Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Aquatic Environment

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KEEYASK

June 2012

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INTRODUCTION

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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].

TABLES, FIGURES, AND MAPS

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.

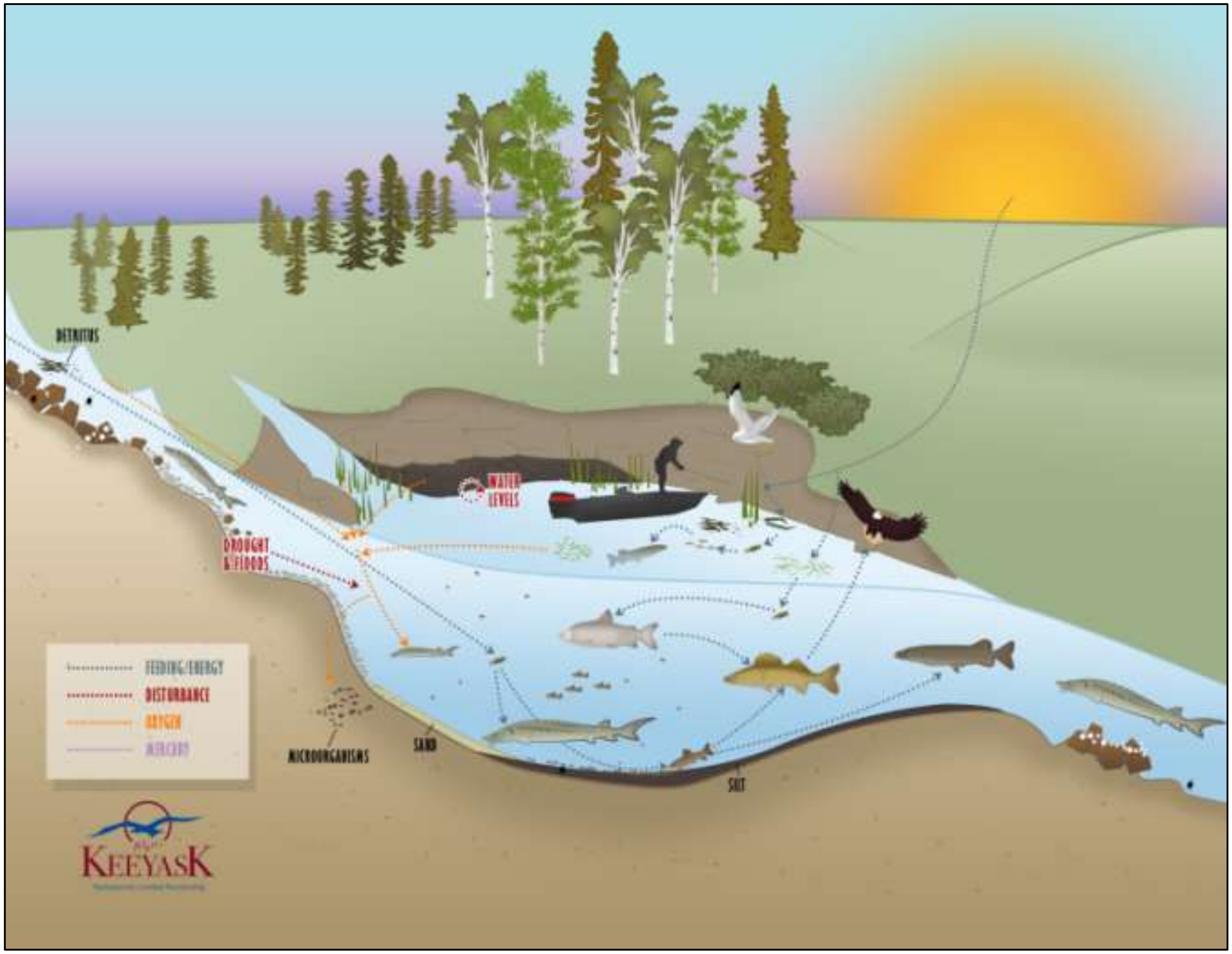

Figure 1-1A: Conceptual diagram of ecosystem in Keeyask area showing major pathways of energy and material transfer among components and major habitat types.

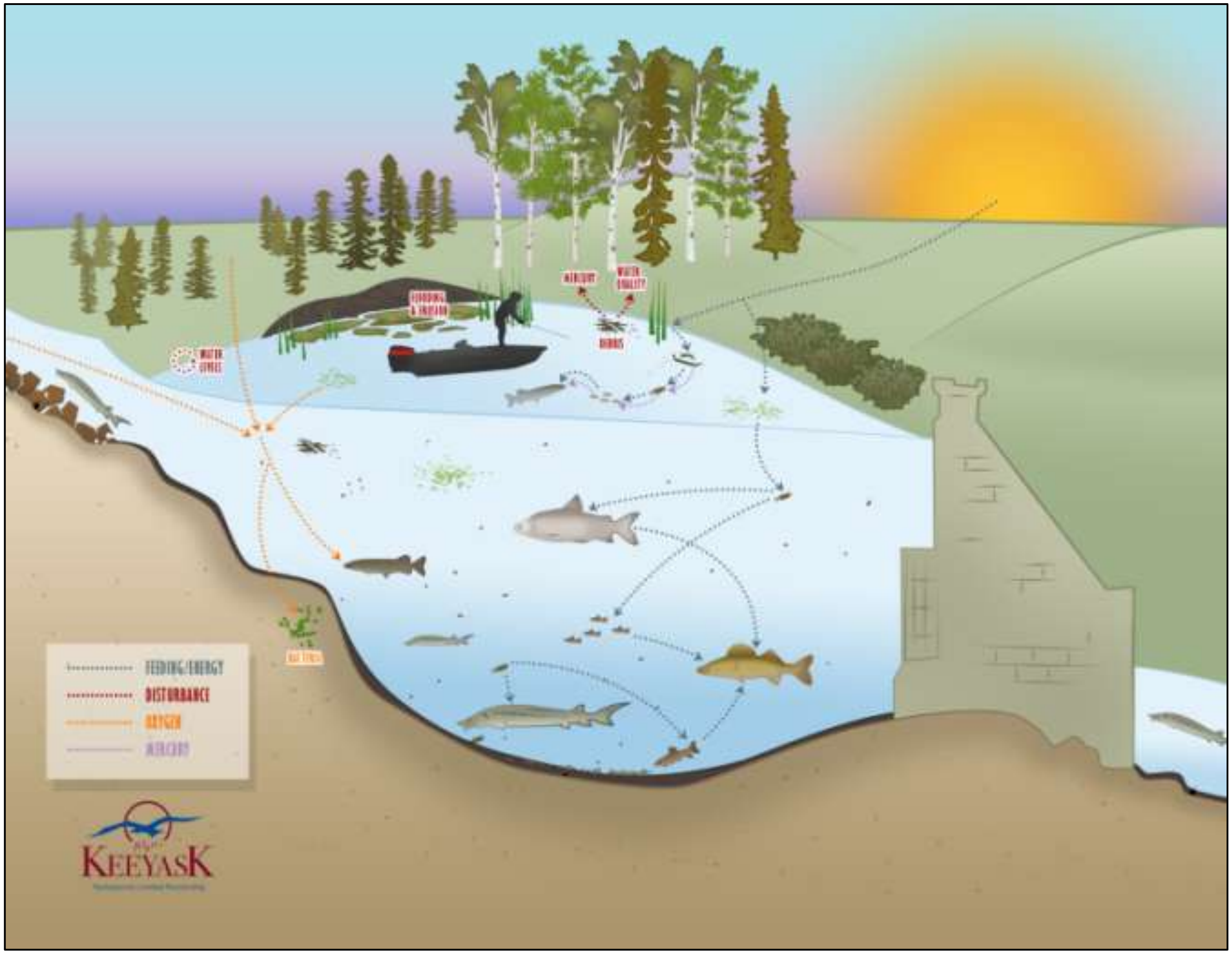

Figure 1-1B: Conceptual diagram of ecosystem in Keeyask area following construction of the Project, showing major pathways of energy and material transfer among components and major habitat types.

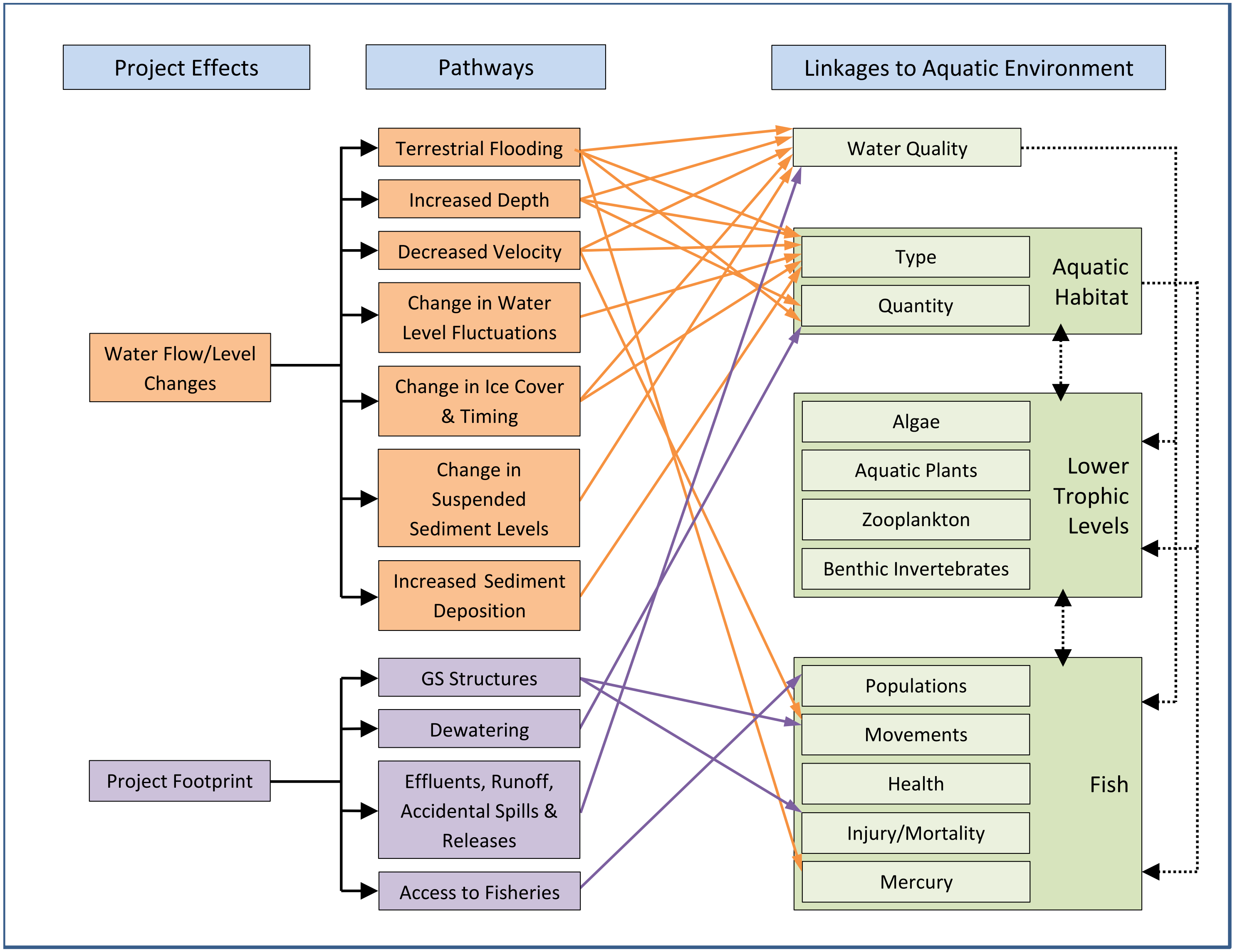

Figure 1-2: Summary of pathways of effect during the operation period