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15. SUBJECTS OF NOTE

15.3 TURBINE AND CONVEYANCE CANAL OPERATION

15.3.1 Introduction

The purpose of this Turbine and Conveyance Canal Operation Subject of Note is to identify the potential interactions during operations between the North Gorge canal, the South Gorge spillway and the Nonacho control structure with the known fish species at those locations.

The intake to the North Gorge canal is located in the Twin Gorges Forebay adjacent to the right abutment of the existing dam. During operations, flows would be directed through a 1,250 m rock cut intake canal, through two turbines contained in the powerhouse, and back into the Taltson River downstream of Elsie Falls. This would operate in addition to the existing turbine and powerhouse, as the intake would be located approximately 100 m from the North Gorge canal.

The South Gorge spillway would be constructed on the left abutment of the existing dam. During a controlled or uncontrolled shutdown event, water typically used for power generation would need to be spilled through the South Gorge spillway where it would reconnect to the existing tailrace and flow downstream over Elsie Falls and into the lower Taltson River. During normal operations, there would be no connectivity and thus no spillage of water through the South Gorge spillway.

The new gated control structure at Nonacho Lake would be located adjacent to the existing rockfill dam and flow controls, and would include a 200 m rock cut canal and the installation of a micro-hydro plant for site-generated power. The Nonacho control structure would regulate flows discharging from Nonacho Lake and into the Taltson River.

In accordance with the Terms of Reference for the Taltson Developer's Assessment Report (DAR) (Mackenzie Valley Environmental Review Board, 2008), the following assessments have been conducted:

- impact review on fish populations associated with allowing upstream fish population to join downstream populations,
- impact review on fish and fish passage through the conveyance canal and turbines (entrainment), and
- identification of mitigation measures to minimize impacts to fish and fish passage through the conveyance canal and turbines.

For the purposes of conducting the effects analyses, the North Gorge canal and the South Gorge spillway have been considered together due to the similarity in habitat conditions, known fish species and their close proximity. The Nonacho control structure has been considered separately as the habitat conditions and fish species composition differ; however, the overall effects classification and determination of significance was conducted for all three sites collectively.

The effects associated with turbine and canal operations would be similar for both the 36 MW and 56 MW operating scenarios. As such, the effects assessment applies to both operating scenarios.

15.3.2 North Gorge Canal And South Gorge Spillway

15.3.2.1 EXISTING ENVIRONMENT

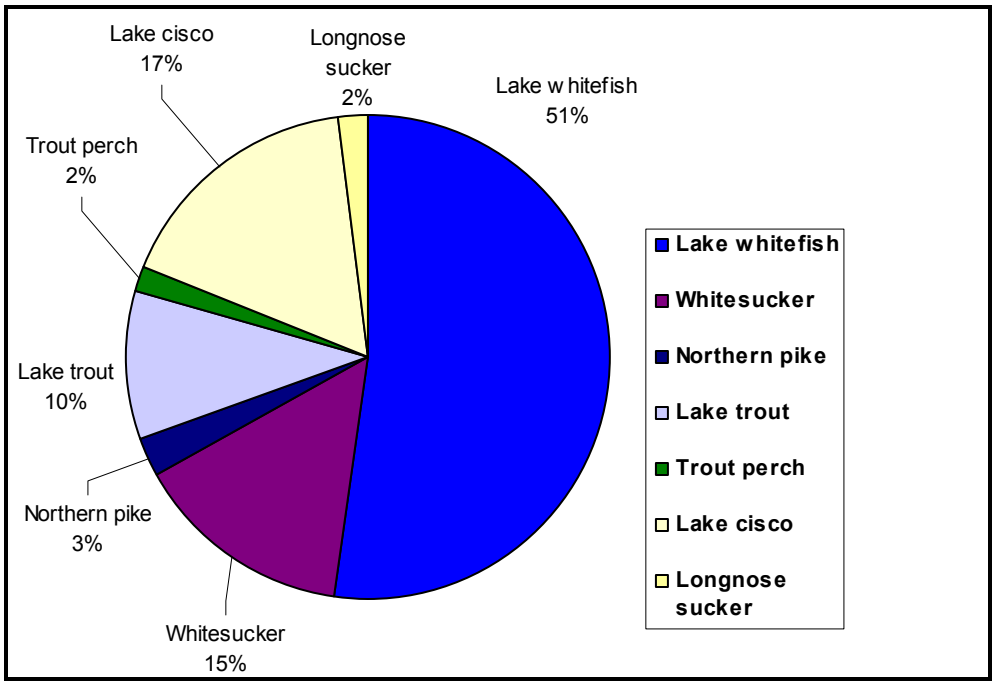
Aquatic habitat at and adjacent to the inlet location to the North Gorge is similar to the surrounding area in the Twin Gorges Forebay and is characterized by a rocky shoreline with steep stream margins (Figure 15.3.1). Under baseline conditions, a shallow bedrock bench extends approximately 2 m to 5 m into the aquatic habitat at the inlet location before dropping off steeply to depths greater than 5 m. No in-stream submergent and/or emergent vegetation or large woody debris is present. During operations, the approach velocities associated with the North Gorge canal at the intake location are anticipated to be 1.0 m/s. The velocities at the penstock location would increase to approximately 3.1 m/s, which would extend approximately 5 m upstream from the penstock.

The aquatic habitat conditions associated with the South Gorge Spillway are nearly identical to those at the North Gorge. Substrates are dominated by bedrock and gravels, and limited in-stream submergent and emergent vegetation is present. Figure 6.4.6 illustrates the location of the South Gorge spillway.

Figure 15.3.1 — Proposed Inlet Location of the North Gorge Canal

Fish species composition in the Twin Gorges Forebay was determined from fish sampling programs conducted by Cambria Gordon Ltd. (2008) and Rescan Environmental Services (2003). In total, 7 fish species were captured as follows: lake whitefish, lake cisco, white sucker, lake trout, northern pike, longnose sucker and trout perch. Based on the sampling results, lake whitefish appears to be the most abundant species upstream of the existing facility and in the Twin Gorges Forebay. The results of these sampling efforts have been compiled and are illustrated in Figure 15.3.2.

Figure 15.3.2 — Species Composition within the Twin Gorges Forebay



Fish sampling conducted by Cambria Gordon (2008) identified one juvenile lake trout at the inlet location to the North Gorge and a school of approximately 60 juvenile lake trout along the existing dam facility.

15.3.2.2 VALUED COMPONENTS

Valued components were selected based on the comments received by government and community agencies during the MVLWB screening, MVEIRB scoping session and known habitat conditions along the proposed North Gorge canal and their sensitivity to change. The identified valued component and rationale for selection is provided below:

15.3.2.2.1 Fish populations

Fish populations were selected as a valued component as it has a significant social, economic, cultural and ecological role in the ecosystem. Fish are present and widely distributed throughout the Project area and follow the requirements for the valued component selection.

15.3.2.3 ASSESSMENT ENDPOINTS AND PATHWAYS

The Department of Fisheries and Oceans Canada (DFO) has developed Pathways of Effects (POE) for common in-stream and land-based activities. These POEs describe "cause and effect relationships" that are known to exist, and the mechanisms by which stressors ultimately lead to effects in the aquatic environment. Each cause-and-effect relationship is represented as a line, known as a pathway, connecting the activity to a potential stressor, and a stressor to some ultimate effect on fish and fish habitat, known as an assessment endpoint. For each pathway, mitigation measures can be applied to reduce or eliminate a potential effect.

To date, DFO has identified 19 in-stream and land-based activities. Of these, none relate directly to the operation of turbines or conveyance canals. Therefore, each of the 19 POE was reviewed and individual pathways relevant to the proposed Project activity were carried forward. Table 15.3.1 summarizes the assessment endpoints and the pathways leading to those endpoints for the valued component. The assessment requirements contained in the TOR for this Subject of Note are contained in the DFO pathways listed.

Table 15.3.1 — Valued Components, Assessment Endpoints and Pathways for Turbine and Conveyance Canal Operation at the North Gorge

Valued Component	Assessment Endpoint	Pathway
Fish populations	Change in fish mortality	Fish passage issues: Entrainment of fish with respect to fish mortality
Fish populations	Change in migration/access to habitats	Fish passage issues: Change in diversion channels with respect to inter basin transfer of fish species
Fish populations	Change in total gas pressure	Flow management with respect to change in total gas pressure

15.3.2.4 SPATIAL AND TEMPORAL BOUNDARIES

The analysis of potential interactions between the operation of the turbine and conveyance canals and the aquatic environment within the Twin Gorges Forebay was conducted on a local study area and a regional study area. The local study area included the in-stream habitats of the Twin Gorges Forebay and its associated fish communities. The regional study area includes the in-stream habitats from Nonacho Lake downstream to the inlet of Tsu Lake.

The operation of the turbine and tailrace canal at the North Gorge is expected to continue throughout the operations phase of the Project. Currently, the Project is expected to be in operation for 20 years to service the existing and proposed diamond mines; however, the Project infrastructure will have a lifespan of 40 years, and it is the intent of Dezé to solicit new customers to extend the Project lifespan beyond 20 years. Therefore, the temporal boundaries of the potential effects from turbine and conveyance canal operation have been assumed to be 40 years.

15.3.2.5 PROJECT COMPONENTS

Project components associated with the operation of the turbine and conveyance canal at the North Gorge are summarized in Table 15.3.2.

Table 15.3.2 — Project Components Associated with Operation of the Turbines and Conveyance Canal at the North Gorge Location

Project Component	Sub-component	Associated Activities	Geographic Extent	Schedule	Duration	Phase
Turbine and conveyance canal operation	None	Passage of water from Twin Gorges Forebay to Taltson River	Twin Gorges Forebay to Taltson River	Continuous	Continuous	Operations
Turbine and conveyance canal operation	None	Plant outage	Facilities footprint	As required	Hours – days	Operations

15.3.2.6 MITIGATION

Mitigation measures, including design features and operational guidelines, have been identified to reduce the overall potential for negative effects to fish populations as a result of the turbine and conveyance canal operation. A brief description of mitigation measures is provided below.

15.3.2.6.1 Turbines

Low-head Kaplan or Francis turbines would be installed in the new powerhouse. Kaplan turbines have been shown to result in lower fish mortality with approximately 95% survivability of entrained fish (Lariner, 2002) and would be the preferred turbine subject to consideration of technical and economic feasibility. In addition, turbines with the least number of blades (fewer blades results in lower fish mortality) could be used where technically viable to further minimize the potential for fish mortality.

15.3.2.6.2 North Gorge Canal / South Gorge Spillway

The North Gorge canal and South Gorge Spillway would be designed as a blasted-rock channel with no in-stream submergent or emergent vegetation, woody debris or other in-stream complexities. The creation of a channel void of habitat features is anticipated to discourage fish use and lower the potential for fish entrainment.

15.3.2.7 PATHWAYS VALIDATION

The validation process involved linking the effects of the turbine and canal conveyance operation activities to the specific life history traits (survival, growth and reproductive potential) of the valued component. Therefore, a pathway was considered Valid if the effect could result in a change to an assessment endpoint. Minor pathways recognize that there may be a change to an assessment endpoint; however, the resulting effect is anticipated to be negligible. A pathway classified as Invalid is often associated with typical hydroelectric projects but is not applicable, or has no effect for this Project.

The results of the pathway validation assessment are summarized in Table 15.3.3. Rationale for the classification of pathways as Valid, Minor or Invalid is provided following the table.

Table 15.3.3 — Results of the Pathway Validation Assessment Associated with Operation of the Turbines and Conveyance Canal at the North Gorge

Project Component	Pathway	Pathway Validation
Turbine and conveyance canal operation	Fish passage issues: Entrainment of fish with respect to fish mortality	Valid
Turbine and conveyance canal operation	Fish passage issues: Change in diversion channels with respect to inter basin transfer of fish species	Minor
Turbine and conveyance canal operation	Flow management with respect to change in total gas pressure	Invalid

In total, three pathways have been identified between the Project component (operation of the turbine and conveyance canal) and the aquatic components associated with the North Gorge canal. Of the three identified pathways, one is a Valid pathway to an assessment endpoint, one is a Minor pathway and one is an Invalid pathway.

15.3.2.7.1 Valid Pathways

Fish passage Issues: Entrainment of Fish with Respect to Fish Mortality.

A small proportion of the fish population in the Twin Gorges Forebay may become entrained in the turbines associated with the North Gorge; there are no turbines associated with the South Gorge canal and thus no possibility of entrainment. Fish passage through the turbines may result in fish mortality and injuries due to various stresses. These stress-inducing mechanisms include cavitation (air bubbles that form due to low water pressure and subsequently collapse), sudden shifts in water pressure, rapid changes in water acceleration or deceleration rates, and collisions with stationary or moving turbine parts (Lariner, 2002). Other stresses include turbulence, which may cause injuries and disorientation, and stress applied to fish surfaces at the border of two water bodies of different velocities (Cada 2001). Effects from fish entrainment include short-term injuries and mortalities as well as the long-term effects on the fish health, survival and reproduction abilities. Therefore, the use of turbines could lead to fish entrapment and potential mortality. As such, the pathway has been classified as Valid.

15.3.2.7.2 Minor Pathways

Fish passage Issues: Change in Diversion Channels with Respect to Inter Basin Transfer of Fish Species.

The diversion of water from one water body to another can promote the insurgence of invasive or other non-native species. Under baseline conditions, fish species can migrate from the Twin Gorges Forebay (upper Taltson River) into the lower Taltson River by two corridors: through the existing power facility and down Elsie Falls located in the original Taltson River channel, and over the SVS or one of its side channels. Migration (purposeful or accidental) down either of these corridors is in a downstream direction; these corridors are barriers to the upstream movement of fish. The addition of the North Gorge canal and the South Gorge spillway would introduce two additional downstream migration channels; however, neither of these corridors would allow for upstream fish migration. Downstream migratory channels exist under baseline conditions; however, the frequency of migration, either accidental or purposeful, could increase as the potential to encounter a downstream migratory corridor increases. As such, the pathway has been classified as Minor.

15.3.2.7.3 Invalid Pathways

Flow Management with Respect to Change in Total Gas Pressure.

Total gas pressure (TGP) occurs when air gets trapped in water and is submerged to sufficient depths to create a pressurized environment. The drop height associated with the North Gorge canal and South Gorge spillway and the lack of plunge pools prevents the potential for TGP increase. Therefore, TGP concentrations would not change from baseline conditions. As such, the pathway has been classified as Invalid.

15.3.2.8 EFFECTS ANALYSIS

The pathway validation analysis identified one Valid pathway, which has been carried forward for effects assessment. The Valid pathway identified is *Fish passage Issues: Entrainment of Fish with Respect to Fish Mortality*. As the biophysical conditions (depth, velocity) would be nearly identical under both a 36 MW and a 56 MW operation scenario, the following effects analysis addresses both operating scenarios.

The probability of fish entrainment associated with the North Gorge canal was estimated through a desktop analysis. The objective of this analysis was to provide an order of magnitude estimate on the potential for fish entrainment at the North Gorge using existing literature and site-specific knowledge of the fish species present within the Twin Gorges Forebay. The assessment methodology was adopted from other hydroelectric development projects (Saluda Hydro Project, 2006; Catawba-Wateree Hydro Project, 2004) and involved the following steps:

- Conduct a detailed literature review of the potential effects associated with fish entrainment.
- Calculate survivability rates of entrained fish.
- Characterize the species composition associated with the aquatic environment.
- Apply any physical or biological filters that may affect entrainment.
- Determine the probability for entrainment associated with the North Gorge canal.

15.3.2.8.1 Incremental Effects

15.3.2.8.1.1 Literature Review

A literature review of recent entrainment study programs at hydroelectric facilities was conducted and included sources from scientific journals, recent hydroelectric projects, and government agencies. The intent of the literature review was to determine the potential effects associated with fish entrainment and a methodology to assess the risks to fish.

The effects of turbine entrainment on fish populations are highest for anadromous species, such as Arctic char, which migrate from the fresh-water streams into the ocean to complete their life cycle (Cada, 2001). Entrainment was found to be relatively low for most resident freshwater species (FERC, 1995), likely related to their non-migratory life history characteristics.

Acres International (2005) indicated that the differences in fish species did not cause significant differences in survival probability of entrained fish (Franke et al., 1997; Winchell et al. 2000); the rates of survival and entrainment are more dependent on the size of fish (Acres International, 2005; CH2M HILL, 2003). Smaller fish size was found to be proportional to a higher survival rate due to lower strike frequency by turbine parts (Collins and Ruggles, 1982); however, the majority (over 90%) of entrained fish is typically represented by young-of-year or small fish (Winchell et al. 2000; Acres International, 2005). Very little is known about the survival rates of adult fish passing through the turbines, as previous research focused mainly on juveniles (Cada, 2001).

Large "low-head" Kaplan turbines have been shown to result in a relatively low fish mortality and be among the most "fish-friendly" turbines (Cada, 2001). High survival rates (>95%) for juvenile salmonids have been recorded for the low-head Francis and Kaplan turbines (Larinier and Travade, 2002). High turbine rotational speeds (>250 rpm) were shown to contribute to higher fish mortality (Acres International, 2005).

15.3.2.8.1.2 Survivability Rate Calculation

Fish mortality resulting from operation of the turbines and conveyance canal at the North Gorge was estimated using equations presented in Lariner and Travade (2002), which were developed by Larinier and Dartiguelongue (1989). Although it is assumed that Kaplan turbines would be used, fish survival rates were also determined for Francis turbines.

For Kaplan turbines, mortality rates were calculated and are based on a typical turbine design for the Expansion Project design capacity:

$$P = [SIN(13.4 + 42.8(TL/esp))]^2$$

Where "P" is mortality rate, "TL" (in m) is the total length of fish and "esp" is the distance between the blades at mid-blade.

For Francis turbines, mortality rates were calculated as follows:

$$P = [SIN(6.54 + 0.218\ H + 118\ TL - 3.88\ D1m + 0.0078\ N)]^2$$

Where P is mortality rate, H is net head, TL (in m) is the total length of fish, D1m is the entrance diameter of the wheel measured at mid-height, and N is the speed of rotation.

The above formulas are based on juvenile salmonids; however; the formula can be applied to other fish, as fish size and not fish species has been shown to have greatest effect on the rate of survival.

As juvenile fish are anticipated to be the age class with the highest potential to become entrained (CH2M HILL, 2003), the fish size classes incorporated into the calculations reflect the size ranges between young-of-year/emergent fish (0.05 m to yearlings (0.15 m). Yearlings would typically move to deeper water habitats in late summer, remaining at depth until returning to spawn as adults. Therefore, size classes larger than 0.15 m were not considered for this assessment. The results of the calculations are shown in Table 15.3.4 and Table 15.3.5.

Table 15.3.4 — Mortality Rate Estimates for Francis Turbines

Head (m)	Fish Length (m)	D1m (m)	N (rpm)	Mortality Rate
40	0.15	2.6	300	18.1%
40	0.10	2.6	300	10.9%
40	0.08	2.6	300	7.9%
40	0.05	2.6	300	5.4%

Table 15.3.5 — Mortality Rate Estimates for Kaplan Turbines

Fish Length (m)	D1m (m)	Number of Blades	esp	Mortality Rate
0.15	2.6	5	1.63	8.9%
0.10	2.6	5	1.63	7.6%
0.08	2.6	5	1.63	7.0%
0.05	2.6	5	1.63	6.5%

15.3.2.8.1.3 Species Composition

In total, seven fish species were captured in the Twin Gorges Forebay (Section 15.3.2.1 – Existing Environment): lake whitefish, lake cisco, white sucker, lake trout, northern pike, longnose sucker and trout perch. Based on the relative densities of the identified species (Figure 15.3.2), it has been assumed lake whitefish, white suckers, lake cisco and lake trout have the highest potential of becoming entrained as they account for 93% of the fish population. A complete review of the life histories of these species can be found in Section 9.5 – Biological Environment.

15.3.2.8.1.4 Physical and Biophysical Filters

Aquatic habitat around the inlet location to the North Gorge is similar to the surrounding area in the Twin Gorges Forebay and is characterized by a rocky shoreline with steep stream margins. Under baseline conditions, a shallow bedrock bench extends approximately 2 m to 5 m into the aquatic habitat at the inlet location before dropping off steeply to depths greater than 5 m. No in-stream submergent and/or emergent vegetation or large woody debris is present.

The preferred habitat conditions of the species that have been identified to potentially become entrained were cross-referenced with the habitat conditions at the intake location under baseline conditions. Table 15.3.6 qualifies the habitat conditions at the intake location with the Forebay by species life stage.

Table 15.3.6 — Habitat Conditions of the North Gorge Intake at the Forebay

Life Stage	Lake Whitefish	White Suckers	Lake Trout	Lake Cisco
Juvenile rearing	Fair	Poor	Good	Poor
Adult rearing	Fair	Fair	Fair	Fair
Overwintering	Fair	Fair	Fair	Fair
Spawning	Poor	Poor	Fair	Poor

The preferred habitat conditions of juvenile rearing lake trout are the most suited to the habitat conditions present at the inlet location of the North Gorge. The lack of preferred spawning substrates within the North Gorge (gravels and cobbles) and adjacent to the inlet to the North Gorge would limit the potential use of the canal for spawning by lake trout. Field sampling programs in the Forebay and local knowledge of the area indicate that lake trout are the only species that have been observed within 100 m of the intake location. Therefore, lake trout are considered to be the species with the highest potential of utilizing the North Gorge canal to carry out one or more stages of their life histories.

The preferred habitat conditions are fair to poor for all life stages of lake whitefish, white suckers and lake cisco. This does not indicate that these species would not use the habitats associated with the North Gorge canal, although the number of individuals of these species is anticipated to be significantly lower in comparison to lake trout. Therefore, the effects assessment considers each of the species listed in Table 15.3.6 but has been weighted towards the analysis of lake trout.

15.3.2.8.1.5 Entrainment Probability

Based on the available fish abundance information, an assessment on the precise number of juvenile lake trout and other species potentially passing by the inlet location of the North Gorge can not be made; however, a correlation of the available habitat and life history characteristics of the species provides insight into the likelihood of fish use of the area at and immediately adjacent to the inlet.

Based on the anticipated good juvenile-rearing habitat conditions adjacent to the North Gorge, during Project operations it can be assumed that a school of juvenile lake trout could pass by the intake on a relatively regular basis. The likelihood of juvenile lake trout entering the canal and using the North Gorge for rearing is considered low for the following reasons:

- The intake location and entrance to the North Gorge extends over a very small area when compared to the entire shoreline of the Twin Gorges Forebay.
- There is a lack of in-stream complexities within the canal and the depth conditions would be shallower when compared to the habitats surrounding the canal.

- Velocity conditions within the North Gorge would be higher in comparison to the habitats adjacent to the inlet, which would require a constant exertion of energy.

Based on the same rationale noted above, the use of habitats within the North Gorge canal by lake whitefish, white sucker and lake cisco is also unlikely. Of the fish that choose to enter and use the habitats in the North Gorge, the likelihood of entrainment is moderate as the approach velocities are the same as the burst speeds of fish 150 mm in length at 1 m/s.

The likelihood of purposeful downstream fish migration is low as the identified species are not migratory and all the preferred habitat conditions for each species life stage are met in the Forebay. If downstream migration does occur (purposeful or accidental), the survivability rate of the entrained fish exceeds 80% as described in Table 15.3.4 and Table 15.3.5. Therefore, the likelihood of fish entrainment resulting in mortality is considered low.

The overall effects classification and determination of significance for entrainment associated with the North Gorge is summarized in Sections 15.3.5 – Effects Classification and 15.3.6 – Significance Determination, respectively.

15.3.3 Nonacho Control Structure

15.3.3.1 INTRODUCTION

The existing Nonacho Lake control structures were constructed in 1968 and consist of a rockfill dam, three timber-lined sluice gates, and a rock channel spillway. The dam and the sluice gates are nearing the end of their serviceable life. As the Project would require greater controlled releases from Nonacho Lake than is currently possible through the timber sluice gates, a new control structure has been designed to replace the existing gates. The new structure would consist of the following components:

- a short intake rock canal from Nonacho Lake at a point upstream of the left abutment of the existing dam,
- a concrete structure accommodating four gated sluice passages, and
- a rock cut canal downstream of the gates to the existing release channel downstream of the dam.

As part of the proposed Project and in addition to the new control facility, in-stream work activities would also include repairs of the dam to reduce leakage, the decommissioning of the sluice gates and a small concrete raise placed on the crest of the existing spillway. The effects of in-stream construction activities are discussed in Section 15.2 – Canal Construction.

By minimizing the accidental leakage that is currently experienced at the rockfill dam and by decommissioning the sluice gates, the aquatic habitat between the rockfill dam and the outlet of the new control structure would experience considerably less flow. In addition, the raising of the existing spillway by 0.5 m would result in periods of reduced flows within the spillway channel with a high frequency of zero flows.

15.3.3.2 EXISTING ENVIRONMENT

Habitat typing of the aquatic environment at and adjacent to the existing Nonacho control structure was completed by Cambria Gordon Ltd. (2008). This assessment identified nine distinct habitat polygons (Figure 15.3.3). The following description of the existing environment at the Nonacho control structure is a summary from the Cambria Gordon Ltd. (2008) Habitat Assessment for In-stream Work Locations report (Appendix 15.2A) and has been broken into three sections: the Nonacho control structure inlet, the Nonacho control structure outlet, and the spillway channel.

15.3.3.2.1 Nonacho Control Structure Inlet

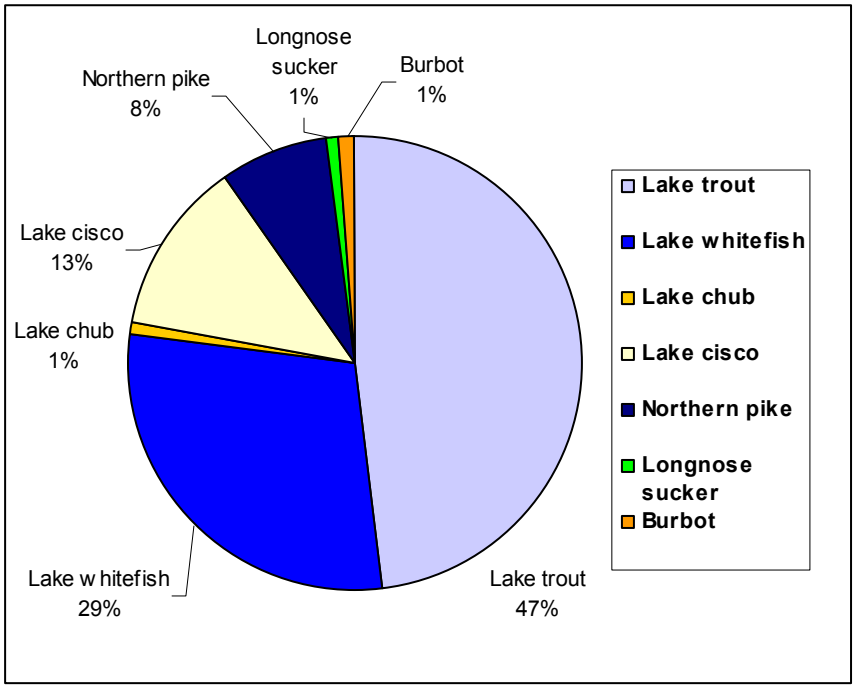
Aquatic habitats at and adjacent to the intake location to the Nonacho control structure (Polygon A in Figure 15.3.3) are similar to the littoral zone surrounding Nonacho Lake. Under baseline conditions, the shoreline habitat is characterized by a small bedrock bench along the lake margin ranging in depths from 0 m to 0.5 m. The bedrock bench drops off steeply to depths 4 m and greater at approximately 10 to 15 m from the wetted edge. Along the lake margin, water velocities are slow; however, an undercurrent exists 10 m from the shoreline. The undercurrent is likely associated with the three timber sluice gates located downstream in the rockfill dam.

The substrate is primarily composed of gravel and cobbles near the lake margin with finer substrates infilling much of the interstitial spaces. Farther offshore, substrate conditions shift primarily to bedrock with boulders frequently interspersed throughout. Along the shallow bench and where the substrates are suitable, sparse submergent and emergent vegetation is present. Immediately adjacent to the inlet location of the intake canal, a sparse 200 m^2 submergent and emergent vegetation community is established. In addition to the vegetation communities, small woody debris (SWD) exists and could provide ample cover for juvenile fish.

Fish species composition was determined from fish sampling programs conducted by Rescan Environmental Services (2003/2004) and Envirocon (1973). In total, seven fish species were captured including: lake whitefish, lake cisco, longnose sucker, lake trout, northern pike, lake chub and burbot. The results of these sampling efforts have been compiled and are illustrated in Figure 15.3.4.

TALTSON HYDROELECTRIC EXPANSION PROJECT	**Developer's Assessment Report 2009**	**Habitat Polygons Identified at Nonacho Control Structure**	**Figure 15.3.3**

Figure 15.3.4 — Fish Species Composition within Nonacho Lake



15.3.3.2.2 **Nonacho Control Structure Outlet**

The habitat conditions immediately downstream of the rockfill dam extending to the outlet of the Nonacho control structure are characterized by pool habitat and are dominated by bedrock and sporadic boulders (Polygon H in Figure 15.3.3). Water velocity within these pools is moderate and no submergent or emergent vegetation or woody debris exists within this section of river. Adult lake trout were observed holding in a large pool approximately 3 m to 4 m in depth, immediately downstream from the sluice gates.

A small riffle pool channel also exists between the rockfill dam and the outlet to the Nonacho control structure (Polygon I in Figure 15.3.3). The water associated with this small section is sourced from the accidental leakage through the rockfill dam.

15.3.3.2.3 **Spillway Channel**

The habitats within the spillway channel are defined by a cascade pool morphology and are characterized by fast flowing waters (Polygon D in Figure 15.3.3). The spillway channel is approximately 350 m in length and ranges in width from 60 m at the inlet to 115 m at the outlet. Water velocity conditions within the channel are very fast, which likely limits the presence of moveable substrate and aquatic vegetation cover. Depth measurements are estimated to be greater than 2 m in most sections.

A riffle pool side channel is located approximately 105 m downstream from the spillway rock sill (Polygon E in Figure 15.3.3). The side channel is 6 m wide on average and 150 m in length. The substrate within the channel is dominated by gravel and frequent large boulders. The riffle-pool channel ranged from 0 m to 1.5 m in

depth and contained large and small woody debris throughout. The entire channel was sampled with an electro-shocker with no fish observed.

15.3.3.3 VALUED COMPONENTS

The selected valued component (fish populations) and rationale for selection are the same as for the North Gorge Canal and are summarized in Section 15.3.2.2.

15.3.3.4 ASSESSMENT ENDPOINTS AND PATHWAYS

Assessment endpoints and pathways were determined through review of the identified DFO POE, as described in Section 15.3.2.3. Table 15.3.7 summarizes the assessment endpoints, and the pathways leading to those endpoints for the valued component.

Table 15.3.7 — Valued Components, Assessment Endpoints and Pathways Identified for Operation of the Nonacho Lake Control Structure

Valued Component	Assessment Endpoint	Pathway
Fish populations	Change in fish mortality	Fish passage issues: Entrainment of fish with respect to fish mortality
Fish populations	Change in migration/access to habitats	Fish passage issues: Change in diversion channels with respect to inter basin transfer of fish species
Fish populations	Change in fish habitat structure and cover	Flow management: Change in waterline elevation with respect to fish habitat structure and cover

15.3.3.5 SPATIAL AND TEMPORAL BOUNDARIES

The analysis of potential interactions between the operation of the Nonacho control structure and the aquatic environment was conducted on a local study area and a regional study area. The local study area includes all in-stream habitats at the inlet of the Nonacho control structure, in the spillway channel, and below the existing rockfill dam to the confluence with the Taltson River. The regional study area includes the in-stream habitats from Nonacho Lake downstream to the inlet of Tsu Lake.

The temporal boundaries of the effects assessment are the same as those outlined for the North Gorge Canal/South Gorge Spillway (see Section 15.3.2.4).

15.3.3.6 PROJECT COMPONENTS

Project components associated with the operation of the Nonacho Lake control structure are summarized in Table 15.3.8.

Table 15.3.8 — Project Components Associated with Operation of the Nonacho Lake Control Structure

Project Component	Sub-component	Associated Activities	Geographic Extent	Schedule	Duration	Phase
Nonacho Lake control structure	None	Regulation of flow from Nonacho Lake to the Taltson River	Spillway channel between existing spillway and Taltson Lake	Continuous	Continuous	Operations

15.3.3.7 MITIGATION

Mitigation measures, including design features and operational guidelines, have been identified to reduce the overall potential for negative effects to fish populations.

15.3.3.7.1 Turbines

A low-head Kaplan turbine is assumed at the Nonacho Lake control structure, in consideration of technical feasibility. Kaplan turbines rank among the top fish-friendly designs, reducing fish mortality from the entrainment. In addition, turbines with the least number of blades (which results in lower fish mortality) would be used where feasible and technically viable to further minimize the potential for fish mortality.

15.3.3.8 PATHWAY VALIDATION

The results of the pathway validation assessment are summarized in Table 15.3.9. Rationale for the classification of pathways as Valid, Minor or Invalid is provided following the table.

Table 15.3.9 — Pathway Validation of Potential Effects during Operations of the Nonacho Control Structure

Project Component	Pathway	Pathway Validation
Nonacho Lake control structure	Fish passage issues: Entrainment of fish with respect to fish mortality	Valid
Nonacho Lake control structure	Fish passage issues: Change in diversion channels with respect to inter basin transfer of fish species	Invalid[1]
Nonacho Lake control structure	Flow management: Change in waterline elevation with respect to fish habitat structure and cover	Valid

[1] This pathway is invalid for this specific subject of note. A full discussion of the change in fish access between Nonacho Lake and Taltson River is contained in Chapter 13 – Water Fluctuations in the Taltson Watershed

In total, three pathways have been identified between the Project component (operation of the Nonacho control structure) and the aquatic components associated with Nonacho Lake and Taltson River. Of the three identified pathways, two are Valid pathways, none are Minor pathways, and one is an Invalid pathway.

15.3.3.8.1 Valid Pathways

Fish passage Issues: Entrainment of Fish with Respect to Fish Mortality.

A small proportion of fish population in Nonacho Lake may become entrained in the turbine associated with the Nonacho control structure. Fish passage through the turbines may result in fish mortality and injuries due to various stresses. These stress-inducing mechanisms include cavitation (air bubbles that form due to low water pressure and subsequently collapse), sudden shifts in water pressure, rapid changes in water acceleration or deceleration rates and collisions with stationary or moving turbine parts (Lariner 2002). Other stresses include turbulence, which may cause injuries and disorientation, and stress applied to fish surfaces at the border of two water bodies of different velocities (Cada 2001). Effects from fish entrainment include short-term injuries and mortalities as well as the long-term effects on the fish health, survival and reproduction abilities. Therefore, the use of turbines at the Nonacho control structure could lead to fish entrapment and potential mortality. As such, the pathway has been classified as Valid.

Flow Management: Change in Waterline Elevation with Respect to Fish Habitat Structure and Cover.

Fish habitat structure and cover is predominately a measure of 4 parameters: depth, velocity, cover and substrate. The operation of the proposed Nonacho control structure would result in a lowered waterline elevation in various habitats immediately adjacent to the existing Nonacho dam. The lowered waterline elevation could alter the baseline depth, velocity and cover conditions throughout the spillway channel and within the pool habitat between the dam and outlet of the control structure. As such, the pathway has been classified as Valid.

15.3.3.8.2 Minor Pathways

No Invalid pathways were identified.

15.3.3.8.3 Invalid Pathways

Fish passage Issues: Change in Diversion Channels with Respect to Inter Basin Transfer of Fish Species.

The diversion of water from one water body to another can promote the insurgence of invasive species or other non-native organic species. At the outlet of Nonacho Lake and under baseline conditions, fish species can migrate downstream from Nonacho Lake and into the Taltson River through the existing sluice gates and over the spillway channel.

The regulation of flows would not result in the addition of any new diversion channels from Nonacho Lake into the Taltson River or the introduction of a new or invasive species to a water body. Therefore, the operation of the new control structure at Nonacho Lake would not result in a new corridor for fish migration that

did not exist under baseline conditions. As such, the pathway has been classified as Invalid.

A full discussion of the change in fish access between Nonacho Lake and Taltson River as a result of the control structure and associated upgrades is contained in Chapter 13 – Water Fluctuations in the Taltson River Watershed.

15.3.3.9 EFFECTS ANALYSIS

15.3.3.9.1 Entrainment

The effects assessment followed the same assessment methodologies as the effects assessment for entrainment at the North Gorge including survival rate calculation, species composition, application of physical and biological filters, and a probability determination on the likelihood of fish entrainment.

15.3.3.9.1.1 Survivability Rate Calculations

Fish mortality for operation of the turbines and conveyance canal at the Nonacho control structure was estimated using equations presented in Lariner and Travade (2002), which were developed by Lariner and Dartiguelongue (1989). These formulas are presented and described in Section 15.3.2.8.1 – Survivability Rate Calculation.

The mini-turbine proposed for the Nonacho control structure would contain four blades (Np) with a 0.65 m diameter (D1m). Based on these specifications, Table 15.3.10 summarizes the fish survivability rates associated with the mini-turbine at the Nonacho control structure.

Table 15.3.10 — Mortality Rate Estimates for the Nonacho Control Structure

Fish Length (m)	D1m (m)	Number of Blades	esp	Mortality Rate
0.15	0.63	4	0.49	19.9%
0.10	0.63	4	0.49	14.2%
0.08	0.63	4	0.49	11.6%
0.05	0.63	4	0.49	9.3%

15.3.3.9.1.2 Fish Species Composition

In total, seven fish species have been identified in Nonacho Lake: lake whitefish, lake cisco, longnose sucker, lake trout, northern pike, lake chub and burbot. Based on the fish composition and relative densities (Figure 15.3.4), it has been assumed that the species with the greatest potential of becoming entrained are lake whitefish, white suckers, lake cisco and northern pike, as they account for 97% of the population. A complete review of the life histories of these species can be found in Section 9.5 – Biological Environment.

15.3.3.9.1.3 Physical and Biological Filters

Aquatic habitat around the inlet location to the Nonacho control structure is similar to the surrounding area in Nonacho Lake and is characterized by a rocky shoreline with steep lake margins. Under baseline conditions, a shallow bedrock bench extends

approximately 10 m to 15 m into the aquatic habitat at the inlet location before dropping off to depths 4 m and greater. Sparse submergent and emergent vegetation exists on the bench and small woody debris is present. Adjacent to the inlet canal, the approach velocities are anticipated to be 1 m/s.

The preferred habitat conditions of the species that have been identified to potentially become entrained were cross-referenced with the habitat at the inlet location to the control structure under baseline conditions. Table 15.3.11 qualifies the habitat conditions at the inlet by species life stage.

Table 15.3.11 — Habitat Conditions of the Potentially Entrained Species at the Nonacho Control Structure

Life Stage	Lake Whitefish	Northern Pike	Lake Trout	Lake Cisco
Juvenile rearing	Fair	Good	Fair	Good
Adult rearing	Fair	Good	Fair	Fair
Overwintering	Fair	Fair	Fair	Fair
Spawning	Fair	Fair	Fair	Good

The preferred habitat conditions for northern pike rearing and lake cisco spawning and rearing are the most suited to the habitat conditions present at the inlet location of the Nonacho control structure. Field sampling programs conducted at the control structure indicate that northern pike use the habitats at the inlet location; however, the use of these habitats by lake cisco can not be ruled out. Therefore, northern pike and lake cisco are considered to be the species with the highest potential of utilizing the habitats at or adjacent to the control structure to carry out one or more stages of their life histories.

The preferred habitat conditions are fair for all life stages of lake whitefish and lake trout. This does not indicate that these species would not use the habitats associated with the control structure, although the number of individuals of these species is anticipated to be significantly lower in comparison to northern pike or lake cisco. Therefore, the effects assessment considers each of the species listed in Table 15.3.11; however, it has been weighted towards the analysis of northern pike and lake cisco.

15.3.3.9.1.4 Entrainment Probability

Based on the available fish abundance information in and/or around the Nonacho control structure, an assessment on the precise number of fish by species potentially passing by the inlet location can not be made; however, a correlation of the available habitat and life history characteristics of the species provides insight into the likelihood of fish use of the area at and immediately adjacent to the inlet.

Based on the good spawning and rearing potential for northern pike and lake cisco adjacent to the proposed inlet location to the control structure, during Project operations it can be assumed that northern pike and/or lake cisco could pass by the inlet on a relatively regular basis. The likelihood of juvenile rearing and/or spawning fish entering the control structure is considered low for the following reasons:

- The intake location and inlet to the control structure extends over a very small extent when compared to the shoreline of Nonacho Lake.
- There would be a lack of the preferred in-stream complexities (i.e., submergent/emergent vegetation) for juvenile rearing in comparison to the area surrounding the control structure.
- There would be a lack of the preferred spawning substrates (i.e., fines and vegetation) in comparison to the area surrounding the control structure.
- Velocity conditions within the intake canal would be higher than the surrounding area, which is outside the preferred habitat conditions of both northern pike and lake cisco.

Based on the same rationale noted above, the use of habitats within the control structure by lake whitefish and lake trout is also considered unlikely. Of the fish that choose to enter and use the habitats in the control structure, the likelihood of entrainment is moderate as the approach velocities are the same as their burst speeds, at 1 m/s.

In addition, the likelihood of purposeful downstream fish migration is low as the identified species are not migratory and all the preferred habitat conditions for each species life stage are met in Nonacho Lake. If downstream migration does occur (purposeful or accidental), the survivability rate of the entrained fish exceeds 80% as described in Table 15.3.10. Therefore, the likelihood of fish entrainment resulting in mortality is low.

15.3.3.9.2 Fish Habitat Structure and Cover

The operation of the Nonacho control structure has the potential to reduce flows between the rockfill dam and the outlet of the new control structure. In addition, the raising of the existing spillway by 0.5 m would result in periods of reduced flows within the spillway channel.

It is anticipated that with the reduction in accidental leakage and decommissioning of the sluice gates, the upstream fish movement into both the pool habitat in Polygon H (Figure 15.3.3) and riffle-pool area in Polygon I (Figure 15.3.3) would become impeded. As such, there would be a loss of approximately 1,100 m^2 of pool habitat in Polygon H and 200 m^2 of riffle-pool channel in Polygon I.

During periods of low flow, it is highly likely that the spillway channel would run at zero flows for prolonged periods of time. During such an event both the spillway and side channel habitats would likely run dry. As such, there would be a temporary loss of 7,000 m^2 of cascade-pool habitat in Polygon D (Figure 15.3.3) and 600 m^2 of riffle-pool habitat in Polygon E (Figure 15.3.3).

Therefore, a potential exists for a loss of the following quantities of habitat at the Nonacho control structure during operation of the Expansion Project:

- 800 m^2 of riffle-pool habitat,
- 1,100 m^2 of pool habitat, and
- 7,000 m^2 of cascade-pool habitat.

With the exception of the 600 m^2 of riffle-pool habitat associated with the spillway channel in Polygon E, no usable or unique habitat features would be lost that are not abundantly present immediately upstream and downstream of the existing Nonacho control facilities. In addition, the use of the riffle-pool channel is likely low as the habitat conditions present within the channel are not required to fulfill any stage of the known species life histories in Nonacho Lake or the Taltson River (Cambria Gordon 2008). Therefore, the magnitude of the effect on fish populations is considered to be low.

The overall effects classification and determination of significance for entrainment and habitat change associated with Nonacho control structure is summarized in Sections 15.3.5 – Effects Classification and 15.3.6 – Determination of Significance, respectively.

15.3.4 Cumulative Effects

This section discusses the anticipated cumulative effects of those pathways that are expected to have an incremental effect from the Project. They are discussed in the context of what is known about the pristine environment at the existing Forebay area and at Nonacho Lake at or near the control structure. The cumulative effect is determined first by assessing the cumulative nature of similar pathways. These are then assessed cumulatively with other Project effects on the Valued Component, discussed in Chapter 13 – Water Fluctuations in the Taltson River Watershed. The pathways "*Fish Passage Issues: Entrainment with Respect to Fish Mortality*" and "*Flow Management: Change in Waterline Elevation with Respect to Fish Habitat Structure and Cover*" result in incremental effects from the Project.

15.3.4.1 ENTRAINMENT

Fish Passage Issues: Entrainment with Respect to Fish Mortality results in an incremental effect from the Project. This would act cumulatively with the effects of entrainment associated with the existing facilities within the Twin Gorges Forebay, but not at the Nonacho control structure, as no turbines exist under baseline conditions.

15.3.4.1.1 Entrainment at Existing Twin Gorges Facility

The cumulative effects assessment followed the same assessment methodologies as the incremental effects assessment including survival rate calculation, species composition review, application of physical and biological filters, and entrainment probability.

The species composition and habitat values adjacent to the gated penstock of the existing facility are nearly identical to those of the North Gorge. As such, the species with the highest potential of becoming entrained is lake trout; however, lake whitefish, lake cisco and white suckers could also become entrained. In order for fish to become entrained in the existing facilities they would have to enter directly through the penstock pipeline that extends into the Forebay. The habitat values of the penstock pipeline are limited, if any, and the likelihood of purposeful migration into the pipeline is low.

The primary variance in the entrainment assessments between the Expansion Project and the existing facilities is the survival rate calculation, as the existing turbine

specifications are different than the turbines proposed for the Expansion Project. The existing power generating facility uses a Francis turbine with a net head (H) of 27.4 m, runner diameter (D1m) of 3.32 m and speed of rotation (N) of 150 RPM. Mortality rate calculations associated with the existing turbine are based on the Lariner and Travade (2002) equations and are summarized in Table 15.3.12.

Table 15.3.12 — Mortality Rate Estimates for Existing Twin Gorges Francis Turbine

Head (m)	Fish length (m)	D1m (m)	N (rpm)	Mortality Rate
27.4	0.15	3.32	150	10.1%
27.4	0.10	3.32	150	4.8%
27.4	0.08	3.32	150	2.8%
27.4	0.05	3.32	150	1.4%

Similar to the North Gorge canal, it can be assumed that a school of juvenile fish could pass by the penstock entrance on a relatively regular basis. Due to the poor habitat conditions associated with the penstock in comparison to the habitats immediately adjacent and within the Forebay, the likelihood of juvenile fish entering and rearing within the penstock is low. Of the fish that choose to enter and use the habitats in the penstock, the likelihood of entrainment is moderate as the approach velocities come close to their burst speeds.

In addition, the likelihood of purposeful downstream fish migration is low as the identified species are not migratory and all the preferred habitat conditions for each species life stage are met in the Forebay. If downstream migration does occur (purposeful or accidental), the survivability rate of the entrained fish is approximately 90% as can be seen in Table 15.3.12. As such, the magnitude of the effects associated with entrainment through the existing penstock is considered to be low.

The life history characteristics of the species known to exist in the Forebay suggest that juveniles do not migrate great distances from their natal grounds, rather they rear in the shallows where they emerged and move to deeper waters in mid to late summer. Therefore, fish that could potentially become entrained during operation of the existing facility and of the Expansion Project are likely associated with juveniles that were spawned at or near the facilities and not the entire population associated with the Twin Gorges Forebay.

15.3.4.1.2 Cumulative Effects of Entrainment

Operation of the Nonacho control structure micro-hydro plant and the North Gorge canal and turbines, coupled with the existing turbine at Twin Gorges, would increase the potential for the entrainment of juveniles, namely lake trout, as these are most susceptible at the existing facility. In addition, the frequency in which the juveniles would encounter a downstream migratory corridor (intake canal or penstock) would increase. The precise magnitude increase can not be determined; however, the likelihood of the juveniles using a canal or the existing penstock remains low and the survivability rates remain high. In addition, entrainment would likely be limited to fish spawned at or near the facilities and not on the entire population found

throughout the Forebay or Nonacho Lake. As such, the magnitude of the cumulative effects associated with entrainment is considered low.

The cumulative effects of entrainment on the fisheries resources within the Taltson River watershed are further discussed in Section 13 – Water Fluctuations in the Taltson River Watershed

15.3.4.2 FISH HABITAT STRUCTURE AND COVER

Flow Management: Change in Waterline Elevation with Respect to Fish Habitat Structure and Cover results in incremental effects from the Project. This would act cumulatively with the effects of habitat changes associated with the existing Nonacho control structure.

15.3.4.2.1 Residual Fish Habitat Effects at Nonacho Control Structure

The Nonacho Lake control structure was constructed in 1968 to enable water storage in Nonacho Lake and flow management for power generation at Twin Gorges. Little information on the habitat or biophysical condition of the area of the control structure could be sourced from which to develop an indication of pristine or pre-development conditions. Therefore, the effects of the existing control structure on the footprint areas discussed in this Subject of Note are difficult to determine.

The physical conditions at the control structure location pre-development likely comprised one channel connecting Nonacho Lake to the Taltson River. This is the channel that the dam is constructed in. The channel containing the spillway is man-made, and was blasted to enable spillage from Nonacho to Taltson River. For the past 20 years, with the reduced power output at Twin Gorges, this channel has flowed almost continuously. It is reasonable to assume that habitat structure and cover changed in the natural channel as a result of the control structure, which included the creation of additional habitat from the blasting of the spillway. The man-made channel contains approximately 7,000 m^2 of cascade pool habitat dominated by bedrock and no in-stream complexities. The habitat within the spillway channel provides poor spawning and rearing potential for all the known species in Nonacho Lake and the Taltson River.

Although it is impossible to determine the magnitude of change on the pristine fish habitat structure and cover conditions associated with the existing Nonacho control structure, it is reasonable to assume that the environment has stabilized from those changes, with the addition of the spillway channel. The incremental loss of habitat associated with the spillway channel and the pool habitat as a result of the Project is on a small scale in comparison to the Taltson River watershed and provides limited habitat value to fish under both current and pristine conditions. Therefore, the magnitude of the cumulative effect is considered low.

Discussion of the effects of changes to fish habitat in Nonacho Lake and fish access between Nonacho Lake and Taltson River as a result of water fluctuation is contained in Chapter 13 – Water Fluctuations in the Taltson River Watershed. In addition, that chapter contains a discussion of the pristine environment at the outlets of Nonacho Lake as they relate to fish access changes in Nonacho Lake and the Taltson River.

15.3.5 Effects Classification

Table 15.3.13 summarizes the classification of the incremental effects on the valued component fish populations for both the North Gorge canal and the Nonacho control structure.

Table 15.3.13 — Incremental Effects Classification of Pathways to the Valued Component Fish Populations

Project Component	Pathway	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Likelihood	Overall Risk / Assessment Effect
Turbine and conveyance canal operation	Fish passage issues: Entrainment of fish with respect to fish mortality	Adverse	Low	Local	Long-term	Reversible	Periodic	Low likelihood	Low / Negative
Nonacho Lake control structure	Fish passage issues: Entrainment of fish with respect to fish mortality	Adverse	Low	Local	Long-term	Reversible	Periodic	Low likelihood	Low / Negative
Nonacho Lake control structure	Flow management: change in waterline elevation with respect to fish habitat structure and cover	Adverse	Low	Local	Long-term	Reversible	Continuous	Highly likely	Low / Negative

The risks to fish populations at the Nonacho control structure are considered to be adverse and low. Compiled with the adverse and low risks to fish populations as a result of canal and turbine operations at the North Gorge, the potential risks to fish on a regional level would also be low.

15.3.6 Significance Determination

Table 15.3.14 summarizes the determination of significance for the incremental effects on he valued component fish populations. The entrainment pathways associated with the North Gorge canal and Nonacho control structure were grouped to provide one overall significance determination.

Table 15.3.14 — Determination of Significance to the Valued Component

Valued Component	Valued Component Assessment Endpoint	Pathways	Overall Significance	Uncertainty
Fish populations	Change in fish mortality	Fish passage issues: Entrainment of fish with respect to fish mortality	Not significant	Low
Fish populations	Change in fish habitat structure and cover	Flow management: Change in waterline elevation with respect to fish habitat structure and cover	Not significant	Low

15.3.7 Uncertainty

The primary assumption made during the analysis of entrainment was that large numbers of fish would not be utilizing the turbine and conveyance canal at the North Gorge or be located at the intake to the Nonacho control structure. This assumption was based on the following parameters:

- The limited area of disturbance associated with each location is small and insignificant in comparison to the shoreline associated with the Twin Gorges Forebay and Nonacho Lake.
- The habitat conditions associated with the intake location at the North Gorge canal and the Nonacho control structure were not unique and were similar to the majority of shoreline associated with each location.
- Fish sampling efforts at and or adjacent to the proposed intakes to each turbine canal resulted in low catch numbers.
- The species compositions associated with each area identified no anadromous or migratory fish species that would leave the existing waterbody to complete any stage of its life history.

An assumption of the Kaplan design for the Nonacho mini-turbine was made based on the design information. Minor changes to the turbine design specifications may occur during the Project detailed design phase, which could affect the calculated fish entrainment survivability rates.

15.3.8 Monitoring

Administration of the potential habitat change at the Nonacho control structure would be addressed by DFO's No Net Loss policy during the development of the Fisheries Act Section 35(2) Authorization for the Project. Post monitoring requirements would be developed and confirmed as part of the Authorization process.