Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Aquatic Environment

KEEYASK

Hydropower Limited Partnership

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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.	

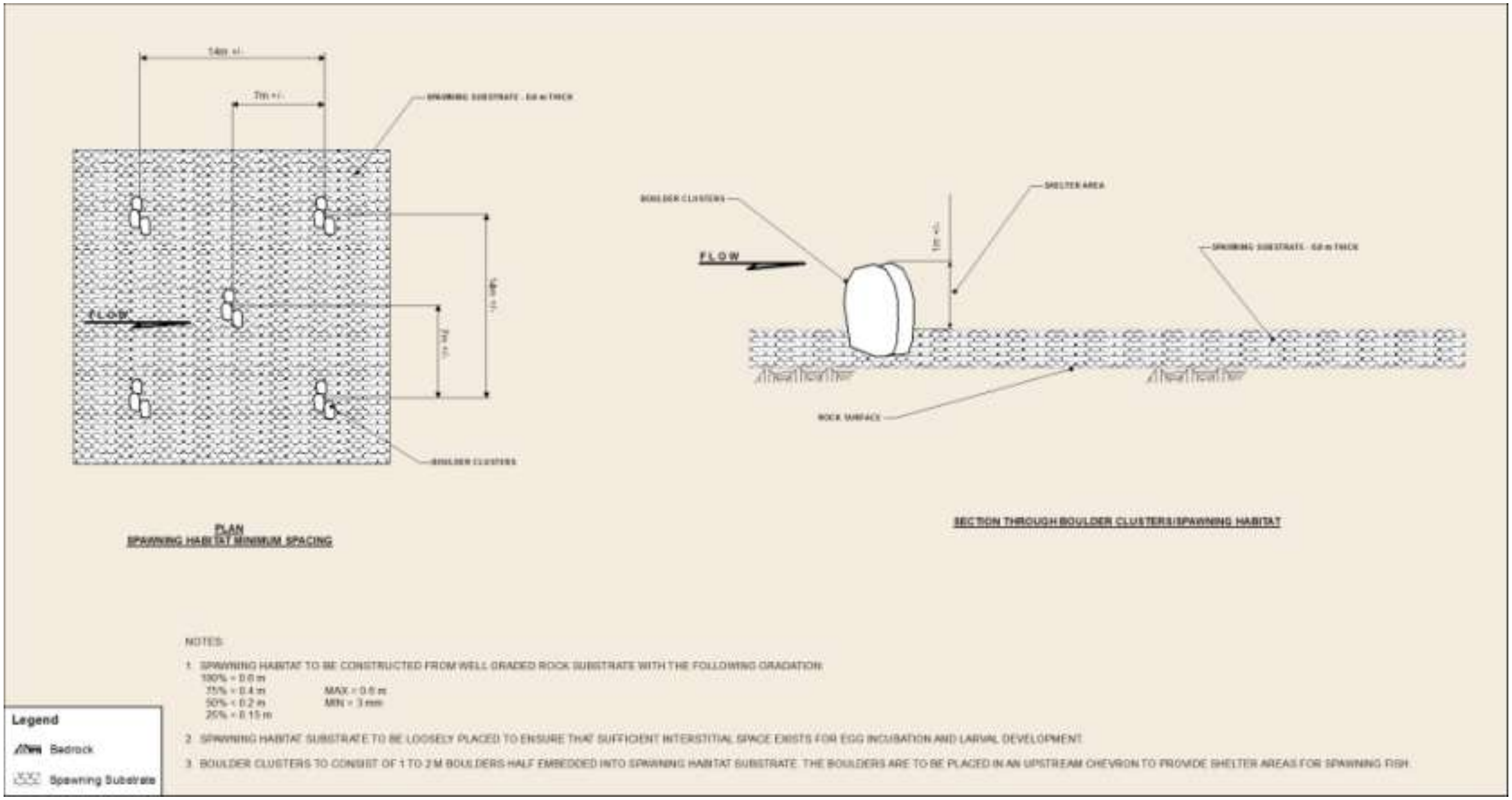

Figure 1A-1: Spawning habitat details showing the arrangement and spacing of boulder clusters

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