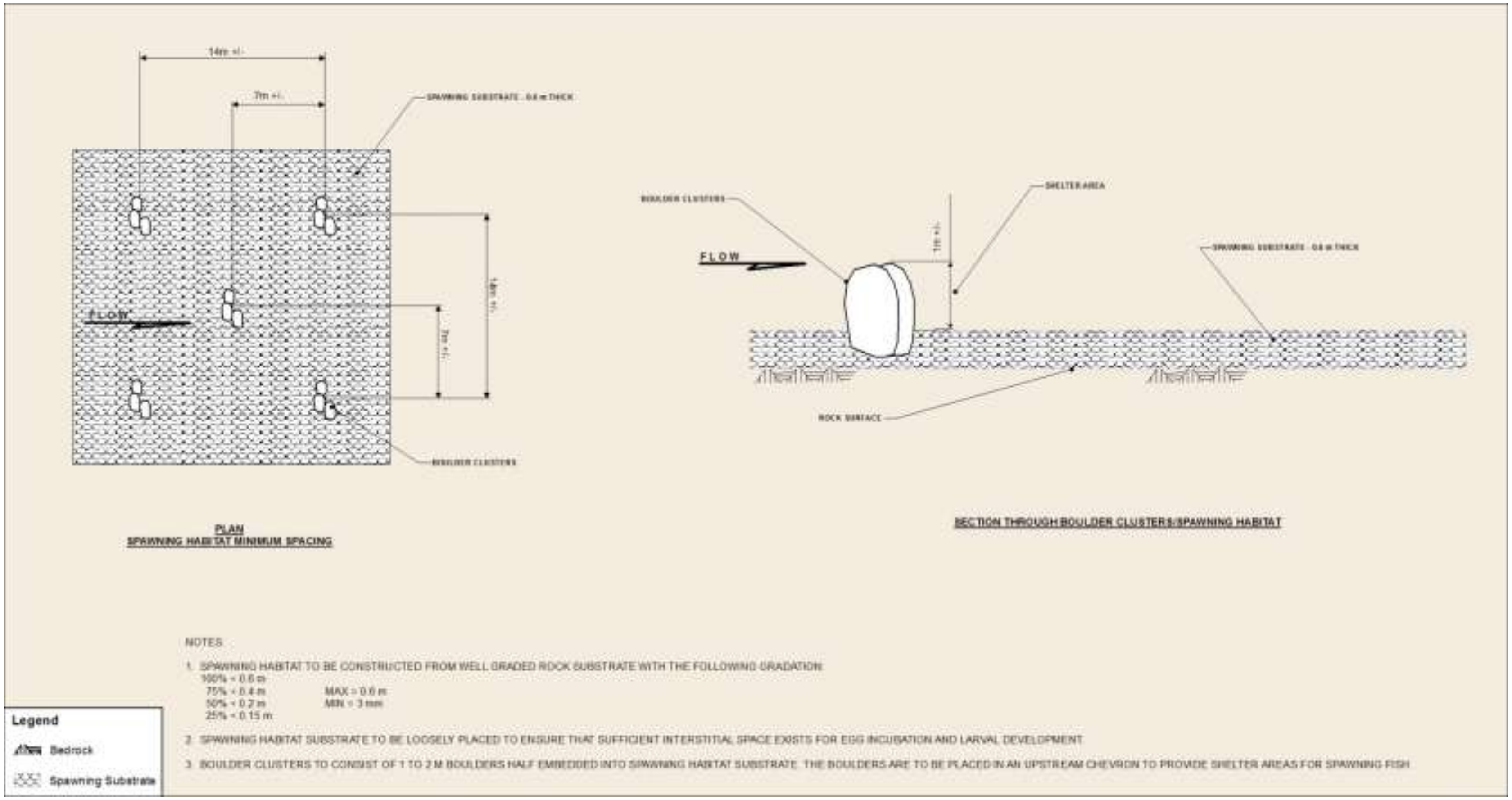


Figure 1A-1: Spawning habitat details showing the arrangement and spacing of boulder clusters

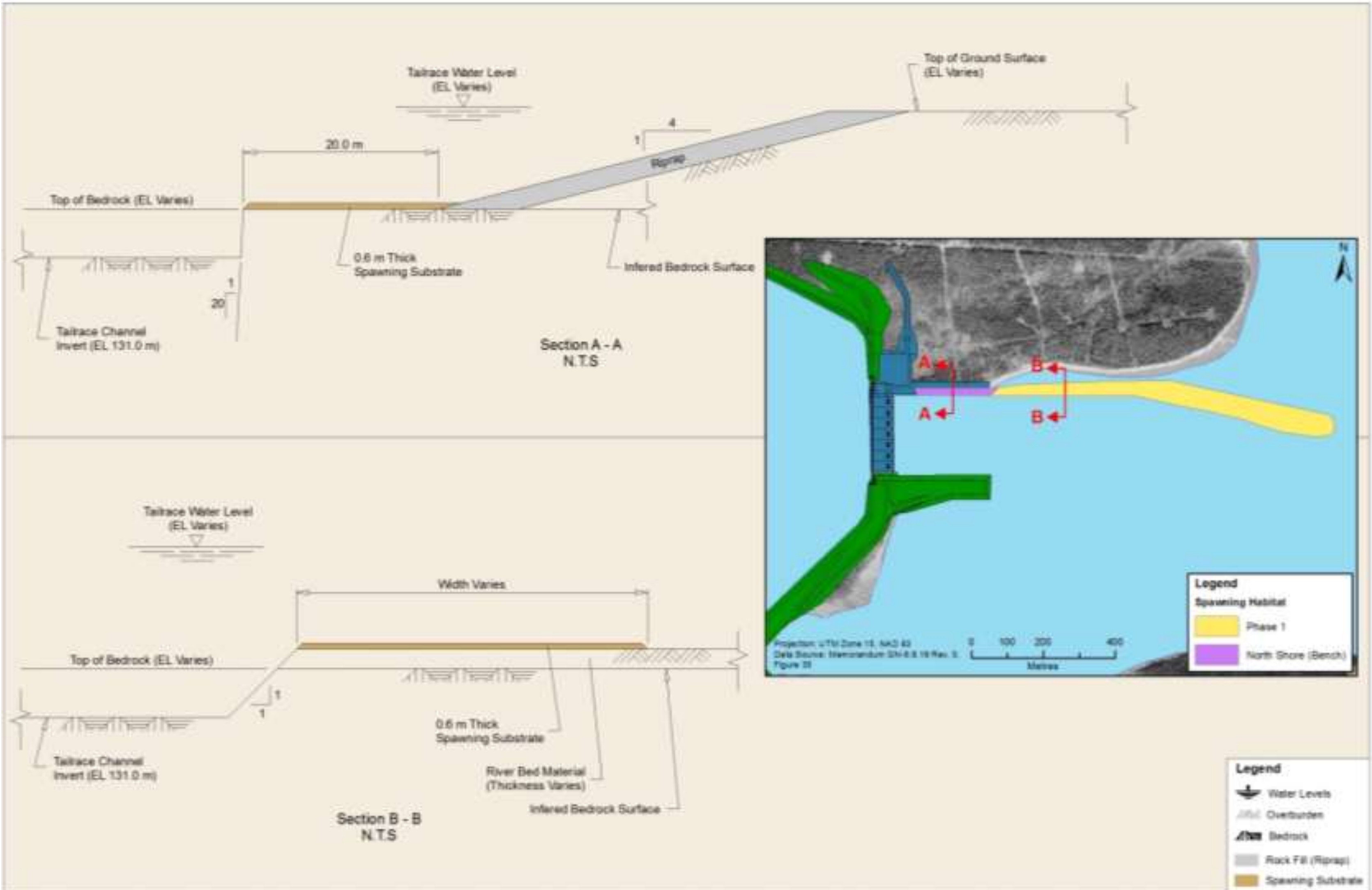


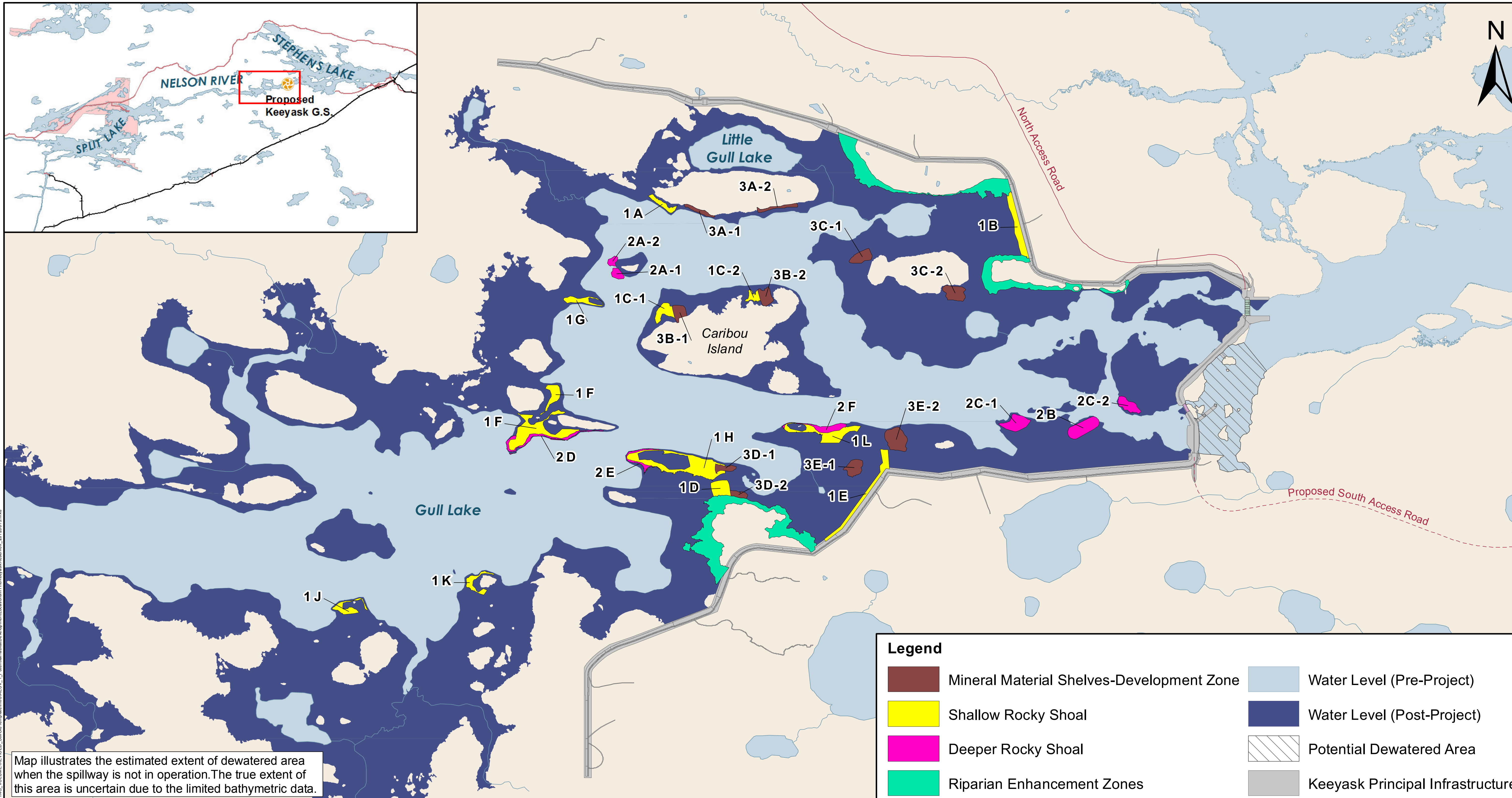
Figure 1A-2: Cross sections of modifications to north bank of tailrace channel to create sturgeon spawning habitat

KEEYASK
Hydropower Limited Partnership

0	2.5	5	7.5	10 Kilometres
0	1.25	2.5	3.75	5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Shows 95th percentile inflow.

Clark Lake to Stephens Lake
Existing Environment

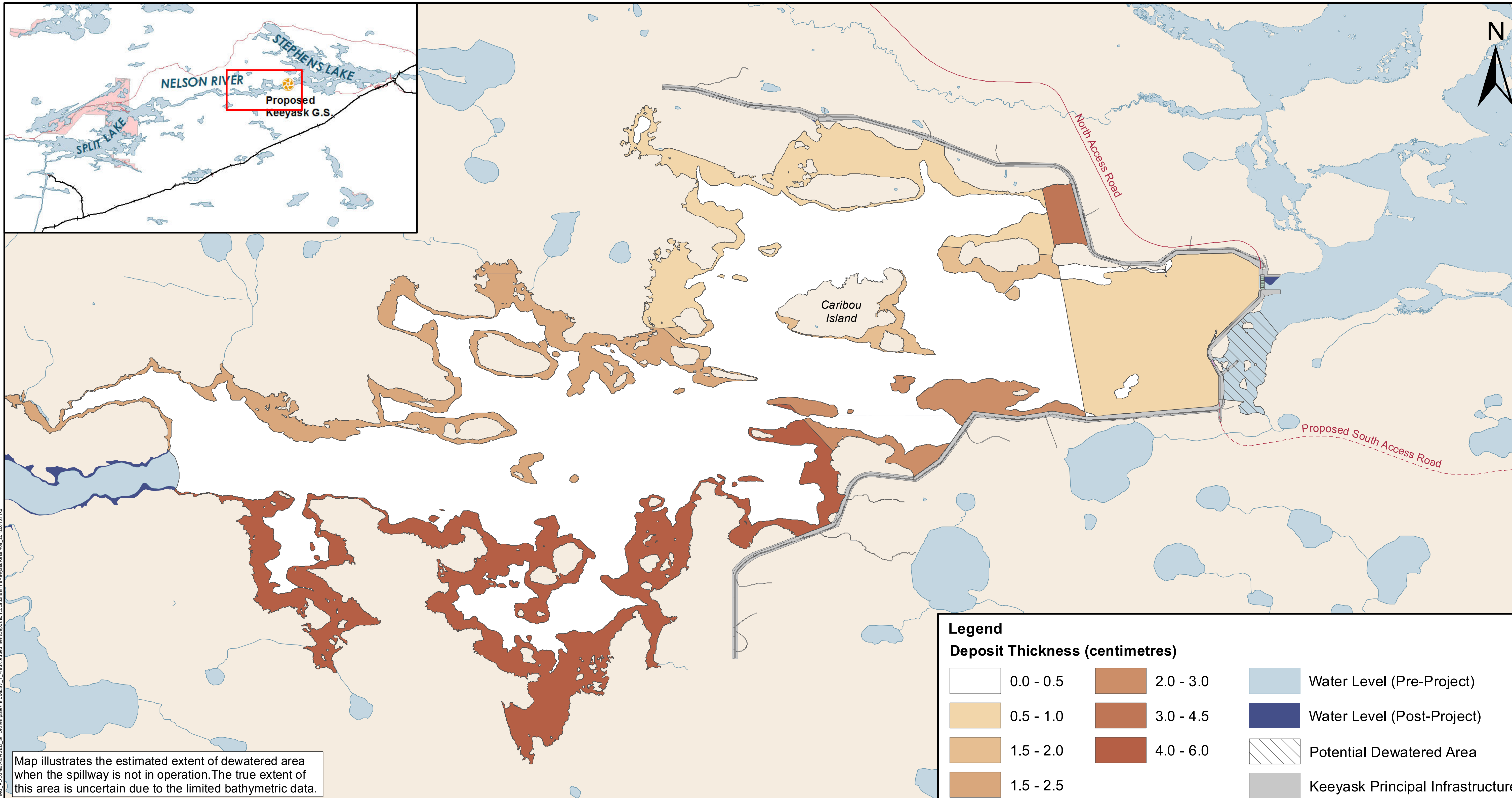


0 1 2 3 4 Kilometres
0 0.5 1 1.5 2 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Potential Habitat Development Locations in the Keeyask Reservoir

Map 1A-2



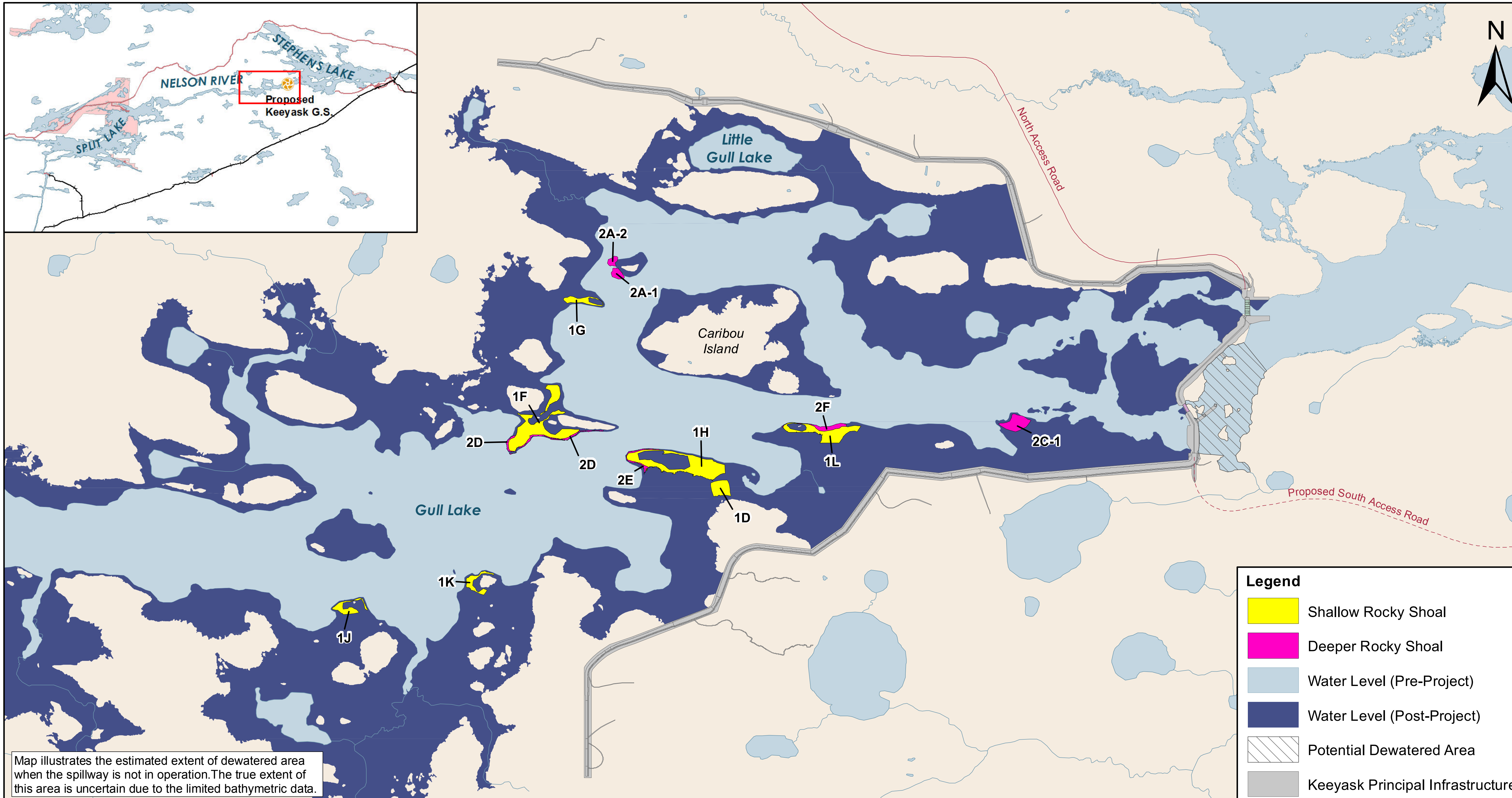
KEEYASK Hydropower Limited Partnership

0 1 2 3 4 5 Kilometres
0 1 2 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Predicted Sediment Deposition Locations in the Keeyask Reservoir

Year 1 Post-Impoundment



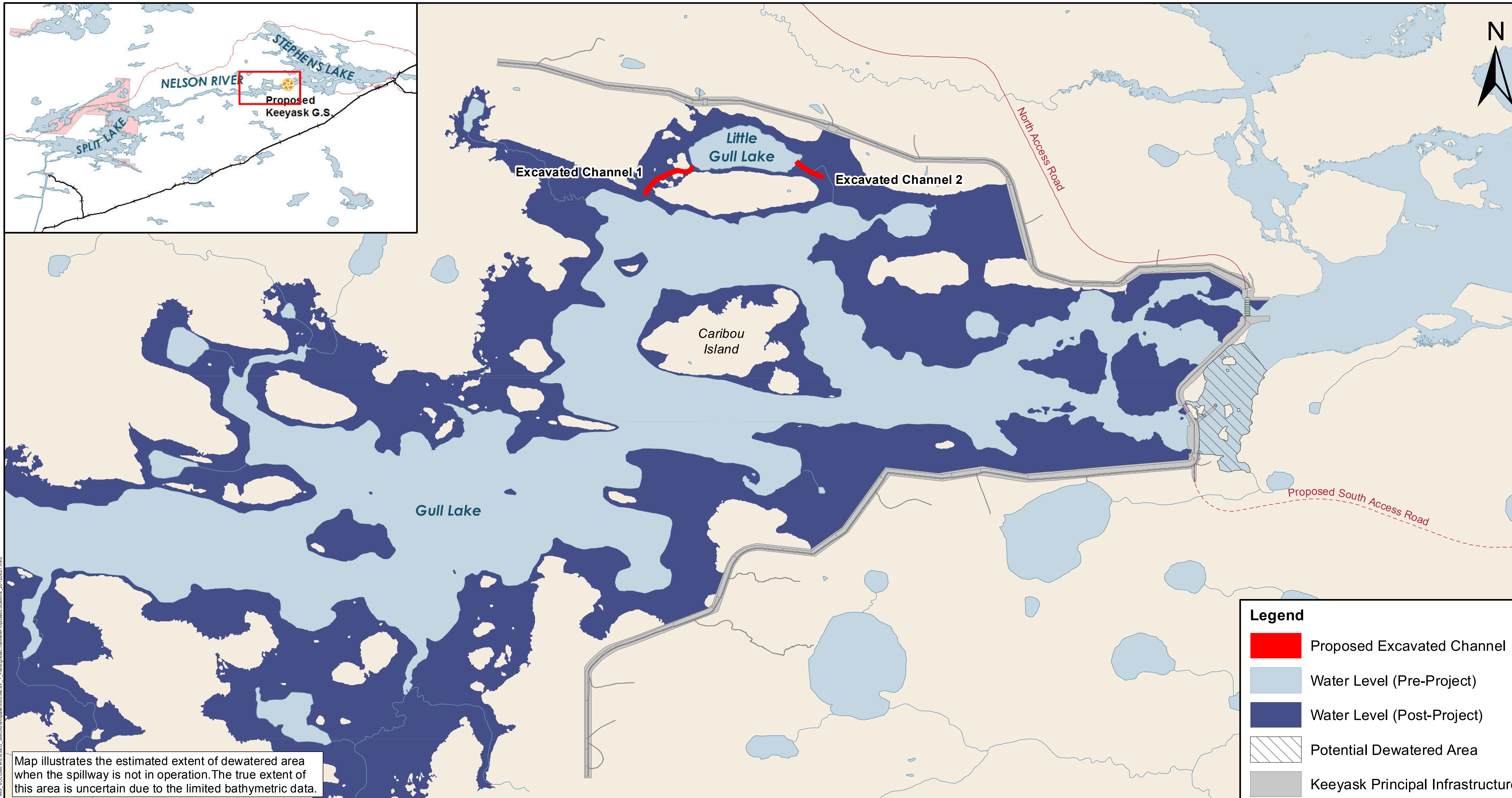
KEEYASK Hydropower Limited Partnership

0 1 2 3 4 Kilometres
0 0.5 1 1.5 2 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Preferred Habitat Development Locations in the Keeyask Reservoir

Map 1A-4

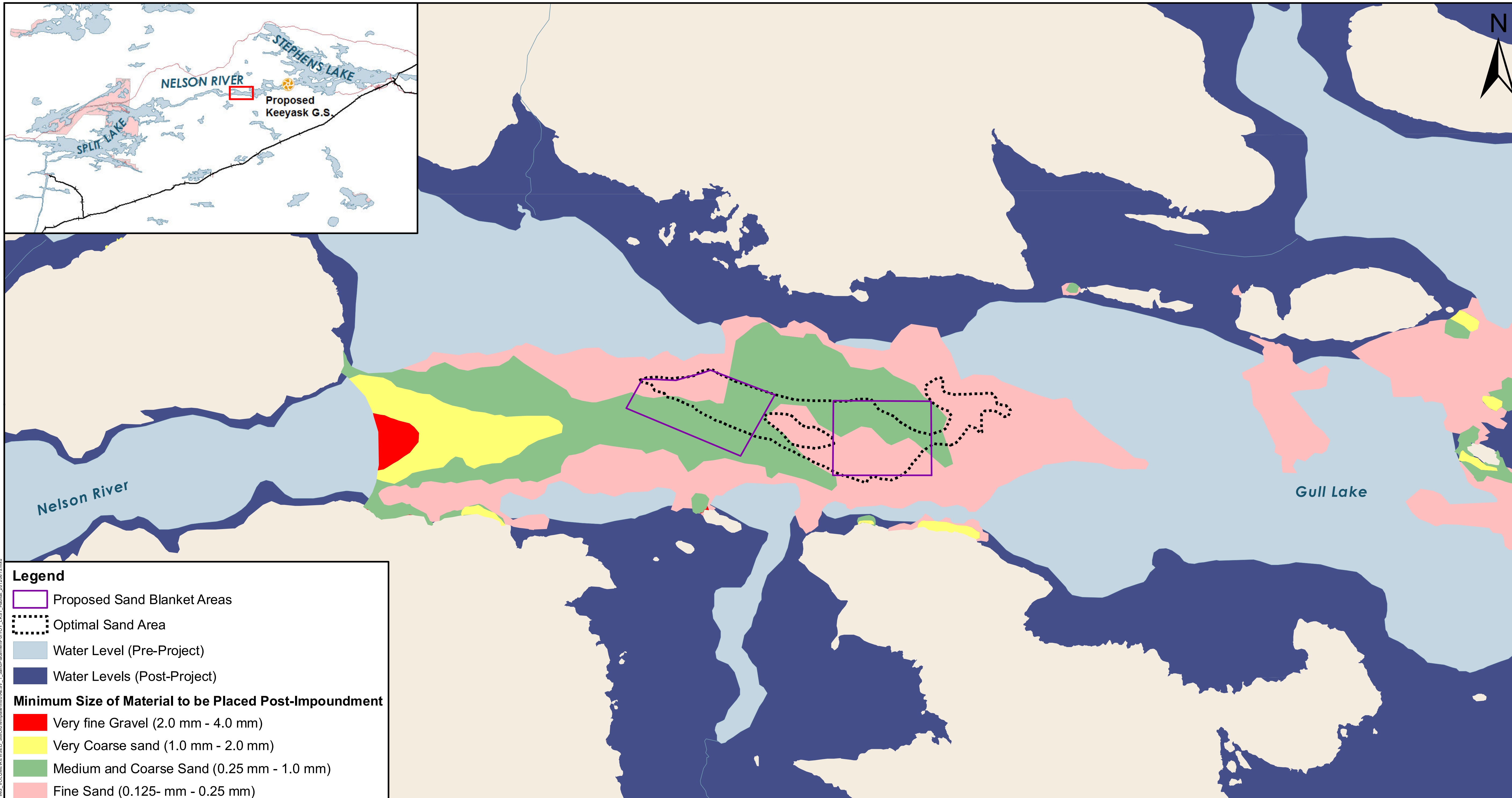


KEEYASK Hydropower Limited Partnership

0 1 2 3 4 Kilometres
0 0.5 1 1.5 2 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Fish Egress Channels - Proposed Locations



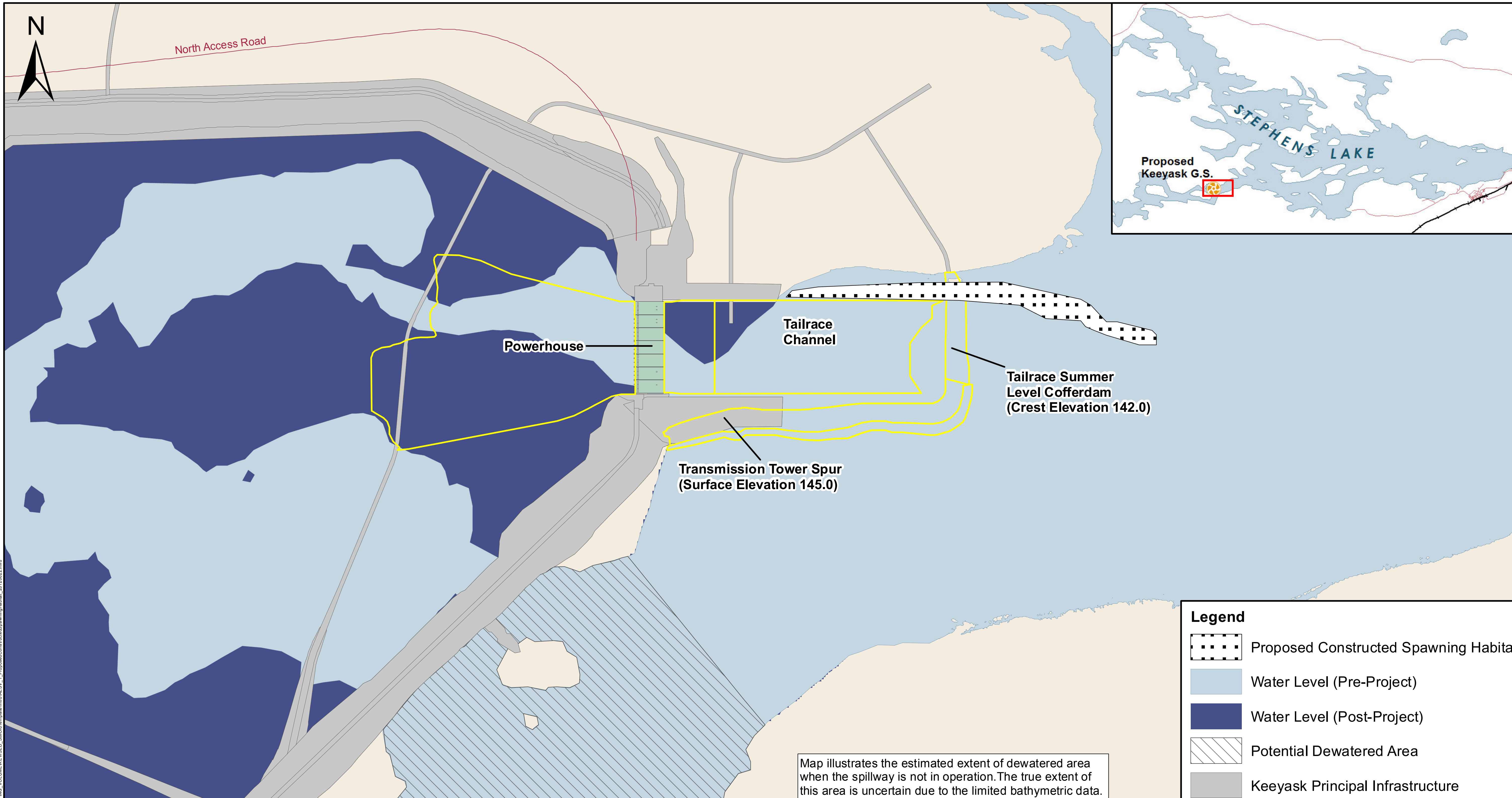
KEEYASK
Hydropower Limited Partnership

0 0.5 1 1.5 Kilometres
0 0.5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Sand Placement Locations for Young-of-the-Year Lake Sturgeon Habitat

Map 1A-6



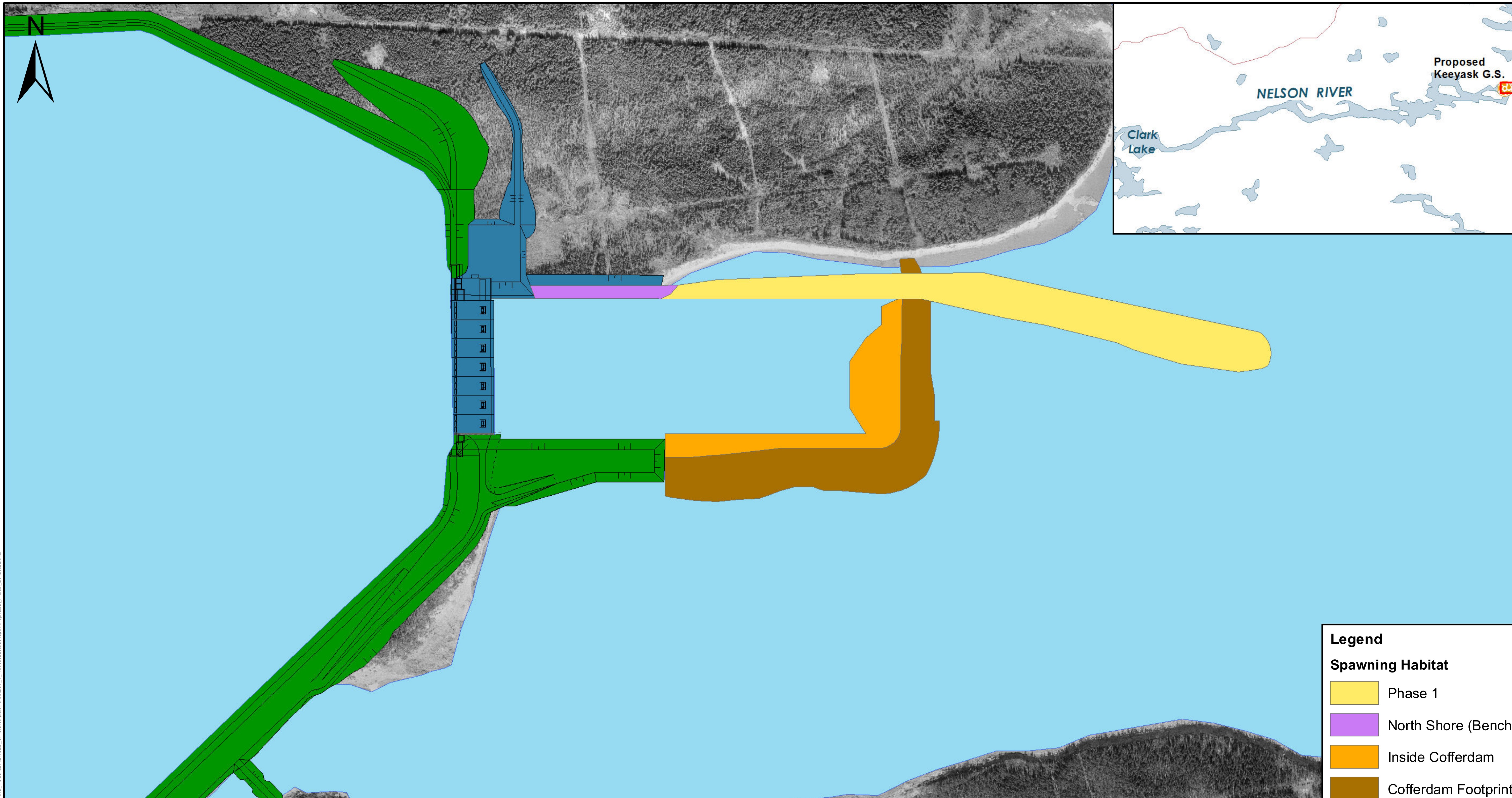
KEEYASK
Hydropower Limited Partnership

0 250 500 Metres
0 500 1,000 Feet

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Proposed Constructed Spawning Habitat
Initial Concept

Map 1A-7



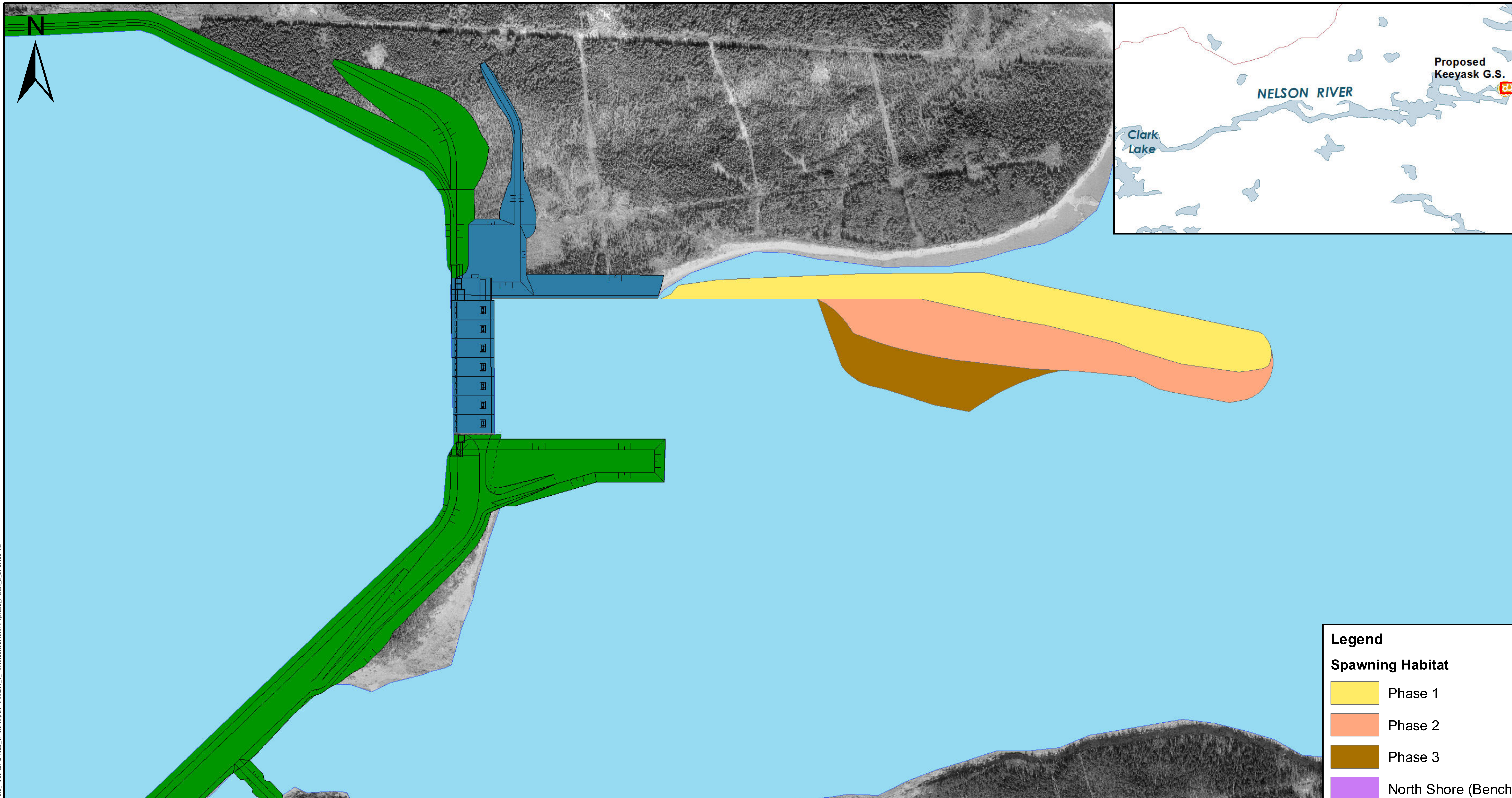
KEEYASK
Hydropower Limited Partnership

0 100 200 300 400 Metres
0 250 500 750 1,000 Feet

Projection: UTM Zone 15, NAD 83
Data Source: Memorandum GN-9.8.18 Rev. 0, Figure 26

Proposed Location of Spawning Habitat
Phase I

Map 1A-8A

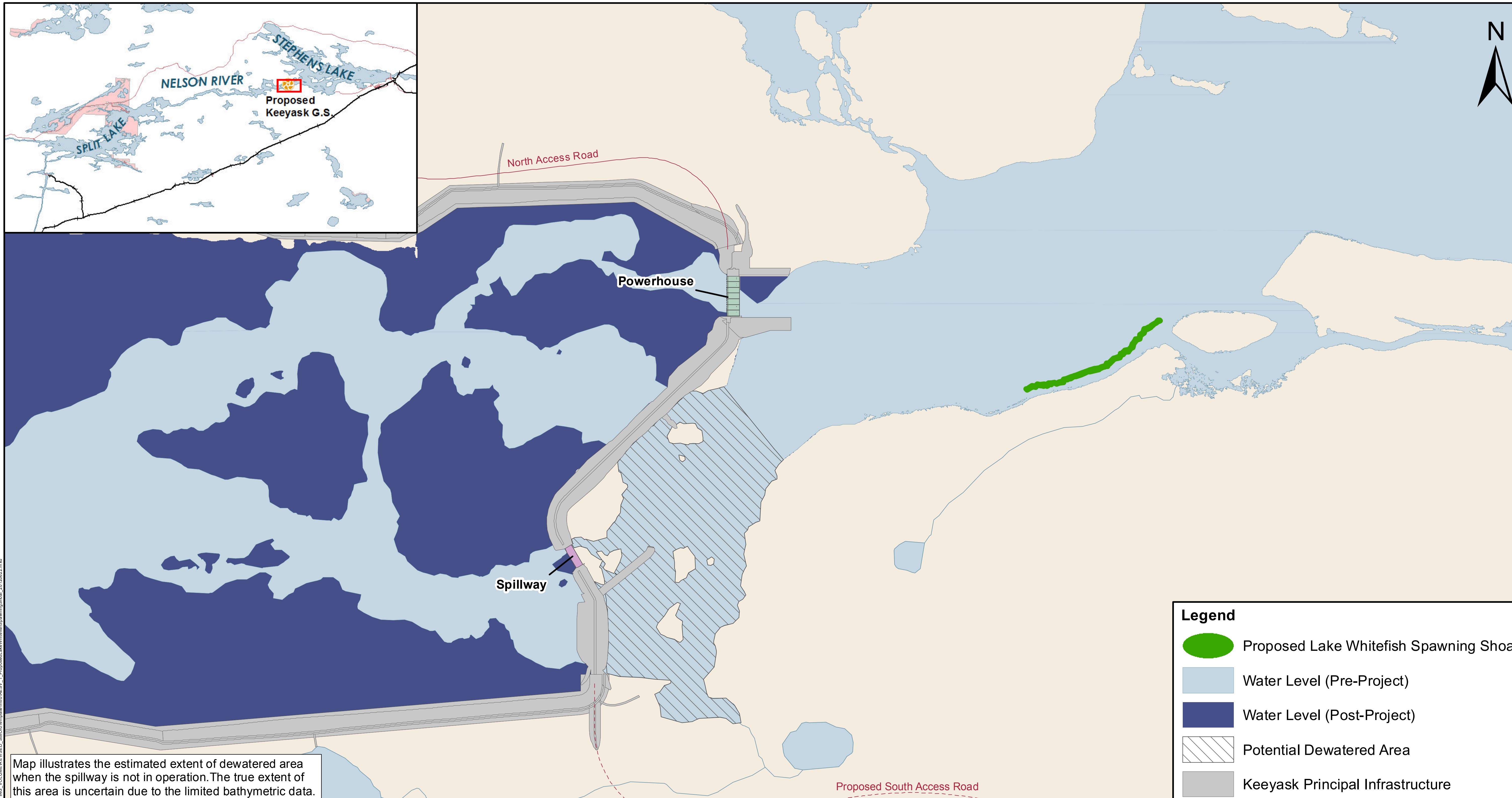


0 100 200 300 400 Metres

0 250 500 750 1,000 Feet

Projection: UTM Zone 15, NAD 83
Data Source: Memorandum GN-9.8.18 Rev. 0, Figure 30

Proposed Locations of Spawning Habitat
Phase II and III

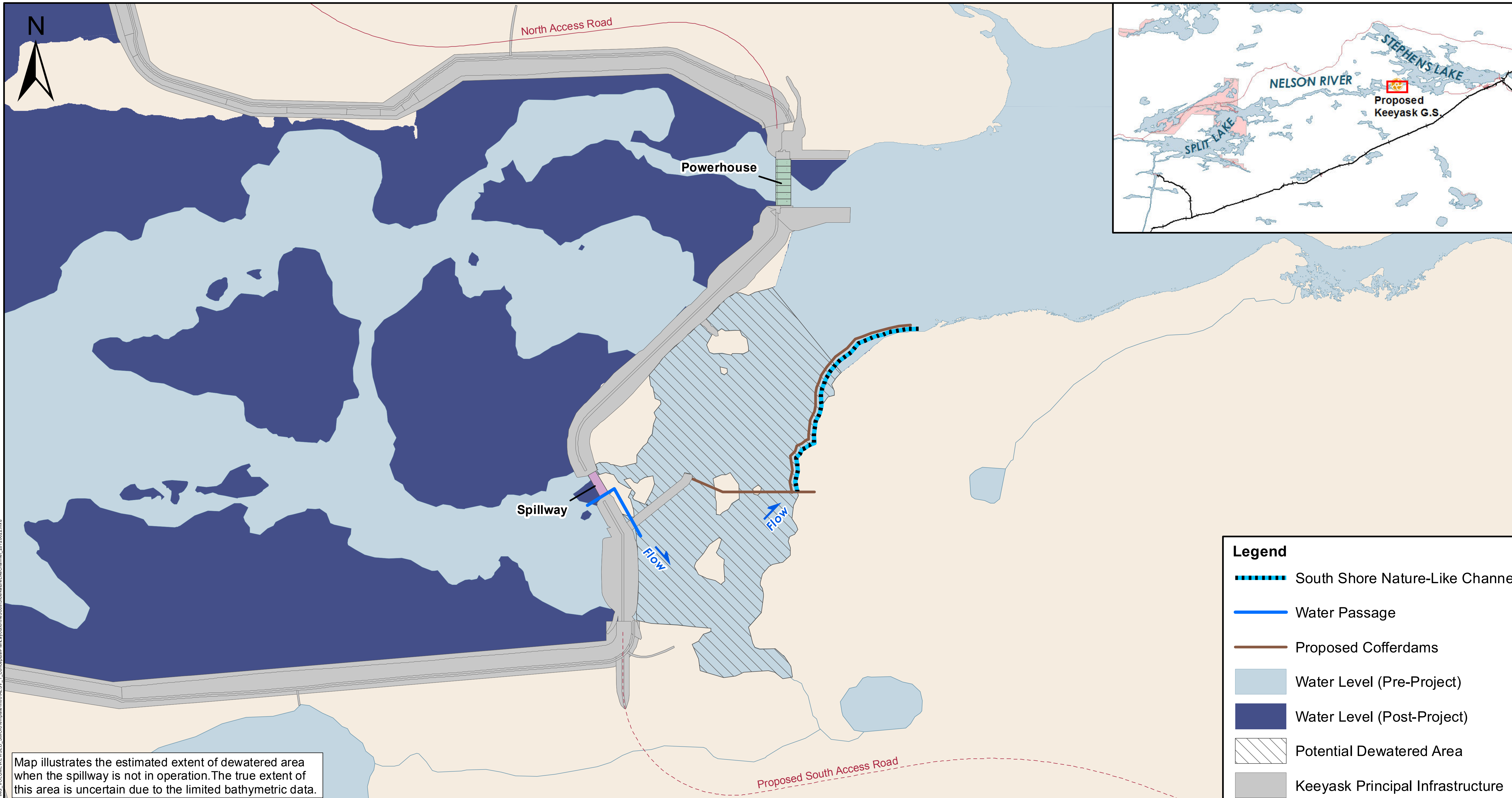


KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Proposed Lake Whitefish Spawning Shoal

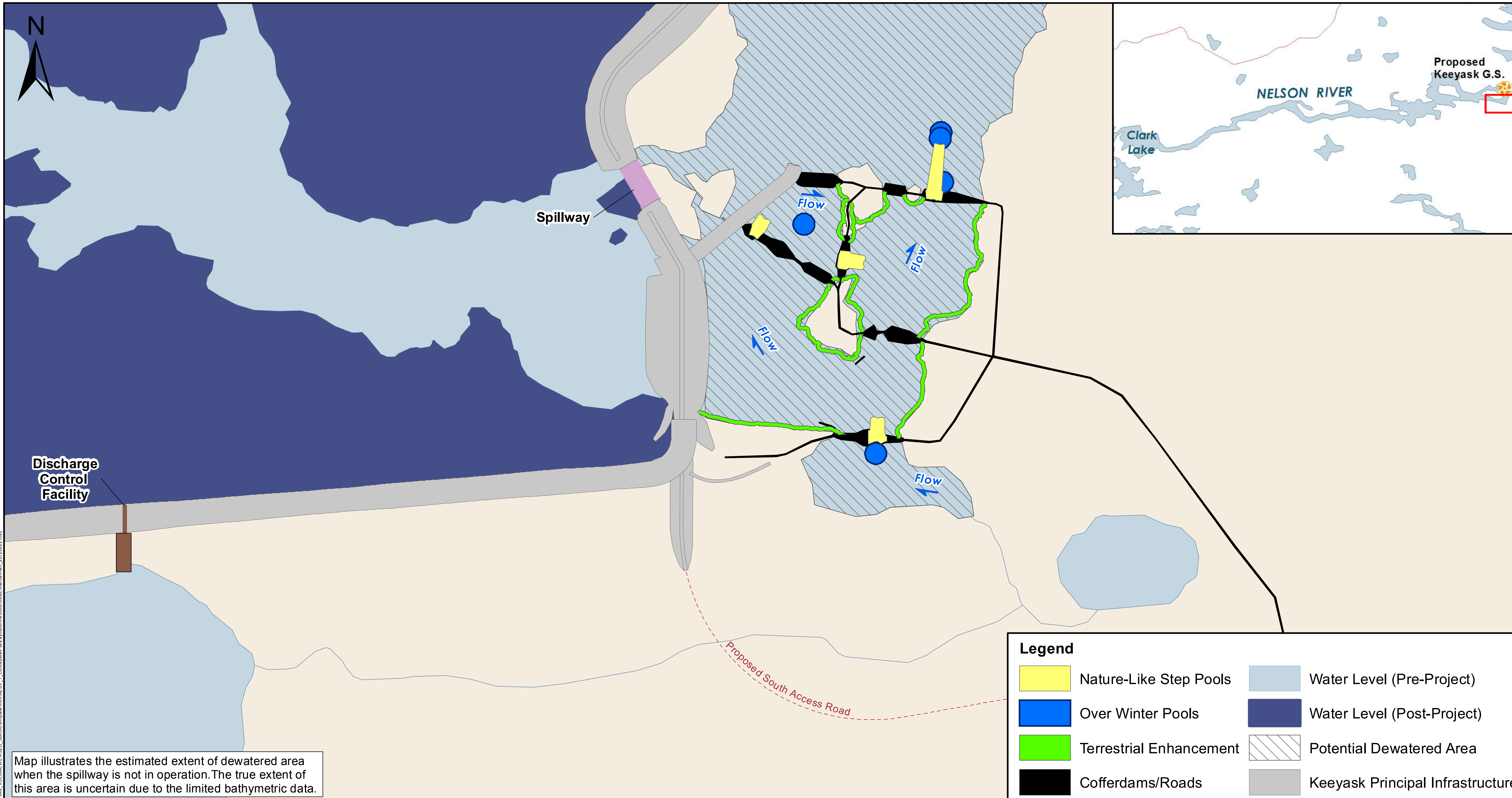
Map 1A-9



0 0.5 1 Kilometres
0 0.5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Conceptual Plan Layout for the South Side Nature-Like Channel



KEEYASK Hydropower Limited Partnership

0 250 500 750 Metres
0 750 1,500 Feet

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Preliminary Conceptual Plan Layout for the South Side Enhancement

ATTACHMENT 1: REFERENCE DOCUMENT FOR KEEYASK EIS: PARAMETERS CONSIDERED IN THE SELECTION AND DEVELOPMENT OF TURBINES FOR KEEYASK GS TO INCREASE FISH PASSAGE SURVIVAL

Manitoba Hydro Interoffice Memorandum

Prepared by: Marilynn Kullman, Environmental Specialist, Fisheries & Stewardship Environmental Licensing & Protection Power Planning Power Supply

Prepared for: Marc St. Laurent, Section Head, Keeyask/Burntwood Planning Hydro Power Planning Power Project Development Power Supply

Date: 2012 04 25

Introduction

The Keeyask GS turbines are the first turbines for which Manitoba Hydro has considered a number of variables affecting fish passage survival in the selection and development processes. Although there are many variables to consider beyond those specifically relevant for fish survival (particularly efficiency and cost), a general objective for the Keeyask GS turbine selection and development is to achieve a minimum survival rate of 90% for fish as large as 500 mm. The following principal features were considered in the selection and will also be considered in the further development of the turbine design: number of blades; thickness and shape of leading and trailing edge of blades: turbine rotation rate; turbine runner diameter and blade speed (impact velocity): stay vane and wicket gate number, alignment and shape, clearance at wicket gates, wicket gate overhang, and low absolute pressure (nadir).

Stay Vane/Wicket Number, Alignment, and Shape

The number and shape of both the stay vanes and wicket gates can affect the condition of fish when they encounter these flow directing structures just upstream of the turbine runner. Additionally, the alignment and distance between the stay vane and wicket gate may also affect the condition of fish that contact the upstream edge and/or pass between these structures. The primary cause of injuries would be due to direct contact, and possible shear forces between the trailing edge of a stay vane and leading edge of a wicket gate. Generally direct contact should inflict only minimal injuries at strike velocities of less than 6.1 m/s (Bell 1991). Few direct survival/injuries studies have been designed to evaluate the condition of fish after encountering the stay vanes and wicket gates. Normandeau et al. (1999) did obtain survival/injury on HI-Z tagged juvenile salmon (average length 154 mm) that were released from three pipes mounted on stay vanes and another pipe mounted 5.5 m directly upstream of the stay vane. The percentage of recaptured fish alive 48 h after turbine passage at the McNary Project (Tables 1 and 2) for fish that potentially encountered the stay vanes/wicket gates (92.4%) was similar to the fish that were released downstream of the stay vanes/wicket gates (90.9–92.7%). Injury rates were actually slightly less for fish that potentially encountered the stay vanes/wicket gates; 3% versus 3.8–5.1% for fish released downstream of the stay vanes/wicket gates.

The turbine selected for Keeyask GS has wicket gates with rounded upstream edges which will minimize direct contact injuries. The extended length and profile design of the stay vanes of the selected turbine design improves the flow conditions in the vicinity of the stay vanes and wicket gates, which reduces turbulence and flow separation. These features should improve passage conditions for fish, particularly through the minimization of the shear and turbulent zones that can injure and disorient fish.

Clearance at Wicket Gates and Runner

Minimizing gaps at the wicket is beneficial for fish, particularly if water accelerates sufficiently enough through these openings to cause shear and/or strike induced injuries to entrained fish. The primary gap areas of potential entrainment are between the trailing edge of the stay vanes and leading edges of the downstream wicket gates; between the top of a wicket gate and the head cover; and between the bottom of the wicket gates and the bottom ring. Laboratory studies on juvenile salmon indicate that shear induced injuries generally begin to occur when areas of contrasting flows produce strain rates >900 cm/s/cm (Neitzel *et al.* 2000); while direct contacts begin to elicit injuries at ≥6.1 m/s (Bell 1991).

The gaps at the bottom and top of the wicket gates of the selected turbine design have been sufficiently minimized to eliminate the chance of fish (except possibly larval fish) being drawn into these areas that have a higher risk of injury/mortality. Gaps between the runner and discharge ring, and the runner and head cover are also sufficiently small in the selected turbine design to minimize the risk of fish being drawn into these areas where they could incur injuries.

Wicket Gate Overhang

The lower edge of a wicket gate guide vane typically over hangs the bottom ring for most conventional turbine designs, depending on turbine load. Depending on the extent of this overhang a zone of turbulent flow can set up downstream of this protrusion point. Each turbulent zone is generally not very extensive but under certain wicket gate openings a turbulent zone can develop at the bottom trailing edge of each wicket gate.

The turbine design selected for Keeyask GS has minimized or eliminated (depending on load) the wicket gate overhang, such that the development of turbulent zones at the trailing edge of the wicket gates is avoided.

Number of Blades

Strike inflicted injuries due to blade contact are the dominant injuries observed in most direct survival/injury studies conducted using HI-Z tag fish recapture method. Therefore, minimizing the number of blades will likely have the greatest effect on reducing fish injury and mortality. Blade number minimization is most beneficial for larger fish, at propeller type turbines, provided good flow characteristics can be maintained through the turbine blades. Examination of the survival/injury results from HI-Z tag turbine passage evaluations conducted on large size turbines (6–8 m diameter) similar to those proposed for Keeyask GS indicate that five-bladed units generally had higher survival (median of 96.2%) and lower injury rates (median of 2.1%) than six-bladed units (medians of 94.8% and 3.6 %, respectively) for juvenile fish (114–184 mm mean length range, Table 2). The trend for higher survival and lower injury rates for turbines with fewer blades persisted whether the turbine had fish friendly features or not. The best example of this was an extensive study (more than 8,000 fish) conducted at Wanapum Dam to evaluate a conventional Kaplan turbine and a new advanced hydro turbine system (AHTS) (Dresser *et al.* 2006 a, b; Normandeau *et al.* 2006; and Table 2). The AHTS had many fish friendly features including, minimal gaps at the hub and blade tip, alignment of stay vanes and wicket gates and minimized wicket gate overhang; however, the AHTS had six blades versus five for the conventional Kaplan Unit. Fish directed towards the hub had slightly higher survival rate for the AHTS (98.5 %) compared to the conventional Kaplan unit (97.9%); however, fish directed towards the mid blade had a higher survival rate at the conventional turbine (97.1%) compared to the AHTS (95.4%).The same trend was observed when recaptured fish were examined for injuries with fewer hub directed fish injured at the AHTS (0.9%) than the conventional Kaplan unit (1.8%) but the opposite for mid blade directed fish (3.3% for AHTS, 2.5% for conventional).

The effects of the number of blades at large units is more pronounced for larger fish (Table 2). This is based on four HI-Z tag fish recapture studies conducted on adult eels (690–1,020 mm), two studies on adult northern pike (595–661 mm), adult walleye (431–447 mm), and adult American shad (423–425 mm) (Table 2) Average survival of the eels decreased with increasing blade number and was 92.4 and 93.0% for the four bladed units, but only 79.9% and 73.5% for five and six bladed units respectively. The corresponding injury rate also increased (6.536.7 %) with an increase in blade number. The average survival of adult northern pike and adult walleye was higher in a five bladed unit (75.6% and 87.7%, respectively) compared to a six bladed unit (65.9% and 80.4%, respectively). Survival of adult American shad passed through a five bladed Kaplan unit was higher (88.2%) than for adult American shad passed through a seven bladed mixed flow unit (84.3%).

The turbine design selected for Keeyask GS has five blades. The selection of a turbine design with a low number of blades will significantly improve the survival of fish and reduce injuries.

Blade Leading Edge Thickness

The shape, thickness, and speed of the leading edge of the turbine blades can affect both survival and injury rate of fish that make direct contact. Generally, the risk of blunt force injury and/or lacerations is reduced with a thicker and rounder leading edge and a slower blade speed. However, a blade leading edge that is too thick can reduce turbine efficiency. The size of the fish, its orientation to the blade and area of the body that makes blade contact affect the extent, type, severity of injuries. Laboratory studies conducted by Amaral *et al.* (2008, 2011) evaluated the effects of fish species, length, and orientation and blade impact speed, and blade thickness on fish mortality. Blade speed and fish length to the thickness of the leading edge of the blade were the primary factors affecting survival of fish encountering the upstream edge of a turbine blade. The length of the fish to the thickness of the leading edge of the blade was designated as L/t.

Empirical field data collected on HI-Z tagged adult walleye and northern pike also demonstrate the effects of narrow leading edge blades on rate and type of fish injuries. North/South Consultants and Normandeau Associates (2009) reported that survival rates were higher for a five bladed unit than for a six bladed unit for both walleye (87.7% and 80.4%, respectively) and northern pike (75.6% versus 65.9%) at the Kelsey Generating Station in Manitoba. However, the rate of injured fish did not show a corresponding decrease (Table 2). The percentage of injured walleye did not decrease with the decrease in blade number and were close to 32% for both the five and six bladed units. The corresponding injury rate for the northern pike was higher for the five bladed unit (61.7%) than the six bladed unit (53.4%). The lack of a decrease in injury rate with a decrease in blade number was attributed to the considerably thinner (sharper) leading blade edge design of the five bladed turbine (Figure 1). Some injured specimens from the five bladed unit also displayed a patch of scales and skin removed from the side of a fish with a distinct line where the fish was initially struck (Figure 2). Specific information on leading edge blade thickness and shape is not readily available for most of the HI-Z tag studies conducted on smaller fish (<200 mm) presented in Table 2.

The selected turbine design allows for an option to increase the thickness of the leading edge blade, and this will be examined and evaluated in the further development of the turbine design, to reduce the risk of injury and mortality of fish due to contact with the blade.

Blade Trailing Edge

The impact of the shape and thickness of the trailing edge of a turbine blade on fish injury has not been extensively evaluated, but eliminating turbulence and wake at the blade's trailing edge is beneficial for both turbine performance and fish that pass close to the trailing edge of a blade.

Without completing extensive testing (that would require working models), it is difficult to estimate whether the blade trailing edge of the selected turbine design would produce minimal or no turbulence zones. In the further development of the turbine design, Manitoba Hydro will strive to reduce turbulence and wake at the blade trailing edge (both for benefit to fish, and for turbine performance). Rounding the edges may also be considered, to reduce the effect of fish directly contacting the trailing edge of the blade.

Rotation Rate, Runner Diameter and Blade Speed

Higher rotation rates of turbine runners can affect the survival of fish by increasing the probability of fish contacting a blade and also increasing the speed at which the leading blade edge could contact a fish. Rotation rate is influenced greatly by runner diameter, with larger units generally having slower rotation rates. If runners are of similar size with the same number of blades, a higher rotation rate would likely make the unit less fish friendly. The large turbine runners (6-8 m diameter) where HI-Z tag tests have been conducted had rotation rates ranging from75–120 rpm (Table 2). Because of the interaction of number of blades, runner diameter, operating head and other factors the direct effects of rpm on fish survival/injury was not always obvious. Juvenile salmon passed through Bonneville turbines with the slowest rpm (75) did have some of the higher survival rates, at 98 and 99% for hub passed fish; however these units also had five blades and a relatively low head (17.4 m). Survival rates for juvenile salmon were lower (all ≤96.1%) at the higher 90 rpm units (Ice Harbor, John Day, Lower Granite, and Rocky Reach); however, these were also all six bladed units and had a higher head (close to 30 m).

The detrimental effects of higher rotational rate (300 rpm), higher head (55 m) and numerous blades (13) was demonstrated at a HI-Z tag test conducted at the Arrowrock Station (Normandeau Associates 2011). Survival of smaller (mean length of 284 mm) and larger (mean length of 457 mm) salmon was only 11.1% and 0.0%, respectively. The unit tested was a Francis type turbine and was also quite small (1.7 m diameter).

The design selected for Keeyask GS is a large diameter turbine runner, with a slower rotation rate (75 rpm), and a low number of blades (five). Based on these parameters, the survival of fish will be very good, particularly when compared to turbines with higher rotation rates and a higher number of blades.

Low Absolute Pressure (Nadir)

Fish passing through a turbine experience pressure changes over a short period of time. In a conventional hydroelectric facility pressure increases as a fish descends to the upstream side of the runner, drops rapidly upon passing the runner, increases in the draft tube, and then returns to near atmospheric pressure at the surface of the tailrace, or greater pressures if the fish swims to deeper water (Figure 3). Low absolute pressure that a fish may experience upon passing the turbine runner can cause decompression injuries (barotraumas) to fish that are acclimated to different depths prior to turbine entrainment. The lowest pressure a fish encounters (nadir pressure), and the depth to which it is acclimated appear to be the primary factors affecting mortality (Figure 4) and the rate, severity, and type of injury. Injuries associated with sudden decompression trauma include ruptured air bladder, ruptured blood vessels, air bubbles in the internal organs and in fins. Many of these injuries result in death. Among fish with swim bladders, the response to rapid pressure changes encountered within a turbine is affected by whether the fish is physostomous or physoclistous. Physostomous fish (*e.g.*, salmon, eels, shad, sturgeon, whitefish and catfish) have a pneumatic duct that connects the swim bladder with the esophagus. Gas can be quickly taken into or vented from the swim bladder through the mouth and pneumatic duct, so that adjustment to changing water pressures can take place rapidly, often on the order of seconds. Physoclistous fish (*e.g.,* sunfishes, basses, perch and walleye) lack a direct connection between the swim bladder and the esophagus. In these fish the contents and pressures within the swim bladder must be adjusted by diffusion into the blood, a process measured on the order of hours.

For both physoclistous and physostomous fish, the depth of acclimation prior to decompression relative to the pressure of exposure influences the magnitude of barotraumas. Laboratory studies indicate that the highest mortalities occur when the pressure reduction was greatest, i.e., when the exposure pressure was a relatively small fraction of the acclimation pressure. Figure 5 shows percent mortality for physoclistous and physostomous fishes following exposure in the laboratory to rapid and brief pressure reductions. Note that all the fish in a laboratory chamber were exposed to large pressure changes, in contrast to a field situation where only a fraction of the fish population may be exposed to large pressure changes. The data were taken from studies that included fish held at a pressures associated with different depths long enough to become acclimated. The fish were then exposed to a rapid and brief pressure drop in order to simulate the duration of low pressure exposure within a turbine. The data suggest that: 1) decompression is more detrimental for physoclistous species compared to physostomous species, and 2) overall mortality is low when the minimum pressure is 40% of the acclimation pressure. The principal species of concern for Keeyask GS are sturgeon, white fish, walleye, and northern pike, of which walleye is the only physoclistous species.

Although controlled laboratory studies have been conducted to assess the effect of sudden decreased pressure on fish; no known controlled field studies were found. The pressure decreases that fish experience within the runner occur rapidly and may be large. The nadir, or lowest pressure a fish may be exposed to depends on where the fish passes the turbine. The lowest pressure occurs on the suction side versus the pressure side of the turbine blade. A device called the Sensor Fish has been used to determine the pressures present in some turbines, primarily Kaplan, on the Columbia River to which fish are exposed during turbine passage (Deng *et al.* 2007; Carlson *et al.* 2008). In some Sensor Fish examples, nadirs below vapour pressure were measured (Carlson *et al.* 2008), but most ranged between 35 and 200 kPa (5 and 29 psi).

Although thousands of HI-Z tagged fish have been passed through turbines with a wide range of nadirs very few (<1%) of the recaptured fish have displayed injuries that could be attributed to sudden decompression trauma. Because the HI-Z tagged fish are held in water less than 40 cm deep prior to turbine passage these test fish are not acclimated to depths that a portion of naturally entrained fish would be. However, it has been very obvious from the HI-Z tag tests that there is little evidence that a sudden increase or decrease in pressure has any substantial negative effects on near surface acclimated fish.

Based on the parameters of the selected turbine design, it is anticipated that fish passing through the Keeyask GS turbines will be not be exposed to sudden increases or decreases in pressure that would have substantial negative effects on the fish.

Predicted Survival: Franke Formula

An analysis of turbine parameters can be used to estimate survival using a formula developed by Franke *et al.* (1997). The formula grew out of efforts by the U.S. Department of Energy (DOE) to design more "fish-friendly" turbines. The formula calculates the probability (P) of blade strike by relating such turbine parameters as the number of blades, runner diameter, and runner rotation rate to fish length and operating condition. Fish length and available passage space are the principal drivers of the output. In developing the formula, Franke *et al.* (1997) considered previous works that calculated turbine strike probability and new information developed by the authors. Existing empirical data were used to validate the model for conventional hydro projects. A thorough discussion of the derivation and application of the formulas is provided in Franke *et al.* (1997).

Based on this formula, the turbine design selected for Keeyask GS will have an estimated survival over 90%. This generalized estimate includes fish up to 500 mm, at a single discharge condition (maximum), three passage locations (near hub, mid blade and tip) and a blade strike correlation factors (0.1 and 0.2). The blade strike correlation factor designated lambda (λ) is used to account for variability in strike potential resulting in mortal injuries and also to relate the output to empirical data available to the Franke study. The value of lambda in the range of 0.1 to 0.2 was determined by Franke *et al.* (1997) from Kaplan survival tests. Although the formula calculates a probability, in the present context it is more conventionally used in the formula Survival (S) = 1 – P, with results expressed as a survival percentage.

Summary

A number of variables were considered in the selection and development of turbines for the Keeyask GS to minimize the risk of injury and mortality of fish as they pass downstream. These variables include the number, alignment, and shape of stay vanes and wicket gates, clearance at the wicket gates and runners, wicket gate overhang, number of blades, blade leading edge thickness, blade trailing edge (related to turbulence), rotation rate, runner diameter, blade speed, and absolute lowest pressure.

The use of a fixed blade vertical shaft turbine design for Keeyask GS results in several advantages for fish passage survivability compared to other turbine styles. The fixed blade pitch of the vertical shaft units allows for the gap between the runner blades and the discharge ring to be minimized, reducing the likelihood of fish impingement and injury. The low rotational speeds associated with large diameter vertical shaft turbines also result in greater fish survivability. To reduce the risk of striking or impingement injuries; runner blades incorporate a thicker rounder leading edge, the gaps between wicket gates and both the head ring and head cover were minimized, and the wicket gate overhang was also minimized. To reduce turbulence levels experienced by fish passing through the turbines, the runner blades incorporate a thinner trailing edge, and the shape of the draft tubes incorporate large sweeping radii. These are all known to improve the probability of a fish passing through a turbine without incurring significant injury or mortality.

This is the first time that Manitoba Hydro has included these variables relevant for fish survival as part of the evaluation in the initial turbine design selection process, and as a priority for further turbine design development. Although there are many variables to consider beyond those relevant for fish survival (particularly efficiency and cost), the objective for the Keeyask GS turbines is to achieve a minimum survival rate of 90% for fish as large as 500 mm.

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Table 1: Summary of turbine passage evaluations conducted utilizing the HI-Z Tag recapture technique (Heisey *et al.* 1992) (Summarized by P. Heisey of Normandeau Associates Inc.)

Number of Clients/Utilities	Number of Projects	Number of Fish Species*
32	48	21

Turbine Types

Propeller	Kaplan	Bulb (Horizontal Kaplan)	Francis	Hydrokinetic
16	26	4	15	1

*Species included: striped bass, rainbow trout, largemouth bass, chinook salmon, European eel, American eel, American shad, smallmouth bass, coho salmon, steelhead, Atlantic salmon, yellow perch, brown bullhead, channel catfish, bigmouth buffalo, white sucker, bluegill, northern pike, walleye, lake whitefish

Table 2: Summary of physical and hydraulic characteristics of hydroelectric turbines similar in type and size to those proposed for the Keeyask Project and HI-Z tag acquired fish survival/injury data (Summarized by P. Heisey of Normandeau Associates Inc.)

Station	Species	Average Size (mm)	Turbine Type	Blade Passage Vicinity[1]	No. of Blades	Runner Speed (rpm)	Dia. (m)	Peripheral Velocity (mps)	Test Discharge (cms)	Project Head (m)	Sample Size	48 d Survival	Visible Injury (%)
Bonneville	salmon	165	Kaplan	T[2]	5	75	7.11	27.9	176-340	17.4	966	0.933	3.9
Bonneville	salmon	166	Kaplan MGR	T[2]	5	75	7.11	27.9	176-340	17.4	963	0.952	1.9
Bonneville	salmon	165	Kaplan	M[2]	5	75	7.11	27.9	176-340	17.4	911	0.961	2.3
Bonneville	salmon	166	Kaplan MGR	M[2]	5	75	7.11	27.9	176-340	17.4	903	0.963	1.0
Bonneville	salmon	165	Kaplan	H[2]	5	75	7.11	27.9	176-340	17.4	681	0.992	0.7
Bonneville	salmon	166	Kaplan MGR	H[2]	5	75	7.11	27.9	176-340	17.4	681	0.980	1.0
McNary Dam	salmon	153-155	Kaplan	H[2]	6	86	7.11	31.9	351	21.6–22.9	330	0.927 [4]	4.1
McNary Dam	salmon	153-156	Kaplan	M[2]	6	86	7.11	31.9	351	21.6–22.9	310	0.916 [4]	3.8
McNary Dam	salmon	153-156	Kaplan	T[2]	6	86	7.11	31.9	351	21.6–22.9	309	0.909 [4]	5.1
McNary Dam	salmon	153-157	Kaplan	WG[2]	6	86	7.11	31.9	351	21.6–22.9	315	0.924 [4]	3.0
McNary Dam	salmon	140-158	Kaplan	M	6	86	7.11	31.9	218	21.6–22.3	2121	0.951	2.6
Wanapum	salmon	154	Kaplan	H&M	5	85.7	7.20	32.3	255-481	22.9	1278	0.943	2.6
Wanapum	salmon	169	Kaplan[5]	H	5	85.7	7.20	32.3	255-481	23.5	1829	0.979	1.8
Wanapum	salmon	169	Kaplan[5]	M	5	85.7	7.20	32.3	255-481	23.5	1829	0.971	2.5
Wanapum	salmon	169	AHT Kaplan[5]	H	6	85.7	7.72	34.7	255-481	23.5	1833	0.985	0.9
Wanapum	salmon	169	AHT Kaplan[5]	M	6	85.7	7.72	34.7	255-481	23.5	1834	0.954	3.3
Ice Harbor	salmon	139	Kaplan	M	6	90	7.11	33.5	246	29.1	2698	0.961	3.4
John Day	salmon	136	Kaplan	M	6	90	7.92	37.4	334-564	31.2	1630	0.947	2.6
Lower Granite	salmon	149	Kaplan	H&M	6	90	7.92	37.4	510	29.9	1830	0.949	3.5
Priest Rapids	salmon	155	Kaplan	M	6	86	7.21	32.4	255	23.8	1239	0.963	3.6
Rock Island	salmon	179	Propeller	H&M	6	100	5.74	30.1	227	12.2–12.8	279	0.932	5.5
Rock Island	salmon	179	Kaplan	H&M	6	100	5.74	30.1	227	12.2–12.5	281	0.961	3.6
Rock Island	salmon	179	Bulb	T&M	4	86	7.01	31.5	481	11.0–12.5	280	0.957	3.6
Rocky Reach	salmon	114	Propeller	H	5	86	7.89	35.4	130 MW	28.0	265	0.961	5.8
Rocky Reach	salmon	161-184	Kaplan	H&M	6	90	7.11	33.5	227-454	29.0	1076	0.949	4.7
Rocky Reach	salmon	185	Imp. Kaplan	H	6	90	7.11	33.5	227-453	28.0	985	0.950	3.1
Conowingo	shad	125	Mixed Flow	H	6	120	5.72	35.9	227	27.4	108	0.929	4.2
Safe Harbor	shad	119	Mixed Flow	H	7	76.6	6.10	24.4	261	16.8	199	0.979	4.85

Table 2: Summary of physical and hydraulic characteristics of hydroelectric turbines similar in type and size to those proposed for the Keeyask Project and HI-Z tag acquired fish survival/injury data (Summarized by P. Heisey of Normandeau Associates Inc.)

Station	Species	Average Size (mm)	Turbine Type	Blade Passage Vicinity[1]	No. of Blades	Runner Speed (rpm)	Dia. (m)	Peripheral Velocity (mps)	Test Discharge (cms)	Project Head (m)	Sample Size	48 d Survival	Visible Injury (%)
Safe Harbor	shad	118	Kaplan	H	5	109.1	5.60	31.9	235	16.8	100	0.970	3.1
Safe Harbor	shad	423	Kaplan	H	5	109.1	5.60	31.9	235	16.8	98	0.882	9.8
Safe Harbor	shad	425	Mixed Flow	H	7	76.6	6.10	24.4	261	16.8	100	0.843	11.3
Kelsey	walleye	431	Propeller	T, M&H	5	102.9	7.92	42.7	312	17.1	91	0.877	31.6
Kelsey	walleye	447	Propeller	T, M&H	6	102.9	7.92	42.7	227	17.1	99	0.804	31.8
Kelsey	pike	595	Propeller	T, M&H	5	102.9	7.92	42.7	312	17.1	95	0.756	61.7
Kelsey	pike	661	Propeller	T, M&H	6	102.9	7.92	42.7	227	17.1	88	0.659	53.4
Beaucaire	eel	690	Bulb	M/T	4	94	6.24	30.7	313	13.7	275	0.93	6.5
Fessenheim	eel	704	Kaplan	H/M/T	4	88	6.67	30.8	362	15.2	281	0.924	11.5
Ottmarsheim	eel	750	Kaplan	H/M/T	5	94	6.25	30.7	316	15.6	300	0.799	26.5
Robert Moses	eel	1020	Propeller	M	6	99	6.10	31.7	244-272	25.0	240	73.5 (88h)	36.7

1. H = near hub, M = near mid-blade, and T = near tip.
2. Fish released at stay vanes and passage directed toward specific areas of turbine blades.
3. Fish released just upstream and directed toward stay vanes/wicket gates.
4. No adjustment for control fish (none released).
5. Tests conducted concurrently under same hydraulic conditions.

Figure 1: Comparison of leading edge shape and thickness of blades for a 6 (A) and 5 (B) bladed turbine at Manitoba Hydro's Kelsey Generating Station

Figure 2: Unique injury observed on some fish passed through a new 5 bladed turbine at Manitoba Hydro's Kelsey Generating Station attributed to leading edge of blades being thin

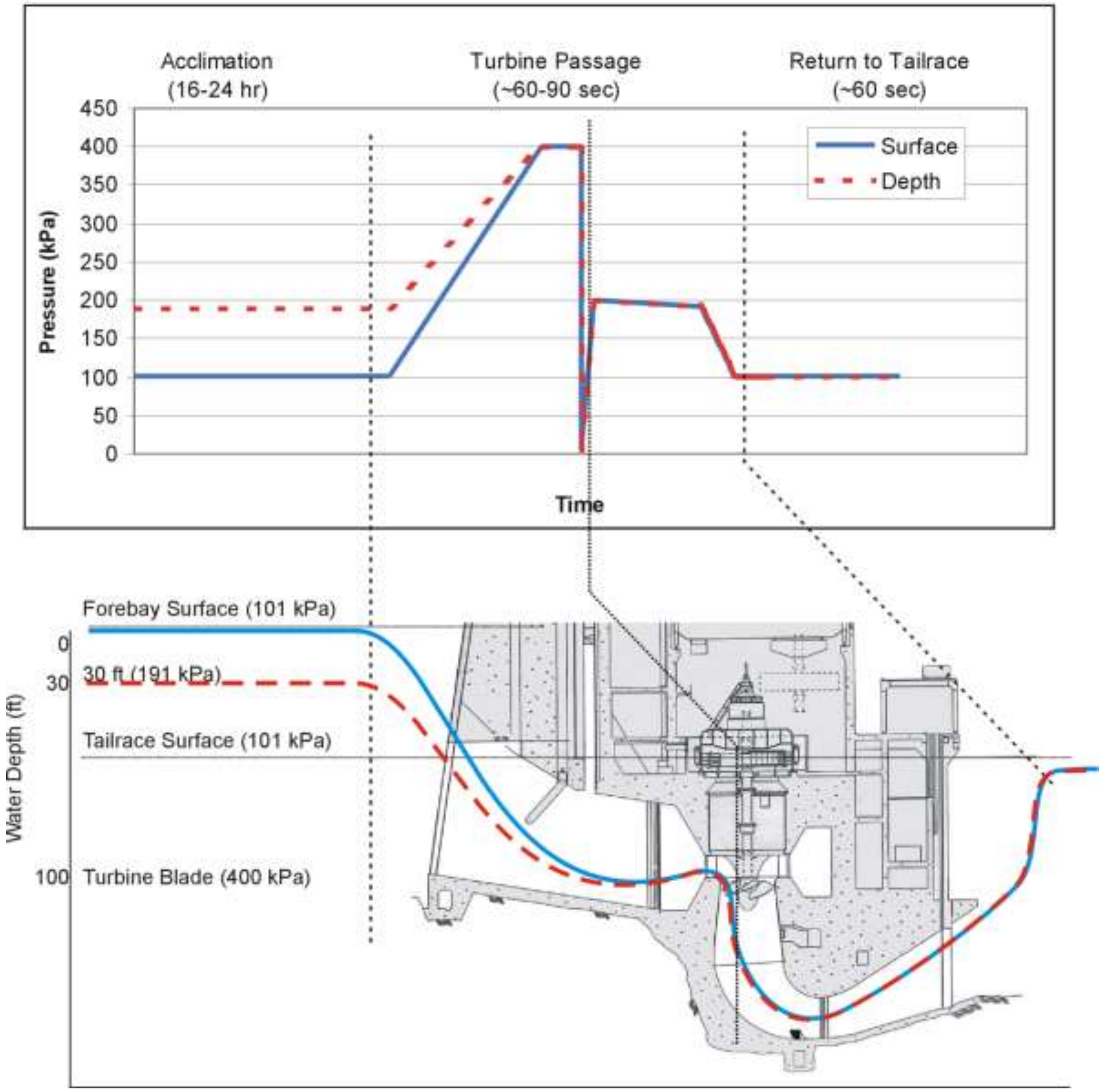

Figure 3: **Laboratory simulated Surface (101 kPa) and 30 ft depth (191 kPa) acclimation and pressure profile for a fish passing a conventional Kaplan turbine. Pressure increases as the fish's depth increases. Pressure spike occurs as fish pass the turbine blades. Pressures then return to surface pressure as fish pass through the draft tube and enter the tailrace. (Source: Abernethy *et al*. 2001)**

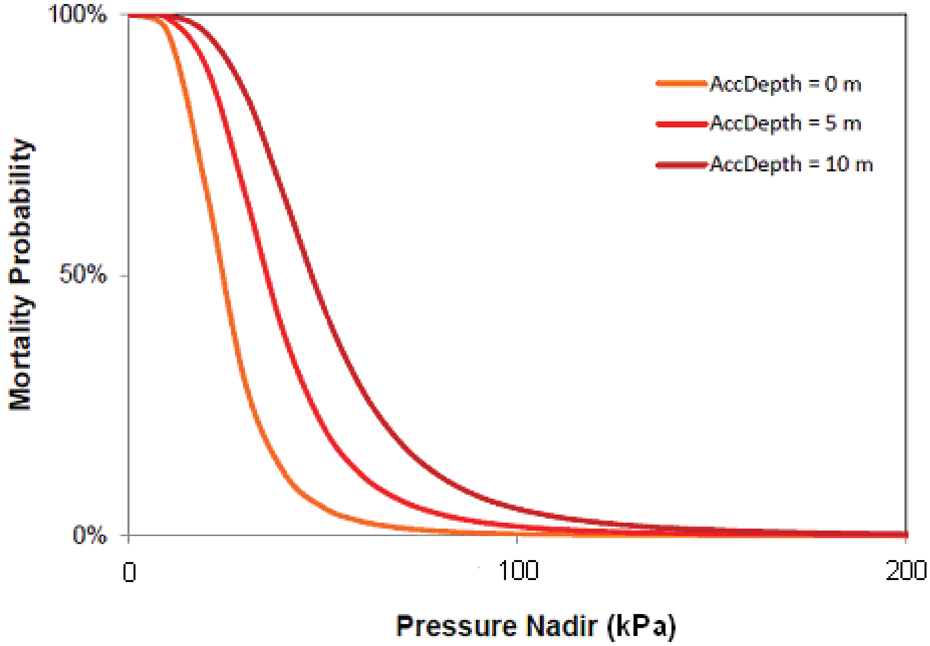

Figure 4: Relationship between barotrauma induced mortality at depth fish are acclimated to when exposed to sudden decrease in pressure (Source: Brown *et al*. 2009)

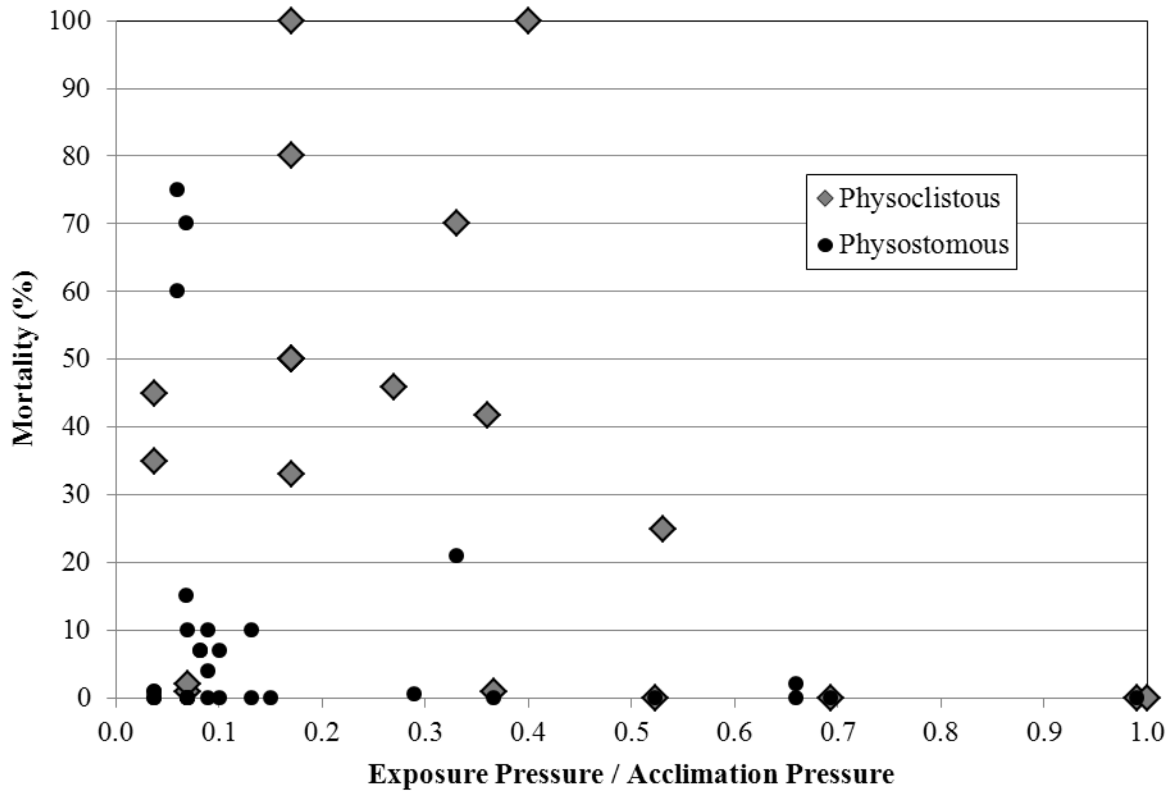

Figure 5: Graphic representation of fish mortalities following exposure to brief and rapid pressure reductions in laboratory test chambers

ATTACHMENT 2: TRASH RACK SPACING AND EFFECTS TO FISH

Introduction

Although trash racks are primarily installed to hold back large debris and ice, they can also act as behavioural and mechanical barriers for fish. Temporary and permanent impingement of fish on the racks is possible. Mainly for these reason trash racks are often perceived by operators of hydroelectric generating stations as mechanical barriers for fish of species of domestic, commercial, or regulatory importance. However, the degree to which trash racks can become a fish hazard or exclusion device varies considerably between trash rack design (mainly bar spacing), fish species and local site conditions (Hadderingh and Bakker 1998; Odeh and Orvis 1998). The current design clear bar spacing for the proposed Keeyask GS is 16.75 cm (KGS ACRES Ltd. 2011).

The following sections establish the primary species and size classes of fish to be considered in an ecological evaluation of trash racks at the Keeyask GS and provide information on fish swimming behaviour and performance relevant to trash rack encounter, the likelihood and consequences of fish impingement, and the use of trash racks for fish exclusion and guidance.

Fish Species and Size

Thirty-seven fish species have been recorded from aquatic habitats close to the proposed Keeyask GS. However, only 17 species are regularly captured within the mainstem of the Nelson River and contribute notably to the fish community in terms of either numbers or biomass (AE SV). All fish species are vulnerable to entrainment but the relative frequencies and magnitudes of entrainment will be largely species specific and be affected by factors such as habitat use, life stage, spawning season, and swimming capacity. For example, extrapolating from drift net catches of ten to hundreds of thousand fish over approximately two- to four-week long periods in early summer and that sampled only a very small portion of the Nelson River cross-sectional area (Pisiak 2005; Bretecher *et al.* 2007; MacDonald 2007), it can be assumed that millions of fish pass downstream over Gull Rapids annually. However, the vast majority of these fish are larvae and juveniles of catostomids (likely white sucker) and, less so, freshwater drum, sculpins, rainbow smelt, emerald shiner, and trout-perch. Downstream movements over Gull Rapids of adults of large bodied species such as lake whitefish, northern pike, walleye, and lake sturgeon have been confirmed in tagging and telemetry studies (AE SV), but this type of data are of limited use for assessing the potential frequencies of entrainment into a powerhouse flow. Qualitative data on fish entrainment frequencies are available from another GS in the Manitoba Hydro system. Based on the results of recent studies applying detection and imaging (*i.e.*, DIDSON) sonar technologies at Manitoba Hydro's Great Falls GS on the Winnipeg River (North/South Consultants Inc. [NSC] *et al.* 2012, 2011; Murray 2012), entrainment rates during summer and early fall were in the order of a few thousands of fish per day, with the vast majority (80%) consisting of fish <15 cm estimated total length[1].

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[1] The trash racks at Great Falls GS are positioned downstream of the turbine intake gates, have 14.0 cm bar spacing (Malenchak *pers. comm.* 2011) and water velocities immediately upstream of the racks range from 0.73–1.03 m/s (Backhouse and Malenchak *pers. comm.* 2011). Except for lake whitefish, the fish species at Great Falls comprised all target species of the Keeyask Project and most of the other species known to occur in the lower Nelson River.

Species identification is difficult with hydroacoustic techniques. By incorporating independent data on the species composition in the Great Falls Forebay during the time of sonar monitoring, NSC *et al.* (2012) suggested that the fish species most susceptible to entrainment were yellow perch, emerald shiner, and walleye or sauger. Because of physical design requirements it is unlikely that trash rack bar spacing can be reduced to physically exclude small bodied (*i.e.*, <15 cm total length) species from passing the racks. Therefore, fish impingement and exclusion will mainly be an issue for the large-bodied species.

In addition to mainly biological parameters, such as the likelihood and frequency of entrainment into the powerhouse flow, other criteria are important when deciding on which species should be considered as the main drivers for trash rack design criteria for the Keeyask GS. Four species (lake sturgeon, lake whitefish, northern pike, and walleye) have been identified as Valued Environmental Components (AE SV). These species were selected as target species for the evaluation of trash racks because of their ecological importance, representation of different fish passage (*i.e.*, swimming performance and behaviour) guilds, and because they are of particular relevance to resource users and regulators. It can be assumed that an assessment of trash rack design options for the target species will also be directly applicable to several other species such as suckers (Catostomidae), yellow perch, sauger, and mooneye.

Except for lake sturgeon, (male) individuals of the other target species first recruit into the spawning population at a length of approximately 200 mm. This length also represents a size of fish that pass through hydroelectric GSs in numbers that can be feasibly monitored by imaging sonar (Murray 2012). For these reasons, a fork length of 200 mm will also be used as the lower bound of the fish size range for the current evaluation. The upper bound is represented by the maximum length expected for the target species in the Keeyask area. These lengths are 170 cm for lake sturgeon, 110 cm for northern pike, 70 cm for walleye, and 60 cm for lake whitefish.

Swimming Behaviour and Performance of Target Fish Species

Two main aspects of fish swimming are relevant when assessing trash rack design in view of fish protection: fish behaviour and fish swimming performance. Behaviour includes the vertical and horizontal position of fish in the water column and their response to sudden changes in water velocity and turbulence, whereas swimming performance refers to a fish's ability to swim against water currents of various velocities.

Swimming Behaviour

Little information exists on the fine-scale behaviour in forebays and near hydroelectric dams of potamodromous fish (*i.e.*, species that migrate entirely within freshwater environments), including the five target species.

The location of a fish in the forebay water column is important for trash rack encounter and dam passage. Coutant and Whitney (2000) have argued that "non-migratory" fish are entrained accidentally, and the likelihood of such events is related to the degree to which these fish use habitats closest to the powerhouse. The powerhouse intake channel at the Keeyask GS is designed for equal flow distribution parallel to the walls of the channel and minimal surface roughness, resulting in approximately equal discharge into each turbine bay. These engineering design criteria translate into a generally structureless, relative high velocity, deep water environment. Because of the consequent lack of, for example, fine sediments and other attractive substrates for invertebrate filterers and grazers, physical shelter, still water resting areas, and visual orientation, the intake channel will not provide suitable habitat for most fish species. Nevertheless, some fish may enter the intake channel due to migratory behaviour or density dependent movements. Larger fish motivated to migrate downstream may initially be deterred by the flow conditions near the trash racks, will search for alternative passage routes, potentially returning to the trash racks repeatedly. Based on the results of the studies at Manitoba Hydro's Great Falls GS on the Winnipeg River (NSC *et al.* 2011, 2012; Murray 2012), entrainment rates during summer and early fall are in the order of a few thousand fish per day, with less than 10% consisting of fish >20 cm estimated total length.

There is evidence that the spatial distribution of larger-bodied potamodromous species moving towards and through hydroelectric plants differs from the surface oriented pattern for downstream moving salmonid smolts. These differences may be partially related to the fact that downstream migration behaviour, including swimming depth, may change during fish ontogeny. For example, Michaud and Taft (2000) found that "small" fish approached the dam of a Wisconsin hydroelectric GS in the surface (<0.5 m depth) waters. Furthermore, walleye larvae mainly drifted in the upper portion of the water column of some small (Franzin and Harbicht 1992) and mid-size (D'Amours *et al.* 2001) Canadian streams. In contrast, the vertical distribution of older walleye does not seem to follow a distinct pattern. Summarizing the results from a review of 45 turbine entrainment monitoring studies at small hydropower sites in the eastern USA dominated by non-salmonid species, Coutant and Whitney (2000) state that the vertical distribution of adult fish, including walleye, yellow perch, and white sucker was rather uniform throughout the water column near the turbine intakes. Similar, although not species-specific results were obtained from a hydroacoustic study at Manitoba Hydro's Great Falls GS on the Winnipeg River that included most species relevant to the Keeyask Project. Although water depths of <4 m could not be assessed and some minor differences existed in the percentage of fish passage at 1-m depth intervals (starting at 4 m depth) in front of the six intake gates, the vertical distribution of fish at each unit (excluding one unit with debris accumulation problems) was quite uniform, with a mean passage depth of 8-10 m (NSC *et al.* 2011, 2012).

Further, indirect support for a relatively uniform depth distribution of older individuals of some of the Keeyask target species during their approach of trash racks comes from telemetry studies on the vertical distribution of fish in forebays and large rivers. Lahti (2003) found pikeperch (*Sander lucioperca*), the Eurasian ecological equivalent of walleye, to use a large range in water depth (1.2–30.8 m) in a Finnish hydroelectric reservoir during the summer. However, the vertical distribution of pikeperch differed seasonally with water temperature and between the sexes, indicating that particularly female fish moved from surface waters into deeper, colder (<10ºC) water in late July. Northern pike are often considered to be surface-orientated, preferring shallow vegetated areas in lakes, although habitat selection can be more versatile (Casselman and Lewis 1996). One of the few studies of pike movements in a large regulated river (up to 19.5 m deep) confirms that pike generally occupy relatively shallow water (<5 m), but that some individuals are regularly found at larger depths (Vehanen *et al.* 2006).

The vertical distribution of lakes sturgeon likely differs from the other target species in that individuals spend most of their time on or near the bottom (*e.g.*, Barth *et al.* 2009). This spatial habitat preference suggests that lake sturgeon will likely approach turbine intakes low in the water column.

In contrast to the lack of a clear vertical distribution pattern, Coutant and Whitney (2000) reported distinct horizontal patterns in fish distribution, indicating that many species, including walleye, yellow perch, and white sucker approach power stations mainly along the shoreline or other physical structures. This hypothesis is supported by data from Johnson *et al.* (1989) showing that fish approached the dam at the Vanceburg GS (three bulb units, 329 cms flow each) on the Ohio River mainly from one shore and that the turbine unit closest to this shore consistently entrained the largest number of fish (43%). These authors also found that between 83% (spring) to 96% (summer) of the fish detected by hydroacoustics immediately in front of the trash racks were actually entrained through the turbines (based on Fyke net captures in front of the turbine). However, only 0.3% of the entrained fish were larger game fish (sauger, channel catfish, white bass [*Morone chrysops*]), whereas 8% and 9% of the approximately 4,200 fish captured by gillnetting and electrofishing in the forebay were sauger and white bass, respectively (Johnson *et al.* 1989).

The hydroacoustic studies at the Great Falls GS on the Winnipeg River also have documented substantial differences in fish entrainment among turbine units, indicative of shore-biased fish approach trajectories (NSC *et al.* 2012, 2011). However, this bias was not entirely consistent between the two study years and may have been affected by station operations. In 2012, Unit 6 closest to the north shore had the second highest discharge of all units over the study period and entrained more fish than the other five units combined. In 2011, when the discharge through Unit 6 was near average, Units 1 and 2 closest to the south shore entrained almost half of all fish.

Slower (0.1–0.4 m/s) than maximum surface and depth-averaged (0.6–0.7 m/s) intake channel water velocities are expected to exist near the shorelines south and, particularly north of the channel upstream of the Kelsey powerhouse and near the bottom of the channel as it slopes down to a depth of approximately 32 m and before it forms a 50 m long, 3 m deep rock trap below the turbine intakes. Thus, it can be expected that most fish volitionally approaching the powerhouse area will primarily be moving within the relatively slow near-shore or bottom currents.

<u>Swimming Performance</u>

Fish approaching trash racks at turbine gates experience an accelerating flow field. For the proposed configuration of the Keeyask powerhouse and intake channel and with the reservoir at full supply level, surface (0.5 m depth) water velocities within the intake channel will increase from 0.56–0.69 m/s to a maximum of 1.25 m/s over the last approximately 15 m upstream of the trash racks. The average flow velocity through the trash racks of each unit ranges from 1.14–1.25 m/s over most of its height, with lower velocities near the bottom. Fish entrained into the flow immediately upstream of the trash racks, including impingement on the trash racks must be able to swim against such velocities long enough to first escape the steep velocity gradient followed by a section of the steady, fast flowing areas of the intake channel until they reach areas where maintaining position poses no problem and they can repay the oxygen debt (*i.e.*, reduce elevated blood and tissue concentrations of anaerobic pathways metabolites; Brett 1964; Beamish 1978) accumulated during burst swimming (see below).

The swimming performance or ability of fish has been categorized into three main types (Beamish 1978):

- Sustained swimming speed: occurs at relatively low velocities and can be maintained for long periods (>200 min) using energy derived from aerobic processes only without resulting in muscular fatigue;
- Burst swimming speed: highest speed of which a fish is capable; the speed can be maintained for a short time (<20 seconds) and is fuelled by energy derived entirely from anaerobic processes; and
- Prolonged swimming speed: covers the spectrum between sustained and burst speed and ends in fatigue.

Because swimming speeds of fish in the wild are difficult to measure and fatigue can rarely be assessed, swim chambers have been developed in which fish are forced to swim in a small tube against uniform current velocities (see reviews in Beamish 1978; Castro-Santos and Haro 2010). One of the key metrics of swimming capacity developed in conjunction with the swimming chambers is the so-called critical swimming speed (CSS), measured by gradually increasing current speeds by approximately 10 cm/s every 60 minutes until the fish fatigue (Brett 1964). Originally designed to measure sustained speed, the time step has subsequently been reduced and CSS should be considered a comparative performance index (Castros-Santos and Haro 2010) or a special category of prolonged swimming. The following section summarizes literature data on the swimming performance of the Keeyask target species (TL= total length; FL= fork length).

Lake Sturgeon

- Information on lake sturgeon swimming performance has mainly been generated from hatchery-reared fish, which likely have lesser swimming ability.
- CSS range from 0.39 m/s at 15°C for juveniles of 15.7 cm mean TL (Webb 1986) to 0.97 m/s at 14°C for fish >120 cm TL (Peake *et al.* 1997).
- Burst speeds have been measured at 0.9 m/s for fish of 23–55 cm TL and at 1.8 m/s for fish 106-132 cm TL (Peake *et al.* 1997; the test temperature was 14°C).
- Maximum sustained speeds of fish of 23–55 cm TL increased from 0.12 m/s at 7°C to 0.26 m/s at 21°C (Peake *et al.* 1997). The temperature effect decreased with increased swimming speeds, such that burst speeds were almost independent of temperature.
- Exercised fish (108 cm mean TL) of hatchery origin volitionally ascended a 38 m long experimental fishway at mean speeds of 1.9–2.4 m/s (range 0.94–3.3 m/s) without an obvious effect of temperature in the range of 11.4–20.6°C (Kynard *et al.* 2011).

Lake Whitefish

- Only one study on lake whitefish swimming performance could be located, no information on burst speeds is available.
- Bernatchez and Dobson (1985) measured CSS of 0.63–0.75 m/s at 5–17°C for fish of 10–39 cm TL.
- Lake whitefish morphology and muscle structure is indicative of relatively strong swimming capabilities, at least compared to non-salmonid species; this species is known to pass rapids of a

length and mean current speed either too long or too high for passage based on critical swimming speeds (Bernatchez and Dobson 1985).

Northern Pike

- Based on regression equations published in Jones *et al.* (1974) CSS of fish of 12–62 cm FL can be calculated as 0.19–0.47 m/s; the test temperature was 12°C.
- Burst speeds (<1 s) of 2.8–3.4 m/s for fish with a mean FL of 41.2 cm and at water temperatures between 8–12ºC (Frith and Blake 1995).

Walleye

- Based on regression equations published in Jones *et al.* (1974) CSS of fish of 8 – 38 cm FL can be calculated as 0.38–0.84 m/s; the test temperature was 19°C.
- Peake *et al.* (2000) measured burst speeds of 1.6–2.6 m/s for fish of 8–67 cm FL at temperatures of 6–21ºC.
- Fish of approximately 32 cm FL could maintain burst speeds of up to 4.0 m/s for approximately 11 seconds (Castro-Santos 2005).

The above values from swimming performance tests do not necessarily reflect the true swimming capacity of the target species. Swimming speeds obtained in forced performance tests inside of small laboratory swimming chamber do not adequately represent the performance of unrestricted fish in the wild, because the laboratory tests limit the range of potential swimming behaviours (*e.g.*, Tudorache *et al.* 2007, 2010). Therefore it is not surprising that free-swimming fish allowed to enter the swimming test arena within large flumes volitionally, consistently exhibit swimming speeds and stamina well in excess of those confined to a chamber and subjected to artificial stimulation (Haro *et al.* 2004; Peake 2004a; 2008; Castro-Santos 2005; see last bullet for walleye).

It should also be noted that most swimming performance tests are conducted at temperatures known to be near the performance optimum for the species. Fish swimming capacity can be compromised at suboptimal temperatures, as has been shown for lake whitefish (Bernatchez and Dodson 1985) and lake sturgeon (Kynard *et al.* 2003). It can be assumed that adults of the target species mainly move, and potentially encounter the trash racks during times when water temperatures will not substantially affect their swimming capacity.

In summary, current speeds that are expected to exist at and near the Keeyask trash racks are unlikely to impose velocity barriers or traps for healthy, adult fish of the target species, particularly considering the likely bottom oriented approach of the relatively weaker swimmer, lake sturgeon.

Fish Exclusion by Trash Racks

Trash racks can also act as behavioural barriers to fish. Trash rack bar dimensions, spacing, and orientation affect water flow characteristics (Katopodis *et al.* 2011) which in turn cause fish behavioural responses as has been demonstrated in laboratory experiments (Hanson and Li 1983; Floyd *et al.* 2007; Enders *et al.* 2009; Russon *et al.* 2010; Silva *et al.* 2011). However, information relevant to realistic flow-conditions found at hydroelectric GS is lacking or speculative (McKinstry *et al.* 2005; Jansen *et al.* 2007). Altered behaviours, such as changes in head-tail orientation (Hanson and Li 1983), aggregation (Floyd *et al.* 2007), searching and upstream escapement (Calles *et al.* 2010) may lead to migratory delays or render fish more vulnerable to predation (Neitzel *et al.* 1990, cited in Baumgartner 2005), but will not permanently exclude motivated fish from moving downstream. However, if these fish are physically unable to pass the openings between the bars, they will be excluded from moving into the turbine flow or, if no alternative passage route exists, from moving downstream of the GS.

A recent study by Dale Wrubleski (Research Scientist, Wetlands Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada) who monitored the movement of fish trying to enter Delta Marsh (Lake Manitoba) provides relationships of body length to body width for some target species. These length-width relationships are presented in Table 1.

From the data provided in Table 1 it is apparent that, based on physical dimensions alone, none of the target species except lake sturgeon grow to a size that would result in their physical exclusion during a head on approach of the Keeyask trash racks. Up to 5% of the number of adult lake sturgeon captured in large mesh gill nets in the Keeyask area would be physically excluded by a 16.75 cm clear bar spacing. However, a clear spacing of as small as 11 cm would not exclude even the largest individuals of the other four target species from the turbine flow.

Assuming that most fish approach the racks from a position close to the shore and/or will exhibit a behavioural avoidance response to the accelerating flow field within the immediate area in front of the racks, they may not face the bars head on but at an oblique angle. In that case or if adult individuals of the target species are unable to maintain rheotactic orientation immediately in front of the trash rack, they could suffer lateral impingement. Considering the prevailing water velocities at the trash racks and the swimming capacities of the target species, permanent lateral impingement is unlikely to occur.

Fish Impingement on Trash Racks

Three alternative outcomes have been documented for fish approaching trash racks: upstream escapement, passage through the racks, and impingement on the racks (Calles *et al.* 2010). For fish motivated to migrate downstream such as European eel (*Anguilla anguilla*), escapement often is not permanent and at a Swedish hydroelectric GS approximately half of the initial escapees died as a result of impingement at the last attempt (Calles *et al.* 2010). The degree to which trash racks can become a fish hazard varies considerably between rack design (mainly bar spacing), fish species and local site conditions (Hadderingh and Bakker 1998; Odeh and Orvis 1998). Based on their swimming capacity and physical dimensions relative to the trash rack openings it is unlikely that individuals of the target (or any other) species will become permanently impinged on the Keeyask trash racks at the currently proposed rack spacing of 16.75 cm. However, because trash rack spacing may be subject to review and because impingement can represent a source of fish mortality at hydroelectric GSs (Calles *et al.* 2010), fish impingement and its consequences will be briefly discussed.

There exists little data regarding water velocities that cause injury/mortality to fish due to impingement on trash racks (and similar physical barriers), or for minimum speeds required for fish to swim off such structures. Furthermore, most of the few existing studies are on small-bodied fish, species not present at

Keeyask, or juveniles of species considered useful surrogates of target species. For example, a narrative account of early (1952) laboratory experiments by Montén (1964) indicates that 5 cm-long European minnows (*Phoxinus* sp.) were trapped against a metal mesh screen (no dimensions given) at current speeds of 0.8 m/s. Current had to be reduced to 0.3 m/s for these fish to swim off the screen, and fish pressed against the screen for ~2 min at velocities of 1.8 m/s suffered serious gill injuries (Montén 1964). Peake (2004b) examined the ability of juvenile (3–7 cm fork length) northern pike to avoid impingement on irrigation intake screens. Pike never became impinged on screens (mesh size 0.25 cm^2) at approach velocities of 0.15 m/s or less, impingement observed at 0.25 m/s did not result in injuries or mortality, and velocities of >0.35 m/s resulted in injury or death of at least 10% of the individuals. In laboratory experiments that primarily evaluated the efficiency of a bottom bypass in passing shortnose sturgeon (*Acipenser brevirostris*) past a trash rack with 5.1 cm spacing, Hogan *et al.* (2008) demonstrated that 1 year-old fish were able to maintain swimming after contact with the rack at approach velocities of up to 0.61 m/s. A laboratory study specifically designed to evaluate the response of adult European eel to bar racks (1.2 cm spacing), indicated that eels did not show avoidance behaviour prior to encountering the racks and reacted only after physical contact with the racks (Russon *et al.* 2010). These authors also found that eels did not get impinged or passed through vertical racks angled relative to the flow and leading to a bypass, whereas impingement and passage was frequent for horizontally inclined racks facing the flow and without a bypass. Frequency of impingement was higher under low discharge (0.13 m^3/s) while passage through the upright rack was common under high discharge (0.28 m^3/s), and impinged eels could swim off the rack at water velocities of 0.9 m/s (Russon *et al.* 2010). A companion telemetry study at a hydroelectric GS (turbine discharge of approximately 65 m^3/s) found that tagged eels could escape upstream from approach velocities at the trash racks (2.0 cm clear bar spacing) of 0.87–1.04 m/s, but that all fish (19 out of 35 attempting passage) that became impinged, died (Calles *et al.* 2010). Substantial impingement mortality was further indicated by the more than 240 untagged eels that were retrieved from the trash racks during the four-week long study.

Conclusions

The currently proposed 16.75 cm clear bar spacing of the Keeyask trash racks will likely not prevent or interfere with the downstream movement of the vast majority of fish approaching the racks. Depending on their approach trajectory and orientation, some of the largest fish of the target species may get initially impinged on the racks. Most of these fish should have the capacity to swim off the racks and move upstream. Some of the impinged fish, particularly if their swimming capacity is compromised may be pushed through the bar spaces by the current when trying to move off the rack. A few fish may not be able to swim off the racks and, consequently, suffer severe injuries resulting in death. As a large proportion of the fish that may get impinged on the trash racks can expected to be mature individuals actively moving downstream, these fish likely make repeated attempts at passing the Keeyask GS. A reduction of the currently proposed bar spacing may result in a reduction in the numbers of fish closely approaching the bar racks (increased behavioural exclusion) and an increase in both the number/proportion of fish being unable to swim off the rack after initial impingement and becoming permanently impinged on the racks or forced through the racks (increased mechanical exclusion, potential increase in approach velocities). Overall, less fish will likely be entrained into the turbine flow than under the currently planned bar spacing. Due to the lack of baseline data, suspected non-linear relationships between, for example, bar spacing and impingement rate, the relative frequencies of the different outcomes of trash rack encounter are difficult to predict. For example, there is evidence that trash rack spacing close to the mean body width of individuals of a target species/population results in high impingement mortality (Calles *et al.* 2010). When trying to evaluate design options for a hydroelectric GS to minimize fish mortality, individual passage routes should not be considered in isolation, but potential rates of injury and mortality have to be compared for each passage route including exclusion and bypass devises, to guide decisions on which option(s) will provide the best solution for a specific location.

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Personal Communications

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Table 1: Regression equation, coefficient of determination (r^2), number of fish, and length range of fish for the relationship between fork length (Lth) and body width (Wd) for target species. Max Lth represents the (theoretical) maximum length of a fish expected to fit through a clear bar spacing of 16.75 cm

Species	Regression equation	r^2	n	Lth range (mm)	Max Lth (mm)	Source
Cisco	Wd = -7.432 + 0.127 Lth	0.76	59	185–300	1375	Wrubleski *pers. comm.* 2010
Northern pike	Wd = -7.392 + 0.105 Lth	0.91	211	230–815	1665	Wrubleski *pers. comm.* 2010
Walleye	Wd = -18.55 + 0.179 Lth	0.83	76	298–740	1040	Wrubleski *pers. comm.* 2010
White sturgeon	$Wd = (0.2765\ Lth^{1.07})/\pi$	-	-	-	1350	Jager (2006)

APPENDIX 1A - PART 2
KEEYASK LAKE STURGEON STOCKING STRATEGY

Lake Sturgeon (*Acipenser fulvescens*) Mitigation in the Keeyask Study Area:

Keeyask Lake Sturgeon Stocking Strategy

DRAFT: FOR DISCUSSION WITH FISHERIES AND OCEANS CANADA AND MANITOBA WATER STEWARDSHIP

North/South Consultants

April 2012

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1.0 INTRODUCTION

The Keeyask Hydropower Limited Partnership[1] is planning to construct the Keeyask Generation Project on the Lower Nelson River at Gull Rapids starting in July 2014. Representatives of the Keeyask Cree Nations, Manitoba Hydro, and biologists working on the Project, have been working together to develop a suite of measures to mitigate effects of the development on the aquatic environment under the auspices of the Keeyask Aquatic Working Group, which was formed in mid-2008.

Development of the Keeyask Generating Station (GS) will affect lake sturgeon populations in the reach of the Nelson River between the Kelsey and Kettle GSs (Figure 1). To mitigate effects of the Keeyask GS on lake sturgeon, as well as support a broad-based recovery plan for this species, a mitigation package, comprised of habitat works and stocking, has been developed. Stocking is one of the most common mitigative strategies used to restore near-extirpated fish species from native environments and has been successfully employed for lake sturgeon in a number of locations throughout much of its range (Appendix 1). Stocking effectively improves recruitment by ensuring survival through the very young life history stages, thereby bypassing a significant portion of mortality that occurs in wild fish populations. The basic goal of any lake sturgeon stocking program is to establish, maintain or enhance a population within a designated area where suitable habitat exists.

1.1 BACKGROUND

Historically, the lake sturgeon was common throughout the Nelson River between Kelsey Rapids (now Kelsey GS) and Kettle Rapids (now the site of Kettle GS) as well as above and below these dams. Commercial exploitation of lake sturgeon in the upper Nelson River above Kelsey began in the early 1900s (MacDonell 1997). Over-harvest contributed to depleted sturgeon stocks throughout the province and the commercial fishery collapsed several times before it was closed permanently in 1992. In addition to commercial harvest, lake sturgeon numbers have declined at all locations on the Nelson River where the construction of generating stations has altered habitat for specific life history requirements such as spawning. Lake sturgeon populations remain in several portions of the Nelson River, including the reach between the Kelsey and Kettle dams, and also are present in the Burntwood River between First Rapids and Split Lake.

[1] The Keeyask Hydropower Limited Partnership is planning to construct the Keeyask Generation Project is comprised of four limited partners and one general Partner. The four limited partners are Manitoba Hydro, Cree Nation Partners Limited Partnership, York Factory First Nation Limited Partnership, and Fox Lake Cree Nation Keeyask Investments Inc. The Cree Nation Partners Limited Partnership is controlled by Tataskweyak Cree Nation (TCN) and War Lake First Nation (WLFN). The York Factory First Nation Limited Partnership is controlled by the York Factory First Nation (YFFN). Fox Lake Cree Nation Keeyask Investments Inc. is controlled by Fox Lake Cree Nation (FLCN). The general partner is 5900345 Manitoba Ltd., a corporation wholly owned by Manitoba Hydro.

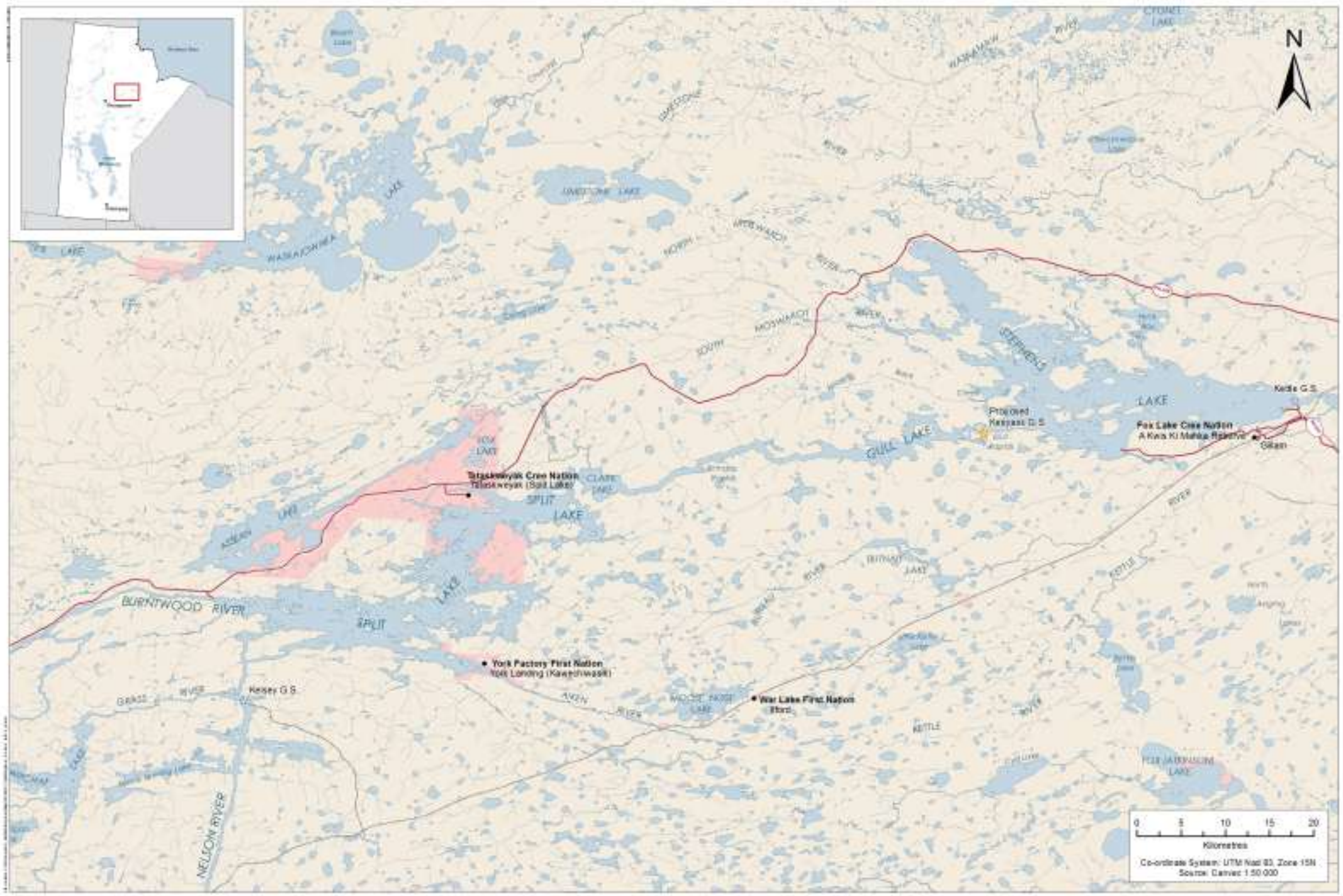

Figure 1. **Map of Kelsey to Kettle GS reach.**

The lake sturgeon has been assessed as a "heritage species" in Manitoba and has been assessed as endangered, threatened or of special concern in western Canada (i.e., those in Manitoba, Saskatchewan, and Alberta) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006). Presently, the lake sturgeon is under consideration for listing under Schedule 1 of Canada's *Species at Risk Act* (SARA), in which lake sturgeon in the Nelson River from Lake Winnipeg to Hudson Bay has been assessed as endangered and this reach is referred to as "Designatable Unit 3". As part of the SARA process, a Recovery Potential Assessment (RPA) has been prepared (DFO 2010). Within the RPA report, the Kelsey to Kettle reach of the Nelson River is listed as Management Unit (MU) 3.

1.2 OBJECTIVES

Maintaining or developing sustainable lake sturgeon populations in the Project area following development of the Keeyask GS is an important post-Project objective. In addition, the overall mitigation program developed for the Keeyask GS should consider the regional goal of recovery of lake sturgeon in the Nelson River, with the specific intent that development of the Keeyask GS should not preclude the recovery of lake sturgeon in the Nelson River, as set out in the DFO (2010) RPA.

During development of the stocking strategy, several information gaps were identified that need to be addressed before the strategy can be finalized. In addition, this strategy provides for an adaptive approach, as it is expected that all aspects of the strategy, including spawn collection, rearing and release, will be refined as additional information is obtained.

The program is comprised of three phases (note that conduct of these phases may overlap and that phases are not independent):

1. Planning phase – this phase provides the overall framework for the program, and refined the objectives to enable creation of a site-specific plan. During this phase, the need for additional information was identified and addressed through specific data collection programs. Specific activities included identification of:
    a. Target locations for stocking
    b. Target numbers, fish ages and duration of stocking program
    c. Source of brood stock
2. Pre-implementation phase – this phase addresses the practical issues related to implementation of the stocking program and includes investigations to address potential issues. It should be noted that additional requirements for field trials will likely be identified as investigations continue. Specific activities identified to date include:
    a. Assessment of brood stock collection
        i. Assessment of numbers of mature fish by spawning location
        ii. Assessment of the use of a hormone (Ovaprim) to facilitate collection of eggs and milt
    b. Assessment of rearing
        i. Investigations of potential lake sturgeon diseases and disease transmission
        ii. Evaluation of rearing conditions with respect to temperature and food supply
    c. Monitoring and assessment of post-release success
        i. Assessment of survival rates (to enable refinement of stocking target numbers)

ii. Comparison of survival rates of fingerling and yearling fish
iii. Measurement of movements from area of release

3. Implementation phase – this phase would mark the transition from a planning/information gathering program to implementation with the objective of supporting the sturgeon population in the directly affected area, and assisting in long-term recovery in the Keeyask region. A detailed plan for this phase will be developed after results of the planning and pre-implementation phase are available. However, it is recognized that the implementation phase would be comprised of three stages:
   a. Construction – during this phase, priority would be given to stocking into areas where spawning may be disrupted due to construction activities, in particular in Stephens Lake and, to a lesser extent, Gull Lake. The intent would be to improve recruitment during years when construction related activities may affect spawning success.
   b. Operation – this phase would comprise approximately the first two decades of operation, when the largest physical changes in the environment are expected. The effectiveness of habitat mitigation measures and stocking will be assessed during this phase based on results of monitoring programs aimed at determining recruitment success, and in particular contributions of hatchery-reared and wild fish to each cohort. Adjustments to the stocking program may be necessary based on results of monitoring.
   c. Long term – stocking in this phase would be designed to provide long-term sustainable populations within MU3. The need for and locations of stocking would depend on the results of monitoring to determine population status.

The following document is comprised of the following sections:

Section 2: Planning phase

Section 3: Pre-implementation phase

Section 4: Next Steps

2.0 PLANNING PHASE

The planning phase of the Keeyask lake sturgeon stocking strategy will address refining overall objectives of the stocking strategy, in terms of:

1. Identifying locations to stock;
2. Determining numbers and life stages of lake sturgeon to stock, and the duration of the program; and
3. Identifying sources of brood stock.

Several field investigations were undertaken in support of this phase, and, as discussed below, further refinements are expected as additional information is obtained. Input from the planning phase has been used to focus activities conducted during the pre-implementation phase (Section 3), which is focused on addressing issues related to the implementation of a lake sturgeon stocking strategy.

2.1 IDENTIFICATION OF TARGET LOCATIONS

As discussed in Section 1, lake sturgeon was historically abundant in the large river systems of northern Manitoba. Overall, waterbodies considered for mitigation as part of the Keeyask Project have been limited to northern Manitoba.

The broad river reaches selected for consideration within the stocking plan were ranked according to the degree of impact on the population that can be attributed to the development of Keeyask, as follows:

1. Direct effect of Keeyask GS on habitat/resident fish (Clark Lake to Stephens Lake reach);
2. Keeyask GS within same Management Unit (MU3 from Kelsey to Kettle GSs);
3. Keeyask GS within same Designatable Unit (Nelson River from Lake Winnipeg to Hudson Bay); and
4. Other locations in northern Manitoba.

Following selection of broad river reaches, potential locations within each reach were further evaluated with respect to the status of the current populations and availability of habitat to support all life history stages. The availability of habitat is important to support the goal of the stocking program, which is to establish self-sustaining populations.

2.1.1 Selection of River Reaches

The area that will be directly affected by the Keeyask Project is the reach of the Nelson River between Clark Lake and the inlet to Stephens Lake. The upstream portion of this reach, from Clark Lake to Gull Rapids, will become the reservoir of the Keeyask GS, while the lower portion will form the tailrace and immediate downstream environment of the GS. This downstream area is part of Stephens Lake. Habitat in this reach will be substantially altered, and habitat works are planned with the objective of providing requirements to support all life history stages. Stocking in this reach is considered the top priority for this stocking plan.

Management Unit 3 is the reach of the Nelson River between the Kelsey and Kettle GSs. Sturgeon use of this area can be broadly divided into three groups: Upper Split Lake (sturgeon use is concentrated in the Nelson River below the Kelsey GS, the Grass River and the Burntwood River to First Rapids), the Clark Lake to Gull Rapids reach, and Stephens Lake. Stocking in the Clark Lake to Gull Rapids reach and the area immediately downstream of the GS has already been identified as the top priority. Stocking in other portions of MU3 have been assigned a secondary priority level.

The Nelson River (DU3) was historically comprised of several sturgeon populations. The management units upstream of the Kelsey GS are currently being addressed by the Nelson River Sturgeon Management Board and so are not considered further in this plan. The Kelsey to Keeyask reach was considered above. The DFO (2010) RPA for the lower Nelson River identified the Long Spruce (MU4) and Limestone forebays (MU5) in assessing potential for recovery of lake sturgeon. For the purposes of this document, these forebays were assigned as the third priority of the stocking plan (subject to further evaluation of potential sturgeon habitat quality and availability). Downstream of the Limestone GS, the Nelson River supports a substantial population of lake sturgeon and stocking is not required.

With respect to other river systems in northern Manitoba, the Hayes and Churchill systems are both known to support sturgeon populations. The Hayes system is largely undisturbed by development, and therefore, stocking has not been considered for this area. The status of lake sturgeon in the Churchill River is not well known, though the river at the confluence of the Little Churchill River is known to support a population of lake sturgeon. Genetic evaluation has indicated that this is a distinct genetic stock (Cote *et al.* 2011). Given that this river is outside of the Designatable Unit and the stock is clearly distinct from that found in the Nelson River, stocking efforts will be focused on the Nelson River. If it is found that there is no potential for successful stocking projects in the Nelson River system, targeting other river systems would be revisited.

In summary, the Nelson River between the Kelsey and Limestone GSs was selected for further examination for suitability for stocking.

2.1.2 Selection of Locations within River Reaches

The overall analysis of broad river reaches identified the Nelson River between Kelsey and Limestone GSs as providing potential locations where population enhancements through stocking could contribute to the mitigation of effects of the Keeyask Project. This mitigation would ameliorate site-specific effects, as well as contribute to the recovery of the regional lake sturgeon stock. These areas were further examined to determine whether habitat was available to support all life history stages, such that a self-sustaining population could be established.

Lake sturgeon in the Kelsey to Kettle reach of the Nelson River occupy three general areas:

1. The Split Lake Area - includes the Nelson River from below Kelsey GS to the outlet of Split Lake and the Burntwood River from First Rapids to Split Lake;
2. The Keeyask Area - includes the reach of the Nelson River extending from the inlet of Clark Lake to the upstream end of Gull Rapids; and
3. The Stephens Lake Area (downstream of Gull Rapids to Kettle GS) (Figure 1).

Each of these areas currently supports a spawning population.

Studies conducted for the Keeyask Generation Project environmental assessment provided information regarding population size, existing habitat, success of current reproduction and relevant life history information for each of the three areas. These data were used as a basis for designing the stocking strategy for Keeyask. For example, key considerations for the design of the Keeyask stocking strategy such as the feasibility of collecting lake sturgeon gametes in the study area, locations to introduce hatchery reared fish, and the relative importance of each area for receiving hatchery reared fish, described later in this document, were based on these data.

Specific studies to address lake sturgeon populations in the Long Spruce and Limestone forebays were not conducted as part of the Keeyask technical studies; however, ATK from the Fox Lake Cree Nation (FLCN) indicates that sturgeon were present in these sections of the Nelson River prior to hydroelectric development but were substantially reduced following construction of the dams.

Split Lake Area

Lake sturgeon population estimates generated from mark and recapture data collected during EA studies (2001 – 2007) for the Split Lake Area ranged from 249 to 1,511 adult fish with the most recent estimate (2007) at 861. This area contains one known lake sturgeon spawning location, First Rapids on the Burntwood River. In addition, lake sturgeon are known to have historically spawned in Grass River below Witchai Lake Falls and in the Nelson River downstream of Kelsey Falls (now the Kelsey GS; MacDonell 1997). Despite substantial effort during EA studies, conclusive evidence of spawning or successful recruitment from either of these areas has not been found. However, based on the information collected during EA studies, it is clear that a remnant lake sturgeon population exists in this area.

In 2010, a coarse scale habitat inventory was conducted in the Split Lake Area, which included four rivers: a) the Burntwood River; b) the Odei River; c) the Nelson River downstream of Kelsey GS; and d) the Grass River (Henderson *et al.* 2011). Habitat suitable for spawning, rearing, and foraging for each life history stage (young-of-the-year (YOY), sub-adult (~200-833 mm) and adult (≥ 834 mm FL)) of the lake sturgeon was found in the Burntwood, Nelson, and Grass rivers. In the Odei River, however, the substrate was composed predominantly of fine particles (i.e., silt/clay) and water velocities were low, suggesting that suitable rearing habitat for YOY lake sturgeon may not exist. Although the Odei River may not provide habitat for YOY lake sturgeon, the presence of lake sturgeon from several age classes in the Burntwood River (Henderson *et al.* 2011) confirms that habitat suitable for each life history stage can be found in the Burntwood River downstream of First Rapids. In the Nelson and Grass rivers, EA studies have documented far fewer adult lake sturgeon (relative to the Burntwood River), despite the relatively high diversity of habitats. Given the diversity of habitat, historic reports of substantial sturgeon fisheries in both the Grass River and Nelson River downstream of Kelsey Falls, it is probable that suitable habitat for each life stage of the lake sturgeon exists in this area. Given that suitable habitat exists for each life stage of lake sturgeon in the Burntwood River, Nelson River near the Kelsey GS and the Grass River, these areas appear to be appropriate for stocking lake sturgeon.

Finally, it should be noted that the Keeyask GS Project is not expected to affect lake sturgeon habitat in the Split Lake area.

Keeyask Area: Clark Lake Inlet to Gull Rapids

Population estimates for the Nelson River between Birthday and Gull rapids (2001 to 2008) ranged from 344 to 1,275 adult fish with the most recent estimate (2008) at 643. This reach of the Nelson River contains two known sturgeon spawning locations: Long Rapids and Birthday Rapids. Based on EA studies, the lake sturgeon population in this reach of the Nelson River is considered to be remnant.

Habitat suitable for each life history stage of the lake sturgeon is believed to exist in this reach of the Nelson River as evidenced by captures of young-of-the-year (YOY), sub-adult, and adult fish. In addition, results from telemetry studies indicate that lake sturgeon over-winter within this reach of the Nelson River.

Construction of the Keeyask GS will alter water depth and flow conditions at Birthday Rapids as the upstream boundary of the open-water hydraulic zone of influence of the Project will be located between the outlet of Clark Lake and Birthday Rapids during open-water conditions. The alteration of water levels and flows at Birthday Rapids may render this area less suitable for spawning lake sturgeon. However, it is possible that lake sturgeon currently using Birthday Rapids for spawning will either continue to spawn at Birthday Rapids, or, move upstream to spawn at Long Rapids, which are not expected to be altered by the Project. Similar behaviours have been observed by adult lake sturgeon in Quebec (Richard Verdon *pers comm*). If monitoring indicates that sturgeon no longer spawn at Birthday Rapids, the potential to modify habitat immediately upstream will also be investigated.

Further to the habitat alteration at Birthday Rapids, construction of the Keeyask GS will also alter habitat between Birthday Rapids and the Keeyask GS. Habitat suitability index models were developed for three lake sturgeon life history stages based on the habitat (depth, water velocity and substrate) expected to exist in the Keeyask reservoir post-Project. Outputs from these models suggest that ample foraging habitat for sub-adult and adult lake sturgeon will exist post-Project; however, the models predict a net loss of YOY habitat. Creation of YOY habitat has been identified in the Keeyask mitigation plan. If monitoring data suggests that post-Project natural recruitment is poor, YOY habitat will be developed.

Stephens Lake

Too few sturgeon were captured in the Stephens Lake area during EA studies to generate a population estimate. Gull Rapids is the only location in the Stephens Lake area that possesses habitat characteristics suitable for lake sturgeon spawning. Catches of YOY, sub-adult and adult fish in Stephens Lake, particularly in the riverine reach downstream of Gull Rapids, indicate that at least some rearing and foraging habitat exists for these life stages in the present day environment. In addition, telemetry studies have shown that lake sturgeon over-winter in Stephens Lake.

Habitat suitability indices developed for YOY, sub-adult, and adult lake sturgeon indicate that there is currently little suitable YOY habitat in Stephens Lake. In addition, the Keeyask GS will eliminate all spawning habitat at Gull Rapids. In order to ensure that habitat suitable for each life history stage will exist following development of Keeyask, creation of a spawning structure downstream of the generating station powerhouse has been planned as a necessary mitigation action. Creation of a lake sturgeon spawning area has been accomplished downstream of the Rivière des Prairies GS in Quebec and this area has been successful in increasing the spawning success of lake sturgeon (Dumont *et al.* 2011). Further, habitat creation for young-of-the-year lake sturgeon is also being considered for an area downstream of the proposed spawning area. Should these habitat enhancement measures prove successful, then habitat suitable for each life stage of the lake sturgeon should remain in Stephens Lake post-Project.

Long Spruce and Limestone Forebays

Construction of the Long Spruce and Limestone GSs created the Long Spruce and Limestone forebays which have been in existence for approximately three and two decades, respectively. Although lake sturgeon populations within these forebays have not been studied extensively, similar to the Stephens Lake populations, lake sturgeon abundance appears to be too low to facilitate quantitative population estimates. In addition, it is unknown if natural recruitment of lake sturgeon is occurring within these two forebays. Young lake sturgeon (born after construction of the GSs) have been captured in both forebays, however, it remains unknown if these lake sturgeon are immigrants from areas further upstream in the Nelson River.

As previously discussed, a successful stocking program aimed at the long-term restoration of a naturally sustainable population must meet several criteria including: a) existence of habitat suitable for the growth of each life history stage in the vicinity of each release location; b) availability of spawning habitat for introduced fish to use once they reach sexual maturity; and c) a location where suitable numbers of brood stock, genetically similar to wild fish, can be collected. These criteria are discussed below in reference to the Long Spruce and Limestone GS forebays.

Habitat mapping of the Limestone and Long Spruce GS forebays indicated that the substrate was comprised almost entirely of coarse substrate such as bedrock, large boulders and cobble. Considering that rearing areas for larval and YOY lake sturgeon are thought to be composed of sand and gravel substrate, it is unknown if sufficient habitat suitable for the growth of each life history stage of the lake sturgeon exists within these forebays. Given the apparent lack of spawning lake sturgeon, it is difficult to determine the suitability of this habitat for larval sturgeon.

The second criterion, availability of spawning habitat, may also not be met in either forebay. Given the low abundance of spawning lake sturgeon however, it is difficult to assess the suitability or availability of spawning habitat. Successful spawning has not been documented below either GS and although lake sturgeon are known to spawn at the base of hydroelectric generating stations, the quality and quantity of habitat downstream of both the Long Spruce and Limestone GSs is smooth bedrock which lacks interstitial spaces sturgeon may need for successful egg incubation. Spawning areas may need to be created downstream of these GSs to provide stocked lake sturgeon a place to spawn.

The third criteria, that suitable numbers of brood stock with similar genetics exists to act as a donor population, could be met for these two areas. Lake sturgeon from the Nelson River downstream of Limestone GS would likely be the most suitable for brood stock for these two forebays.

In summary, because suitable habitat may not currently exist within the Long Spruce or Limestone forebays for each life history stage of the lake sturgeon, it was decided that lake sturgeon stocking into either of the forebays would not be included in the Keeyask stocking strategy. Any future consideration of lake sturgeon stocking in either of the Long Spruce and/or Limestone forebays would likely necessitate the creation of spawning and rearing habitats to support population recovery.

2.2 NUMBER OF FISH, AGE AT RELEASE AND DURATION OF STOCKING PROGRAM

The following section provides a rationale for the proposed number of fish stocked, age at release and duration of the stocking program required to meet the DFO (2010) RPA objective for MU3 (Kelsey GS to Kettle GS). The actual number of fish stocked and locations for stocking within MU3 will depend on ongoing monitoring and assessment, the age at which fish are stocked, and the success of spawn collection and rearing.

2.2.1 Number of Fish to Stock

The determination of the number of fish to stock within MU3 was based on stocking rates for lake sturgeon at the fall fingerling life stage. Stocking plans for older (i.e., yearling) or younger life stages would be adjusted according to expected survival rates for those stages.

Two approaches were followed to estimate the appropriate fall fingerling stocking density: 1) lake sturgeon stocking guidelines developed in Wisconsin; and 2) a recruitment model targeting reaching a specific adult spawning female population over the course of the program.

Wisconsin Guidelines

The Wisconsin Guidelines were developed based on Wisconsin rivers, which are smaller than the Nelson River. These guidelines suggest that fall fingerlings should be stocked at a rate of 80 fish/river mile (50 fish/river km). The river length in MU3 is 213 km; this was calculated by measuring river length from Kelsey GS to Kettle GS, plus the river length from First Rapids to a mid-point in the upper portion of Split Lake, plus the distance from the apex of the north arm of Stephens Lake to a mid-point in Stephens Lake. Based on the estimated river length, the Wisconsin Guidelines prescribe an annual fall fingerling stocking rate of 10,650 fish. As noted above, these guidelines are based on smaller rivers than the Nelson River; therefore, these estimates may be low.

Lake Sturgeon Recruitment Model

The DFO (2010) RPA provides a target number of a minimum number of 413 spawning females to achieve healthy, viable populations of lake sturgeon in each MU. To obtain an upper estimate on the number of sturgeon that could be stocked, targets for the release of fall fingerlings into the combined three reaches (Upper Split Lake, Nelson River between Clark Lake and Gull Rapids, and Stephens Lake) were developed based on a recovery target of 500 Adult Spawning Females (ASF) per year (which equates to 2500 ASF in the population based on females spawning every five years) within three generations (90 years) over the three areas combined.

The number of fall fingerlings required for stocking each year to achieve the ASF objective was derived through construction of a lake sturgeon life table with age, survival at age, and fecundity. The stocked cohorts were propagated through time using a matrix. For surviving spawning fish at each age over 25 years, a fecundity value was calculated based on literature values and a fecundity with age function was applied. The eggs that hatched and survived to fingerling stage were added to the population each year and the cycle repeated. The contribution of the existing population of "wild" adult spawning females to meeting the Management Unit ASF objective was not included in the recruitment model. Consequently, recruitment model results represent an over-estimate of the number of stocked fish required to meet the recovery target.

Three potential scenarios were explored and compared to determine the potential impact that ongoing harvest would have on the time to achieve the ASF objective (Figure 2). The stocking rate chosen for this comparison was the minimum rate that would achieve the ASF objective with both natural and fishing mortality factored into the adult survival rate.

1. **Unexploited Population** – This scenario (Figure 2 - top-most graph) assumes that only natural mortality (6.7%) would determine adult survival rates (i.e., no lake sturgeon fishing). Under these conditions, annual stocking of 19,722 fall fingerlings (includes both sexes at assumed 1:1 gender ratio) for 25 years would achieve the 2500 ASF objective in 32 years. Survival rates used in the model were as follows:
   - 0.300 annual survival of fall fingerlings;
   - 0.6998 annual survival of one-year olds; and
   - 0.933 annual survival for lake sturgeon older than two years of age (juvenile through all adult year classes).
2. **Exploited Population** – This scenario (Figure 2 – middle graph) shows how fishing mortality (in addition to natural mortality) would affect attainment of the ASF objective under the same stocking plan as above. No direct estimate of fishing mortality is available for the area. Therefore, an estimate of 8.3% was derived from the difference between the estimated population survival in the Nelson River between Clark Lake and Gull Rapids (85%) and the average adult survival provided by DFO (2010) (93.3%). Use of this estimate may result in an over-estimate of the effects of fishing mortality on the population as it was applied to the entire Kelsey to Keeyask reach, and fishing mortality in the other parts of the reach may be lower than in the Clark to Gull Rapids reach. Survival rates used in this run of the model were as follows:
   - 0.300 annual survival of fall fingerlings;
   - 0.6998 annual survival of one-year-olds;
   - 0.933 annual survival for year classes two through 24; and
   - 0.8496 annual survival for fish older than 24 years.

   The modelled results show that at the same stocking rate and duration (i.e., 25 years) as above, the 2500 ASF objective would be met at approximately year 45. However, within five years the ASF population would begin to decline, reaching 500 ASF by year 90 and continuing a slow decline thereafter.

3. **Exploited Population but with Enhanced Stocking to Maintain ASF Objective** – Survival rates at each life stage for this scenario (Figure 2 – bottom graph) are identical to those used in the middle graph. In this case, the ASF objective in the exploited population would be met the same as above (approximately 45 years). However, to sustain and grow the ASF population, stocking would be required for as long as annual fishing mortality remained at or above the estimated rate of 8.3%. In the example shown, continued stocking at a constant rate of 19,722 fall fingerlings would result in growth of the ASF population to approximately 3,900 fish by year 90. Stocking at this rate would meet and exceed the DFO RPA objective.

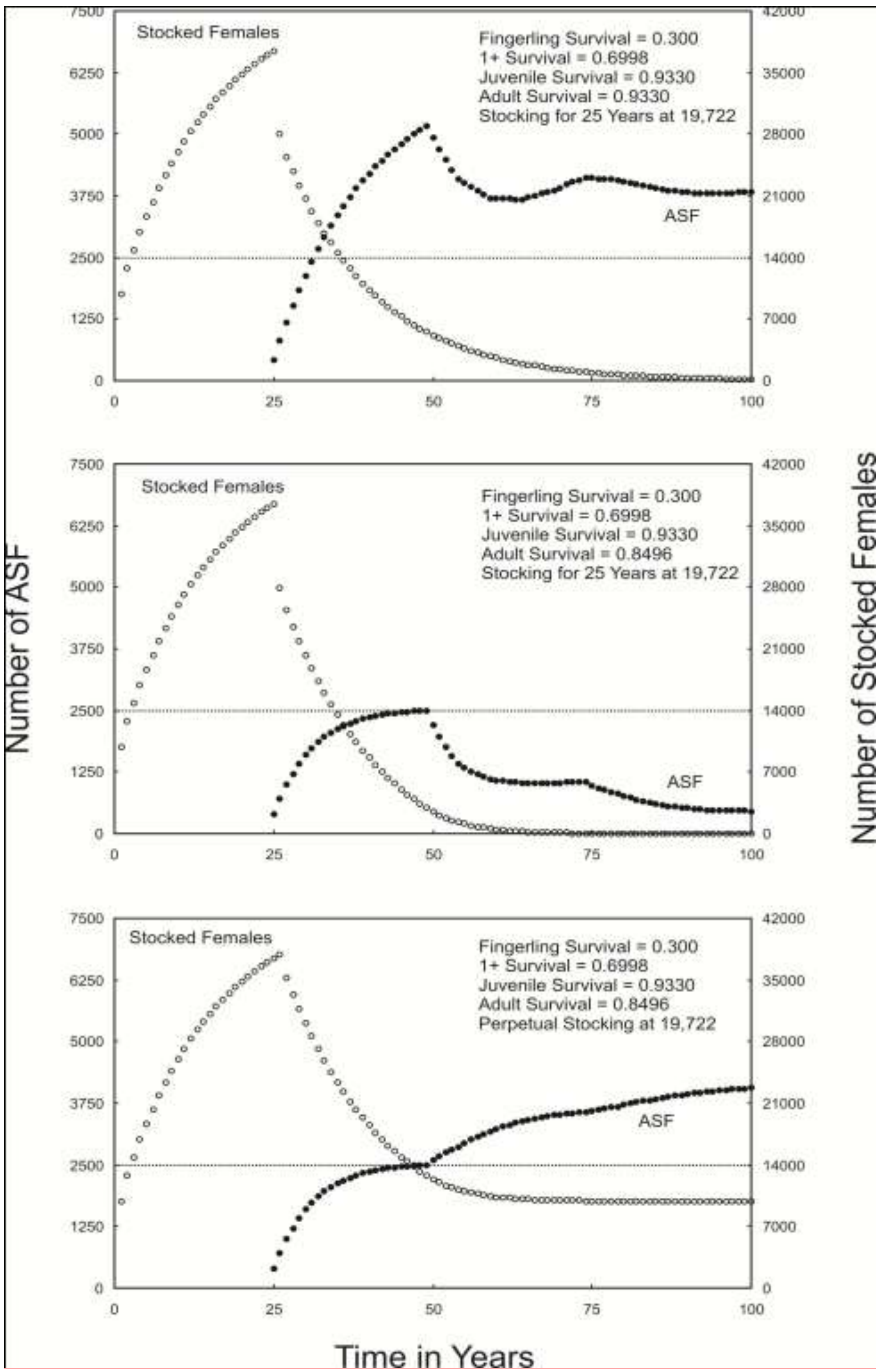

Figure 2. **Adult spawning female (ASF) population response to fall fingerling stocking: Upper graph – stocking with no harvest; Middle graph – stocking with harvest (8.3% fishing mortality); Lower graph – stocking to compensate for harvest.**

In the Exploited Scenario (i.e., assumes a constant annual 8.3% fishing mortality), to achieve the same objective in the same time frame as in the Unexploited Scenario, an annual stocking rate of 19,770 fall fingerlings would be required. However, to maintain the ASF population at or above the objective, ongoing stocking would be required in perpetuity providing fishing mortality remained at the current rate.

Of these three scenarios, it is recommended to use Scenario 3 as the basis for setting initial annual targets for stocking density. It is assumed that a sturgeon harvest on the Nelson River would continue since it is culturally important. It is important to note that lake sturgeon year-class strength and the proportion of the hatchery reared versus wild fish that comprise each year class will be monitored annually. Stocking rates would be modified based on monitoring results, to avoid either under or over-stocking.

Recommended Stocking Rate based on Fall Fingerling Stage

Using the Wisconsin Guidelines as a basis for determining the density of fish to be stocked, a fall fingerling stocking rate of 10,650 fish/year, annually over one generation or 25 years, would be recommended. However, stocking at this rate does not explicitly account for any assumed fishing mortality and may be too low considering the Wisconsin guideline was developed based on rivers smaller than the Nelson River.

Summary and Recommendation

The lake sturgeon recruitment model (Unexploited Scenario) indicates that, in the absence of fishing mortality, a stocking rate of 19,722/year for 25 years would achieve the ASF objective (DFO RPA) within 32 years. However, an analysis of how different rates of annual stocking affect the time (and cost) to achieve the long-term ASF objective indicates that stocking at a rate of 10,440/year for 25 years would attain the ASF objective in 45 years (Figure 3). This stocking rate appears to be the most cost-effective rate at which to stock fall fingerlings to achieve the DFO (2010) RPA objective within a reasonable period of time (i.e., within three generations). In the absence of fishing mortality, the ASF objective would be sustained over the long term at or above that level. This rate is essentially (and coincidentally) the same as the rate derived using the Wisconsin Guideline.

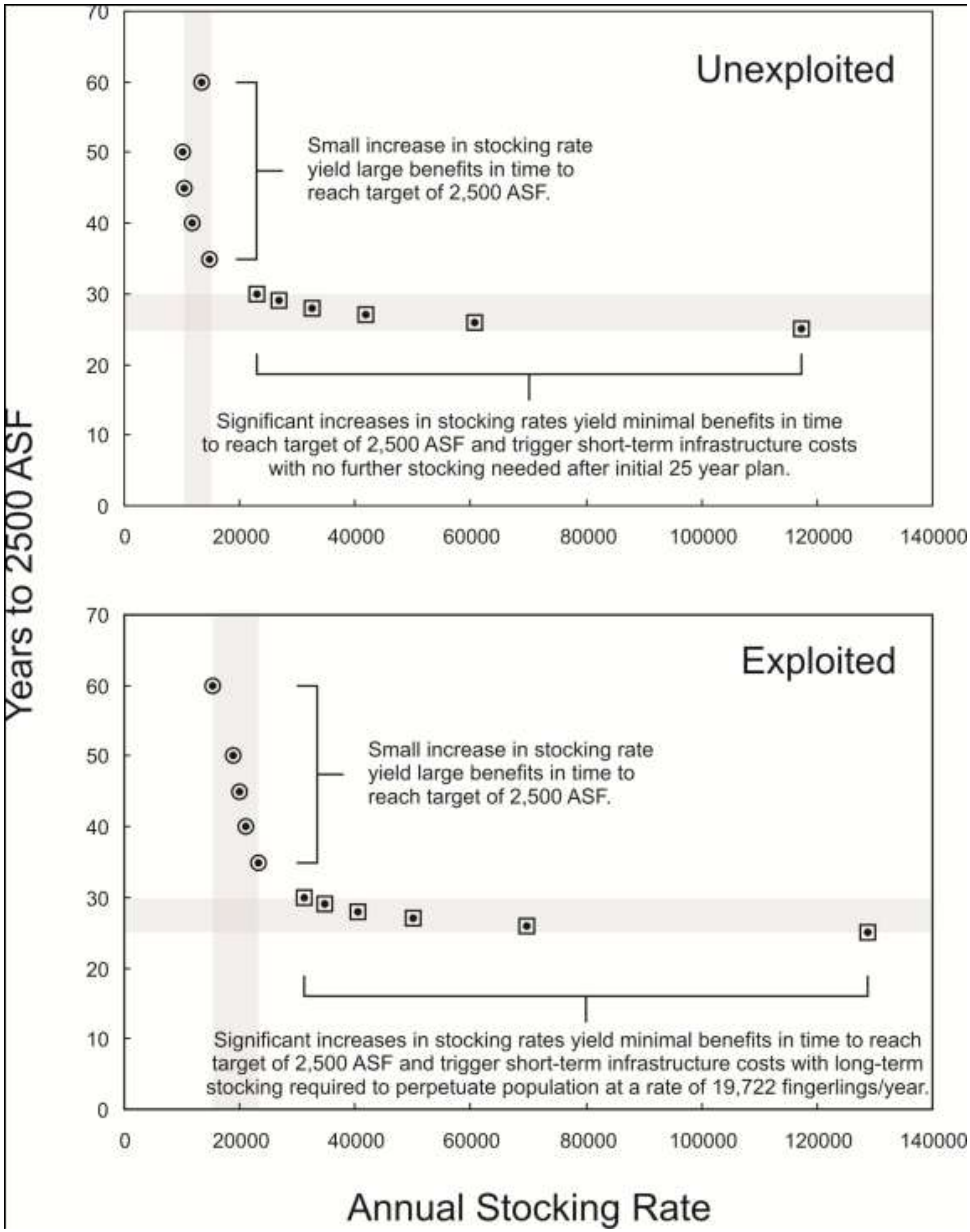

Figure 3. **Relationship between number of lake sturgeon fall fingerlings (male and female) stocked and time to meeting the adult spawning female objective.**

2.2.2 Age of Fish to Stock

Larvae (feeding stage; following yolk sac absorption), fall fingerlings (17 weeks old) and spring yearlings (1 year old) are the three life stages being considered for stocking. Advantages and disadvantages that are being considered in determining which life stages to stock are described below:

- Larval (feeding stage) fish have the advantage of lower rearing costs; however, mortality is considerably higher than older life stages due to starvation and predation once fish are released from the protective hatchery environment. Whether or not earlier life stage introduction to their receiving environment would result in higher future reproductive success is unknown, but it has been suggested that fish introduced at an early life stage would benefit in the long-term from effects of natural selection on maintaining desirable within-population genetic variation (Welsh *et al.* 2010). Habitat requirements of larval lake sturgeon are poorly understood, and further, uncertainties remain regarding the availability of this habitat following construction of the Keeyask GS. The number of larval sturgeon that are hatched in the hatchery may exceed the rearing requirement for fall fingerling and spring yearling release, as well as exceed the rearing capacity of the hatchery/rearing facility. Excess supply of larval lake sturgeon would be released into receiving reaches at locations in the same general area from which the gametes were sourced or where known YOY habitat is present.
- Fall fingerlings are the life stage released in many stocking programs as survival is higher relative to larval fish, and there are fewer uncertainties regarding the availability of suitable habitat. Crossman (2008) reported that recapture rates and dispersal distances were significantly higher for fish stocked at 17 weeks than for fish released at earlier ages. Additionally, given the uncertainty with the suitability of early young-of-the-year rearing habitat in the Keeyask reservoir, the release of fall fingerling may be more successful than the release of larvae. Although fall fingerlings cost more to raise than larvae/fry, the cost is significantly less than culturing the fingerlings over the winter. Literature sources suggest a first winter survival rate for fall released fingerlings of between 20 and 40% (Aloisi *et al.* 2006; Crossman *et al.* 2009).
- Spring yearlings would have the advantage of even higher survival relative to the earlier life stages and would be least likely to be limited by available foraging habitat in Stephens Lake and the newly created reservoir. Rearing costs would be the highest of the three life stages; however, the higher survival rate of one-year old lake sturgeon would also offset requirements to stock as many fall fingerlings to meet ASF recovery objectives. Other factors as noted by Welsh *et al.* (2010) (such as natural selection) need to be considered when making decisions on early versus later fish release.

The life stages proposed for stocking would depend on the availability of suitable habitat to support each life stage during and following construction of the Keeyask GS, the year-to-year variation in the supply of gametes, and consideration of survival rates versus rearing costs associated with each life stage. Population monitoring post-Project will play a key role in determining year-class strength and the relative contributions to each cohort from hatchery reared or wild fish. Monitoring will also be used to determine survival of each life stage of lake sturgeon released. These data will be used to fine-tune the stocking program by determining the optimal number, life stage and location to stock lake sturgeon.

2.2.3 Duration of Program

The Keeyask lake sturgeon stocking program is expected to be implemented for as long as required to achieve and maintain the stated DFO (2010) RPA objective for MU3. However, the focus and priorities attached to stocking program components are expected to change with time depending on Project phase (construction versus operation), habitat limitations, area-specific lake sturgeon population growth, and brood stock availability.

As discussed in Section 1.2, monitoring would be conducted during the pre-implementation and implementation phases of the stocking program to determine the effect on fish populations and avoid potential effects of overstocking. The duration of the program could vary depending on location and monitoring results as follows:

Short term – the aim of a short-term stocking program would be to prevent missing year classes in the sturgeon population in the Keeyask area during years of construction, as mitigation measures to support spawning and YOY rearing are refined. Therefore, stocking numbers and age at release would be modified once it is understood how the natural processes may have been affected by the project and how stocked lake sturgeon are surviving in the wild. A short-term stocking program would continue while the Keeyask GS is under construction.

Long term – the aim of a long-term stocking program would be to re-establish a sustainable population. Therefore, a long-term stocking program would continue through an entire generation (25 years). After 25 years, it is hoped that the number of naturally reproducing fish would be sufficient to sustain the population. For example, it is likely that the Stephens Lake area would be targeted with a 25-year program.

Permanent – as discussed in Section 2.2.1, the rates of exploitation in these areas may be sufficient to require stocking in perpetuity to support the populations. Monitoring would determine if densities are reaching levels that are too high; otherwise, stocking could continue for as long as mortality rates exceed a self-sustaining recruitment rate.

2.3 IDENTIFICATION OF "SOURCE" POPULATION

In order for a stocking program to be successful, a population of lake sturgeon must be identified from which gametes can be collected. Several factors must be considered when selecting a suitable source population:

1. The source population must be genetically similar, or as similar as possible, to the existing (remnant) population.
2. The population must be large enough to provide sufficient gametes and genetic variability.
3. It must be feasible to collect eggs and milt from the source population and transport fertilized eggs to a facility for rearing.

Cote *et al.* (2011) provided an analysis of the genetic structure of lake sturgeon from three river systems in northern Manitoba: the Nelson River from Sipiwesk Lake to the Nelson River Estuary; the lower Hayes River; and the Churchill River at the confluence with the Little Churchill. The study found that the Churchill River sturgeon were distinct from the other groups. Within the Nelson/lower Hayes group, there was evidence for four subpopulations: the Landing River (Nelson River); Kelsey/Grass and Burntwood (Split Lake); Birthday/Gull (Nelson River reach from Birthday Rapids to Kettle GS); and lower Nelson/Angling/Weir/lower Hayes rivers. The level of genetic difference among these four groups was low. The importance of conserving this genetic differentiation is unknown, but maintenance of existing genetic structure is the preferred approach in conservation genetics (Welsh *et al.* 2010). With respect to the Keeyask stocking strategy, a conservative approach to maintaining the existing genetic structure would require obtaining gametes and rearing lake sturgeon from the same resident lake sturgeon subpopulation for each area of interest for stocking. However, given the low level of difference found among the sites, an alternate, less conservative approach would be to consider the Nelson River below the Kelsey GS as a single population.

At least one known spawning location exists in each of the areas identified by Cote *et al.* (2011). However, in many cases, the total population and number of sturgeon spawning each year at some of these locations is small; pilot studies are being conducted to determine the feasibility of collecting gametes at these locations (Section 3.1). Even if spawn collection is feasible, the numbers of fish collected at some locations will be below recommended levels. Elliot *et al.* (2005) recommended that over 25 years, gametes should be collected from at least 250 different females. Although this goal would be difficult to achieve in the Keeyask area due to small populations, it would be feasible to collect eggs from a minimum of two different females annually. If the two females were crossed with a minimum of four males, this would ensure that genes from at least eight families were stocked annually. In addition, fish used for spawn collection will be marked for future identification to ensure that they can be recognized during subsequent spawn collection activities and not reused (i.e., the proposed plan would not retain adult sturgeon for use as brood stock).

It should be noted that, despite the small subpopulation size at some locations, none of the subpopulations had lower than expected genetic diversity and are considered genetically 'healthy' (Cote *et al.* 2011). In addition, recent work by Schueller and Hayes (2011) suggests that lake sturgeon have potentially lower minimum viable population sizes because the long-lived overlapping generations of lake sturgeon may buffer populations from inbreeding depression. Further, these authors suggest that populations between 80 and 150 individuals are required for long-term persistence. These studies, as well as additional genetic studies currently being planned for lake sturgeon in the Nelson River as part of Keeyask EA studies, will continue to contribute to refinement of this stocking strategy, specifically with regards to numbers of fish and numbers of families to stock.

With respect to the third consideration listed above, the collection of spawn is feasible (see Section 3.1) from each subpopulation. Therefore, given the uncertainties surrounding genetic mixing of stocks, the initial stocking plan would likely attempt to maintain the existing genetic structure and collect spawn from the same subpopulations as will be stocked. However, given uncertainties and difficulties associated with spawn collection, a second contingency strategy may be required. If the number of spawning fish is too small to support the above approach, then spawn will be collected at sites that are genetically the most similar to proposed stocking locations.

3.0 PRE-IMPLEMENTATION PHASE

This phase addresses the practical issues related to implementation of the stocking program and includes investigations to address potential issues. It should be noted that requirements for additional field trials will likely be identified as investigations continue.

Specific activities identified to date include:

1. Assessment of brood stock collection:
   - Assessment of numbers of mature fish at potential spawn collection locations;
   - Assessment of the use of hormones (e.g. Ovaprim) to facilitate collection of gametes; and
   - Field trials of gamete collection and fertilization.

2. Assessment of rearing:
   - Investigations of issues related to lake sturgeon disease and disease transmission;
   - Evaluation of the effect of water temperature on growth and survival rates; and
   - Evaluation of the effect of food type on growth and survival rates.

3. Assessment of post-release success:
   - Assessment of survival rates (refine stocking objectives);
   - Comparison of survival rates of fingerling and yearling fish; and
   - Measurement of movements from the area of release.

3.1 ASSESSMENT OF BROOD STOCK COLLECTION

Within the Kelsey to Kettle reach, spawning is known to occur at First Rapids on the Burntwood River, and at Long, Birthday and Gull rapids on the Nelson River. On the lower Nelson River downstream of the Kettle GS, spawning has been documented at the Lower Limestone Rapids, and the Weir and Angling rivers. Due to the estimated small annual female spawning population size in the area between the Kelsey and Kettle GSs, it is rare to catch a female lake sturgeon in spawning condition from which eggs can be readily expressed. Lake sturgeon are more abundant in the Nelson River below the Limestone GS. Collection of lake sturgeon for brood stock at Lower Limestone Rapids would be difficult given fluctuating water levels during moderate to low flow years. Further, spawn collection at the Angling River would also be difficult due to the low abundance of spawning lake sturgeon. Therefore, due to the high abundance of spawning fish, and their relative ease of capture, the Weir River provides the best opportunity to collect sturgeon gametes.

In spring 2010, field trials to capture spawning female lake sturgeon at First Rapids on the Burntwood River and at Birthday Rapids on the Nelson River did not yield any sturgeon from which eggs could be expressed. Given the relatively low numbers of spawning lake sturgeon, chances of capturing female lake sturgeon that would readily express eggs are low. One potential approach to spawn collection at these locations would be to inject a hormone that stimulates egg and milt production (e.g. Ovaprim), into fish that are maturing to spawn during the current year. Ovaprim is a commercially available hormone that contains gonadotropin releasing hormone and a dopamine inhibitor. This hormone is used to stimulate and induce ovulation in adult female lake sturgeon and spermiation in male sturgeon. As an example, it has been used successfully from 2008 to 2010 to induce spawning in female lake sturgeon in the Winnipeg River (C. Klassen *pers. comm.*) and has been used during lake sturgeon spawn taking operations in the Rainy River (J. Hunter *pers. comm.*). The benefits of using a hormone such as Ovaprim to induce spawning in lake sturgeon include:

1. Ensuring the collection of eggs and milt from wild spawning sturgeon;
2. The coordinated collection of eggs from ovulating females; and
3. Substantial increase in the volume of eggs collected from each female.

While the use of Ovaprim has proved successful for collecting eggs and milt from lake sturgeon, little is known regarding the effects of Ovaprim on adult lake sturgeon. Manitoba Hydro has engaged a physiologist from the University of Manitoba to examine the following:

1. The effect of Ovaprim on circulating blood and muscle levels of sex hormones, and the duration that these hormones persist in the blood and muscle;
2. The influence of Ovaprim administration on the endocrine stress response; and
3. The influence of Ovaprim administration on egg quality and fertilization success.

Through systematic analysis of plasma and muscle hormonal levels, egg and sperm quality and female and male condition following administration of Ovaprim, this study will determine the effects of Ovaprim on fish condition, gamete quality and viability.

Additionally, in spring 2011, the Nelson River Sturgeon Co-management Board (NRSB) conducted trials using Ovaprim during its spawn collection program on Nelson River near the mouth of the Landing River. Over 35,000 eggs were successfully collected, the largest number ever collected by the NRSB; without Ovaprim, the NRSB would likely have collected very few eggs and may not even have been able to fertilize them (D. MacDonald *pers. comm.*). Results of this initial field trial show that it is technically feasible to collect sturgeon gametes streamside using Ovaprim.

3.2 ASSESSMENT OF REARING

Sturgeon are presently reared in several hatcheries in the USA and Canada, including the Grand Rapids Hatchery in Manitoba. A new hatchery would be constructed in northern Manitoba to provide facilities to raise sturgeon for the Keeyask lake sturgeon stocking strategy. A new hatchery would be designed in consultation with individuals experienced in the design and operation of hatcheries.

Several issues specific to sturgeon culture have been identified at existing sturgeon hatcheries, including the transmission of disease, feeding of larval sturgeon after the yolk sac has been absorbed, and the effect of temperature on growth (fish held at low temperatures to reduce the transmission of disease grow very slowly).

Very little is known with respect to disease transmission among cultured lake sturgeon or the risks associated with transmission of diseases from cultured to wild fish. Manitoba Hydro is funding a study through the Department of Fisheries and Oceans (DFO) to improve the understanding of disease and disease transmission in lake sturgeon. The overall objective of this study is to generate a lake sturgeon infectious disease management plan that will work to prevent the spread of infectious diseases and minimize the incidence of disease in cultured lake sturgeon.

One measure that may work to reduce disease infection in cultured sturgeon is rearing sturgeon at low water temperatures. This measure is currently being employed at the Grand Rapids hatchery but further investigation is warranted as young fish grow more slowly at low temperatures.

The initiation of feeding of lake sturgeon immediately following absorption of the yolk sac and the switching of food types as the young fish grow may be associated with increased rates of mortality. Consultations with other hatchery operators and possible feeding trials in Manitoba will be used to identify an approach that achieves the optimum balance between mortality and cost. It should be noted that acceptable rates of mortality will vary depending on the success of initial egg collection and hatch.

3.3 ASSESSMENT OF POST-RELEASE

In order to monitor the success of any stocking program, hatchery reared fish must be marked prior to release. There are many challenges associated with marking very small fish; however, advances in technology are continually improving enabling smaller fish to be marked.

Several options currently exist for marking small fish and some of these are listed below:

1. Passively Integrated Transponder (PIT tags) – These are very small tags (8 mm now available) that have been successfully applied to fingerling lake sturgeon released into the Winnipeg River.
2. Scute removal – This has been done successfully in several white sturgeon stocking programs along the west coast of North America. A different scute, or combination of scutes, are removed from lake sturgeon annually allowing determination of the year the sturgeon was released as well as differentiation from wild sturgeon.
3. Coded wire tags – These are very small tags that can be inserted into lake sturgeon. A scanner is used to determine if a coded wire tag has been inserted into the fish; however, fish cannot be individually identified without removing it from the fish. Once removed, the tag can be read under a microscope to determine the tag number.
4. Visible Implant Elastomer – This is a plastic that is injected into the fish under the skin. It is visible for two to three years following implantation.

In addition to the techniques listed above, sturgeon raised to yearling size could be tracked with conventional telemetry tags.

The specifics of programs designed to monitor the survival of stocked lake sturgeon, and their behaviour relative to wild sturgeon, will be determined when hatchery-raised sturgeon are available, as specifics of the program would depend on the source of the brood stock and number of sturgeon.

4.0 NEXT STEPS (2012 – 2037)

With the planned date for the start of construction of the Keeyask GS in 2014, it is recommended that a preliminary lake sturgeon stocking trial be conducted as soon as possible (i.e., spring 2012). A preliminary stocking trial would have numerous benefits:

- Further refinement of spawn collection and rearing techniques;
- Identification of equipment needs and number of personnel required;
- Allow an opportunity to train KCN members how to collect gametes and rear lake sturgeon in a hatchery; and
- Allow participation by numerous individuals in the rearing and release (e.g., conservation and awareness program).

Following completion of the preliminary stocking trial and its successes/failures, refinements to this plan will be made to improve the success of the stocking plan.

Following completion of the trial stocking program in 2012, a ten-year plan to encompass the construction of the Keeyask GS would be developed.

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APPENDIX I

FEASIBILITY OF SUCCESS – WHAT IS KNOWN FROM ATTEMPTS AT STOCKING LAKE STURGEON IN OTHER LOCATIONS

OVERVIEW

Conservation-based lake sturgeon stocking programs have been conducted in numerous jurisdictions within the United States since the early 1980s (Menominee and St. Louis rivers, WI). Since then, each state bordering the Great Lakes, plus a number of other states that lake sturgeon historically occupied (Red River of the North, MN; Coosa River GA; Mississippi and Missouri rivers, MO), have implemented stocking programs with the aim of restoring self-sustaining populations. In Canada, lake sturgeon stocking initiatives have been undertaken in Quebec, Manitoba, and Saskatchewan.

Lake sturgeon stocking programs, at virtually each location that they have been attempted, have demonstrated the ability to culture and rear young sturgeon in either a hatchery or stream-side rearing facility. In addition, most programs have succeeded in releasing young fish into the wild and demonstrating adequate survival and growth of the released fish.

Recently, researchers studying a population of lake sturgeon comprised entirely of re-introduced stocked fish, found evidence of natural reproduction. Lake sturgeon (Lake Winnebago strain) were stocked into the St. Louis River, a tributary of Lake Superior, over a 25-year period starting in the early 1980's. Monitoring of this population prior to 2011 confirmed that the stocked fish were growing and that several age classes were present (Schram *et al.* 1999). Genetics analysis from fish naturally recruited in spring 2011 confirmed that these were Lake Winnebago strain fish and therefore, stocked fish had spawned approximately 30 years following the initial reintroduction of lake sturgeon into the river (R. Bruch *pers. comm.*). This is the first recorded evidence of natural reproduction in lake sturgeon resulting from stocked fish.

What follows are some examples of stocking plans and strategies that are being employed in other jurisdictions, as well as a brief summary of a few stocking programs that have been undertaken in North America, including Manitoba.

WHAT CAN BE LEARNED FROM EXISTING LAKE STURGEON STOCKING PROGRAMS

GUIDELINES FOR STOCKING

Stocking guidelines were developed for the rehabilitation of lake sturgeon in Michigan State watersheds (Elliot *et al.* 2004 in Quinlan et al. 2005). Guidance was provided for:

- **evaluating** the appropriateness (and success) of stocking;
- the selection of **donor populations**;
- the **collection of gametes**;
- **mating schemes**;
- **numbers to stock**; and
- **rearing and release** techniques.

Each of the items listed above (bold text) are described below.

Evaluation - Prior to initiating rehabilitation, the underlying reasons why a system is not populated or why a remnant population is at risk should be understood. Stocking should only be initiated when water quality and habitat are capable of supporting stocked fish. Furthermore, the system should be capable of supporting natural reproduction by the time stocked fish mature. Evaluation measures capable of documenting the success of rehabilitation actions should be planned and implemented prior to stocking.

Donor populations - should be selected based on similarities in genetic lineage, life history, and ecology between the donor population and the population being rehabilitated. A donor population also needs to be of sufficient size and genetic diversity to support gamete or larval collections. To protect the donor population, gamete collections should be made from no more than 5% of the annual adult spawning stock in any year, or should not exceed 10% of that population's annual production of eggs or larvae.

Collection of gametes and mating schemes - Over the period of rehabilitation (25 years), gametes should be collected from a minimum of 250 different females and 250-1250 males. Eggs from individual females should be divided equally among available males and fertilized 1:1. An alternative is to collect naturally deposited eggs or drifting larvae so that genes from as many families as possible contribute to the year class. Family contribution should be equalized throughout the rehabilitation or restoration process by rearing and stocking equal numbers from each contributing family.

The number of fish stocked - should be based on habitat availability and expected survival rates so that a minimum population of 750 mature adults (including males 15 years and older and females 20 years and older) that produces a minimum annual spawning run of 250 fish is established. All stocked fish should be permanently marked, and genetic analysis of parents and progeny should be conducted to document the genetic diversity of fish produced.

Rearing and release - Fish should be reared and released in a manner that imprints stocked fish to receiving waters. Streamside rearing, stocking of eggs or early stage larva, and within system transfers are examples. Sturgeon should be released at locations where wild fish of that life stage are known or would be expected to occur.

Elliot *et al.* (2005) note that although the guidelines listed above are still in draft form, Lake Michigan resource management agencies have and are taking actions to follow these guidelines for current reintroduction initiatives.

The question of timing of release (i.e., at what life stage/age) grapples with the trade-off between realizing significantly increased survival with age of released fish versus the cost and space required to rear older fish. The longer a fish is held and grown in a rearing facility, the greater the cost and the more extensive the facility requirement. There are also concerns that fish reared in hatcheries with a different water source to the waterbody in which they are stocked may not imprint to the location and thus move away. To address the imprinting issue, a number of agencies are moving to streamside rearing/grow-out facilities (SRF) that use water from the release location. However, the success and/or importance of imprinting are yet to be determined.

LAKE STURGEON REHABILITATION PLANS

A Lake Sturgeon Rehabilitation Plan for Lake Superior (Auer 2003) was among several considered in the development of the Keeyask lake sturgeon stocking plan. The following were among the recommendations that provided guidance for stocking plans:

- Stocking should be undertaken concurrent with exploitation controls and with habitat protection and restoration.
- Stocked fish should be of similar genetic origin as the extant wild population.
- Before a stocking program is implemented, fish-health issues should be considered to prevent introduction of unwanted pathogens.
- The capture of wild adults during spawning runs remains the most reasonable method of obtaining gametes for artificial propagation.
- To optimize the success of rehabilitation efforts, both larvae (15-30 mm) and fingerlings (100-250 mm) should be stocked.
- All stocked fingerling sturgeons should have a mark/tag to monitor stocking success.
- Spawning operations should follow a brood-stock management plan to maximize genetic variability. Wild brood stock should be bred and distributed following principles designed to maximize the genetic variability of the progeny and minimize genetic drift and inbreeding.
- The annual establishment of year-classes consisting of marked individuals at historic spawning sites and subsequent recruitment in three of every five years over a 20-year period will determine stocking success.

Stocking and genetic strategies should include:

- Regular evaluation of the impact that stocking lake sturgeons has on remnant populations;
- Ongoing assessment and determination of optimal stocking and survival rates; and
- Determining if lake sturgeons imprint on spawning habitat and, if so, at what life stage.

LAKE STURGEON CULTURE

The U.S. Fish and Wildlife Service and Department of Interior have published Standard Operating Procedures for lake sturgeon culture at the Genoa National Fish Hatchery in Genoa, WI. The culturing techniques described were originally adapted from methods developed by Wisconsin DNR at Wild Rose Fish Hatchery. The document provides guidance concerning gamete collection, egg transport, incubation, feeding through fry and fingerling growth stages, fish health concerns, environmental conditions in hatcheries, and release and distribution of reared fish. The document (FDS-2006-3) is available on-line at http://www.fws.gov/midwest/Fisheries/pubpolicy.html .

BRIEF REVIEW OF SELECTED LAKE STURGEON STOCKING PROGRAMS

Manitoba

In Manitoba, lake sturgeon have been stocked into the Assiniboine, Winnipeg, Saskatchewan and Nelson rivers. A brief review of the stocking history of each river is provided below.

Assiniboine River

Lake sturgeon were historically abundant in the Assiniboine River but believed to be completely extirpated by the early 1900's. Efforts to reintroduce lake sturgeon to the Assiniboine River began in 1996 (Appendix Table 1). The river was stocked each year from 1996 to 2008 with the exception of 1998, 2005 and 2007. Lake sturgeon stocked into the Assiniboine River were reared at either the

Whiteshell Hatchery or the Grand Rapids Hatchery, and released near Brandon, Manitoba. It should be noted that lake sturgeon from the Winnipeg, Saskatchewan and Nelson rivers were used to stock the Assiniboine River.

Although a study has not been conducted to formally assess the success of lake sturgeon stocking in the Assiniboine River, lake sturgeon are now commonly captured by anglers (B. Bruderlein, Manitoba Fisheries Branch). Anglers have reported catches of lake sturgeon each year since 1998, and at present, most of the lake sturgeon being captured are longer than 43 inches in length, with the largest reported measuring 60 inches. Because the stocked fish are likely at, or nearing sexual maturity, further study is necessary to determine if the stocked fish will begin to naturally reproduce in the river.

Winnipeg River

Lake sturgeon stocking in the Winnipeg River in Manitoba began in 1996 and has been conducted during most years until 2010 (Appendix Table 1). During this time, substantial numbers of lake sturgeon have been stocked, at various life stages, into the Manitoba portion of the Winnipeg River between the Pointe Du Bois GS and the MacArthur Falls GS (Appendix Table 1). Prior to 2008, lake sturgeon eggs and milt were collected without the aid of a hormone that would induce gamete release in ripe fish. However, in 2008 and 2009, a hormone was used as an aid to collect gametes.

Considerable research into various aspects of lake sturgeon stocking have been conducted in the Winnipeg River. Research to assess the survival, movement and growth of stocked lake sturgeon fingerlings and yearlings, as well as techniques to mark hatchery-reared fish were conducted by Cheryl Klassen (PhD candidate, University of Manitoba) from 2008 to 2010. Subsequently, in 2011, Gary Anderson (Professor, University of Manitoba), initiated a research project focused on assessing the physiological effects of hormone (Ovaprim) injection on adult lake sturgeon.

Despite the considerable amount of research conducted on lake sturgeon in the Winnipeg River, there is a limited understanding in terms of the role that stocking has had on present day lake sturgeon populations.

Nelson River

Lake sturgeon stocking in the Nelson River was conducted on an intermittent basis from 1994 to 2011 by the Nelson River Sturgeon Co-management Board and Manitoba Fisheries Branch (Appendix Table 1). Spawn collection generally occurred from a camp located at the Landing River, a tributary of the Nelson River located approximately 30 km upstream of the Kelsey GS. In spawn taking operations prior to 2011, both male and female lake sturgeon were held streamside in tanks until temperatures were appropriate for spawning. Once temperatures were appropriate, attempts were made to collect eggs and milt from these fish. Because success was limited using this technique, Ovaprim was used during spawn taking operations in 2011. During each year, fertilized eggs from the Landing River site were transported to the Grand Rapids Hatchery for rearing. Lake sturgeon were stocked by into the Nelson River in two general locations, in the Northeast channel and the west channel.

Similar to the other rivers stocked with lake sturgeon in Manitoba, it is difficult to determine the success of stocking efforts in the Nelson River. Annual monitoring of the lake sturgeon population in the Northeast channel of the river suggests that lake sturgeon abundance may be increasing and given that the abundance of younger fish in the catch has increased in the years since stocking commenced, stocking may have be responsible for these increases. In the western channel of the Nelson River, although a formal study has yet to take place, commercial and domestic fishermen have begun to catch lake sturgeon in their gill nets in the years since stocking began. Prior to stocking, lake sturgeon had not been captured for at least a decade. Although not conclusive, these sources of information suggest that the stocked fish may be responsible for these recent increases in catch (D.MacDonald *pers. comm.*).

Saskatchewan River

Lake sturgeon were stocked into the Saskatchewan River in 1999 and 2000, as well as from 2003 - 2007. Brood stock were collected below either the EB Campbell Dam or the Francois Findlay Dam on the Saskatchewan River by Saskatchewan Environment. Ovaprim was used during each year as an aid to collect lake sturgeon eggs. Fertilized lake sturgeon eggs were transported and subsequently reared in the Fort Qu'Appelle hatchery. Considerable numbers of lake sturgeon have been stocked into the Saskatchewan River as either fry or fingerlings (Appendix Table 1), however, the success of the lake sturgeon stocking program remains unknown.

Quebec

Eastmain River Stocking Program

In 2004, lake sturgeon fry and fingerlings were propagated in a field hatchery. This program produced 89,000 fry (2 cm), 25,000 fry (3 – 4 cm), and approximately 21,000 fingerlings (6 - 10 cm), and approximately the same number of young fish were introduced both upstream and downstream of the dam. A total of 88 adult sturgeon were also introduced upstream of the dam. Lake Sturgeon stocking efforts are continuing annually in the Eastmain River.

United States

Coosa River, Georgia

The Coosa River lake sturgeon population was extirpated sometime in the late 1950's or early 1960's. Over-fishing and pollution were identified as the main reasons for the sturgeon's demise in this river. Once most of the pollution sources were eliminated, a stocking program was developed to re-introduce lake sturgeon into the river. Wisconsin DNR provided fertilized lake sturgeon eggs to the State of Georgia, Wildlife Resources Division Summerville Hatchery, where they were raised prior to release.

The initial release of 1,100, six-inch (15 cm) fingerlings took place in 2002. Subsequently, between 2002 and 2008, 85,000 fingerlings were released into the river. Angler reports indicate that the stocked lake sturgeon are thriving. Lake sturgeon survival and growth was higher than expected based on the recapture and observed growth of over 350 tagged sturgeon. Lake sturgeon between 11" (28 cm) and 36" (90 cm) have been caught and released. In 2009, lake sturgeon over 40" (101 cm) and weighing up to 15 lbs (7 kg) were reported by anglers.

Genesee River, Rochester, New York

Phase I of the Genesee River lake sturgeon restoration project focused on the assessment of physical habitat parameters in the river and the evaluation of the suitability of the current aquatic habitat for lake sturgeon.

Phase II included "experimental stocking" of 900 juveniles (approx. 200 mm/44g) in 2003 and 1000 juveniles (approx. 170 mm/23g) in 2004. Recapture of marked fish indicate that:

- lake sturgeon were remaining in the river in good numbers;
- the habitat in which the fish were captured was gravelly to sandy and the sturgeon were generally occupying the deepest sections (6-10 m) of a given river reach;
- growth for the year classes was similar to growth in other systems (95-115 mm/year); and
- lake sturgeon diet was similar to that in other systems.

St. Louis River - tributary of Lake Superior (Lindgren and Schram 2008)

Lake sturgeon stocking in lower reaches of the St. Louis River began in 1983. Between 1983 and 2000, 762,000 fry, 143,000 fingerlings, and 500 yearlings have been stocked. More recently, 120,000 eggs in Astroturf nest boxes were placed at known historical spawning locations.

Marking of lake sturgeon during the re-habilitation project included: 81,134 marked with a coded wire tag, either in the snout or under a scute, or both; 990 marked with an external tag (50 also with a PIT tag); and 65 marked with a PIT tag under a dorsal scute (50 of which also had an external tag).

Gillnet catches of lake sturgeon in St. Louis Bay increased from zero (prior to stocking) to a maximum of 6.5 per set in 1996. An average of approximately two lake sturgeon per set was caught during 2000-2006 sampling. The mean length at capture of juveniles steadily increased over time (e.g., 1991 cohort increased from 18.5 cm to 101.3 cm mean length over 17 years).

Distribution and movement studies indicate that the stocked lake sturgeon remain in the St. Louis estuary for approximately five years. They then move into and remain in the western portion of Lake Superior for a number of years before returning to the estuary. Large sturgeon have been observed within the historical spawning area for a number of years (post-2006); however, natural reproduction has yet to be documented.

Spawning habitat enhancement works are being undertaken in previously disturbed areas in the St. Louis River.

Minnesota - Red River Basin: Appendix G – Restoration of Extirpated Lake Sturgeon (*Acipenser fulvescens*) in the Red River of the North Watershed (MDNR 2002)

In 2002, Minnesota DNR, in cooperation with USFWS and the White Earth Band, implemented a 20-year stocking plan with a goal of re-establishing a naturally reproducing population over the next 20-30 years. Lake sturgeon releases (fry and fingerlings) accomplished to date are shown in Appendix Table 1. Anglers are now catching the stocked fish. Further, results of test netting in 2011 suggest that the stocking efforts have been highly successful, so successful that the number of fish being stocked in future years are being reduced by half (R. Zortman, White Earth Band).

Michigan – Ontonagon River

Michigan Department of Natural Resources began stocking in 1998. Approximately 33,000 fall fingerlings have been stocked in the mainstem since 1998. Fillmore (2003) observed that juvenile lake sturgeon stocked in the Ontonagon River moved downstream and were most abundant near the river mouth.

Due to genetic concerns (lack of imprinting on native waters), a stream-side rearing facility (SRF) was constructed. Fish in the SRF were raised to fall fingerling stage using water from the Ontonagon River. Approximately 750 lake sturgeon were stocked in October 2007.

Appendix Table 1.

A summary of lake sturgeon life stages that have been released during a number of stocking programs in the United States and Canada with an indication of success.

Location	River/Lake	Year	Number/Life Stage	Success
Georgia	Coosa River	2002-2008	85,000/fingerlings	Juvenile growth and survival confirmed
New York	Genesee River	2003-2004	1,900 juveniles	Juvenile growth and survival confirmed (See summary notes)
	Cayuga Lake	1995-2004	3,732 age 0 and 1	1995 year-class (YC) male ripe in 2006. Mean TL of 1995 YC =1.12 m
	Oneida Lake	1995-1999	40,000 larvae 8,000 juveniles	High mortality of larvae (starvation). Rapid growth of juveniles. Age 8 males readily released sperm. Each YC has been recaptured
	Oswegatchie River	?	30,857 juveniles	Downstream movement pattern of newly released fish compared with naturalized fish
	St. Regis River	?	5,000 juveniles	LKST growing well
Wisconsin	St. Louis River	1983-2000 2000?	762,000 fry 143,000 fingerlings 500 yearlings 120,000 eggs in Astroturf nest boxes	LKST growing well. Large LKST observed on historical spawning grounds. No natural recruitment after 25 years.
	Yellow River	1995	10,000 fry 13,400 fingerlings	
	Upper Flambeau/Manitowish River	1993-2008	152,578 fry 56,946 fingerlings	Stocked fish are surviving and growing

Location	River/Lake	Year	Number/Life Stage	Success
	Menominee River	1982 1995-1999 and onward (2004?)	? 25,300 fingerlings 600 yearlings	
	Middle Wisconsin River	1997 - ? 2003	200,000 fingerlings Yearlings	1997 cohort still present in river and growing well
Michigan	Ontonagon River	1998-2004 2007 2008	Fingerlings Yearlings 723 fingerlings (SRF) 880 fingerlings (SRF)	Age 0 and yearling captured over soft substrates of sand and silt
	Cheboygan River watershed	2006	7,800 fingerlings	
	Black Lake	2007	1,000 fingerlings (SRF)	Plan is to release 65,000 fingerlings over 20 years. Target is 2,000 adult sturgeon in Black Lake.
Minnesota	Detroit Lake	1998-2008	25 sub-adults 1,671 yearlings 17,998 fingerlings 22,500 fry	Angler success indicates movement and growth of stocked lake sturgeon. As of 2011, numbers of fish stocked are being reduced by half.
	Round Lake	2004-2008	33,000 fingerlings	
	White Earth Lake	2004-2008	43,000 fingerlings	
	Otter Tail Lake	2002-2008	2,031 yearlings 37,000 fingerlings	
	Otter Tail River	1998-2008	172 sub-adults 250 yearlings 10,300 fingerlings	

Location	River/Lake	Year	Number/Life Stage	Success
	Buffalo River	2002-2008	350 yearlings 10,178 fingerlings	
	Roseau River	2004-2008	345,550 fry	
	Red Lake River	2004-2008	785,000 fry	
	St. Louis Bay	2000	7,980 fingerlings	
Manitoba	Nelson River	1994 - 2008	491 yearlings 15,974 fingerlings 1,025 fry	
	Winnipeg River	1996-2009	221 sub-adults 24,387 fingerlings	
	Nutimik Lake	1998-2008	4,950 fingerlings	
	Assiniboine River	1996-2008	5,000 fry 11,216 fingerlings 60 sub-adults	Angler success indicates that individuals have achieved a large size. Some individuals > 800 cm.
	Saskatchewan River	2003	67 fingerlings	
Saskatchewan	Saskatchewan River	1999-2007	157,000 fry 7,850 fingerlings	
Quebec	Eastmain River Riviere l'Eau Claire	2004	114,000 fry 21,000 fingerlings 88 adults	Plans to repeat over next few years

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APPENDIX 1B
KEEYASK GENERATION PROJECT
AQUATIC ENVIRONMENT STUDY
REPORT LIST

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
99-01	Remnant, R.A. and C.C. Barth. 2003. Results of Experimental Gillnetting on the Nelson River between Birthday and Gull Rapids, Manitoba, Fall 1999. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 75 pp. *Draft*.	Completed	Dec-03
99-02	Zrum, L. and C.L. Bezte. 2003. Water Chemistry, Phytoplankton, Benthic Invertebrate, and Sediment Data for Gull Lake and the Nelson River between Birthday Rapids and Gull Rapids, Manitoba, Fall, 1999. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 66 pp. *Draft*.	Completed	Dec-03
01-01	Zrum, L. and T.J. Kroeker. 2003. Benthic Invertebrate and Sediment Data from Split Lake and Assean Lake, Manitoba, Winter, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 78 pp. *Draft*.	Completed	Dec-03
01-02	Barth, C.C., R.L. Bretecher, and J. Holm. 2004. Floy-tag Application and Recapture Information from the (Gull) Keeyask Study Area, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 88 pp. *Draft*.	Completed	Nov-04
01-03	Barth, C.C., D.L. Neufeld, and R.L. Bretcher. 2003. Results of Fisheries Investigations Conducted in Tributaries of the Nelson River Between Birthday Rapids and Gull Rapids, Manitoba, Spring, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 53 pp. *Draft*.	Completed	Dec-03
01-04	Juliano, K.M. and L. Zrum. 2003. Zooplankton Data from Split, Clark, Gull, Stephens, and Assean Lakes, Manitoba, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 59 pp. *Draft*.	Completed	Dec-03
01-05	Dunmall, K.M., J. Holm, and R.L. Bretcher. 2003. Results of Index Gillnetting Studies Conducted in Assean Lake, Manitoba, Summer 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 70 pp. *Draft*.	Completed	Dec-03
01-06	Dolce, L.T. and M.A. Sotiropoulos. 2004. Aquatic Macrophyte and Associated Epiphytic Invertebrate Data Collected in Gull Lake and Portions of the Nelson River Between Birthday Rapids and Gull Rapids, Manitoba, Fall 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 56 pp. *Draft*.	Completed	Jan-04

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
01-07	Dunmall, K.M., J.E. MacDonald, and R.L. Bretecher. 2004. Results of Summer Index Gillnetting Studies Conducted in Split Lake and Clark Lake, and Spring Investigations of Adult and Larval Fish Populations in Portions of the Burntwood River, Grass River, and Nelson River flowing into Split Lake, Manitoba, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 116 pp. *Draft*.	Completed	Feb-04
01-08	Remnant, R.A., N.J. Mochnacz, and J.E. MacDonald. 2004. Results of Fisheries Investigations Conducted in the Assean River Watershed, Manitoba, Spring and Fall, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 106 pp. *Draft*.	Completed	Oct-04
01-10	Pisiak, D.J., T. Kroeker, and R.A. Remnant. 2004. Results of Summer Index Gillnetting Studies in Stephens Lake, Manitoba, and Seasonal Investigations of Adult and Larval Fish Communities in the Reach of the Nelson River between Gull Rapids and Stephens Lake, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 110 pp. *Draft*.	Completed	Oct-04
01-11	Sotiropoulos, M.A. and L.J. Neufeld. 2004. Benthic Invertebrate, Sediment, and Drifting Invertebrate Data Collected from the Gull (Keeyask) Study Area, Manitoba, Spring - Fall 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 138 pp. *Draft*.	Completed	Oct-04
01-13	Remnant, R.A., C.R. Parks, and J.E. MacDonald. 2004. Results of Fisheries Investigations Conducted in the Reach of the Nelson River between Clark Lake and Gull Rapids (Including Gull Lake), 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 154 pp. *Draft*.	Completed	Oct-04
01-14	Barth, C.C. and N.J. Mochnacz. 2004. Lake Sturgeon Investigations in the Gull (Keeyask) Study Area, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 146 pp. *Draft*.	Completed	Oct-04

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
01-15	Badiou, P.H., and H.M. Cooley. 2004. Water Chemistry, Phytoplankton, and Sediment Chemistry Data for the Nelson and Assean River Systems, Manitoba, 2001. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 210 pp. *Draft*.	Completed	Oct-04
02-03	Barth, C.C., L.J. Neufeld, and J.R. Olynik. 2003. Movements of Northern Pike, Walleye, and Lake Whitefish Tagged with Radio and Acoustic Transmitters in the Gull (Keeyask) Study Area, 2001/2003. Draft report prepared for Manitoba Hydro by North/South Consultants. 137 pp. *Draft*.	Completed	Dec-03
02-04	Juliano, K.M. and L. Zrum. 2004. Zooplankton Data from Split, Clark, Gull, Stephens, and Assean Lakes, and the Nelson River, Manitoba, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 65 pp. *Draft*.	Completed	Jan-04
02-05	Holm, J., V.L. Richardson, and R.L. Bretecher. 2003. Results of Index Gillnetting Studies Conducted in Assean Lake, Manitoba, Summer 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 80 pp. *Draft*.	Completed	Dec-03
02-06	Hartman, E.J. and R.L. Bretecher. 2004. Results of Fisheries Investigations Conducted in the North Moswakot and South Moswakot Rivers, Manitoba, Fall 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 69 pp. *Draft*.	Completed	Jan-04
02-08	Mochnacz, N.J., C.C. Barth, and J. Holm. 2004. Results of Fisheries Investigations Conducted in the Aiken River and at the Mouth of the Ripple River, Manitoba, Spring 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 106 pp. *Draft*.	Completed	Mar-04
02-09	Holm, J. and R.A. Remnant. 2004. Results of Summer Index Gillnetting Studies Conducted in Split Lake and Clark Lake, and Spring Investigations of Adult and Larval Fish Communities in Portions of the Burntwood, Grass, and Nelson Rivers Flowing into Split Lake, Manitoba, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 131 pp. *Draft*.	Completed	Apr-04

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
02-10	Dolce, L.T. and M.A. Sotiropoulos. 2004. Aquatic Macrophyte and Associated Epiphytic Invertebrate Data Collected in Gull Lake and Portions of the Nelson River between Birthday Rapids and Gull Rapids, Manitoba, Fall 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 57 pp. *Draft*.	Completed	Mar-04
02-12	Juliano, K.M. and L.J. Neufeld. 2004. Benthic Invertebrate and Sediment Data from Split Lake and Assean Lake, Manitoba, Winter 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 67 pp. *Draft*.	Completed	Dec-04
02-13	Juliano, K.M. and L.J. Neufeld. 2005. Benthic Invertebrate, Sediment, and Drifting Invertebrate Data Collected from the Gull (Keeyask) Study Area, Manitoba, Spring - Fall 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 161 pp. *Draft*.	Completed	Jan-05
02-14	Badiou, P.H. and H.M. Cooley. 2005. Water Chemistry, Phytoplankton, and Sediment Chemistry Data for the Nelson and Assean River Systems, Manitoba, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 255 pp. *Draft*.	Completed	Feb-05
02-15	Johnson, M.W. 2005. Results of Fish Community Investigations Conducted in the Assean River Watershed, Manitoba, Spring and Fall 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 133 pp. *Draft*.	Completed	Feb-05
02-16	Pisiak, D.J. 2005. Results of Summer Index Gillnetting Studies in Stephens Lake, Manitoba and Seasonal Investigations of Adult and Larval Fish Communities in the Reach of the Nelson River between Gull Rapids and Stephens Lake, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 179 pp. *Draft*.	Completed	Jan-05
02-17	Richardson, V.L. and J. Holm. 2005. Results of Fish Community Investigations Conducted in Tributary Systems of the Nelson River between Birthday Rapids and Gull Rapids, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 98 pp. *Draft*.	Completed	Jan-05

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
02-18	Holm, J., V.L. Richardson, and C.C. Barth. 2005. Floy-tag Application and Recapture Information from the Gull (Keeyask) Study Area, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 175 pp. *Draft*.	Completed	Feb-05
02-19	Barth, C.C. 2005. Lake Sturgeon Investigations in the Keeyask Study Area, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 131 pp. *Draft*.	Completed	Feb-05
02-20	Johnson, M.W. and C.R. Parks. 2005. Results of Fish Community Investigations Conducted in the Reach of the Nelson River between Clark Lake and Gull Rapids, 2002. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 222 pp. *Draft*.	Completed	Aug-05
03-01	Ryland, D. and B. Watts. Fish Taste Studies for Tataskweyak Cree Nation. Draft report prepared for Manitoba Hydro by the University of Manitoba. 44 pp. *Draft*.	Completed	Jan-04
03-02	Ryland, D. and B. Watts. Fish Taste Studies for Fox Lake Cree Nation. Draft report prepared for Manitoba Hydro by the University of Manitoba. 43 pp. *Draft*.	Completed	Jan-04
03-03	Maclean, B.D. and D.J. Pisiak. 2005. Results of Fish Community Investigations Conducted at the Mouth of the Ripple River, Manitoba, Spring 2003. Year II. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 43 pp. *Draft*.	Completed	Feb-05
03-05	Badiou, P.H., H.M. Cooley, and T. Savard. 2005. Water Chemistry Data for the Lower Nelson River System, Manitoba, 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 219 pp. *Draft*.	Completed	Dec-05
03-06	Murray, L., C.C. Barth, and J.R. Olynik. 2005. Movements of Radio- and Acoustic- Tagged Northern Pike, Walleye, and Lake Whitefish in the Keeyask Study Area: May 2002 to April 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 125 pp. *Draft*.	Completed	Aug-05
03-08	Barth, C.C. and L. Murray. 2005. Lake sturgeon Investigations in the Keeyask Study Area, 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 127 pp. *Draft*.	Completed	Oct-05

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
03-09	Pisiak, D.J. and E.J. Hartman. 2005. Results of Fish Community Investigations Conducted in the North Moswakot and South Moswakot Rivers, Manitoba, Spring and Fall 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 157 pp. *Draft*.	Completed	Sep-05
03-11	Kroeker, D.S. and W. Jansen. 2005. Results of Fish Community Investigations Conducted in Tributaries of the Nelson River between Clark Lake and Gull Rapids, Manitoba, 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 72 pp. *Draft*.	Completed	Jan-06
03-12	Maclean, B.D. and J.Holm. 2005. Results of Fish Community Investigations Conducted in the Mistuska River, Manitoba, Spring 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 90 pp. *Draft*.	Completed	Sep-05
03-13	Maclean, B.D. and D.J. Pisiak. 2005. Results of Fish Community Investigations Conducted in the Aiken River, Manitoba, Spring 2003, Year II. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 108 pp. *Draft*.	Completed	Dec-05
03-14	Pisiak, D. 2005. Results of Summer Index Gillnetting Studies in Stephens Lake, Manitoba, and Seasonal Investigations of Fish Communities in the Reach of the Nelson River between Gull Rapids and Stephens Lake, 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 313 pp. *Draft*.	Completed	Oct-05
03-15	Holm, J. 2006. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 244 pp. *Draft*.	Completed	Sep-06
03-16	Dolce, L. T. and M.J. Burt. 2008. Aquatic Macrophyte and Associated Epiphytic Invertebrate Data Collected from the Keeyask Study Area, Manitoba, Late Summer 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 111 pp. *Draft*.	Completed	Feb-08

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
03-17	Gill, G. 2007. Invertebrate Drift and Plant Biomass Data from the Nelson River at Birthday Rapids, Gull Lake, Gull Rapids, and Kettle Generating Station, Manitoba, Summer and Fall 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 72 pp. *Draft*.	Completed	Nov-07
03-35	Maclean, B.D. and P. Nelson. 2005. Population and Spawning Studies of Lake Sturgeon (Acipenser fulvescens) at the Confluence of the Churchill and Little Churchill Rivers, Manitoba, Spring 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 70 pp. *Draft*.	Completed	Jan-06
03-36	Bretecher, R.L., G.C. Dyck, and R.A. Remnant. 2007. Results of Fish Community Investigations Conducted in the Reach of the Nelson River Between Clark Lake and Gull Rapids (Including Gull Lake), 2003. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 275 pp. *Draft*.	Completed	Feb-07
03-37	Cooley, H.M. and M.W. Johnson. 2008. An Evaluation of Walleye Condition from Stephens Lake. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 59 pp. *Draft*.	Completed	Mar-08
04-03	Holm, J. 2005. Results of Fish Community Investigations Conducted in Clark Lake, 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 116 pp. *Draft*.	Completed	28-Oct-05
04-04	Badiou, P.H., T. Savard, and H.M. Cooley. 2007. Water Chemistry and Phytoplankton data for the Lower Nelson River System, Manitoba, 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 247 pp. *Draft*.	Completed	Jan-07
04-05	BARTH, C.C. and K. AMBROSE. 2006. Lake Sturgeon Investigations in the Keeyask Study Area, 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 105 pp. *Draft*.	Completed	Jan-06
04-06	Cooley, H.M. and T.G. Savard. 2008. Results of Greenhouse Gas Sampling in the Keeyask and Conawapa Study Areas: 2001-2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 76 pp. *Draft*.	Completed	Feb-08

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
04-07	T. Savard and H.M. Cooley. 2007. Turbidity Monitoring Data for Clark and Gull Lakes, Fall 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 51 pp. *Draft*.	Completed	Jan-07
04-08	Holm, J. 2007. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 148 pp. *Draft*.	Completed	Jan-07
04-09	Johnson, M.W. 2007. Results of Fish Community Investigations Conducted in the Reach of the Nelson River Between Clark Lake and Gull Rapids (Including Gull Lake), 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 159 pp. *Draft*.	Completed	Jan-07
04-10	Johnson, M.W. and C.C. Barth. 2007. Results of Fish Community Investigations in the Kettle and Butnau Rivers, Manitoba, Spring 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 59 pp. *Draft*.	Completed	Jan-07
04-11	Holm, J., H.M. Cooley, and E. Shipley. 2007. Trace Elements in Fish from the Keeyask Study Area: Fall 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 62 pp. *Draft*.	Completed	Feb-07
04-12	Johnson, M.W. and B.D. Maclean. 2007. Results of Fish Community Investigations Conducted in the Mistuska River, Manitoba, Spring 2004. Year II. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 87 pp. *Draft*.	Completed	Jun-07
04-13	Johnson, M.W. and B.D. Maclean. 2007. Results of Fish Community Investigations Conducted in the York Landing Arm of Split Lake and Its Major Tributaries, Manitoba, Fall 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 74 pp. *Draft*.	Completed	May-07
04-14	Pisiak, D.J. and B.D. Maclean. 2007. Population Studies of Lake Sturgeon (*Acipenser fulvescens*) in the Fox River, Manitoba, Summer 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 42 pp. *Draft*.	Completed	Apr-07

Table 1B-1: Keeyask Generation Project aquatic environment study reports

Report Number	Report Title	Status	Date Completed
04-15	Neufeld, L. 2007. Benthic Invertebrate and Sediment, Data Collected from Littoral Zones in the Keeyask Study Area, Manitoba, Fall 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 92 pp. *Draft*.	Completed	Apr-07
04-16	MacDonald, J.E. 2007. Results of Fish Community Investigations in Gull Rapids and Stephens Lake, 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 113 pp. *Draft*.	Completed	May-07
04-17	Burt, M.J. and L.T. Dolce. 2008. Aquatic Macrophyte and Associated Epiphytic Invertebrate Data Collected from the Keeyask Study Area, Manitoba, Summer 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 130 pp. *Draft*.	Completed	Feb-08
04-18	Gill, G. 2007. Invertebrate Drift and Plant Biomass Data from the Nelson River at Birthday Rapids,Gull Rapids, and Kettle Generating Station, Manitoba, Summer and Fall 2004. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 91 pp. *Draft*.	Completed	Nov-07
05-02	Holm, J. 2007. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2005. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 56 pp. *Draft*.	Completed	Apr-07
05-03	Murray, L. and C.C. Barth. 2007. Movements of Radio- and Acoustic- Tagged Northern Pike, Walleye, and Lake Whitefish in the Keeyask Study Area: May 2003 to August 2004 and a Summary of Findings from 2001-2005. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 111 pp. *Draft*.	Completed	Apr-07
05-04	Jansen, W. and N. Strange. 2007. Mercury Concentrations in Fish From the Keeyask Project Study Area for 1999-2005. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 168 pp. *Draft*.	Completed	Aug-07
05-05	Barth, C.C. and J.E. MacDonald. 2008. Lake Sturgeon Investigations in the Keeyask Study Area, 2005. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 63 pp. *Draft*.	Completed	Mar-08

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Report Number	Report Title	Status	Date Completed
05-06	Mazur, K.M. and T.G. Savard. 2008. Proposed Keeyask Access Road Stream Crossing Assessment, 2004 and 2005. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 68 pp. 83 pp. *Draft*.	Completed	Feb-08
06-02	Holm, J. 2007. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 61 pp. *Draft*.	Completed	Apr-07
06-03	Savard, T. and H.M. Cooley. 2007. Dissolved Oxygen Surveys in the Keeyask Study Area: Winter 2005 and 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 54 pp. *Draft*.	Completed	Apr-07
06-04	MacDonald, J.E. 2008. Lake Sturgeon Investigations in the Keeyask Study Area, 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 110 pp. *Draft*.	Completed	Mar-08
06-05	Cassin, J. and R.A. Remnant. 2008. Results of Fish Spawning Investigations Conducted in Gull Rapids Creek, Pond 13, and Selected Tributaries to Stephens Lake, Spring 2005 and 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 45 pp. *Draft*.	Completed	Mar-08
06-06	MacDonald, J.E. 2007. Fish community assessments of selected lakes within the Split Lake Resource Management Area, 2004-2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 145 pp. *Draft*.	Completed	Nov-07
06-07	Jansen, W. 2008. Infection Rate of the Parasite *Triaenophorus crassus* in Lake Whitefish from the Keeyask Study Area for 2003-2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 35 pp. *Draft*.	Completed	Mar-08
06-08	Cooley, P.M. and L. Dolce. 2008. Aquatic Habitat Utilization Studies in Stephens Lake: Macrophyte Distribution and Biomass, Epiphytic Invertebrates, and Fish Catch-Per- Unit-Effort in Flooded Habitat. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 75 pp. *Draft*.	Completed	Mar-08

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Report Number	Report Title	Status	Date Completed
06-09	Cooley, P.M. 2008. Carbon dioxide and methane flux from peatland watersheds and divergent water masses in a sub-arctic reservoir. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 45 pp. *Draft*.	Completed	Mar-08
06-10	Capar, L.N. 2008. Benthic Invertebrate Data Collected from O'Neil Bay and Ross Wright Bay in Stephens Lake, Manitoba, Fall 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 34 pp. *Draft*.	Completed	Mar-08
06-11	Jansen, W. and N. Strange. 2009. Fish mercury concentrations from the Keeyask Project Study Area for 2006. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 68 pp. *Draft*.	Completed	Jul-09
06-12	Larter, J.L. and P.M. Cooley. 2010. Substratum and Depth Distribution in Flooded Habitat of Stephens Lake, Manitoba, Thirty-Five Years after Impoundment. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 57 pp. *Draft*.	Completed	Dec-10
06-13	Cooley, P.M., L. Dolce Blanchard, and J. Larter. 2009. The effect of local and regional watersheds on the spectral composition and attenuation of light and water quality parameters in the surface waters of Stephens Lake, Manitoba. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 51 pp. *Draft*.	Completed	May-09
08-01	MacDonald, J.E. 2009. Lake Sturgeon Investigations in the Keeyask Study Area, 2007-2008. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 116 pp. *Draft*.	Completed	Apr-09
08-02	Holm, J. 2009. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2007 and 2008. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 63 pp. *Draft*.	Completed	Apr-09
09-01	Holm, J. 2010. Results of Index Gillnetting Studies Conducted in the Keeyask Study Area, Summer 2009. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 110 pp. *Draft*.	Completed	Oct-10
09-02	Holm, J. 2010. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2009. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 48 pp. *Draft*.	Completed	Oct-10

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Report Number	Report Title	Status	Date Completed
09-03	Michaluk, Y. and J.E. MacDonald. 2010. Lake Sturgeon Investigations in the Keeyask Study Area, 2009. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 83 pp. *Draft*.	Completed	Dec-10
09-04	Savard, T. S. Hnatiuk-Stewart, and H.M. Cooley. 2010. Water Quality Data for the Lower Nelson River System, Manitoba, 2009. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 240 pp. *Draft*.	Completed	Jul-10
09-05	Jansen, W. 2010. Fish Mercury Concentrations in the Keeyask Study Area, 2009. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. 42 pp. *Draft*.	Completed	Dec-10
10-01	North/South Consultants Inc., 2011. Adult Lake Sturgeon Investigations in the Keeyask Study Area, Spring 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 78 pp. *Draft*	Completed	Dec-11
10-02	North/South Consultants Inc., 2011. Results of Lake Whitefish Spawning Surveys in Ferris Bay and the North and South Moswakot Rivers, Fall 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 51 pp. *Draft*	Completed	Nov-11
10-03	North/South Consultants Inc., 2011. Results of a Coarse Scale Habitat Inventory in the Upper Split Lake Area, Fall 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 75 pp. *Draft*	Completed	Dec-11
10-04	North/South Consultants Inc., 2011. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 53 pp. *Draft*	Completed	Dec-11
10-05	North/South Consultants Inc., 2011. Fish Community Assessment of Armstrong Lake,2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 90 pp. *Draft*	Completed	Dec-11
10-06	North/South Consultants Inc., 2011. Benthic Invertebrate Surveys in Gull Lake and Stephens Lakes, Fall 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 78 pp. *Draft*	Completed	Dec-11

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Report Number	Report Title	Status	Date Completed
10-07	North/South Consultants Inc., 2011. Young-of-the-Year and Sub-Adult Lake Sturgeon Investigations in the Keeyask Study Area, Spring and Fall 2010. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. 60 pp. *Draft*	Completed	Dec-11
TBA	Ambrose, K.M. and R.A. Remnant. 2011. Results of fish community investigations in Armstrong Lake, Manitoba, 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	Capar, L.N., and F. Schneider-Vieira. 2011. Results of benthic invertebrate sampling conducted in Gull and Stephens lakes, fall, 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	Henderson, L. M., C. C. Bart, J.E. MacDonald, and S.J. Garner. 2011. Results of a coarse scale habitat inventory in the upper Split Lake area, fall 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	Henderson, L.M. and C.C. Barth. 2011. Young-of-the-year and subadult lake sturgeon investigations in the Keeyask Study Area, 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	Holm, J. 2011. Floy-tag application and recapture information from the Keeyask Study Area, 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	MacDonald, J.E. and C.C. Barth. 2011. Lake sturgeon investigations in the Keeyask Study Area, Spring 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	Michaluk, Y. J.E. MacDonald, and C. C. Barth. 2011. Results of lake whitefish spawning surveys in Ferris Bay and the North and South Moswakot rivers, fall, 2010. Draft report prepared for Manitoba Hydro by North/South Consultants Inc. *Draft*	In preparation	
TBA	North/South Consultants Inc., 2011. Adult Lake Sturgeon Investigations, 2011. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. *Draft*	In preparation	

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Report Number	Report Title	Status	Date Completed
TBA	North/South Consultants Inc., 2011. Floy-tag Application and Recapture Information from the Keeyask Study Area, 2011. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. *Draft*	In preparation	
TBA	North/South Consultants Inc., 2011. Lake Sturgeon Telemetry Juvenile, 2011. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. *Draft*	In preparation	
TBA	North/South Consultants Inc., 2011. Young-of-the-year and Sub-Adult Lake Sturgeon Investigations in the Keeyask Study Area, Spring and Fall 2011. Keeyask Project Environmental Studies Program Report prepared for Manitoba Hydro. *Draft*	In preparation	