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Yukon Next Generation Hydro and Transmission Viability Study
Yukon, Canada

Positive and Negative Environmental and Socio-economic Effects – Technical Paper

FINAL

November, 2015
SLR Project No.: 234.01009.00000

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YUKON DEVELOPMENT CORPORATION

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EXECUTIVE SUMMARY

The Yukon Development Corporation ("**YDC**") has commissioned Midgard Consulting Incorporated ("**Midgard**") and its team of sub-consultants to complete the *Yukon Next Generation Hydro and Transmission Viability Study*. The study, delivered through a series of technical papers, is intended to help focus future discussions and inform the decisions necessary to fill the territory's growing energy gap, and to support Yukon's continued economic growth and development. This technical paper, entitled "*Positive and Negative Environmental and Socio-economic Effects"* has been prepared by SLR Consulting Global Environmental Solutions ("**SLR**") in association with Hatfield Consultants (**"Hatfield"**).

Objective

The objective of this technical paper is to provide a review of key environmental and socio-economic effects of six (6) priority sites that have been identified for developing hydroelectric facilities with storage in the Yukon Territory over the planning period from 2035 to 2065. The six priority sites are:

- Fraser Falls – located in the Yukon River basin along the Stewart River;
- Two Mile Canyon – located in the Yukon River basin along the Hess River;
- Granite Canyon – located in the Yukon River basin along the MacMillan and Pelly Rivers;
- Detour Canyon – located in the Yukon River basin along the Pelly River;
- Slate Rapids and Hoole Canyon (Run-of-River, or ROR) – located in the Yukon River basin along the Pelly River; and
- False Canyon and Middle Canyon (ROR) – located in the Mackenzie River basin along the Frances River.

Approach

This review of the key environmental and socio-economic effects of each of these six priority sites was undertaken in three steps:

First, a high level overview of the general effects of hydroelectric projects on three primary areas of interest is provided, namely: fish and fish habitat, wildlife and wildlife habitat and on socio-economic conditions. This overview identifies and/or provides examples of the types of environmental and socio-economic effects that are common to all six priority sites along with examples of "Best Management Practices" (BMPs) that would need to be considered in future project development.

Second, a more focused evaluation of the six priority sites is undertaken. The scope of this environmental evaluation was focused on fish and fish habitat, including species at risk and Aboriginal fisheries; and wildlife and wildlife habitat, including protected or conservation areas, species at risk and Environment Yukon's Wildlife Key Areas (WKA). Environmental effects are often characterized as "potential" given that the evaluation is based on secondary sources and additional baseline studies are required to verify presence or absence of a species or habitat feature. The scope of the socio-economic evaluation of the priority sites was focused on various forms of land tenure and dispositions, historic and archaeological resources, jobs and GDP, and qualitative assessments of effects on local labour supply, traditional Aboriginal activities and community well-being. This scope includes broad indicators of potential effects. Socio-economic effects are characterized as "potential" given the many opportunities that exist to mitigate adverse effects and enhance positive ones.

Third, scorecards for each priority site and an overall comparative scorecard are presented that illustrates the study findings. The comparative scorecard is supported by a table of advantages and disadvantages that allows for the key differences between the priority sites to be highlighted. These differences, whether they are advantages or disadvantages, represent those positive effects that could occur and might need to be enhanced; and, those negative effects that will likely require attention through design and further mitigation.

<u>Study Findings</u>

The high level overview of the general effects of hydroelectric power generation projects found that:

- Hydroelectric power generation is a well-established technology that uses water in a renewable manner. The Yukon has a long history and experience with developing, operating and maintaining hydroelectric facilities.

- Hydroelectric power generation is regarded as the most reliable renewable energy source that can be readily integrated with other generation sources (e.g., intermittent renewables such wind and solar and fossil fuel based sources). This is because hydroelectric power generation responds well to generation and load variability and is regarded as flexibly being able to "store" energy by storing water (i.e. fuel) until needed.

- Hydroelectric power generation is also regarded as a clean energy source because it emits very little greenhouse gases. In the boreal environment, GHG emissions associated with hydropower are limited to the first 3 to 5 years after creating a reservoir, and after that they reduce to levels consistent with natural lakes.

- After many decades of experience with hydroelectric projects across Canada and internationally, the key environmental and socio-economic issues are known and understood by the scientific community, various regulatory bodies and the waterpower industry as a whole.

- With respect to effects on fish and fish habitat, hydroelectric developments normally involve modifications to river channels, impoundment of rivers, and regulation of discharge. These modifications inevitably change the aquatic ecosystem in which fish live. The degree to which any project affects fish and fish habitat varies widely depending on location and many other factors. In general however, some fish species end up doing quite well, others decline, and some are minimally affected. Although hydroelectric development can affect fish and fish habitat both directly or indirectly, these facilities can be designed and operated in a manner that avoids or minimizes serious harm to fish.

- Similar to the effects on fish and fish habitat, the degree to which any project affects wildlife and wildlife habitat depends on location and many other factors. Many of the negative environmental effects can be mitigated through site selection, facility design and operations (e.g., water management protocols) or adaptive management plans that evolve over time. In the Yukon, the selection of hydropower sites away from Wildlife Key Areas (WKAs) will serve to avoid those areas that are limited in availability, most valuable to the species/population, and/or where wildlife is most vulnerable. Ultimately, some species end up doing quite well, others decline, and some are minimally affected. These positive and negative effects over time do not necessarily diminish local biodiversity, but rather change its character.

- The socio-economic consequences of a hydroelectric project are numerous and varied, and can include both positive and negative effects on individuals, families, groups and organizations and their communities. Socio-economic effects tend to be highly community-specific and time dependent because every community is unique with its own mix of "assets" that change over time. Most notably, many negative socio-economic effects can be mitigated or managed over time and most positive effects can be enhanced. Ultimately, these positive and negative effects will either strengthen or diminish a community's assets which will have either positive or negative implications for its overall well-being.

As noted above, a more focused evaluation of the six priority sites was undertaken and the key differences between the priority sites were highlighted. On the basis of this evaluation, the following two sites appear to offer some key advantages with respect to wildlife and wildlife habitat and potential socio-economic effects relative to the others. They include:

- Two Mile Canyon
- Detour Canyon

The following site offers a mix of advantages and disadvantages with respect to effects on wildlife and wildlife habitat and socio-economics; however, substantial constraints with respect to fish and fish habitat were noted:

- Slate Rapids + Hoole Canyon ROR

The following three sites have their own unique mix of advantages and disadvantages, but there are key constraints identified with each that will likely need to be mitigated for the sites to be more acceptable:

- Fraser Falls' key constraints are with respect to effects on fish and fish habitat, wildlife and wildlife habitat;
- Granite Canyon's key constraints are with respect to effects on fish and fish habitat and socio-economics; and
- False Canyon + Middle Canyon ROR's key constraints are with respect to effects on wildlife and wildlife habitat and socio-economics.

At this stage in planning, each of the six priority sites remain viable locations for a new hydroelectric project. However, the advantages or disadvantages highlighted in this study, represent those potential positive effects that could occur and might need to be enhanced; and, those negative effects that will likely require attention through assessment, design and further mitigation. To identify any one of these six priority sites as the preferred location for a new hydroelectric project, more detailed studies and enhanced consultation is required. For example, additional environmental and socio-economic baseline information is required as well as a consultation program with affected First Nations and Yukon stakeholders within the context of Yukon's environmental and socio-economic assessment process under the *Yukon Environmental and Socio-economic Assessment Act.*

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1.0 INTRODUCTION

The Yukon Development Corporation ("**YDC**") has commissioned Midgard Consulting Incorporated ("**Midgard**") and its team of sub-consultants to complete the *Yukon Next Generation Hydro and Transmission Viability Study*. The study, delivered through a series of technical papers, is intended to help inform the decisions necessary to fill the territory's growing energy gap and to support Yukon's continued economic growth and development. This technical paper, entitled "*Positive and Negative Environmental and Socio-economic Effects"* has been prepared by SLR Consulting Global Environmental Solutions ("**SLR**") in association with Hatfield Consultants (**"Hatfield"**). It presents a high level overview of the key positive and negative environmental and socio-economic effects of six (6) sites that have been identified as priority sites for developing hydroelectricity facilities with storage in the Yukon Territory over the planning period from 2035 to 2065.

1.1 Summary of Findings from Site Screening Report 2

Midgard and its team of sub-consultants completed a *Site Screening Inventory (Parts 1 & 2)* (Midgard, 2015a, Midgard 2015b) to identify a set of sites that had potential for developing hydroelectricity facilities with storage in the Yukon Territory over the planning period from 2035 to 2065. Projects were evaluated based upon their ability to meet Yukon's capacity and energy requirements, high level environmental effects, constructability issues, and project economics. This Site Screening Inventory identified ten (10) sites.

Some themes that came out of the Site Screening Inventory (Parts 1 & 2) for the shortlisted sites were that:

- Historic hydroelectric project designs were sometimes larger than could be reasonably utilized in Yukon;
- All projects had environmental effects that required further study; and
- All projects affected stakeholder and First Nations lands, including both surface and sub-surface rights.

As a result, Midgard completed a *Scalability Assessment* (Midgard, 2015c) that studied ways to match the size and scale of potential hydroelectric projects to Yukon's forecast needs for electrical energy and capacity while reducing negative effects. The scalability assessment process:

- Revised project designs on a standalone basis to match their size to satisfy Yukon's forecasted baseline electricity needs in 2065;
- Combined projects to see if their footprints could be reduced when compared to standalone projects while still meeting the Yukon's forecasted baseline electricity needs in 2065;
- Compared resized projects and cascaded projects to see which projects have smaller reservoirs; and
- Evaluated project designs in terms of a staged build out over time. Because projects sized to meet the baseline 2065 electricity needs were not fully utilized in 2035, the projects were evaluated on the basis of progressively increasing their energy and capacity over time.

At the end of the *Scalability Assessment*, six (6) projects were identified along with their associated build out timelines. These six projects are referred to as the six priority sites in the following report and are described below.

1.2 Priority Sites Overview

The locations of the six (6) priority sites identified by the Midgard Team are identified on Figure 1. Key features of each site are summarized in Table 1. Transmission line distances assume a Faro to Watson Lake transmission line corridor exists. Figure 2a and Figure 2b show the location of each dam site and depict the reservoir footprints. The build out timelines for the six priority sites are shown on Table 2. For the purposes of this study, construction would be undertaken over a three year construction phase ending in 2035. Of note are the two sites with cascaded layouts, where the Run-of-River (ROR) sites are not operational until 2050 (Hoole Canyon) and 2060 (Middle Canyon).

1.3 Objective and Scope

The objective of this technical paper is to provide a review of the key environmental and socio-economic effects in key areas of the six priority sites that have been identified through the Yukon Next Generation Hydro and Transmission Project. This objective is achieved in three steps.

First, a high level overview of the general effects of hydroelectric projects is provided with a focus on three primary areas of interest, namely: fish and fish habitat, wildlife and wildlife habitat and on socio-economic conditions. This overview identifies and/or provides examples of the types of environmental and socio-economic effects that are common to all six priority sites along with examples of “Best Management Practices” (BMPs) that would need to be considered in future project development.

Second, a more focused evaluation of the six priority sites is undertaken. The scope of this environmental evaluation was focused on fish and fish habitat, including species at risk and Aboriginal fisheries; and wildlife and wildlife habitat, including protected or conservation areas, species at risk and Environment Yukon’s Wildlife Key Areas (WKA). Environmental effects are often characterized as “potential” given that the evaluation is based on secondary sources and additional baseline studies are required to verify presence or absence of a species or habitat feature. The scope of the socio-economic evaluation of the priority sites was focused on various forms of land tenure and dispositions, historic and archaeological resources, jobs and GDP, and qualitative assessments of potential effects on local labour supply, traditional Aboriginal activities and community well-being. This scope includes broad indicators of potential socio-economic effects. Socio-economic effects are characterized as “potential”, given the many opportunities that are available to mitigate adverse effects and enhance positive ones.

Third, scorecards for each priority site and an overall comparative scorecard are presented using a “Higher”, “Moderate” and “Lower” rating scheme. The ratings provide a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. In general, a “Higher” rating means:

- the priority site may result in negative environmental and socio-economic effects and/or offers the least potential for positive socio-economic effects. In some cases, the “Higher” rating means the effects are of greater magnitude relative to other priority sites.

- the analysis shows there is greater certainty that an adverse effect may occur, due to factors such as the known presence of key fish species (e.g., salmon), environmental features (e.g., WKA, species at risk) or important socio-economic attributes (e.g., Category A Settlement Lands, areas with subsurface rights for minerals) within the project footprint.
- the site will likely require a greater level of investigation through more detailed, complex and site specific environmental analyses.
- the site may require special site-specific design features to address technical, environmental and socio-economic constraints; and
- a greater effort will likely be required in the design of mitigation, compensation and enhancement measures to manage adverse effects and maximize benefits.

A “Moderate” rating means that the priority site offers a mix of positive and negative environmental and socio-economic effects.

A “Lower” rating means that the priority site has less potential for negative environmental and socio-economic effects and/or offers greater potential for positive socio-economic effects than other sites. A “Lower” rating does not mean that the site is constraint free or will require less attention through further assessment, design and mitigation.

Finally, a comparative scorecard is presented that illustrates the overall study findings. In this context, a “Higher” rating means the priority site poses more known constraints than other sites, and conversely, a “Lower” rating means that there are fewer known constraints than elsewhere. This scorecard is supported by a table of advantages and disadvantages that allows for the key differences between the priority sites to be highlighted. Final project approvals will require additional environmental and socio-economic baseline information as well as a consultation program with affected First Nations and Yukon stakeholders within the context of Yukon’s environmental and socio-economic assessment process under the *Yukon Environmental and Socio-economic Assessment Act.*

Figure 1: Locations of the Six Priority Sites

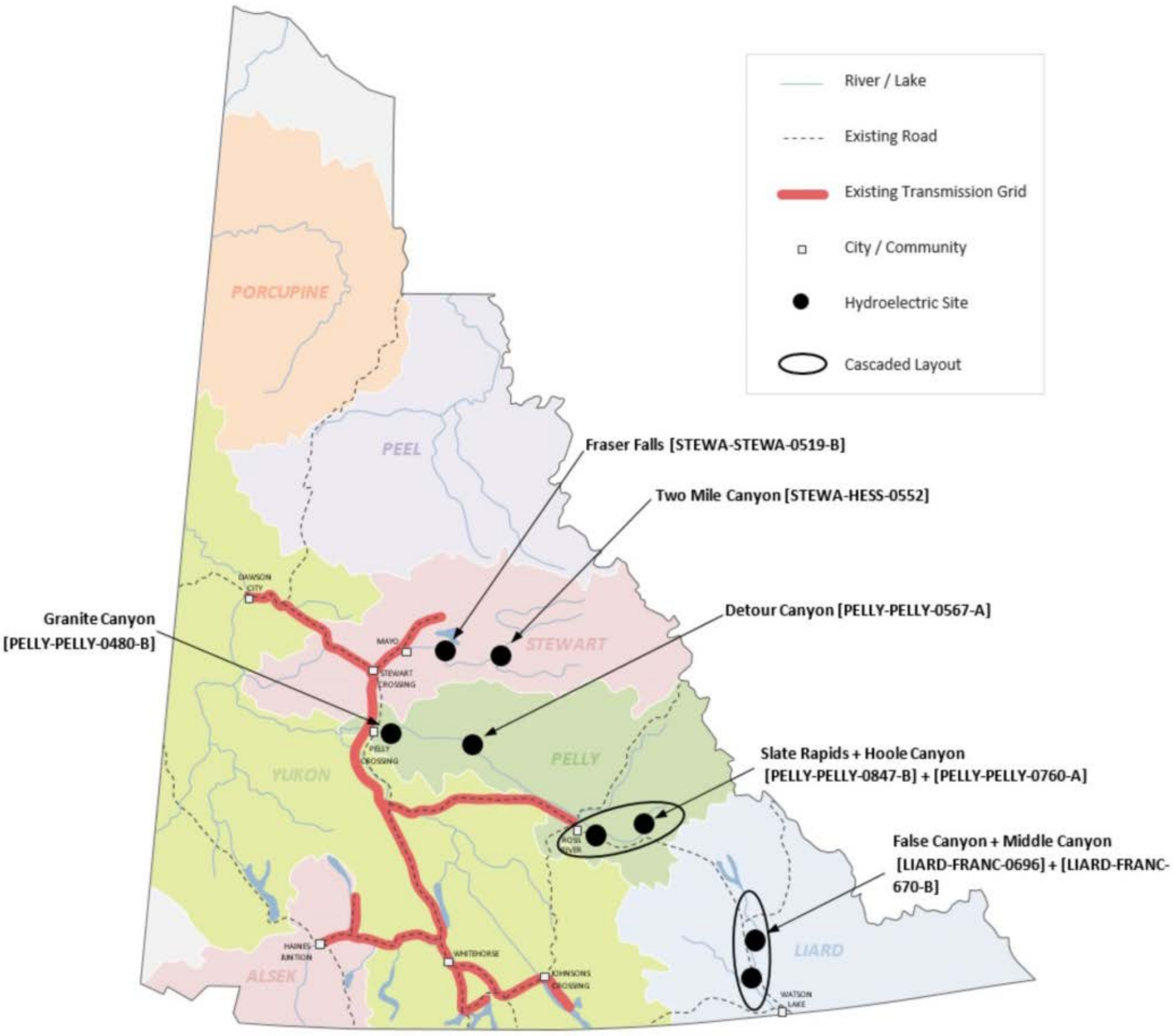


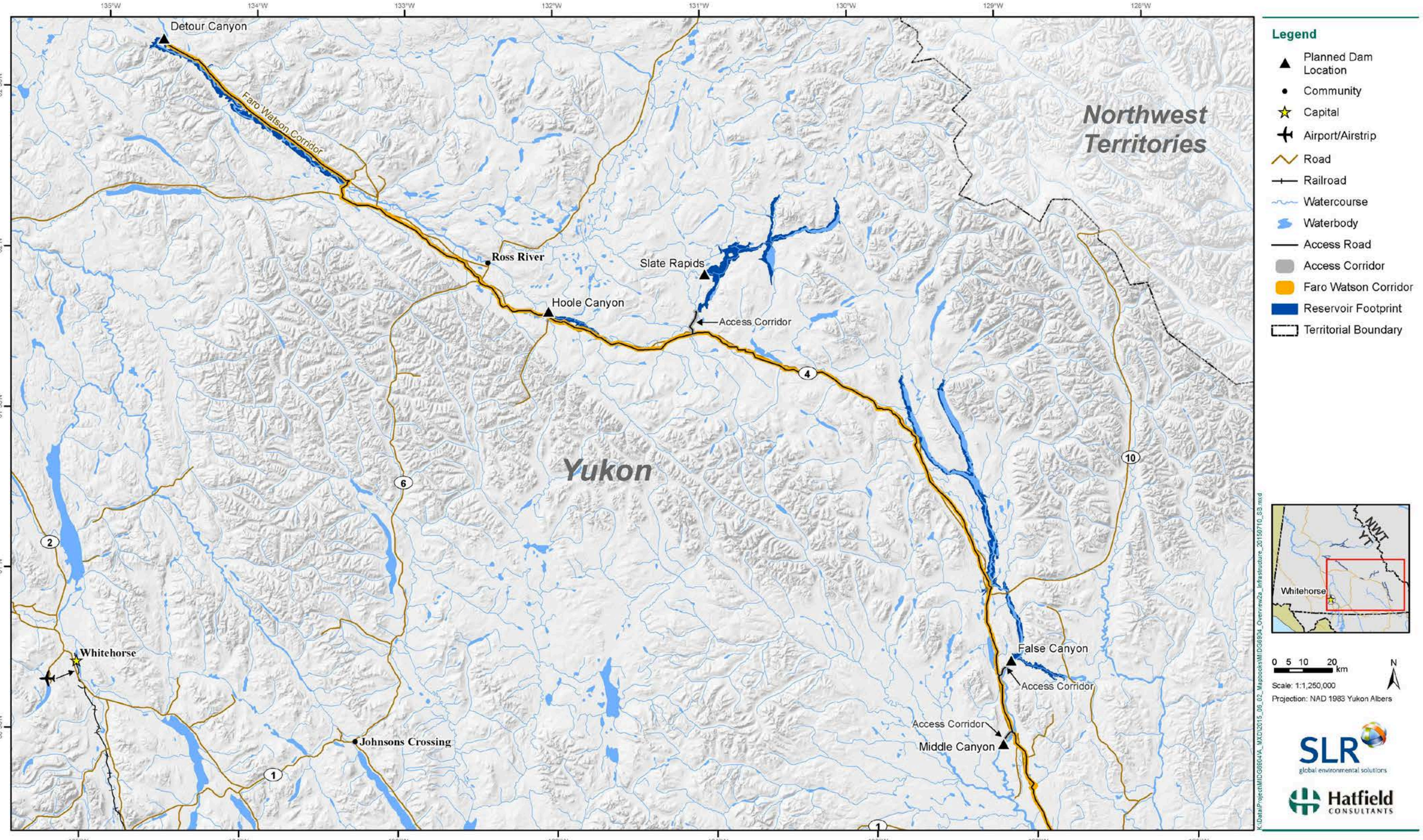
Table 1: Key Features of the Six Priority Sites

Priority Site	Basins and Rivers	Dam Dimensions	Ancillary Features	Total Reservoir Size (Ha)	Total Generation Capacity (MW)
Fraser Falls	Yukon River Basin: ▪ Stewart River	48 m (height) 56 m (height with excavation)	▪ Spillway is on the west abutment. ▪ Water intake, conveyance, powerhouse are on the east abutment. ▪ 40 km new road and 48 km new transmission line.	~ 31,200	57
Two Mile Canyon	Yukon River Basin: ▪ Hess River	62 m (height) 68 m (height with excavation)	▪ Spillway and powerhouse. ▪ Approximately 110 km new road and 113 km transmission line.	~ 10,300	54
Granite Canyon	Yukon River Basin: ▪ MacMillan River ▪ Pelly River	52 m (height) 60 m (height with excavation)	▪ Gated crest spillway is built into the dam. ▪ Water intake, conveyance, powerhouse and tailrace are on the west abutment. ▪ Approximately 15 km new road and transmission line.	~ 17,600	57
Detour Canyon	Yukon River Basin: ▪ Pelly River	57 m (height) 72 m (height with excavation)	▪ Spillway and control structure. ▪ Water intake and conveyance and powerhouse are on the north abutment. ▪ 90 km new road and 83 km new transmission line.	~ 13,000	60

Table 1: Key Features of the Six Priority Sites

Priority Site	Basins and Rivers	Dam Dimensions	Ancillary Features	Total Reservoir Size (Ha)	Total Generation Capacity (MW)
Slate Rapids and Hoole Canyon ROR	Yukon River Basin: ▪ Pelly River	Slate Rapids (main dam): 37 m (height); 57 m (height with excavation) Hoole Canyon: 56 m (height) 71 m (height with excavation)	Slate Rapids: ▪ Spillway, saddle dams, penstock from intake to powerhouse located 20 km downstream of dam. ▪ Approximately 9 km of new road and transmission line. Hoole Canyon: ▪ Spillway and water intake are on the west abutment. ▪ 600 m buried penstock cutting across the downstream river to the powerhouse. ▪ Approximately 2 km new transmission line and 50 km of new road required.	~ 19,100	Slate Rapids: 42 Hoole Canyon: 65 Total: 107
False Canyon and Middle Canyon ROR	Mackenzie River Basin: ▪ Frances River	False Canyon: 56 m (height) 65 m (height with excavation) Middle Canyon: 13 m (height) 17 m (height with excavation)	False Canyon: ▪ Spillway is on the east abutment. ▪ Water intake, conveyance, powerhouse and tailrace are on the west abutment. ▪ Approximately 7 km of new road and new transmission line. Middle Canyon: ▪ Spillway, water intake and powerhouse are constructed within the dam. ▪ Less than 6 km new transmission	~ 26,100	False Canyon: 56 Middle Canyon: 22 Total: 78

Figure 2a: Regional Context of the Priority Hydro Sites



Figures 2b: Regional Context of the Priority Hydro Sites

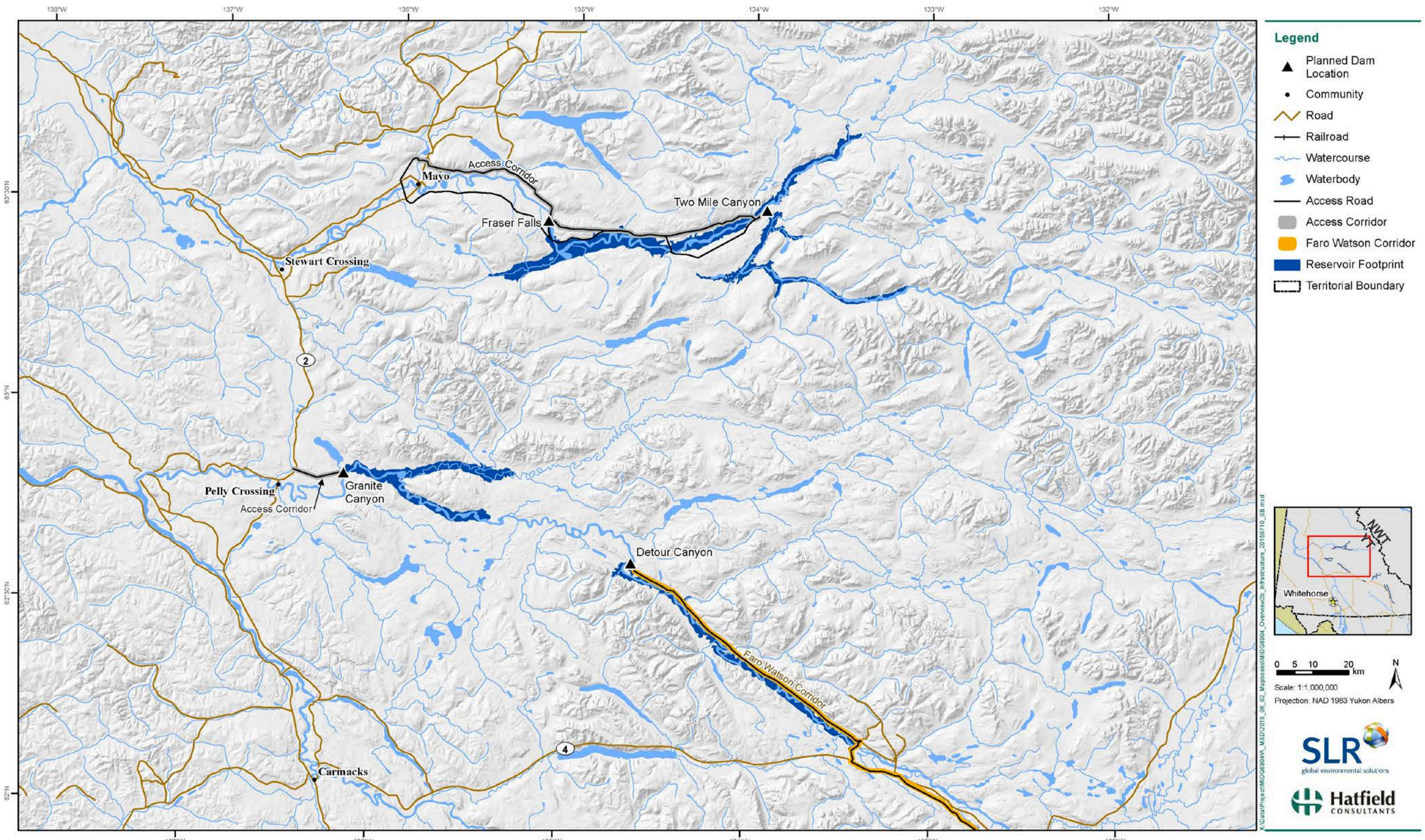


Table 2: Build Out Timeline of the Six Priority Sites

Project Name and Site ID	Build Out Timeline				
Detour Canyon [PELLY-PELLY-0567-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Fraser Falls [STEWA-STEWA-0519-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Granite Canyon [PELLY-PELLY-0480-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Two Mile Canyon [STEWA-HESS -0552]	2035: First 2 turbines installed	2045: 3rd Turbine Added	2050	2055	2060
False Canyon + Middle Canyon ROR [LIARD-FRANC-0696 + LIARD-FRANC-0670-B]	2035: Upstream Project Operation with 2 Turbines	2045	2050: 3rd Turbine Added	2055	2060: ROR Operation
Slate Rapids + Hoole Canyon ROR [PELLY-PELLY-0847-B + PELLY-PELLY-0760-A]	2035: Upstream Project Operation	2045	2050: ROR Operation	2055	2060

2.0 APPROACHES, METHODS AND ASSUMPTIONS

2.1 Environmental Analysis

2.1.1 Fish and Fish Habitat Approach and Methods

Fish species distributions in and around the reservoir footprint for each project were initially determined using Fisheries and Oceans Canada's Fisheries Information Summary System (DFO, 2015a). Further refinement and verification of each fish species distribution was determined using a variety of literature sources and government websites, as referenced throughout the text. Where feasible, fish species distributions both upstream and downstream (within 5 km) of each dam site were determined for each of the areas of interest. Species life histories were then compiled from literature sources to determine potential interaction with each priority site. Key effects assessed for each fish species include:

- Effects on migration (i.e., barriers to fish movement), both localized for non-anadromous species and regional for anadromous species;
- Effects on migration/spawning timing and triggers;
- Effects on spawning habitat and incubation of eggs;
- Effects on rearing habitat;
- Effects on outmigration (where applicable); and
- Effects on habitat that supports adult life stages (feeding, holding, etc.).

Documented occurrences of Aboriginal fishing camps, both historical and present, and known traditional fishing locations were compiled based on published literature sources, government websites (including aboriginal government websites), and Fisheries and Oceans Canada's Fisheries Information Summary System (DFO, 2015a). This compilation is not a complete list and additional important aboriginal fishing camps and fisheries are expected to be identified during future environmental approvals. These sites are identified in the Fish and Fish Habitat section of this report as indicators of fisheries values for each project; however they are factored into the evaluation of the six priority sites as socio-economic attributes (i.e., Traditional Aboriginal Activities).

2.1.2 Wildlife and Wildlife Habitat Approach and Methods

Each priority site was evaluated based on:

- The presence of a protected or conservation area;
- Species at risk with a documented occurrence within the proposed reservoir footprint;
- The potential occurrence of additional species at risk; and
- Environment Yukon's Wildlife Key Areas (WKA) representing a large aggregation of individuals (i.e., staging, nesting, moulting areas for water birds).

Consideration was also given to:

- WKAs for species not at risk; and
- Project overlaps with a caribou range (reservoirs may overlap with winter foraging caribou habitat).

Species at risk include those designated as endangered, threatened, or special concern by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) or under Canada's *Species at Risk Act* (SARA). They also include species of conservation concern in the Yukon. More specifically, species ranked as critically imperilled (S1), imperilled (S2) or vulnerable to becoming imperilled (S3). These ranks are defined by NatureServe based on territorial rarity, range restrictions, or declining numbers.

The Yukon Conservation Data Centre (YCDC) has a species at risk spatial database of known occurrences. Information was extracted from this database for species at risk records occurring within the reservoir footprint of priority projects. As occurrence records are uncommon, particularly in remote locations, a listing of all amphibians, birds, and mammal species at risk in the Yukon was retrieved from the YCDC (YCDC, 2014a). Each of the 68 species on this list (3 amphibians, 46 birds, and 19 mammals) was then screened for potential physical overlap with, or interaction with the priority sites. To do so, Environment Yukon's wildlife species accounts and distribution mapping website (Environment Yukon, 2011a) was consulted and additional information was gathered on birds (Sinclair et al. 2003), amphibians (Environment Yukon, 2013), bats (Environment Yukon, 2011b), small mammals (Eder and Kennedy, 2011), and caribou (Adamczewski et al., 2010).

For a broad overview, it is equally important to look at available information on notable wildlife habitats in the Yukon. The location of key habitats was obtained from Environment Yukon's Wildlife Key Area (WKA) mapping (Environment Yukon, 2011a). WKAs are geographic areas used by wildlife for critical, seasonal life functions; they include ungulate winter ranges, calving/rutting grounds, and mineral licks, predator dens, large mammal movement corridors and feeding ranges, traditional raptor nest sites, and the staging, nesting, and moulting wetlands used by water birds. WKAs typically represent areas where wildlife aggregate in large numbers, making populations vulnerable to disturbance or direct habitat loss.

2.1.3 Key Assumptions

2.1.3.1 *Fish and Fish Habitat Analysis*

Assumptions applicable to the analysis of fish and fish habitat at priority sites include the following:

- An environmental assessment and regulatory approvals will be required prior to any hydroelectric development in the Yukon which will document site-specific fish and fish habitat values, mitigation, monitoring and management planning at a localized scale. Overall effects on stream channel geomorphology, regional and local hydrology and site topography will affect the extent to which fish habitat becomes dewatered or inundated at each project site. These site-specific details are beyond the scope of this evaluation and are expected to be assessed during the environmental assessment should a suitable site be chosen for development.
- Documented occurrences of fish species may not be complete, and some inaccuracies as to actual species and specific distributions for each watershed may vary due to changes in knowledge in fish genealogy and classifications over time and changes to localized and regional conditions of each watershed over time.
- Spawning, rearing and adult stage habitat may be present for species at risk if these species have been sighted within the watershed, or if the priority site is within their distribution range.

- The First Nations fisheries sites identified in this document does not represent a complete list. Traditional Knowledge is an important link to fish and fish habitat information; however collecting and applying this knowledge is beyond the scope of this study.
- Priority site footprints are compiled at a scale of 1:250,000, using National Topographic Database maps by Natural Resources Canada. This scale is suitable for an overview study such as this one. It does not necessarily include all important fish habitat values of tributary streams and lakes within each project footprint.
- The fish and fish habitat inventory is based on fish sightings and captures and does not include an evaluation of the actual habitat features being used by species.
- Assessment of project effects is limited to the operational period of each project. Additional effects during construction can be expected to occur and BMPs would need to be applied.
- Given the importance of salmon in the Yukon and for Aboriginal peoples, the approach to rating the effects in Section 6 is considered to be precautionary rather than an absolute conclusion regarding the significance of the effect (See Appendix C for details).

2.1.3.2 *Wildlife and Wildlife Habitat Analysis*

Assumptions made during the evaluation for wildlife and wildlife habitat at priority sites, include the following:

- An environmental assessment in accordance with the *Yukon Environmental and Socio-economic Assessment Act* (YESAA), will be required prior to hydroelectric development to document site-specific wildlife and wildlife habitat values and mitigation requirements.
- Documented occurrences of species at risk are uncommon due to the remote nature of the priority sites, and do not represent a complete list of local species at risk.
- Breeding habitat may be present for other species at risk if these species have been sighted within the watershed, or if the priority site is within their distribution range.
- WKAs available on the Yukon Government website in 2015 are those that have been identified to date and do not represent a complete list of key wildlife habitat areas in the Yukon. Much of the Yukon has not been surveyed intensively or at critical times of year.
- First Nations and other people that travel the land know a great deal about wildlife distribution. This knowledge has not yet been incorporated into the boundaries of WKAs (Environment Yukon, 2014). Traditional knowledge (TK) and traditional land use (TLU) studies have not been included in this evaluation.
- WKA polygons are compiled at a scale of 1:250,000, using National Topographic Database maps by Natural Resources Canada. This scale is suitable for an overview study such as this one.
- The WKA inventory is based on wildlife sightings and does not include an evaluation of the actual habitat features being used by species.

2.2 Socio-economic Analysis

2.2.1 Approach and Methods

At this stage in planning, the potential positive, neutral or adverse socio-economic effects of the six priority sites were identified either quantitatively or qualitatively on the basis of several key indicators of potential effects. The quantitative analysis of potential effects was largely undertaken within a GIS environment by querying various data layers and estimating the area (ha) of an attribute that overlaps with the reservoirs associated with each priority site. The qualitative analysis of potential effects relied entirely on readily available secondary source information and professional judgement. Overall, consideration was given to the following socio-economic attributes:

- *First Nation Settlement Lands and Other Land Tenures and Dispositions -* considers the overlap of the reservoirs with various types of First Nations settlement lands, interim protected lands and other non-resource related forms of land tenure.
- *Land Use Plans* – considers the presence or absence of regional land use plans applicable to each priority site.
- *Renewable Resources* - considers the overlap of the reservoirs with parcels of land that are protected or otherwise managed for their renewable resources and/or environmental values.
- *Non-Renewable Resources* – considers the overlap of the reservoirs with parcels of land that have subsurface rights for minerals and oil and gas.
- *Historic and Archaeological Resources -* considers the presence or absence of known historic or archaeological sites within the reservoir areas and the likelihood for the project sites to be located within areas of high archaeological potential. All information was provided by the Government of Yukon's Department of Tourism and Culture (2015).
- *Employment and Business Activity -* provides the estimated number of direct and indirect jobs created and the GDP generated by each project in the Yukon for the construction and operations phases. In addition, because all jobs and value are not captured by the Yukon economy, an estimate of "leakage" to other Canadian provinces is also provided. These estimates were developed using the Yukon Government's "Economic Impact Calculator" (see http://economics.gov.yk.ca/impactcalculator.htm).
- *Labour Force and Skills Supply* – identifies those communities nearest the six priority sites that have some potential to supply local labour for construction. Generally, these communities are within approximately 100 km of a priority site by road.
- *Traditional Aboriginal Activities* – quantifies the direct loss of areas available for traditional activities due to flooding of reservoir areas, and qualitatively examines the potential changes in access to land that might be afforded by the development of each priority site. This attribute also considers the presence of known or documented Aboriginal fishing sites/camp locations within the reservoir footprint and downstream. The historic and current traditional use of the reservoir area and vicinity would need to be the subject of Traditional knowledge (TK) and traditional land use (TLU) studies as part of an environmental assessment to be completed in accordance with the *Yukon Environmental and Socio-economic Assessment Act* (YESAA).

- *Community Well-Being* – The general positive and negative effects of hydroelectric projects on community well-being are discussed in Section 5 of this report. For the purposes of this study, specific consideration is given to the potential for in-migration of workers to the Yukon and communities nearest the priority sites that might experience growth and consequently, positive or negative effects on their community well-being. Consideration is also given to the potential displacement of people and infrastructure that might cause community disruption and project phasing that may increase the potential for community disruption. The compatibility of a hydro project with a community's documented socio-economic development goals are noted (where available).

2.2.2 Key Assumptions

The following key assumptions guided the identification of potential socio-economic effects:

- A full socio-economic assessment, including historic and archaeological surveys, traditional knowledge (TK) and traditional land use (TLU) studies, and economic modelling would be part of any future hydro development project to determine site-specific socio-economic effects, and mitigation and monitoring requirements.

- It is assumed that the construction of a hydro project would require the establishment of a self-contained construction camp operated as a fly-in-fly-out operation as a key mitigation measure for the potential negative effects on community well-being associated with in-migration and boom-bust effects. Access roads for the transportation of materials and equipment would be co-located with transmission lines.

- The access to land afforded by new access roads, transmission facilities and the reservoirs themselves could be considered either a positive or negative effect.

- The GIS analysis considered the overlap areas between reservoirs and conflicting values only. The additional losses of area that are likely to be incurred by access corridors and other areas required for construction (e.g., construction camps, airstrips, lay-down areas, etc.) have not been quantified.

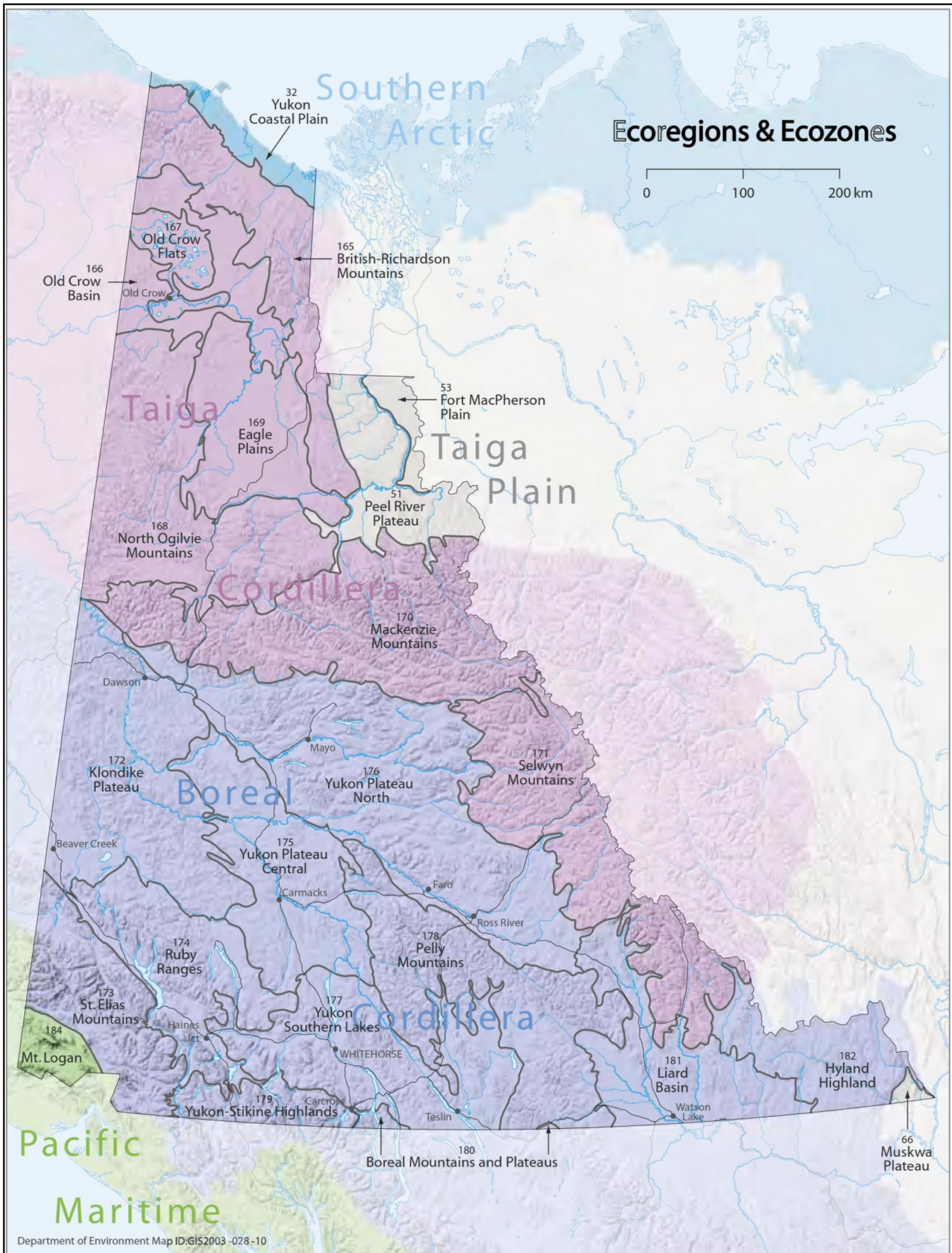
- The estimated number of direct and indirect jobs created and the GDP generated by each potential project in the Yukon are based on preliminary capital and operating costs for each priority site. The calculation of construction phase effects utilized impact multipliers for the "Construction" industry sector, and operations phase effects calculations utilized impact multipliers for the "Utilities" industry sector. Estimates were based on level "S" level of aggregation in the Yukon Government's "Economic Impact Calculator".

3.0 ENVIRONMENTAL CONTEXT OF PRIORITY SITES

3.1 Yukon Ecozones and Ecoregions

The Canadian national ecological framework (Ecological Stratification Working Group, 1996) categorizes Canada into fifteen distinct terrestrial ecozones. An ecozone is defined as an area representative of large and generalized ecological units with similar characteristics and processes. Ecozones are sub-divided into smaller areas of land called ecoregions. An ecoregion is characterized by distinctive physiography and ecological responses to climate as expressed by the development of vegetation, soil, water and fauna (Smith et al. 2004). Yukon ecoregions are shown in Figure 3.

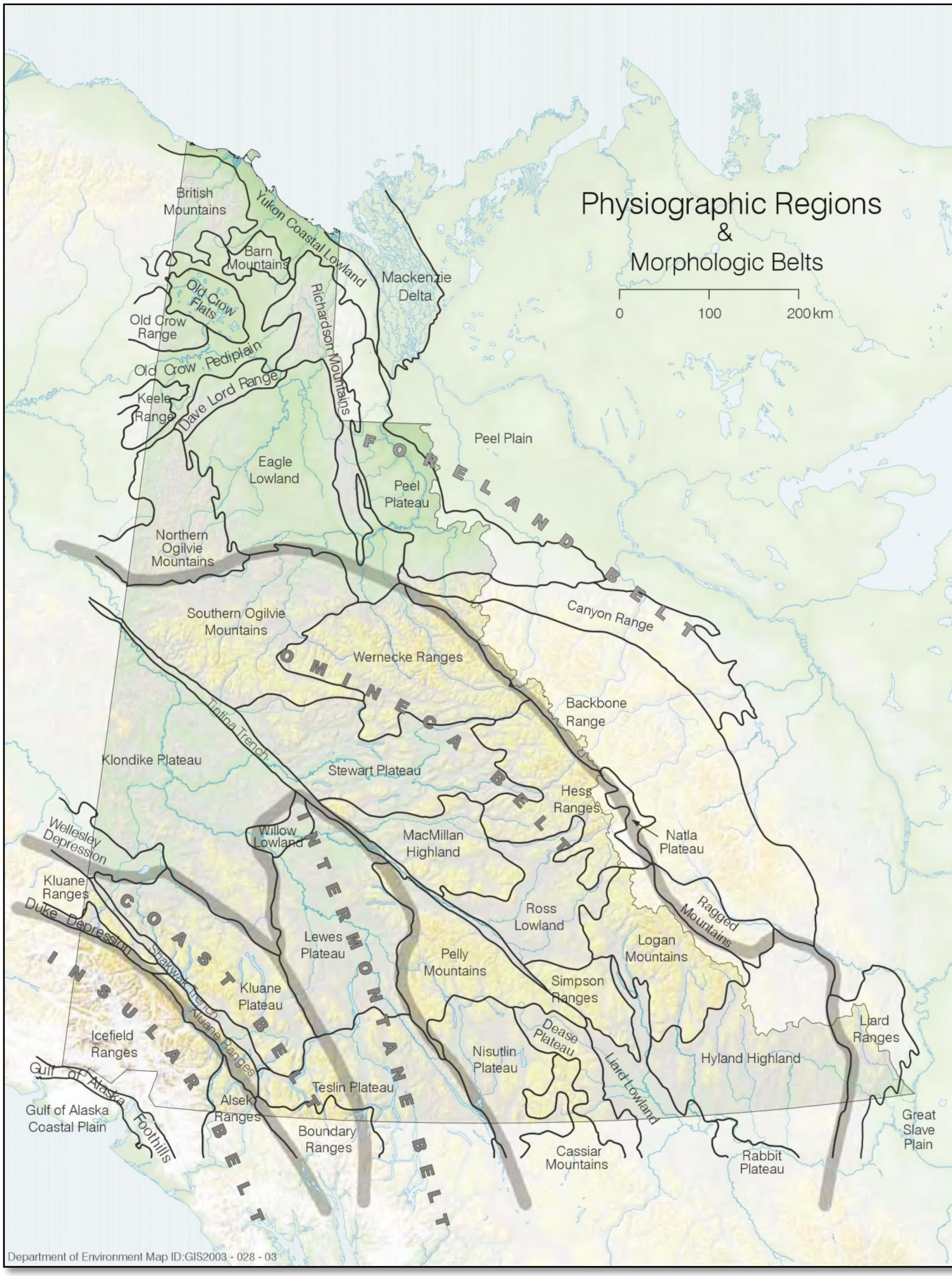
Figure 3: Yukon Ecoregions



Source: Smith et al. 2004

The Next Generation Hydro priority sites are situated within the Boreal Cordillera ecozone which extends across the western and interior sections of the Canadian Cordillera and covers sections of northern British Columbia and the Yukon south of the Mackenzie Mountains range. The Interior System contains extensive plateau and several mountain ranges such as the Southern Ogilvie, Wernecke, Selwyn, Hess, Pelly, and Cassiar Ranges. The Western System is dominated by the St. Elias and Coast Mountains. The Yukon Plateau, extending over most of the Yukon, consists of large rolling hills, deep narrow valleys and many long narrow lakes. The Tintina Trench valley runs in a northwest direction intersecting the Stewart Plateau, Macmillan Highland and Ross Lowland to the north, and the Klondike Plateau, Lewes Plateau and Pelly Mountains, to the south (YRBC, 1984a). The Liard Lowland is situated southeast of the Tintina Trench valley and is bordered by the Logan Mountains to the east and the Simpson Ranges to the west. The physiography of the Boreal Cordillera ecozone in shown in Figure 4.

Figure 4: Physiography of the Boreal Cordillera Ecozone



Source: Smith et al. 2004

Climate in the Boreal Cordillera is subarctic continental ranging from sub-humid to semi-arid with long, cold winters and short warm summers. Mean annual precipitation is highest in the St. Elias and Coast Mountains Range (from 2,000 – 3,500 mm) and lowest in the valley floors of south central Yukon (from 250 – 300 mm), (Smith et al. 2004). Vegetation includes grasslands on the south-facing slopes with boreal forest vegetation on the north-facing slopes. At higher elevations there are areas of rolling alpine tundra with sedge-dominated meadows and lichen-colonized rock fields (Smith et al. 2004).

Within the Boreal Cordillera Ecozone, there are 11 ecoregions, three of which contain the six priority sites as shown in Table 3.

Table 3: Ecoregions and Priority Hydro Sites

Ecoregion Name	Priority Hydro Sites
Yukon Plateau – Central Ecoregion	• Granite Canyon
Yukon Plateau – North Ecoregion	• Two Mile Canyon • Detour Canyon • Fraser Falls • Slate Rapids and Hoole Canyon
Liard Basin Ecoregion	• False Canyon and Middle Canyon

Table 4 summarizes the ecological characteristics of the ecoregions which contain the priority hydro sites.

Table 4: Ecological Characteristics of Priority Sites Ecoregions

Ecoregions & Hydro Sites	Physiography	Geology and Soils	Climate	Hydrology	Vegetation	Fish and Wildlife
Yukon Plateau – Central • Granite Canyon	Total area is 26,803 km^2 or approximately 6% of the Yukon Territory. Extends from Lake Laberge to the lower Stewart River. Incorporates the Lewes Plateau, the northern portion of the Teslin Plateau, part of the Yukon Plateau and the eastern slopes of the Dawson Range. The Tintina Trench (a steep sided valley 5-22 km wide) forms the northern boundary. Terrain is characterized by glaciated, rounded and rolling hills and plateaus, and separated by a network of deep broad valleys, surrounded by low elevation mountains (up to 1500 m asl).	Lies primarily within the Yukon-Tanana terrane. This region is characterized by igneous bedrock, and granitic batholiths. Surficial deposits are coarse and dry and largely free of ground ice, except in valley bottoms where deposits are moist, fine-grained and prone to perennial freezing. Both discontinuous and sporadic permafrost is present. Eutric Brunisols are dominant and are developed on loamy morainal and sandy fluvioglacial material.	Semi-arid. Mean annual precipitation ranges from 250 to 300 mm, two-thirds of which fall in summer. Mean annual temperature is near - 4 ^oC. Extreme temperature minimums (-65 ^oC) and maximums (35 ^oC) occur in the lower valley floors.	Intersected by the Yukon River. Major drainages include the Pelly, South MacMillan, Teslin and Stewart Rivers. Runoff and peak flow events are low relative to the other ecoregions due to lower relief. Contains several large lakes (Tatl'á Män, Tatchun, Frenchman, Diamin Lakes). Needlerock and Nordenskiold wetland complexes are important components of the landscape. Lakes and wetlands comprise 5% of this ecoregion. See also section 3.2.1.	Montane boreal forest below 1,200 m asl and alpine tundra above the treeline. Grasslands are common on low elevation sidehills of southern Yukon River valleys. Mixed forest of lodgepole pine, white and black spruce and aspen is kept at early successional stages by very frequent forest fires. Land Cover: Boreal/subalpine coniferous forest: 65% Alpine tundra: 30% Other: 5 %	As described in section 3.6, 3.7 and in Appendix A.
Yukon Plateau – North • Two Mile Canyon • Fraser Falls • Detour Canyon • Slate Rapids and Hoole Canyon	Total area is 57,091 km^2 or 12% of Yukon Territory. Extends from the northern limit of the Pelly Mountain Range to the southern limit of the Mackenzie Mountains. The Selwyn Mountains border this ecoregion to the east. Incorporates the Stewart Plateau, the MacMillan Highland, and the Ross Lowland. The Tintina Trench forms the southern boundary. The terrain of the Stewart Plateau is characterized by a series of tablelands separated by a network of broad, deeply cut valleys. The MacMillan Highland consists of small mountain ranges (up to ~ 2,200 asl). The Ross Lowland comprises rounded, rolling hills separated by broad U-shaped valleys.	The northern section lies within the Selwyn Basin which consists primarily of metamorphosed sedimentary rock. The south east area includes siliceous sedimentary and volcanic rocks of the Yukon-Tanana terrane and metabasaltic rocks of the Slide Mountain terrane. Valley walls are covered by till matrix and valley floors are blanketed by glaciofluvial sand and gravel. Discontinuous permafrost is extensive, but is thinner and less extensive in the south. Ice content is estimated as low to moderate in colluvial and morainal deposits. Turbic Cryosols and Eutric Brunisols are dominant and are developed on morainal and fluvioglacial parent materials. This ecoregion contains considerable potential for metallic mineral deposits.	Sub-arid. Mean annual precipitation ranges from 300 – 600 mm with highest amounts of rainfall in July and August. Mean annual temperature is near - 5 ^oC. Extreme temperature minimums (-62 ^oC) and maximums (36^oC) occur in the lower valley floors.	Intersected by the Yukon River. Major drainages include the Pelly, Ross, MacMillan, Stewart, Hess, McQuesten, and Klondike Rivers. Relief is greater relative to the Yukon Plateau-Central Ecoregion, therefore runoff and peak flow events are greater. Contains several large lakes (Mayo, Finlayson, McEvoy, Earn, Stokes, Ethel Lakes). Horseshoe Slough (40 km east of Mayo) is a designated Habitat Protection Area. There are significant wetland complexes within the Macmillan, Pelly and Stewart River valleys. Lakes and wetlands comprise 5% of this ecoregion. See also section 3.2.1.	Northern boreal forest below 1,500 m asl and alpine tundra above the treeline. Grasslands are found along banks of larger rivers. Lakes, marshes and shallow open water host willows and sedges. Land Cover: Boreal/subalpine coniferous forest: 75% Alpine tundra: 20% Other: 5%	As described in section 3.6, 3.7 and in Appendix A.

Table 4: Ecological Characteristics of Priority Sites Ecoregions

Liard Basin • False Canyon and Middle Canyon	Total area is 21,113 km^2 or 4% of the Yukon Territory. Located in southeast Yukon in the Liard Lowland, south of the Simpson Ranges and Logan Mountains and west of the Hyland Highland. This ecoregion comprises the Liard Valley which is part of the southern Tintina Trench. This ecoregions extends from British Columbia in the south to the base of the Logan Mountains. Terrain is characterized by low hills separated by broad plains, and surrounded by mountains (up to 1,890 m asl) and plateaus. There are also numerous large wetlands within wide river valleys.	Lies in the Yukon-Tanana terrane between the Tintina Fault (trending parallel to the Liard River) and the Finlayson Lake Fault zone (beneath the Frances River). Continental margin clastic and carbonate rocks cross the faults and ocean margin volcanic and ultramafic rocks are present east of the faults. Bedrock protrudes on higher ground and in river canyons. Surficial deposits consist of a thick mantle of unconsolidated glacial sands and gravel over fluvial sediments. Permafrost is sporadic. Brunisolic Gray Luvisols are common on morainal parent materials with high clay content. Eutric Brunisols are dominant on terraced glaciofluvial materials. Cumulic Regosols (nutrient-rich silty alluvium) extend over the Liard River floodplain. This ecoregion has significant mineral potential (lead, zinc, barite and lignite to sub-bituminous coal).	Sub-arid. Mean annual precipitation ranges from 400 – 600 mm with heavier amounts of rainfall occurring in summer months. Mean annual temperature is -4^{o}C. Extreme temperature minimums (- 59 ^{o}C) and maximums (34 ^{o}C) occur at lower elevations. Summer is longer relative to other ecoregions.	Intersected by the Liard River. Major drainages include the Frances, Hyland, Coal, Meister and Smith Rivers. Runoff and peak flow events are relatively low due to moderate relief. Contains two large lakes: Frances and Simpson. Lakes and wetlands comprise 5% of this ecoregion. See also section 3.2.2.	Boreal forest below 900 m asl and open stands of subalpine fir occur in the subalpine between 900 – 1,500 m asl. Nutrient-rich loamy floodplains of the Liard, Meister, Frances, Hyland and Coal Rivers are highly productive. Tree heights reach 30 m or more. <u>Land Cover</u>: Boreal coniferous and mixed wood forest: 90% Alpine tundra: 5% Other: 5%	As described in section 3.6, 3.7 and in Appendix A.

Source: Smith, C.A.S, Meikle, J.C., Roots, C.F, 2004.

3.2 Regional and Sub-regional Drainages

3.2.1 Yukon River Drainage Basin

The Yukon River basin drains an area of 262,600 km^2 within the Yukon and British Columbia (YRBC, 1984a). From its headwaters south and west of Whitehorse in the north Coast Mountains of British Columbia, the Yukon River flows north and west for 3,018 kilometres draining the southern portion of the Yukon. Major sub-drainages within Yukon River drainage basin are the:

- Teslin River;
- White River;
- Pelly River;
- Stewart River; and
- Mainstem Yukon River.

The Yukon mainstem is joined by Teslin River below Lake Laberge and by the Pelly River downstream, just west of Pelly Crossing. North of the Dawson Range and upstream of Dawson City, the White and Stewart rivers enters the mainstem of the Yukon River. The mainstem flow continues down a wide valley to Dawson, through the Tintina Valley and across the international boundary. Crossing Alaska, it eventually outlets to the Bering Sea.

Most runoff occurs between May and October with maximum flows in the spring or summer as a result of storm events and high elevation snow or glacier melt. Severe flooding can occur as a result of a sudden, prolonged rise in spring temperatures and from ice jams in major rivers. High spring flows are dampened in areas affected by the presence of large lakes. Lower flows occur in March or April. Runoff volumes across the basin are variable with the highest mean annual runoff from streams in the Coast Mountains, and the lowest along the Yukon mainstem in the centre of the basin. Most of the flow within the basin originates from the headwaters of the White, Stewart and Pelly River systems (YRBC, 1984b).

3.2.1.1 *Pelly River*

The Pelly River drains an area of 50,200 km^2 from its headwaters in the Selwyn Mountains and 250 kilometres downstream through the Tintina Valley before turning west to join the Yukon River (YRBC, 1984b). Four of the six priority sites are on the Pelly River. From upstream to downstream they are:

- Slate Rapids and Hoole Canyon;
- Detour Canyon; and
- Granite Canyon.

3.2.1.2 *Stewart River*

The Stewart River drainage area is slightly larger than the Pelly River sub-drainage extending over 51,000 km^2 of northeastern portion of the Yukon River Basin. Its headwaters drain the Selwyn Mountains. The Stewart generally flows in a westerly direction from the Selwyn Mountains to the Tintina Valley before joining the Yukon River 90 kilometres upstream of Dawson City (YRBC, 1984b). The Fraser Falls priority site is located on the Stewart River, approximately 50 km southeast of Mayo.

3.2.1.3 *Hess River*

The Hess River is a tributary to the Stewart River. It joins the Stewart approximately 60 km upstream of Fraser Falls. The Two Mile Canyon priority site is located on the Hess River a few kilometres upstream of the confluence with the Stewart River.

3.2.2 Mackenzie River Basin

The Mackenzie River basin drains an area of approximately 1,804,444 km^2 from the headwaters of the Finlay River to the Arctic Ocean. Major sub-drainages within the Mackenzie River Basin are the:

- Peace River;
- Athabasca River and Lake Athabasca;
- Great Slave Lake;
- Great Bear Lake and River, and
- Liard River.

As this paper is only concerned with priority sites in the Yukon, only the Liard River drainage is described below.

3.2.2.1 *Liard River*

The Liard River sub-drainage spans the territorial and provincial boundaries of Yukon, NWT and British Columbia, and is the third largest Mackenzie River sub drainage after the Great Slave Lake and Peace River drainage areas. The Liard River originates in the southeastern portion of the Yukon, and follows a southeasterly course for a short distance into British Columbia, after which it turns northeastward to meet the Mackenzie River at Fort Simpson. The Liard River sub-drainage contains Frances Lake which is the largest lake in Yukon that does not flow into the Yukon River. Frances Lake drains into Frances River, which flows south to its confluence with the Liard River 40 kilometres northwest of Watson Lake (Environment Yukon, 2012).

The majority of the Mackenzie River basin has a subarctic climate characterized by short, cool summers and low mean annual precipitation.

The runoff pattern of the Liard River sub-drainage is generally similar to the pattern described for the Yukon River sub-drainages in that peak flows mainly develop in the spring snowmelt period (freshet). Peak flow for smaller streams may result from heavy summer rains. During winter, stream flow is largely dependent on ground water with the lowest flows usually occurring in March (MacDonald Environmental Sciences Ltd., 1993).

The False Canyon and Middle Canyon priority sites are located on the Frances River.

3.3 Hydrology

Many factors such as spring runoff or freshet, storm events, unusually high or low seasonal temperatures affect the natural hydrological cycle. Development of a hydroelectric dam will alter natural flow characteristics upstream and downstream and over the long term affect the fluvial geomorphology of a drainage basin. Upstream changes to the natural flow regime are largely due to the presence of a reservoir created by the dam, while changes downstream of the dam site are due to the discharge of water from the reservoir. The effects from dam construction and operation will vary based on existing site-specific climatic and physiographic characteristics of each drainage basin under evaluation. These characteristics, broadly described below, have seasonal ranges that interact in an integrated manner. Additional information regarding hydrology can be found in the Yukon Next Generation Hydro and Transmission Viability Study: Scalability Assessment Report (Midgard Consulting Inc., 2015c).

3.3.1 Temperature

Mean annual temperatures ranging from 0 ºC in south Yukon to -7 ºC in north Yukon results in low flow during the winter months, with groundwater providing an important source of streamflow (baseflow).

Typically, the open water season extends from April to mid-October across southern and central Yukon. Freeze-up usually begins in late October beginning at higher elevations and in north and central Yukon. Large lakes freeze over more slowly than rivers and some remain partially open until late December or January. Lake outlets can remain open through the winter, due mainly to warmer deep water that circulates vertically from lower levels (YRBC, 1984b). Spring break up can occur gradually, or can result in rapid change of river flows if temperatures are unusually high for the season. Large ice jams and floods on major rivers can occur and are associated with rapid warming and sudden flow fluctuations leading to the break-up of ice.

3.3.2 Precipitation

Runoff variability is influenced by the type of precipitation, the seasonal distribution and its intensity (Environment Canada, 1972). Winter snow storage and subsequent melt are strongly related to timing and magnitude of spring flows. High flows usually occur in June due to snowmelt. Streams affected by glacier melt experience a rapid rise in discharge in early summer due to snow melt at lower elevations, followed by maximum discharge in late summer due to glacier melt at higher elevations.

3.3.3 Evaporation and Evapotranspiration

The majority of evaporation occurs during the open water season and varies with the proportion of lake and pond area in the drainage basin, and the water retaining characteristics of the ground surface (Environment Canada, 1972). Evapotranspiration from regional vegetation can also have a significant effect on runoff variation.

3.3.4 Topography

Mountainous areas receive higher precipitation relative to plateau areas due to changes in atmospheric conditions caused by a change in elevation. Mountainous relief also influences the amount of solar radiation received by the ground surface and the amount of snow accumulation. (Environment Canada, 1972).

3.3.5 Lake Storage

Headwater lakes play an important hydrological role by storing summer inflows and maintaining flows in winter when precipitation is stored on the ground surface in the form of snow. Lakes have a dampening effect on high rapid inflow to streams and also influence water quality, temperatures and sediment concentrations downstream (YRBC, 1984a). Lakes can also contribute directly to groundwater recharge or behave as groundwater discharge areas

(Environment Canada, 1972). Several large lakes located in the headwaters of the Yukon River have a significant effect on the temporal distribution of runoff and on flood characteristics along the river (YRBC, 1984b).

3.3.6 Groundwater

Groundwater is an important component of streamflow, especially in winter and in streams that do not have lakes in the headwaters. In winter, fish and wildlife depend on open areas of streams maintained by groundwater flow. The volume of groundwater contribution to streams is dependent on local surficial and bedrock geology, presence of permafrost, and the timing and areal distribution of precipitation. Where there is a high degree of surface imperviousness, groundwater contribution to runoff is low (Environment Canada, 1972).

3.3.7 Permafrost

Groundwater contribution to runoff is also affected by the type of permafrost present. Next Generation priority sites are in the extensive discontinuous permafrost zone or along the northern edge of the sporadic discontinuous zone. Changes in the ground thermal regime can affect the aggradation and degradation of the permafrost table. Permafrost degradation can affect stream baseflow through the melting of massive ground ice or interstitial ground ice.

3.3.8 Vegetation

Vegetation affects runoff by intercepting rainfall, increasing evaporation, retarding surface runoff, slowing snowmelt in spring time, and increasing permeability of the soil. Forested river valley areas have greater runoff losses due to interception and transpiration (YRBC, 1984b). Higher elevation moss covered tundra areas produce rapid runoff due to low evaporation and low infiltration to frozen soils.

3.4 Surface Water Quality

Surface water quality is affected by seasonal runoff flows and by the variation in climatic and physiographic characteristics described above. Concentrations of dissolved metals can be higher in winter relative to summer due to lower flows. Groundwater in highly mineralized areas may also contribute higher metals concentrations. In the spring and summer, water quality is also affected by high suspended sediment loads. Suspended sediment concentrations (including total and dissolved metals) vary widely according to seasonal changes (e.g. high flow, low flow) and local geological conditions, stream characteristics and fluvial geomorphic settings. An effect that has been associated with hydro impoundments is methylation of naturally occurring mercury in surface sediments, primarily by anaerobic sulfate-reducing bacteria, and also through chemical (abiotic) reactions (Celo et.al., 2005). These biochemical processes have resulted in high levels of methylmercury in impoundments of other hydroelectric projects in Canada such as South Indian Lake in Manitoba and in Northern Quebec (Bodaly et al. 1984). Additional information regarding this phenomenon is provided in Section 5 of this report.

Seasonal variations of stream temperature can also affect the concentrations of some water quality parameters, notably dissolved oxygen. Aquatic species are adapted to seasonal changes in physical and chemical water quality parameters and the effects on food availability, life cycle development and reproductive capacity.

A regional water quality sampling program is conducted by Environment Canada and Environment Yukon at six locations across the Yukon. Four sites are relevant to the Next Generation Hydro drainages, including the Yukon River mainstem sites (below Marsh Lake and above the Takhini River), the Rose Creek site (a tributary of the Pelly River), and the Liard River site at Upper Crossing. Based on the Water Quality Index developed by the Canadian Council of Ministers of the Environment rating water quality on a scale of 0-100, the water quality at these four sites is currently rated as Good (84-90) to Excellent (95-100) (Environment Yukon, 2015).

3.5 Climate and Climate Change

There is broad agreement that climate change will affect Yukon water resources and that changes in streamflow and water balance will vary from region to region (Environment Yukon, 2011*).* A growing body of research suggests that hydropower generation will be susceptible to both positive and negative impacts from climate change over the long term and over the short term annually due to increases in extreme precipitation events.

A summary paper on climate change and hydrology (SLR, 2015) prepared for the Yukon Next Generation Hydro Viability Study project (Appendix F) summarizes trends in climate and hydrological parameters for the project region based on results from monitoring and research. Major hydrological parameters potentially affected by climate change were considered in relation to Next Generation Hydro options. The following are the key findings of that report:

3.5.1 Temperature

- The seasonal pattern and average rate of warming in Yukon since 1950 is consistently greatest in winter. A warming trend in the spring was also noted. Across Canada, warming trends in winter and spring are strongest in western Canada. Increased spring temperatures are causing earlier snow melt which affects the timing and magnitude of spring runoff; and,
- The increase in winter air temperatures has been identified as a major contributor to the observed warming of the permafrost ground thermal regime in northern Canada. This effect is most pronounced in the sporadic permafrost zone of southern Yukon and northern BC.

3.5.2 Precipitation

- The trend in total annual mean precipitation is not consistent across Yukon. Only Mayo and Whitehorse monitoring locations showed significant increases from 1950-2009.
- Snowfall has increased since 1950 at some Yukon monitoring locations, and an overall increase in winter precipitation is forecasted for Yukon.
- Increased glacier melt rates are enhancing flows upstream of the Whitehorse dam. This may cause an average increase in annual runoff, with higher flows in the early spring and late fall.

3.6 Fish and Fish Habitat

3.6.1 Overview

Fish populations play an important role in the Yukon commercial, recreational and Aboriginal fisheries. Fish species identified within the footprints of the six priority sites include: Arctic grayling, chinook and chum salmon, lake trout, bull trout, northern pike, inconnu, least cisco), Arctic lamprey, lake whitefish, round whitefish, broad whitefish, mountain whitefish, burbot, longnose sucker, lake chub, and slimy sculpin. The specific habitat characteristics for each of these species are summarized in Table 5.

Table 5: Habitat Requirements for Fish Species Occurring within Project Footprints

Species	Spawning Habitat	Young of Year and Juvenile Habitat	Adult Habitat	References
Arctic grayling	Travel to headwaters to spawn	Side channels, pools and riffles	Pools, riffles, runs and back channels of mainstem rivers	Roberge et al. 2002; Environment Yukon 2010
Chinook	Gravel and cobble substrates; gravel bars and islands	Cobble and boulder substrates along stream margins and near the confluence of tributary streams; aquatic vegetation for cover	Ocean	Chapman 1943; Scott and Crossman 1973; Geist and Dauble 1998; Dauble et al. 2002; Bravender and Shirvell 1990; Porter and Rosenfeld 1999; Yukon River Panel 2015a; Gregory and Levings 1996 in Roberge et al. 2002
Chum	Cutbanks and riffles of mainstem river; side channels and sloughs; shore spawning in Kluane Lake. Groundwater upwelling sites with constant flow rates.	Spawning grounds; outmigration to ocean shortly after emergence	Ocean	Yukon River Panel 2015*e*
Lake trout	Shoals and shorelines of lakes over cobbles or boulders	Shallow shorelines of lakes	Cold, deep lakes	BC MOF and HCTF 2015
Bull trout	Cold, unpolluted moving streams with cobble or loose gravel substrates.	Pool habitat (summer), run habitat (fall); shallow (< 0.5 m), low velocity areas with ample cobble and boulder substrates. Deeper, faster water at night over silt substrates.	Cold, high gradient, unproductive waters	COSEWIC 2013; (Baxter 1997, in Roberge et al. 2002; McPhail and Baxter 1996, in Roberge et al., 2002; Baxter and McPhail 1997, in Roberge et al., 2002
Northern pike	Low-gradient pools and marshy areas connected to rivers; low gradient banks and floodplains	Flooded, densely vegetated areas	Shallow rivers	Cott 2004

Table 5: Habitat Requirements for Fish Species Occurring within Project Footprints

Species	Spawning Habitat	Young of Year and Juvenile Habitat	Adult Habitat	References
Inconnu	Lake tributaries or river headwaters (fluvial); broadcast spawners in clear water; migrations triggered by ice break-up	Streams for first 2 years; lakes for remaining years	Lakes or lower reaches of rivers	DFO 2010; Scott and Crossman 1973; Wright and Prichard 1993.
Mountain Whitefish	Gravel or cobble in riffles or along lake shores in shallow waters	Lake shallows; deeper offshore areas in summer or upstream overwintering sites in rivers. Cover in the form of aquatic vegetation, woody debris.	Cool lakes; large, low-gradient rivers. Bottom feeders. Inhabit water 4-6 m deep (maximum 20 m depth). Cover in the form of aquatic vegetation, woody debris.	Roberge et al. 2002; Environment Yukon, 2010
Lake whitefish	Shoals and shallow riffles	Steep shorelines; move to deeper water during summer	Deep shoal waters in winter; deeper water during winter (generally 18-53 m); bottom feeders	McPhail 2007
Round whitefish	Shallows of lakes near outlets or in areas with current; river mouths or in rivers, over gravel or cobble surfaces	Spawning grounds, shallow shorelines, backwaters, mainstem side channels	Deep lakes but in shallow areas less than ~35 m deep; tributary mouths, mainstem and side channels or rivers	Scott and Crossman 1973; Stewart et al. 2007.
Broad whitefish	Swift currents and sand-pebble bottom; broadcast spawning before or after ice-up	Hatching timed to spring freshet; disperses juveniles downstream. Inhabit shallow water <1 m along shores of floodplain lakes, sloughs, side channels and estuaries; overwinter in deeper > 3 m lakes	May overwinter in mainstem rivers and migrate to feeding lakes in spring	McPhail 2007; Carter 2010; Harper et al. 2012

Table 5: Habitat Requirements for Fish Species Occurring within Project Footprints

Species	Spawning Habitat	Young of Year and Juvenile Habitat	Adult Habitat	References
Lamprey	Clear streams away from main currents; in moderate flow	Ammoceotes (larvae) burrow into soft substrates of stream margins and back waters	Ocean, lakes, or larger rivers depending on host	NatureServe 2013; Hammerson 1993
Burbot	Shallows of lakes, occasionally in deeper water over sand, gravel or cobbles; downstream end of gravel bars in rivers; broadcast spawners	Shallows of lakes, moving to deeper water (3-7.5 m) in summer; hide under stones and debris in shallow bays during the day	Deep, oligotrophic lakes, up to 300 m in depth.	McPhail 2007
Slimy sculpin	Shallow water under rocks/woody debris	Unknown	Stream bottoms under rocks and logs in cold headwater streams or glacial rivers with rock or cobble substrates	Mansfield 2004
Least cisco	Sand and gravel in deep pools of lakes, estuaries and large rivers	Shallow waters and sheltered areas of lakes	Deep, cold lakes; large rivers, brackish coastal waters. Pelagic in lakes with some bottom foraging	McPhail 2007
Longnose sucker	Inlet and outlet streams, in low velocity run habitat over gravel and cobble up to 0.6 m in depth; occasionally in shallow lake margins 15-30 cm deep over gravel and sand of rocky shorelines. Broadcast spawners.	Shallow vegetated and sandy areas of lakes	Benthic habitats of lake shorelines or streams; generally in deeper, cool water, generally up to 17 m (Great Slave Lake) but have been found as deep as 183 m	Richardson et al. 2001; Roberge et al. 2002
Lake chub	Tributary streams over gravel or over/under large rocks in shallow water; shallow lake shores over rocky (or variable) substrates	Unknown	Stream and lake bottoms in shallow water with high cover	Roberge et al. 2002

Of all the species identified as occurring within the footprints of the priority sites, salmon is commonly considered the most important fish species because of its importance to Yukon's commercial, recreational and Aboriginal fisheries. It is a highly valued species whose management on the Yukon River is governed by the federal *Fisheries Act* and Chapter 8 of the Pacific Salmon Treaty (Canada-United States, 1985).

Salmon stocks in the Yukon River drainage travel one of the longest spawning migration routes in the world, with some stocks traveling almost 3,000 kilometres to their natal streams (Yukon River Panel, 2015*a*). Commercial salmon fisheries are relatively limited in the Yukon, due to declining returns of salmon stocks. Historically, fishing activities primarily targeted chinook salmon, with average returns from 1982-1997 of approximately 300,000 fish annually. During this time, commercial fisheries in the Yukon accounted for 68% of the total annual Yukon Territory chinook harvest. From 1998-2010, chinook stocks have declined by 45% from that seen during the 1982-1997 period (Schindler *et al.,* 2013), and in 2014 returns in the Canadian-origin Yukon River salmon run were estimated at approximately 63,000 fish (Yukon River Panel, 2015*b)*. At present, 26 commercial licenses are active in the Yukon, targeting chum salmon as the primary harvest species (DFO, 2015*a*).

Studies conducted by the Yukon River Panel from 2002-2004 indicate that the mainstem Yukon River and other tributaries account for approximately 30% of the Canadian portion of the chinook salmon run. Within the Canadian portion of the run, the Teslin and Pelly Rivers each account for approximately 20% of the run; the Stewart and Big Salmon Rivers each account for approximately 10% of the run, and the White, South Yukon and Klondike Rivers each contribute approximately 5% of the run (Mercer, 2005).

Other resident fish populations play an important role in Yukon fisheries and are a key aspect of Yukon's tourism market. Proportionally, recreational fisheries comprise approximately 85% of the total annual catch in the Yukon, with the primary target species consisting of Arctic grayling, lake trout (*Salvelinus namaycush*) and northern pike (*Esox lucius*) (Environment Yukon, 2010a).

Commercial fisheries in the Yukon comprise only 5% of the annual harvest of resident fish species (by weight). Commercial harvests are limited to four lakes in which lake trout are targeted, in addition to the Teslin River and Yukon River, where fall whitefish are harvested (Environment Yukon 2010b).

3.6.2 Aboriginal Fisheries

Yukon fisheries are a shared resource, between different peoples, cultures and countries. There are many human, natural and commercial pressures on fish stocks, particularly salmon stocks. Aboriginal people continue to fish, but take a great responsibility to ensure that fish and salmon stocks in particular are sustainable for generations to come (Linklater, 2014).

Aboriginal fisheries comprise approximately 7% (by weight) of the annual fish harvest in the Yukon. However, the Aboriginal fishery accounted for 65% of the harvest of chinook salmon and 37% of the chum harvest in the Yukon from 1993 to 2002 (Yukon River Panel, 2015*c*). A study conducted of three First Nations in four Yukon communities in 1995 indicated that fish comprised approximately 27% of traditional protein sources overall, with chinook salmon being the most frequently consumed species, particularly in Teslin. Other species frequently consumed included but were not limited to sockeye in Haines Junction, coho in Whitehorse, coho, chum and broad whitefish in Old Crow, and lake whitefish and lake trout in Teslin (Wein and Freeman, 1995).

A number of First Nations in the Yukon have had voluntary closures to chinook subsistence harvesting over the past several years as a result of poor run returns:

- The Teslin Tlingit near Teslin Lake have maintained a voluntary fishery closure since 2010;
- The Vuntut Gwitchin First Nation have switched to harvesting coho and chum due to the lack of chinook in the Porcupine River;
- The Selkirk First Nation at Pelly Crossing have sustained reduced catch quotas for the past 15 years at Pelly Crossing;
- The Na-Cho Nyäk Dun have maintained a fishing ban on chinook for a period of 8 years; and
- The Champagne and Aishihik First Nations have voluntarily closed fisheries at variable times to help maintain fish populations (Linklater, 2014).

Fishing camps play an important role in the traditional lifestyle of First Nations, creating a space for social gathering; sharing stories and food, and for elders to pass on their knowledge of catching, cleaning and smoking fish with the community youth (Linklater, 2014). Some of the key locations of traditional fishing camps in the Yukon include but are not limited to:

- Frances Lake (Kaska Dena/Liard First Nation; Millar et al., 2012);
- Annie Lake and Fish Lake near Whitehorse (Kwanlin Dün First Nation; Kwanlin Dün, 2015);
- Fort Selkirk just downstream of the Pelly River outlet (Selkirk First Nation; Yukon Department of Tourism and Culture 2015a);
- Pelly River near the confluence with Little Kalzas River (Selkirk First Nation; DFO, 2015a);
- Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Selkirk First Nation; Yukon Department of Tourism and Culture 2015b);
- Horseshoe Slough Habitat Protection Area encompasses the Na-Cho Nyäk Dun First Nation settlement of "Nogold" near the outlet of Nogold Creek on the Stewart River, which is used for traditional hunting and fishing purposes;
- Youth fish camps are currently being or have recently been held at Moosehide on the Yukon River (Tr'ondëk Hwëch'in First Nation); and
- Fraser Falls on the Stewart River. The Fraser Falls camp replaces the Na-Cho Nyäk Dun First Nation's traditional fishing camp on the Yukon River near Mayo due to the closure of the chinook fishery (Linklater, 2014).

3.6.3 Fish Species at Risk

There are numerous fish species at risk found in virtually all major rivers in the Yukon, including those at the six priority sites. As such, direct effects to at least some of these species from a hydroelectric project are largely unavoidable but nevertheless, need to be carefully considered in project planning and design. Effects to species at risk and their mitigation will need to be the subject of more detailed studies during any future environmental assessment in accordance with the *Yukon Environmental and Socio-economic Assessment Act* (YESAA) and in the development of offset plans in accordance with the *Fisheries Act.*

Fish species at risk in the Yukon may be classified at the federal and/or territorial level. Federally-listed species are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or by Canada's *Species at Risk Act* (SARA) as endangered (E), threatened (T), of special concern (SC), or not at risk (NAR). A number of species in Canada have yet to be assessed by COSEWIC but are suspected of being at risk. COSEWIC publishes a list of candidate species and ranks their assessment priority as high (HPC), mid (MPC), or low (LPC) based on a number of risk factors for each species. In addition to species that have not been assessed, species listed as NAR may be added to the candidate list if there is new evidence to suggest that they may be at risk of extinction or extirpation from Canada (COSEWIC, 2015).

In the Yukon, fish species at risk are classified according to their level of vulnerability to extinction or extirpation at the global (G), national (N), and sub-national (regional) (S) scales. Species are ranked in the Yukon according to NatureServe Conservation Status Assessment methodology (Faber-Langendoen et al. 2012) as: (1) critically imperilled, (2) imperilled, (3) vulnerable, (4) apparently secure, (5) secure, or (U) unrankable. Rankings that are inexact or uncertain may be followed up with a (?), and rankings that apply specifically to a breeding population may be followed by a (B).

The Yukon Conservation Data Centre maintains two lists to track the status of fish and wildlife populations in the Yukon. The Animal Track List (YCDC, 2014*a*) provides a list of species of conservation concern for which a status ranking has been designated. The Animal Watch List (YCDC, 2014*b*) contains a list of species that may be threatened or endangered in the Yukon but for which a conservation status has yet to be determined due to lack of sufficient information. A summary of fish species on the Animal Track List and Animal Watch List and their federal and provincial rankings are listed in Table 6. Those fish species, identified as occurring within the footprints of the six priority sites are highlighted in yellow in Table 6.

Table 6: Yukon Fish Species at Risk

Scientific Name	Common Name	Federal Ranking		Territorial Ranking		
		COSEWIC	SARA	Global	National	Sub-national
Fish Species on the Yukon Conservation Data Centre Animal Track List						
Catostomus commersonii	White sucker	None	None	G5	N5	S2S3
Coregonus laurettae	Bering cisco	SC	None	G4	N3	S3
Coregonus sp. 2	Squanga whitefish	SC	SC	G3	N3	S3
Oncorhynchus kisutch	Coho salmon	None	None	G4	N4	S3S4
O. mykiss	Rainbow trout	None	None	G5	N5	S3
O. nerka	Sockeye salmon	None	None	G5	N4	S2S3
Salvelinus confluentus	Bull trout – western arctic populations	SC	None	G4	N3N4	S3

Table 6: Yukon Fish Species at Risk

Scientific Name	Common Name	Federal Ranking		Territorial Ranking		
		COSEWIC	SARA	Global	National	Sub-national
S. malma	Dolly Varden	SC	None	G5	N4	S3S4
Fish Species on the Yukon Conservation Data Centre Animal Watch List						
Coregonus autumnalis	Arctic cisco	MPC	None	G5	N3	SU
Cottus ricei	Spoonhead sculpin	NAR/MPC	None	G5	N5	S3
Esox Lucius	Northern pike	None	None	G5	N5	S5
Lampetra camtschatica	Arctic lamprey	None	None	G4	N3N4	S4?
Oncorhynchus keta	Chum salmon	None	None	G5	N5	S4
O. tshawytscha	Chinook salmon	None	None	G5	N4	S2S3B
Osmerus mordax	Rainbow smelt	None	None	G5	N5	SU
Percopsis omiscomaycus	Trout-perch	None	None	G5	N5	SU
Platygobio gracilis	Flathead chub	None	None	G5	N5	SU
Prosopium williamsoni	Mountain whitefish	None	None	G5	N5	S3
Pungitius pungitius	Ninespine stickleback	None	None	G5	N5	S2S3
Salvelinus alpinus	Arctic char	LPC	None	G5	N5	S1
Stenodus leucichthys	Inconnu	MPC	None	G5	N4	S4
Thymallus arcticus	Arctic grayling western arctic populations	HPC	None	G5	N5	S4
Additional COSEWIC Candidate Species						
Coregonus autumnalis	Arctic cisco	MPC	None	na	na	na
Coregonus nasus	Broad whitefish	MPC	None	na	na	na
Coregonus sardinella	Least cisco	MPC	None	na	na	na
Cottus cognatus	Slimy sculpin	MPC	None	na	na	na
Cottus ricei	Spoonhead sculpin	MPC	None	na	na	na
Oncorhynchus clarkii clarkii	Coastal cutthroat trout	MPC	None	na	na	na

Table 6: Yukon Fish Species at Risk

Scientific Name	Common Name	Federal Ranking		Territorial Ranking		
		COSEWIC	SARA	Global	National	Sub-national
Prosopium cylindraceum	Round whitefish	LPC	None	na	na	na
Salvelinus alpinus	Arctic char	LPC	None	na	na	na
Salvelinus confluentus	Bull trout (upper Yukon watershed populations)	MPC	None	na	na	na
Salvalinus namaycush	Lake trout	LPC	None	na	na	na
Stenodus leucichthys	Inconnu	MPC	None	na	na	na
Thymallus arcticus	Arctic grayling	HPC	None	na	na	na

Appendix A of this report provides further details regarding the characteristics and habitat requirements for those species found in Yukon waters identified as: critically imperilled, imperilled, vulnerable or COSEWIC's high priority candidate species. It is noteworthy, that not all of these species have been identified within the footprints of the six priority sites.

3.7 Wildlife and Wildlife Habitat

3.7.1 Key Habitat Features

Good quality wildlife habitat is often subject to loss, degradation, alteration, or fragmentation as a result of development activities. The Habitat Programs section of the Yukon Department of Environment has conducted inventories to catalogue the location, distribution and abundance of key areas for populations of legally harvested species and for some protected wildlife species and for areas used by wildlife for critical, seasonal life functions. More specifically, Wildlife Key Areas (WKAs) have been identified for species with known areas of seasonal use such as waterfowl, raptors, ungulates, and fur-bearers (Environment Yukon, 2014). WKAs have not been identified for wide-ranging species that lack well-defined areas of use. Nor have WKAs been identified for bats because the location of hibernacula and maternal colonies are largely unknown.

The WKA inventory provides comprehensive information on wildlife values for land use planning. The WKA inventory also serves to focus mitigation/protection efforts to those areas that are limited in availability, most valuable to the species/population, and/or where wildlife is most vulnerable. WKAs that overlap with priority hydro sites include:

- Fall staging areas – geese, swans, ducks, and grebes undergo complete wing moults that render them flightless for three to five weeks after the breeding season. During this time, they congregate on large water bodies with an abundance of food. Waterfowl as well as shorebirds congregate in relatively large numbers prior to their southward migration;

- Spring staging areas – waterfowl species need ice-free areas to rest and recover from migration prior to the breeding season. Spring staging areas generally comprise lake outlets or portions of rivers that become free of ice early in spring. Waterfowl congregate in relatively large numbers during this time;

- Wetland complexes – concentrations of small ponds or large, extensive marshes generally contain the highest densities of breeding ducks. Through the summer, the young of the year rear in these natal areas to build enough body reserves for the long slight south in the fall;

- Ungulate winter ranges – sheep, goat, caribou, deer, elk and moose populations are constrained in their foraging, security, and thermal requirements during winter, and rely on areas with good cover and low snow levels for survival during this time (e.g., forests with southern exposures and well-developed canopies to intercept snow);

- Major feeding ranges for large carnivores – some areas within large tracts of wilderness have been identified as containing seasonally high food concentrations for grizzly bears (e.g., high-producing berry crops; major salmon spawning rivers). Research on critical foraging and denning habitats for grizzlies is ongoing (i.e., WKA inventory for this species is incomplete). Some seasonally concentrated feeding areas for black bears have also been identified;

- Important denning areas for mid-sized carnivores – wolf and red fox maternal den sites used in spring and summer have been mapped as key in northern Yukon where suitable sites are limited by the presence of permafrost. Dens not subject to collapse are used each year by the same mating pair. Wolf dens tend to be situated next to rivers or streams whereas fox dens are typically found in sandy soils along cutbanks; and

- Raptor nesting areas – In the Yukon, gyrfalcon, peregrine falcon, golden eagle, bald eagle, osprey, merlin, and rough-legged hawk are given management priority because of their high vulnerability to disturbance (most resource managers agree that disturbance within two kilometres of raptor nests can impede with breeding success; Yukon Environment 2014). Summer nesting areas are mapped as key for this reason, and because habitat requirements tend to be specific. Bald eagles for example, commonly nest in large riparian trees, which are limited in the Yukon. Peregrine falcons nest on riparian cliffs. Raptors generally return to the same nest area from one year to the next.

Depending on the land use activity, the Yukon government makes specific recommendations to help maintain wildlife key habitat areas and reduce impacts.

3.7.2 Wildlife Species of Concern

There are several wildlife species of concern found across the Yukon which are also found in their habitats at or near the six priority sites. As such, direct effects to at least some of these species from a hydroelectric project are largely unavoidable but nevertheless, need to be carefully considered in project planning and design. Effects to wildlife species of concern habitat and their mitigation will need to be the subject of more detailed studies during any future environmental assessment in accordance with the *Yukon Environmental and Socio-economic Assessment Act* (YESAA) and in the development of project-specific management plans.

The following provides a summary of their protected status federally and in the Yukon. Appendix B of this report provides further details regarding the characteristics and habitat requirements for each of these wildlife species.

- The trumpeter swan is not considered “At Risk” in the Yukon (Environment Yukon, 2015a) but it receives special protection under the territorial *Wildlife Ac*t because Yukon contains breeding habitat and critical staging areas where swans recover from their long distance migration before accessing their breeding grounds.

- The little brown myotis is a bat species listed as “Critically Imperilled” in Yukon Territory, largely due to White-nose Syndrome (WNS) which is an emerging disease among North American bats caused by a fungus which colonizes the bat's skin. It has also been designated as “Endangered” federally by COSEWIC, and was recently listed under *SARA.* Both the Yukon and federal designations mean that the species is at risk of extirpation or extinction.

- Barn swallows and bank swallows are listed as “Imperilled” in Yukon Territory. They have also been designated as ‘Threatened’ federally by COSEWIC and are listed as such under *SARA*. Both of these designations mean that the species is threatened with becoming endangered. In addition, swallows are protected under the federal *Migratory Bird Convention Act*, which prohibits harm, disturbance or destruction to birds or their nests eggs, nestlings, or fledglings.

- The common nighthawk is considered “Threatened” nationally and “Imperilled” in the Yukon. It is also protected under the federal *Migratory Bird Convention Act*, which prohibits harm, disturbance or destruction to birds or their nests eggs, nestlings, or fledglings.

- The American kestrel is listed as “Imperilled” in the Yukon (Smallwood et al., 2009).

- The fisher is currently listed as “Imperiled/Apparently Secure” (S2S4) in the Yukon, and is not listed federally by COSEWIC or on Schedule 1 of SARA.

- The western jumping mouse is found in southern Yukon, and is at the northern limit of its distribution. This species is listed as “Imperilled” in the Yukon but is listed as “Apparently Secure” throughout the remainder of its range in western North America.

- Woodland Caribou is considered a “Vulnerable” wildlife species in the Yukon. The Finlayson Caribou Herd (FCH) and Ethel Lake Caribou Herd (ELCH) are within the “Northern Mountain Population” (NMP) of woodland caribou identified by Environment Canada (2012). A 2007 survey estimated the FCH at 3,100 caribou, and it is considered to be a “declining” population. The ELCH was last inventoried in 1993, and had an estimated population of 300 caribou. It is considered to have a “stable” population (Environment Canada, 2012).

- The sharp-tailed grouse is considered a “Vulnerable” wildlife species in the Yukon but is not federally listed as a species at risk. The Yukon government has identified some critical habitat areas for sharp-tailed grouse (i.e., referred to as Wildlife Key Areas) as this species is considered an immediate management concern because of its limited distribution in the Yukon, unique habitat requirements, restricted movements, and intense social behaviours that make it particularly vulnerable to disturbance (Environment Yukon, 2014).

- The peregrine falcon receives special protection under the Yukon *Wildlife Act*. WKAs have been identified for this species to protect its breeding habitats. It was designated by COSEWIC as a species of “Special Concern” in 2002 and is now listed under *SARA* as such.

- Rusty blackbirds are designated by COSEWIC as a species of “Special Concern” and are now listed under *SARA* as such. In the Yukon, the rusty blackbird is also considered as being of special concern as a result of population declines.

- Olive-sided flycatcher is federally designated as “Threatened” by COSEWIC and on Schedule 1 of SARA. Within the Yukon it is listed as “Imperiled/Vulnerable” (S2S3B).

3.7.3 Rare Plant Species

There are no documented rare plant occurrences in the eight areas (six project configurations) being assessed for this hydroelectric viability study.

4.0 SOCIO-ECONOMIC CONTEXT OF PRIORITY SITES

4.1 Yukon and Regional Context

The six priority hydro sites are located in the central and south-eastern portions of the Yukon. This area includes the City of Whitehorse and numerous smaller towns, villages and settlements. The communities and settlements nearest the priority sites are:

- The Village of Mayo, located along the edge of the Stewart River in the centre of Yukon, approximately 406 kilometres north of Whitehorse.
- Pelly Crossing, located along the Pelly River, approximately 283 kilometres north of Whitehorse on the Klondike Highway.
- Stewart Crossing, located along the Stewart River, approximately 354 kilometres north of Whitehorse at the crossing of the Klondike Highway and the Silver Trail.
- The Town of Faro, located along the Pelly River, approximately 359 kilometres northeast of Whitehorse just off the Robert Campbell Highway.
- Ross River, located at confluence of the Ross and Pelly River, approximately 410 kilometres northeast of Whitehorse; and
- The Town of Watson Lake, located along the Alaska Highway, approximately 12 kilometres north of the B.C. border and 438 kilometres southeast of Whitehorse.

The six priority sites are also located within the traditional territories of several First Nations:

- The First Nations of Na-Cho Nyäk Dun (NND), whose traditional territory includes the Village of Mayo;
- The Na-Cho Nyäk Dun people are affiliated with the Northern Tutchone people of the Selkirk and Little Salmon/Carmacks First Nations (AANDC, 2014a); and
- Selkirk First Nation, centred on the community of Pelly Crossing.

The Kaska Dena Nation, which includes:

- The Ross River Dena whose territory is located near the community of Ross River and includes the historic Frances Lake settlement and Tuchitua, located off the Robert Campbell Highway south-east of Ross River.
- The Liard First Nation, located near the Town of Watson Lake, and includes the adjoining settlements of the Upper Liard, Two-Mile Village and Two and a Half Mile Village.

The population in Yukon has been steadily increasing by 1.8% annually since 2005, and is projected to continue to grow into the foreseeable future. The 2014 population of the territory was 36,667. Yukon's Aboriginal population (2014) was approximately 21% of the total population. The proportion of Aboriginal population has remained relatively constant since 2005. In general, Yukon's population is slightly younger than that of Canada, and there are slightly more men than women in the territory.

The territory's economy is largely driven by the government services sector, while its private sector economy is largely resource based (i.e., mineral exploration and mining). The Yukon exploration and mining industry also includes aggregate quarries, and mining-related services. The minerals economy in Yukon is heavily influenced by commodity prices and the investment climate which undergoes cycles according to commodity prices and metals consumption on a global basis. The effect of these cycles on smaller communities can be significant in terms of local employment and an overall lack of opportunities in a relatively small market.

The City of Whitehorse is the capital of Yukon and is located on the Yukon River, approximately 97 kilometres north of the British Columbia border at the crossing of the Klondike Highway and the Alaska Highway. The city's population has increased by 17% from 23,272 people in 2005 to 27,962 people in 2014 (Yukon Bureau of Statistics, 2015a). The First Nation population of Whitehorse is 15 percent (%) of the city, compared to 21% for Yukon overall, and mostly from the Kwanlin Dün First Nation or Ta'an Kwäch'än Council. As the capital city of Yukon, Whitehorse is the centre of government and the economic hub of the Territory. The city offers all major community services including health care, education, recreation, public safety, and other social services. Given the importance of the exploration and mining industry in the Yukon, Whitehorse has a large concentration of service businesses that support the sector and provide employment and career opportunities. Tourism is also an active economic sector within Whitehorse with tourists visiting the capital of the territory for the city's large number of festivals and attractions.

Whitehorse is the major road and air transportation hub for the Yukon. The Whitehorse airport offers scheduled air services between Whitehorse and Yellowknife, NWT; Edmonton and Calgary, Alberta; and Vancouver, British Columbia; Ottawa, Ontario and connects Whitehorse to other towns in the Territory.

4.2 First Nations Settlement Lands and Other Dispositions

Significant changes have occurred since the late 1990's in the jurisdictional framework for land, resources, land use and development in the Yukon. These changes are primarily a result of:

- The finalization of many Aboriginal land claim agreements (Umbrella Final Agreement or UFA); and
- The devolution of responsibilities from the federal to the territorial government.

The UFA is the foundation agreement for individual Final and Self-Government Agreements. It defines a number of land tenure categories which are linked to surface and subsurface rights.

For the purposes of this study, the effects on First Nations considered the overlap of the six priority sites with their Settlement Lands and Interim Protected Lands.

Settlement lands are held by First Nations in the following ways:

- *Category A Settlement Lands* provide First Nations with fee simple equivalent to the lands and a fee simple title to all mines and minerals. For these lands, the First Nation acts in general as a private landowner. They are not Crown lands.

- *Category B Settlement Lands* provide First Nations with fee simple equivalent title to the lands, excluding mines and minerals. The First Nations have the right to specified substances, including sand and gravel. These surface lands are not Crown lands, but the federal government retains jurisdiction over them, while the territorial government manages them.

- *Fee Simple Settlement Lands*. These are the same as Category B lands, except that the First Nation has a fee simple title rather than a fee simple equivalent title.

- *Interim Protected Lands.* These are parcels of land located within the traditional territories of First Nations without a ratified land claim agreement. These lands are protected for future First Nation Settlement Lands and are generally withdrawn from minerals staking.

In addition to First Nation tenured lands, other non-resource related land dispositions have been considered. These other dispositions are various types of reservations issued to a Government agency to reserve some right or interest in Yukon land. Examples include various types of easements (e.g., roads, pipelines, transmission lines) and areas under land applications.

4.3 Land Use Plans

Regional planning in the Yukon is a multi-party, multi-year process to be undertaken within eight (8) proposed or accepted planning regions. The six priority hydro sites are located within two proposed planning regions:

- Northern Tutchone region that includes the Na-cho Nyäk Dun, Little Salmon Carmacks and Selkirk traditional territories; and
- Kaska planning region that includes the Ross River Dena and Liard First Nation traditional territories.

Regional land use plans are intended to facilitate orderly development that considers the values of the land, provide for economic, social and environmental well-being of the residents of the region, and to reduce or avoid conflicts between different land uses. Land use plans are written by Regional Land Use Planning Commissions, consisting of individuals nominated by the Yukon Government and the First Nations whose traditional territory falls within the planning region. The Yukon Land Use Planning Council helps Government, Yukon First Nations and Regional Planning Commissions coordinate their efforts to conduct regional land use planning.

Land use planning cannot occur in the traditional territories of First Nations with unsettled land claim agreements because there is no legislated mandate that supports the creation of a planning commission. Currently, there are no approved regional land use plans and regional planning cannot proceed in the Kaska region because of unsettled land claims.

4.4 Renewable Resources

For the purposes of this study, the effects on renewable resources considered overlap of the six priority sites with parcels of land that are protected or otherwise managed for their resource and/or environmental values, including:

- Special management and protected areas;
- Trapping concession lands;
- Outfitting concession lands;
- Agricultural areas; and
- Timber harvest areas.

Many parcels of land have been identified as Special Management Areas in need of management and protection. Special Management Areas and protected areas are identified within each traditional territory and may include:

- National wildlife areas;
- National parks or national park reserves, territorial parks, and national historic sites;

- Special wildlife or fish management areas;
- Wildlife or migratory bird sanctuaries;
- Designated Heritage Sites; and
- Watershed protection areas;

Climate and soil conditions pose significant challenges for farming in the Yukon. Nevertheless, there are several small agricultural areas spread across the Territory. Agricultural areas are parcels of land designated for agricultural production or grazing or have applications pending.

Forest resources are limited in the Yukon, but commercial logging is carried out in some southern areas. Sawmills produce lumber required for local building, for mining timbers, and for fuel. Timber Harvest Areas are parcels of land with existing approved Timber Harvest Plans and/or site specific plans. These plans identify areas proposed for harvesting of forest resources.

Trapping continues to be a commercial activity in the Yukon, albeit a very small contributor to the territorial economy. There are many species of furbearing mammals trapped for their fur, including: beaver, coyote, fisher, fox, lynx, marten, mink, muskrat, otter, squirrel, weasel, wolf, and wolverine. The Government of Yukon regulates trapping activities through registered trapping concessions. These are parcels of land on which the holder is granted the rights to harvest fur-bearing animals.

There are 333 Registered Trapping Concessions (RTCs) in Yukon and 18 group areas, most of which are held either by a collective group or family or First Nation members (Environment Yukon, 2013). Currently, there are 29 trapping concessions directly affected by the six hydro priority sites.

In the Yukon, outfitting activities are managed through outfitting concessions. A total of 19 registered outfitters operate in Yukon, each with concession rights to guide non-resident hunters. Outfitting concession boundaries are legally defined and each outfitter can maintain hunting camps, airstrips, horse grazing areas, and trails. Currently, there are six outfitting concessions directly affected by the six priority hydro sites.

4.5 Non-Renewable Resources

Yukon has significant mineral potential with large deposits of minerals such as copper, lead, tungsten, zinc, silver and iron ore. There are also significant hard rock and placer gold deposits and important occurrences of other minerals and coal. Over the past several years, there has been considerable investment by the exploration and mining industry in Yukon. As such there are numerous operating and closed mine sites, quarries and parcels of land under a claim, lease and/or land use permit.

In addition to mineral resources, there are known oil and gas resources in the northern portion of the Territory and in the off-shore. Sedimentary rock basins with potential oil and gas deposits exist between Carmacks and Teslin (i.e., the Whitehorse Trough) and in the south-eastern most portion of the Territory (i.e., Liard Basin).

For the purposes of this study, the effects on non-renewable resources considered the overlap of the six priority hydro sites with parcels of land that are used or proposed for use for mining, oil and gas extraction, including:

- Mine sites and quarries;
- Placer operations, claims, leases and tenure areas;
- Quartz (i.e., Hard Rock) claims, leases, land use permits;
- Coal licenses, tenure areas and titles; and
- Oil and gas dispositions and leases; tenure areas and land plats.

Placer operations, claims, leases and tenure areas exist near Frances Lake, along the Pelly River, and in the vicinity of Mayo. There exist areas of mineral and metal mining claims, leases, land use permits at or near every priority site. No oil or gas resource areas exist at or near the six priority sites.

4.6 Historic and Archaeological Resources

Historic and archaeological resources are protected from disturbance under the *Yukon Historic Resources Act* and the Yukon Archaeological Sites Regulation. There are numerous historic and known archaeological sites in the Yukon, but only a few (less than 30 known sites) have been identified through systematic inventories at the six priority sites. However, given the vastness of the Territory, systematic surveys or inventories of historic and archaeological resources have been not undertaken in many areas, particularly in remote areas.

The Government of Yukon’s Department of Tourism and Culture have concluded that the six priority sites identified are nearly entirely in zones that would be considered to be of high archaeological potential. Systematic inventories to identify archaeological and historic sites would necessarily be part of any future development in association with the Yukon Next Generation Hydro project (Yukon Tourism and Culture, 2015).

The Government of Yukon’s Department of Tourism and Culture also indicated that localities with high archaeological potential can be identified based on factors such as distance to water, elevation, slope, and terrain type. Generally, archaeological sites are found on well drained, level ground (terraces, or ridges, for example), often elevated or slightly elevated with a view over the surrounding landscape and within 30 – 100 m of water. The potential for cultural sites increases if these factors are combined with a strategic location. For example, strategic locations for fish camps are fish spawning localities at lake outlets or at the mouths of Creeks, or lake narrows, and places where schooling fish can be netted.

4.7 Employment and Business Activity

Employment is a major determinant of overall community well-being as it determines the participation of residents in its economic life. To individuals, families or households, employment provides income that people use to achieve their personal financial objectives, which define their style and quality of life. Employment provides a sense of personal security and has a symbolic value which contributes to a person’s own self-image and their status within a community. To the municipality, community or region, employment opportunities influence the way a community, municipality or region is perceived; that is, its attractiveness as a place to live or undertake business. As such, the availability of employment opportunities ultimately affects population levels, housing, community infrastructure and services.

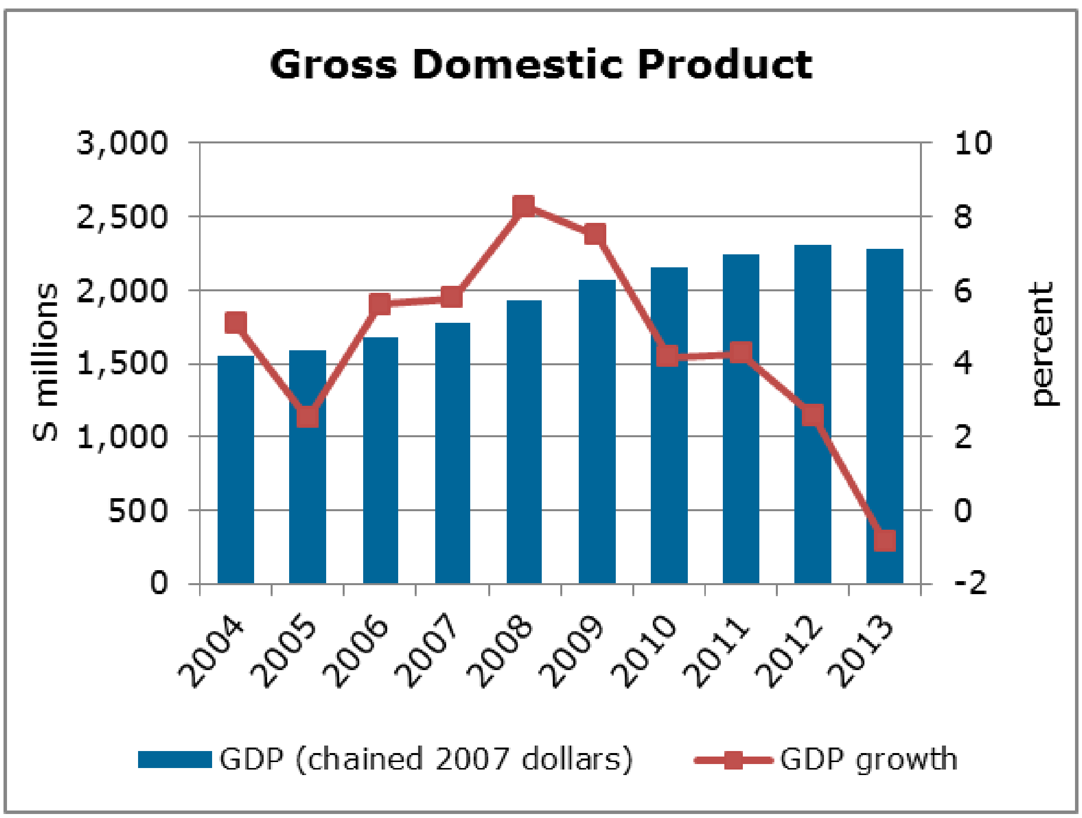
Although the Yukon has historically been prone to boom-bust cycles associated with its resource-based economy, employment and business activity in the Territory has been strong overall, but growth has slowed in recent years. Recent data from the Yukon Bureau of Statistics (2014) indicates that:

- In 2014, the number of Yukoners employed was 19,800 and the number unemployed or not in the labour force was 7,900;
- Yukon's average employment rate over the past ten years (2005 to 2014) was 70.8%, higher than all other provinces and territories. Yukon's 2014 unemployment rate of 4.3% was the second lowest in Canada, following Saskatchewan (3.8%) and marked the eleventh consecutive year of Yukon's unemployment rate being below the national rate; and
- Yukon's Aboriginal employment rate over the past ten years (2005-2014) has been variable and generally lower than Yukon's non-Aboriginal population. In 2014, the Aboriginal employment rate was approximately 61% as compared to 74% for non-Aboriginal persons.

Detailed employment statistics for all of the communities nearest the six priority sites are not available. However, in general these smaller communities have lower employment rates (~60% employed) than the Yukon (~70% employed) as a whole. The remainder of the population is either not in the workforce or unemployed.

Gross Domestic Product (GDP) is an estimate of the final value of all goods and services produced in the economy within a specific time period. GDP statistics are available for Yukon as a whole but not for individual regions or communities. Economists and policy makers generally use GDP as one broad indicator of the potential for new wealth creation and potential business activity. Figure 5 shows that Yukon's GDP has grown since 2004 to approximately $2.25 Billion, but the rate of growth has declined since 2008.

Figure 5: Yukon GDP (2004 – 2013)



For the purposes of this study, the number of direct and indirect jobs created and the GDP generated by each project in the Yukon has been estimated for the construction and operations phases. These are Class 5 or "order of magnitude" estimates, suitable for a screening or feasibility study.

It is noteworthy, that the direct and indirect GDP generated by a three year construction phase for many of these hydroelectric projects and potentially captured by the Yukon may range from approximately $380 Million to $1,329 Million (See Section 6), representing between 5% and 20% to the Territorial total GDP over three years (i.e., between 2011 and 2013). As such, a hydroelectric project of such magnitude will be a major contributor to the economy.

Nevertheless, because all jobs and value are not captured by the Yukon economy, these estimates of jobs and GDP are likely to be overestimated. This is because major construction projects in the Yukon often use a "fly-in-fly-out" workforce rotation system that utilizes labour from outside the territory. Similarly, many components (e.g., turbines) required for a hydroelectric facility are designed and manufactured outside of the territory. For some context, this study provides an estimate of "leakage" to other Canadian provinces. This "leakage" represents an opportunity for the Yukon to capture more of the economic benefits associated with a hydroelectric project.

4.8 Labour Force and Skills Supply

The skills and amount of labour available in the Yukon and any community (i.e., labour supply) are important determinants of community well-being. Skills and labour supply directly influence the proportion of the Project's labour needs that can be met within the Territory and hence the potential for individuals and households to realize employment and income benefits. Overall, the labour force in the Yukon has grown since 2005 to approximately 20,700 in 2014.

Persons in sales and service, and in business, finance and administrative occupations represented 41% of the labour force. Skilled tradespeople, transport and equipment operators and those working in primary industries represented approximately 19% of the labour force.

Detailed labour force statistics are not available for all of the communities nearest the six priority sites. Typically, the availability labour and skills in these smaller communities needed for a major Project is very limited and community specific.

4.9 Traditional Aboriginal Activities

The lands and waters within the Traditional Territories of Yukon's First Nations are important for hunting, trapping, fishing, gathering and cultural activities. These traditional activities play an important role in providing food, medicine, and materials and supplemental income and food purchases.

Caribou and moose are hunted as a food source. Salmon and other freshwater fish are caught, often at fish camps. Plants are gathered for food, medicine, or for use in construction. A wide variety of birds, waterfowl and other game are harvested for food, clothing, and other uses. In general, harvests of animals, fish, or plants by Aboriginal people are managed to ensure their ongoing availability and regeneration. More remote areas are more time-consuming and more costly to access, and in some instances are not used as often as those in closer proximity to settlements.

Information regarding traditional Aboriginal activities undertaken near the six priority sites (e.g., types of traditional activities undertaken, locations, species harvested etc.) is not typically publicly available. Traditional Knowledge (TK) and Traditional Land Use (TLU) studies would necessarily be part of any future development in association with the Yukon Next Generation Hydro project.

For the purposes of this study, a focus has been placed on the loss of areas available for traditional activities and access to land that might be afforded by the development of each priority site. In addition, given that fishing sites/camps play an important role in the traditional lifestyle of First Nations (Linklater, 2014), consideration is given to the locations of known and well documented Aboriginal fishing sites/camps at or downstream of the six priority sites.

4.10 Community Well-Being

In general, people want to feel healthy, safe, secure and satisfied with living in their communities. Community well-being encapsulates these ideals, which are the outcomes of people living together harmoniously in vibrant and sustainable communities with a strong future.

The state of a community's well-being is highly community-specific and time dependent because every community is unique and each changes over time. At this stage in project planning, it is acknowledged that a comprehensive examination of the well-being of each community near the priority sites is not feasible. This is because data regarding the well-being of communities near the six priority sites is not typically available nor possible to gather without focused sociological study and engagement. Such studies and engagement would be required for any future development of hydro projects.

The following Section discusses some of the general effects of hydroelectric projects on community well-being. Section 6 provides some basic community profile information for those communities nearest the six priority sites (approximately within 100 km by road). In general, the communities nearest the six priority sites are characterized by small and declining population levels, a small labour force and generally higher unemployment rates than in larger centres (e.g., Whitehorse), a smaller range of housing options and available community services.

5.0 GENERAL EFFECTS OF HYDROELECTRIC PROJECTS

Hydroelectric power generation is a well-established technology that uses water in a renewable manner. The Yukon has a long history and experience with developing, operating and maintaining hydroelectric facilities.

Hydroelectric power generation is regarded as the most reliable renewable energy source (International Energy Agency, 2006) that can be readily integrated with other generation sources (e.g., intermittent renewables such wind and solar and fossil fuel based sources). This is because hydroelectric power generation responds well to generation and load variability and is regarded as flexibly being able to “store” energy by storing water (i.e. fuel) until needed.

Hydroelectric power generation is also regarded as a clean energy source due to low greenhouse gases (GHG) emissions over the life of a project (International Energy Agency, 2006). In the boreal environment, GHG emissions associated with hydropower are limited to the first 3 to 5 years after creating a reservoir, and after that they reduce to levels consistent with natural lakes (Temblay et al., 2004)

When considering new hydroelectric power development, there are a number of other general environmental and socio-economic considerations that should be taken into account.

- New hydro development at the six priority sites in the Yukon will require the creation of reservoirs. This causes flooding or inundation of land. The impoundment of rivers, regulation of discharge, the need for road access and transmission rights-of-way and the physical works associated with hydroelectric facility construction and operations inevitably cause changes in the ecosystems and specific habitat in which wildlife live.

- Hydropower development effects stream flow, which affects fish and fish habitat and fish migration. Yukon people of all cultures place a high value on fish. Salmon in particular has a long history of tradition of use by Yukon First Nations. The importance of salmon is reflected in their lifestyles and ceremonies. Fish and wildlife resources are an important part of recent land claim agreements, which are changing the way these resources are managed.

- Hydropower developments can affect people and their communities. The socio-economic consequences are numerous and varied, and can include both positive and negative effects on individuals, families, groups and organizations and their communities.

After many decades of experience with hydroelectric projects across Canada and internationally, the key environmental and socio-economic issues are known and understood by the scientific community, various regulatory bodies and the waterpower industry as a whole. Within this context, the following sections provide a high level overview of the general effects of hydroelectric projects on:

- fish and fish habitat
- wildlife and wildlife habitat; and
- socio-economic conditions.

In addition, the following section identifies some examples of “Best Management Practices” (BMPs) that can be considered in subsequent planning, design and project decision-making regarding the viability of new hydroelectric power generation in the Yukon. These BMPs help demonstrate that hydroelectric facilities can be designed, constructed and operated in a sustainable manner.

5.1 General Effects on Fish and Fish Habitat

Hydroelectric developments normally affect the river/stream environment due to changes in channels, bars and the overall hydrologic regime by the impoundment of rivers, and the regulation of discharge to meet energy needs. These modifications inevitably change the aquatic ecosystem in which fish live (Zhong and Power, 1996).

The degree to which any project affects fish and fish habitat varies widely depending on the size and flow rate of the river or tributary stream where the project is located; the make-up of the fish community present in the river system; the existing habitat; climatic conditions; the type, size, design and operating regime of the hydroelectric facility itself; and whether the project is located upstream or downstream of other projects. As changes in habitat occurs, some fish species end up doing quite well, others decline, and some are minimally affected (FWEE, 2015).

Although hydroelectric development can affect fish and fish habitat both directly or indirectly (Zhong and Power 1996), these facilities can be designed and operated in a manner that avoids or minimizes serious harm to fish. The following Sections provide an overview of the general types of direct and indirect impacts to fish and fish habitat along with the types of mitigation measures that are commonly associated with hydroelectric facilities.

5.1.1 Direct Effects

The primary impact of a hydroelectric project on fish is that it can present a barrier that impedes the ability of a fish to move or migrate within the river system in order to access habitats important to its lifecycle (e.g., spawning grounds).

In many cases, the design of the hydroelectric project incorporates a “fishway” that helps fish, especially salmonids, bypass the dam structure or other barrier (Zhong and Power, 1996). Fish ladders are the most common types of fishways; however other options include the installation of fish locks, fish elevators or transportation of fish upstream via truck (FWEE, 2015). To be most effective, fish passage facilities need to be designed giving consideration to the swimming abilities of various fish species, their preferred flow velocities and abilities to locate the structures. An ineffective fish ladder may expose some fish to predation or overfishing (Zhong and Power 1996).

Fish passing through or around a dam can become stressed, injured, disoriented, or die because of contact with turbines, the walls of the dam, or deflection screens. Mitigation measure that can be effective in minimizing such effects include the installation of screens or bypass systems so fish can avoid contact with turbines (Columbia Basin Trust, 2012). Experience indicates that fish passage rates are often better than 90%. Nevertheless, a series of hydroelectric dams on a river can result in cumulative losses among migrants (Zhong and Power 1996).

Fish, particularly salmon species, present above a dam can become disoriented by slower moving waters in the reservoir. A disoriented fish may take longer to reach the ocean. With disorientation and lengthened travel time comes an increased exposure to predators (FWEE, 2015).

Fish below a dam may be harmed by the operational schedule of the facility. Operating protocols regarding how control gates are closed and reopened (Zhong and Power, 1996) can serve to avoid or minimize serious harm to fish.

5.1.2 Indirect Effects

5.1.2.1 *Within Reservoirs*

Reservoirs tend to increase the surface area and depth of affected lakes and rivers. These changes represent shifts in habitat conditions that influence species composition and abundance. For example:

- raising the water depth over habitual spawning grounds may discourage reproduction in some species, but benefit others;
- surface water temperatures in reservoirs tend to increase in the summer months since there is a larger surface area and slower moving waters are exposed to sunlight (Zhong and Power, 1996). Some species may be harmed, while others (e.g., species that prefer deeper or warmer waters) will benefit;
- fish populations often increase rapidly in a new reservoir partly because of expansion of water volume and partly because food organisms increase in the impoundment (Zhong and Power, 1996); and
- stratification of water may occur in the reservoir with the colder water that sinks toward the bottom having reduced oxygen content (FWEE, 2015).

Changing water levels in reservoirs that lack of riparian vegetation can lead to increased erosion and sedimentation (FWEE, 2015). The likely consequences can include:

- increased turbidity and the settling of sediment on fish eggs that can be detrimental to their development;
- shifts in primary productivity from nutrient-limited to light-limited condition because of poor light penetration (Hecky and Guildford, 1984 in Zhong and Power, 1996);
- increased sedimentation behind a dam that can result in nutrient loading and oxygen depletion (FWEE, 2015); and
- gravel can be trapped behind a dam in the same way as sediment. In cases where the movement of gravel downstream is part of establishing spawning areas for fish, important habitat conditions can be affected (FWEE, 2015).

Hydroelectric developments constructed on the mainstem of rivers can cause water quality to deteriorate when organic wastes settle in reservoirs and decompose anaerobically. This is especially true for reservoirs with long retention times (Zhong and Power, 1996). Retention times are typically longer in large and deep reservoirs with low annual discharge rates. Such adverse effects may not occur at all hydroelectric facilities.

BMPs and a wide variety of other mitigation measures are available for minimizing erosion and maintaining riparian vegetation along the reservoir. Operating protocols regarding water discharge rates can be developed to minimize adverse effects to fish and fish habitat upstream and downstream of a hydroelectric facility. Other examples of BMPs are provided in Section 5.4.

Increased mercury concentration in fish has been observed at a number of hydroelectric projects in Canada since the late 1970s (Bodaly and Hecky 1979; Zhong and Power, 1996). The increase in fish mercury levels is the consequence of bacterial methylation stimulated by decomposition of organic materials in the flooded reservoir area. Methylmercury is absorbed by the fish directly from water or from their food (Hecky et al. 1991 in Zhong and Power, 1996). The length of time that water resides in a reservoir and the duration of the reservoir filling can be correlated with fish mercury levels (Zhong and Power, 1996). A variety of BMPs are available to address the potential build-up of methylmercury. Examples of these BMPs are provided in Section 5.4.

5.1.2.2 *Downstream Effects*

Changes in discharge from a hydroelectric project can affect downstream fish habitat that may result in serious harm to fish (e.g., stress, injury, mortality) and influence their distribution and movement (Zhong and Power, 1996). Examples of such changes are:

- higher and lower flows that affects in-stream velocities and water turbulence;
- fluctuating water levels resulting in the potential loss of backwater areas and stranding of fish or eggs (Marmulla, 2001);
- increased downstream erosion (Baxter and Claude 1980 in Zhong and Power, 1996)
- discharge of water with a low oxygen content;
- increased nitrogen content (FWEE, 2015);
- changed water temperatures (Zhong and Power, 1996);
- reduced flooding and floodplain areas;
- limited formation of pools and riffles; and
- loss of gravelly substrate and less frequent movement of fines from substrates can result in fine sediment entrapment and accumulation in suitable habitat for some species of spawning fish (Gregory et al. 2002).

However, it is important to note that mitigation measures are abundant for minimizing erosion and maintaining riparian vegetation downstream of a dam site. Operating protocols regarding water discharge rates can be developed to minimize adverse effects to fish and fish habitat downstream of a hydroelectric facility.

5.2 General Effects on Wildlife and Wildlife Habitat

The impoundment of rivers, regulation of discharge, the need for road access and transmission rights-of-way and the physical works associated with hydroelectric facility construction and operations inevitably cause changes in the ecosystems and specific habitat in which wildlife live. The nature and significance of these effects largely depends on habitat complexity (differences in temperature, moisture, topography, availability of limiting nutrients, oxygen levels, pH) and biodiversity (i.e., both in richness – the number of species, and in abundance across species types) of the affected areas. Biodiversity in turn, is directly proportional to biomass production regardless of which species are dominant in an ecosystem (Huston 1994; Wisley and Potvin 2000).

River valleys and their associated wetlands tend to have a high degree of habitat complexity and biodiversity because they have:

- variable topographic and geomorphic settings;
- contrasting habitats over relatively short distances;
- transition zones between habitats;

- important micro-climates that support biodiversity;
- irregular shorelines; and
- high productivity associated with the influx of nutrients from upstream habitats.

Similar to the effects on fish and fish habitat, the degree to which any project affects wildlife and wildlife habitat depends on where the project is located; the existing habitat and climatic conditions and the type, size, design and operating regime of the hydroelectric facility. As changes in habitat occur, observation and time make it increasingly clear which plants and wildlife are affected.

Hydroelectric projects can reduce habitat diversity as a result of:

- loss of habitats (i.e., riparian zones, wetland complexes, and the lower reaches of tributaries);
- the alteration of existing river channels and bars and their chemical and physical characteristics;
- effects on the shape, geomorphology and fluvial dynamics of rivers and streams within drainage basins. Water levels in rivers, lakes, and wetlands rise and fall on a seasonal, basis, creating a shoreline that has an important “function” in maintaining the environmental integrity of an area. For example, variable shorelines, relatively stable water levels, high plant and invertebrate productivity, and small areas of elevated ground are important breeding habitat attributes for waterfowl;
- loss of large, riparian trees along the edges of reservoirs (Polzin, 2015; Herbison, 2015). Large trees are important nesting or roosting sites for wildlife, as well as foraging substrates and perches from which to hunt; and
- the rate, extent and timing of inundation or drawdown (Abrahams, 2005). Plant and invertebrate communities will change with changes in the near shore environment and the bordering riparian zone of a waterbody. Plant and animal species are not all able to adapt to changes in water levels through inundation (flooding) and drawdown.

Vegetation loss is directly proportional to wildlife habitat loss. For example, in assessing biodiversity levels at the Columbia Reservoir, Boulanger et al. (2002) found that songbird diversity, richness and abundance was significantly higher in the willow and cottonwood borders, than in the uniform planted rye and native grasslands along the borders of the reservoir basin. Songbirds nesting in the reservoir grasslands are subject to flooding and mortality each year.

Overall, many of the negative environmental effects can be mitigated through site selection, facility design and operations (e.g., water management protocols) or adaptive management plans with monitoring that evolves over time. In the Yukon, the selection of hydropower sites away from Wildlife Key Areas (WKAs) will serve to avoid those areas that are limited in availability, most valuable to the species/population, and/or where wildlife is most vulnerable.

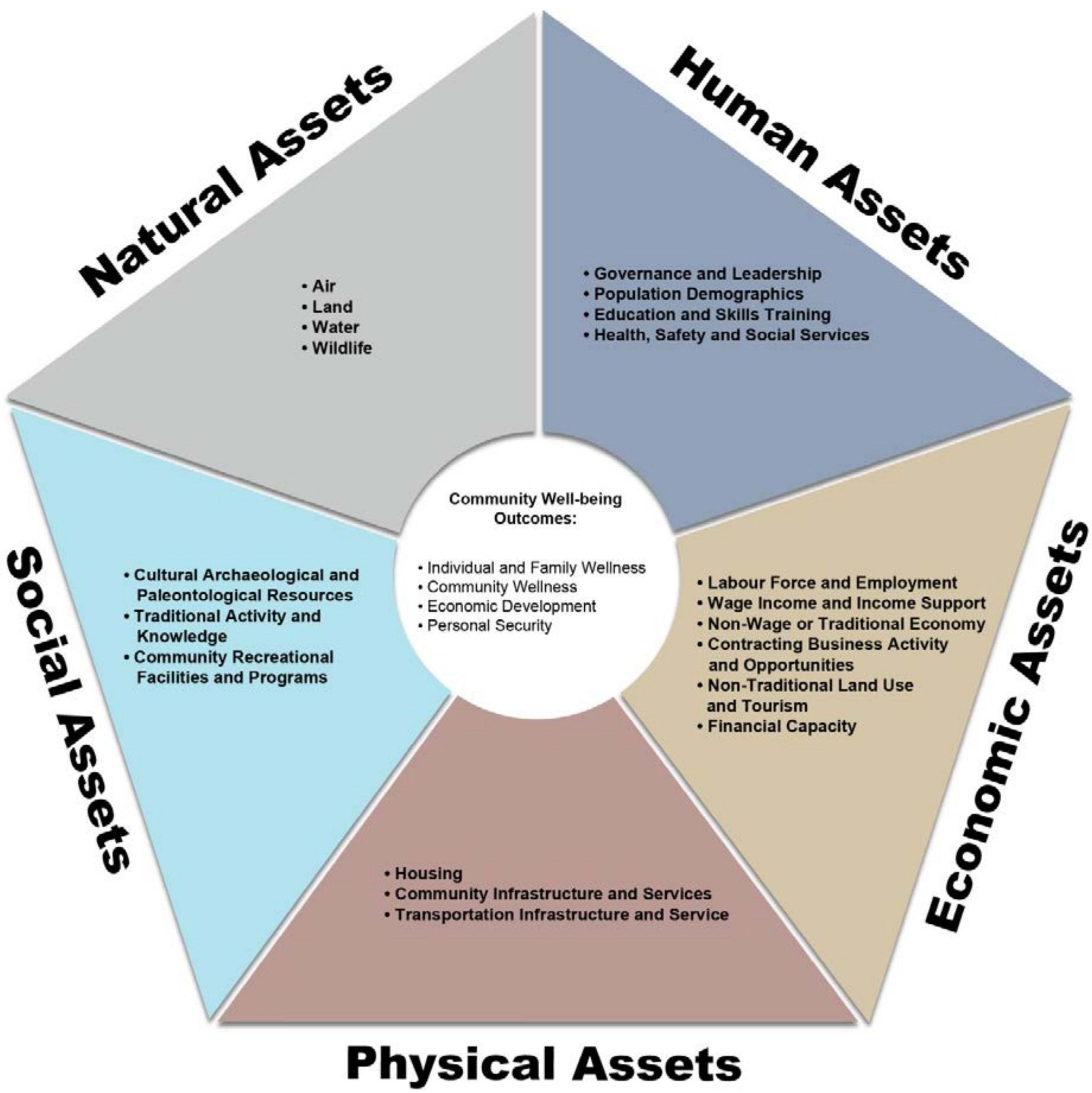
Ultimately, some species end up doing quite well, others decline, and some are minimally affected (FWEE, 2015). These positive and negative effects over time do not necessarily diminish local biodiversity, but rather change its character.

5.3 General Effects on Socio-economic Conditions

The socio-economic consequences of a hydroelectric project are numerous and varied, and can include both positive and negative effects on individuals, families, groups and organizations and their communities. Socio-economic effects tend to be highly community-specific and time dependent because every community is unique with its own mix of "assets" that change over time. Examples of these assets are shown on Figure 6.

Most notably, many negative socio-economic effects can be mitigated or managed over time and most positive effects can be enhanced. Ultimately, these positive and negative effects will either strengthen or diminish a community's assets which will have either positive or negative implications for its overall well-being.

Figure 6: Examples of Community Assets



Hydroelectric projects may affect a community's ***Human Assets***, namely the skills and knowledge inherent in the community, its opportunities for growth and learning, access to skills and knowledge, and access to essential services that are fundamental in maintaining individual, family and community wellness. The following are examples of how a hydroelectric project may affect a community's human assets:

- A dam and reservoir may overlap with places where people live or have legal rights / claims to (e.g., settlement lands, interim protected lands). In the case of the six priority sites, care has been taken to avoid flooding of cities, towns, villages and existing settlements (i.e., census subdivisions);

- The potential in-migration of workers, who may be different in age, sex, ethnicity, etc. may result in changes in population levels and the demographic make-up of communities. Some communities welcome growth and seek diversity, while others prefer stability;

- Increased population levels brought about by a project's need for a stable and skilled workforce may increase enrolment in existing schools and/or attract people to the education system seeking opportunities for skills training; and

- Population changes due to the presence of a construction workforce may place new or additional demands on local and regional health, infrastructure, safety and social services.

Hydroelectric projects may affect a community's ***Economic Assets***, namely the opportunities available to people for employment and their participation in the economic life of the community and region, including the monetary or financial resources that people and governments use to achieve their economic objectives. The following are examples of how a hydroelectric project may affect a community's economic assets:

- A large construction project and an operating hydroelectric facility may change the economic development potential of a community or region, due to access to a source of energy, the presence of new infrastructure and the legacy of a larger trained workforce;

- A dam and reservoir may overlap with places where investment has occurred or is planned. It may displace other current or economic activities (i.e., the use renewable or non-renewable resources, traditional Aboriginal activities) and diminish economic potential;

- The construction and operation of a hydroelectric facility will generate direct and indirect employment opportunities and business activity resulting in increased wage income for some. Depending on the size and location of a facility both positive and adverse effects may occur on the tourism industry and individual tourist operators (e.g., outfitters, hotel/motel/campground operators);

- A major hydroelectric project may result in competition of existing local labour, particularly the skilled trades. However, in most cases major projects tend to result in a positive legacy of a larger trained workforce; and

- A major hydroelectric facility may change the financial capacity of government should they be able to attract new or additional revenues from the project.

Hydroelectric projects may affect a community's ***Physical Assets***, namely the basic infrastructure that allows a community to function effectively. The availability and quality of temporary and permanent housing, water, sewage, waste management and roads may be affected by changes in population and demographics. These effects will have implications on the ability of the community to attract and retain people and investment.

Hydroelectric projects may affect a community's ***Social Assets***, namely the traditional Aboriginal activities and/or other community activities in which people participate; and the facilities or amenities that they draw upon to access them. For example:

- a dam and reservoir may displace historic or archaeological resources, spiritual places and/or areas used by Aboriginal people for traditional activities (i.e., fishing, hunting, trapping, gathering,) and diminish social cohesion and vitality; and

- population changes due to the presence of a construction workforce or new long-term residents may place new or additional demands on local and regional government services such as transportation, health and recreational facilities and programs.

Hydroelectric projects will affect a community's ***Natural Assets***, namely the biophysical environment upon which community well-being also depends. These natural assets can be the air, land, waters and wildlife. Previous sections presented the general effects of hydroelectric projects on fish and fish habitat, and wildlife and wildlife habitat.

As mentioned previously, ultimately, these positive and negative effects will either strengthen or diminish a community's assets which will have either positive or negative implications for its overall well-being. These overall implications of these changes may be felt in terms of:

- Economic development (e.g., enhanced labour force and skills, increased business activity and economic stability);
- Individual and family wellness (e.g., improved or diminished personal health, changed family problems);
- Community wellness (e.g., changed crime rates, community cohesion, use of Aboriginal language and preservation of culture); and
- Personal security (e.g., financial security and food security).

5.4 Best Management Practices for Hydroelectric Projects

The Yukon Next Generation Hydro and Transmission Viability Study, including this review of the positive and negative environmental and socio-economic effects of the six priority sites is an early and initial step in the consideration of the effects of future hydroelectric projects in the Yukon.

After over a century of experience with hydroelectric projects across Canada and internationally, key environmental and socio-economic issues are known and understood by the scientific community, various regulatory bodies and the waterpower industry as a whole. This knowledge and experience has led to the identification of "Best Management Practices" (BMPs) that can be considered in subsequent planning and decision-making regarding the viability of new hydroelectric power generation in the Yukon. For the purposes of this study, these BMPs also assist in demonstrating that hydroelectric facilities can be designed, constructed and operated in a sustainable manner.

BMPs are available and methods, practices or technologies that, if followed should allow the development of a hydroelectric project to not only meet required standards, but also achieve a high level of environmental and socio-economic performance and other objectives desired by Yukoners.

For the purposes of this study, examples of BMPs were primarily sourced from the International Energy Agency's technical reports from the Implementing Agreement for Hydropower Technologies and Programmes (2006); the Ontario Waterpower Association (2012); the Food and Agriculture Organization of the United Nations (2001); and, the Sustainable Hydropower Foundation's "Sustainable Hydropower Website " (available at http://www.sustainablehydropower.org).

5.4.1 BMPs for Construction Effects

Best management practices are available to address the many different types of construction effects on wildlife and wildlife habitat, fish and fish habitat and socio-economic conditions. Numerous BMPs have been developed from extensive experience with hydroelectric and other infrastructure projects in Canada and internationally. In Canada, for example, the Ontario Waterpower Association has developed a "Best Management Practice Guide for the Mitigation of Impacts of Waterpower Facility Construction" (2012) that provides current and practical guidance on how best to construct, rehabilitate or repair a hydroelectric power facility. This guide addresses a wide range of construction activities, including:

- Dewatering
- Water diversions and In-water works
- Drilling and Blasting
- Clearing and Grubbing
- Watercourse Crossings (bridges, culverts)
- Excavations and Dredging
- Road and Trail Construction
- Concrete Batch Plant and On-site Crushing Operations
- Earth Dam and Dike Construction
- Concrete Production and Use
- Snow Management
- Erosion and Sediment Control
- Air Quality, Dust and Noise Management

It is important for project proponents to identify and commit to BMPs for construction effects during the environmental assessment stage and to incorporate them into Environmental Management Plans (EMPs). An EMP includes details and outlines processes that the project proponent, its contractors and others are required to follow and to manage specific issues. Having identified the construction effects that need to be managed through the environmental assessment and EMP development process, construction effects can be closely monitored so that any unanticipated effects or issues can be quickly addressed through adaptive management.

5.4.2 BMPs for Operational Effects

Best management practices are available to address the many different types of operational effects on wildlife and wildlife habitat, fish and fish habitat and socio-economic conditions. Table 7 provides examples of these BMPs. In the Yukon, there is a history of the application of some of these BMPs at existing hydroelectric facilities. For example, a fish ladder was built at the Whitehorse Rapids in a series of steps that span a rise of more than 15 m, from the Yukon River up to Schwatka Lake. A fish hatchery was constructed and began operation in 1984 at

Whitehorse Rapids. The hatchery was built to produce a specific number of chinook salmon fry for release each year at natural spawning sites in tributaries of the Upper Yukon River system, (Yukon Energy Corporation, Undated).

Table 7: Examples of BMPs for Operational Effects

Key Issues	Best Management Practices
Erosion and Sedimentation	Examples of BMPs for managing erosion and sedimentation in the reservoir and downstream areas, include: • Installing sediment by-pass systems for floodwaters, gated structures for sediment flushing, sediment trapping and filtration systems, or direct dredging have all been utilized to deal with high reservoir sedimentation rates. • Installing shoreline erosion controls such as rip-rap or bank protection works, or directly planting stabilizing vegetation. • Optimising the operating regime of the hydroelectric facility using ramp-down rules, constraints on time spent at particular operating levels, and operating to maintain the stabilizing characteristics of existing or planted vegetation. • Removing sediment retaining weed species, and replanting with more appropriate species. • Flushing of the river channel itself through controlled releases. • Reducing sediment input to reservoirs through specific catchment controls on road construction, mining, agriculture or other land uses and/or upper catchment vegetative cover protection, terracing, upstream check structures or reforestation.
Water Flows	Examples of BMPs for managing water flows in downstream areas include: • Establishing an effective operating regime that optimizes the use of water by the facility and does not significantly affect its generating potential; • Optimising the operating regime of the hydroelectric facility to meet environmental or socio-economic objectives by maintaining minimum flows in the river, capping maximum flow releases, constraining draw-down or ramp-up rates and periodic flushing flows (as appropriate). These measures can be permanent, temporary, year-round or by season. • Establishing downstream regulating ponds and/or smaller off-stream storages to deliver minimum flows.
Water Quality	Examples of BMPs for managing water quality in the reservoir and in downstream areas include: • Limiting the amount of water drawn into the power station from colder anoxic depths. Seasonal management of lake levels can also be utilized to ensure offtake of oxygenated water at seasonally appropriate temperatures. • Using stilling basins, spillways and other facility designs that favour degassing (e.g., installing air injection facilities and aerating turbines) • Reservoir clearing (e.g., controlled burning of vegetation and/or removal of organic materials) prior to inundation to limit the amount of organic decomposition in the reservoir, and thus the consumption of oxygen and methylmercury production.

Table 7: Examples of BMPs for Operational Effects

Key Issues	Best Management Practices
	• Pumping of selenium into reservoirs to lower the rate of methylation and bioaccumulation or the addition of lime to acidified systems to reduce acidity of reservoirs and the methylation of mercury. Current research is focussing on using materials than can absorb methylmercury and other contaminants and thereby enhance their removal from the environment (e.g., synthesized charcoal materials) (Pappoe, undated. available at http://neia.org/wp-content/uploads/2013/06/MeHg-and-Dams.pdf). • Optimising the operating regime of the hydroelectric facility to reduce the residence time in reservoirs and ensuring flow-through • Using baffles in shallow lakes to direct circulation and ensure adequate water flow-through and mixing. • Planting of appropriately selected aquatic vegetation to control turbidity. • Implementing broader catchment management and pollution control measures to improve water quality in the reservoir (e.g., control of industrial emissions).
Fish Passage and Mortality	Examples of BMPs for maintaining fish passage and preventing fish mortality include: • Designing and installing site-specific fish ladders or mechanical fish elevators to assist fish with their upstream migration. • Diverting fish away from the turbine intake using purpose built channels or pipes going around or through a dam wall. • Diverting fish away from intakes using fish screens, strobe lights, sound or air bubbles, and electrical fields. • Utilizing turbine, spillway and/or overflow designs that minimize fish injury or mortality.
Ecological Diversity	Examples of BMPs for maintaining terrestrial and aquatic biodiversity include: • Limiting effects on ecosystems by constructing various types of structures underground. • Optimising the operating regime of the hydroelectric facility to preserve important aquatic and terrestrial (e.g., riparian) ecosystem functions that will protect biodiversity. • Implementing catch and release programs, hatcheries and re-stocking programs. Fish hatcheries can help maintain populations of native species that thrive within the reservoir but cannot successfully reproduce. • Developing targeted management plans for species at risk or species of conservation concern, as well as for managing construction related impacts. • Implementing fisheries offsets, species relocations, habitat restoration and/or habitat compensation measures. Examples may include measures aimed at establishing and managing protected areas of comparable area and biodiversity quality to the area inundated by reservoir creation, and/or setting up trust funds and grants for environmental purposes.

Table 7: Examples of BMPs for Operational Effects

Key Issues	Best Management Practices
Invasive Species	Examples of BMPs for minimizing the introduction and effects of invasive species in reservoirs and downstream areas, include: • Reservoir clearing prior to inundation to make reservoirs less conducive to weed growth. • Physical removal or containment of invasive vegetation species along with replanting of native species. • Periodic drawdown of reservoir water levels and/or periodic flushing of reservoir and downstream areas. • Optimising the operating regime of the hydroelectric facility to reduce residence times or to create better circulation.
Socio-economic Effects and Benefits	BMPs to address the socio-economic effects of hydroelectric projects are typically focused on minimizing community disruption and on sharing of benefits with affected communities and other stakeholders. Methods for minimizing community disruption and for sharing benefits vary with circumstance. They may include but are not limited to: • Establishing attractive and functional work camps and appropriate workforce management / rotation systems to help retain workers, and to limit short term population growth and worker influx into small communities. • Replace and/or enhance community infrastructure, housing and services (as required) affected by the project and/or workforce. • Setting up various community agreements, regional economic development organizations and/or equity-sharing partnership solutions with local communities and regional institutions. • Ensuring that those affected by the project become early beneficiaries by ensuring their access to new job and business opportunities during the early years of development. This could involve: o Preferential hiring of local workers for construction work and ancillary services and/or providing training for local workers in order to improve their chances of employment. o Supporting local economic development and businesses by dividing construction contracts, in order to allow smaller regional companies to bid and ensuring large contractors use local businesses to supply part of their services. • Design and implementation of river basin management plans that take into account the water needs of communities and other stakeholders in the catchment. • Providing a variety of value added uses and benefits, particularly those that involve the reservoir. Affected communities can benefit from the availability of drinking water supply and sanitation, water for business and industry, flood mitigation, water-based transport, and recreation and tourist opportunities. • Establishing suitable processes for on-going consultation and engagement of all stakeholders and affected communities. Affected communities must view the engagement process as being open, fair and inclusive.

6.0 ENVIRONMENTAL AND SOCIO-ECONOMIC EVALUATION OF THE SIX PRIORITY HYDRO SITES

This section presents a focused evaluation of the six priority sites based on the approaches and methods described in Section 2. It present the key features of each project, their environmental and socio-economic setting and their positive and negative effects.

Scorecards for each priority site are presented using a "Higher", "Moderate" and "Lower" rating scheme. The ratings provide a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. In general, a "Higher" rating means:

- the priority site may result in negative environmental and socio-economic effects and/or offers the least potential for positive socio-economic effects. In some cases, the "Higher" rating means the effects are of greater magnitude relative to other sites.
- the analysis shows there is greater certainty that an adverse effect may occur, due to factors such as the presence of key fish species (e.g., salmon), environmental features (e.g., WKA, species at risk) or important socio-economic attributes (e.g., Category A Settlement Lands, areas with subsurface rights for minerals) within the project footprint.
- the site will likely require a greater level of investigation through more detailed, complex and site specific environmental analyses.
- the site may require special site-specific design features to address technical, environmental and socio-economic constraints; and
- a greater effort will likely be required in the design of mitigation, compensation and enhancement measures to manage adverse effects and maximize benefits.

A "Moderate" rating means that the priority site has a mix of positive and negative environmental and socio-economic effects.

A "Lower" rating means that the priority site has less potential for negative environmental and socio-economic effects and/or offers greater potential for positive socio-economic effects than other sites. A "Lower" rating does not mean that the site is constraint free or will require less attention through further assessment, design and mitigation.

Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

6.1 Fraser Falls

6.1.1 Site Development Overview

Fraser Falls is a hydroelectric project on the Stewart River, located in the Stewart River Basin approximately 40 km upstream of Mayo. The total drainage is estimated to be 30,700 km^2. The dam site and reservoir footprint area are shown in Figure 7.

The preliminary project layout includes the following components:

- Dam (height 48 m; 56 m with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse with two additional turbine and generator bays for post 2065 upgrades;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

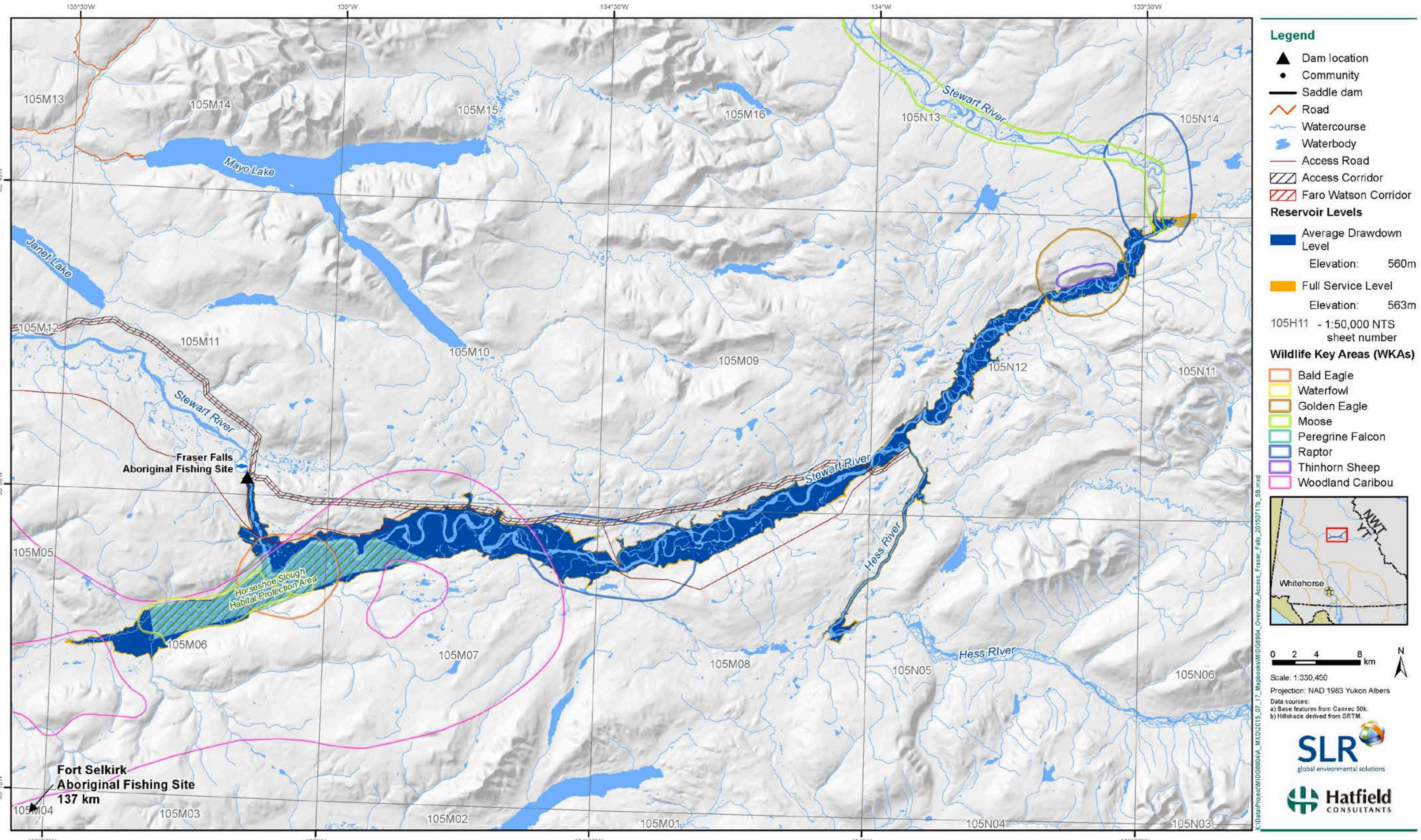
The estimated full supply level of the water reservoir is 563 m above sea level, flooding a total area of approximately 31,200 ha. The average drawdown level of the water reservoir is 560 m ASL, resulting in the reservoir water level fluctuating by 3 m over an average year.

Approximately 40 km of new road and 48 km of new transmission line are required to access and interconnect the project.

Fraser Falls is able to meet the forecasted Baseline 2065 energy demand for the Yukon on a year round basis. In addition to the spilled water (i.e. energy) in the months of May through November, there is "Must Run"[1] energy from June to October that would require other Yukon facilities (e.g. Whitehorse) to restrict generation in the months from June to October to balance Yukon electrical load and demand. A Class 5 cost estimate of its capital cost (i.e., 3 year construction phase) is approximately $1,233 Million, and operational costs are estimated at $8.7 Million per year over a 65 year lifespan.

[1] Must Run energy is generated energy that is surplus to the Yukon demand. Excess energy must be produced due to operational constraints such as minimum turbine flow requirements or minimum environmental water flow releases.

Figure 7: Fraser Falls Priority Site and Reservoir Footprint



6.1.2 Environmental Setting

6.1.2.1 *Fish and Fish Habitat*

The Stewart mainstem accounts for approximately 10% of the Canadian portion of the Yukon River basin chinook salmon run (Osbourne, 2005). In addition, the Stewart River supports populations of chum salmon (Linklater, 2014), burbot, Arctic grayling, lake trout, round whitefish, lake whitefish, and longnose sucker (DFO, 2015*a*). The river is characterized as having excellent habitat for rearing fish (DFO, 2015a). Lake trout and whitefish commercial and domestic licenses are held in the vicinity of the proposed project, and evidence suggests that salmon may have been harvested commercially within the reservoir footprint during the late 1990's (DFO, 2015a).

The Hess River supports populations of Arctic grayling, chinook, chum, slimy sculpin, northern pike, lake trout, inconnu, lake whitefish, round whitefish (DFO, 2015*a*) and least cisco (Elson, 1974 and DFO, 2015*a*). Both the Hess River and Pleasant Creek are characterized as good spawning habitat for chinook and excellent habitat for Arctic grayling (DFO, 2015*a*).

6.1.2.2 *Aboriginal Fisheries Values*

The Na-Cho Nyäk Dun First Nation currently operate a fishing camp at Fraser Falls on the Stewart River, which replaces their traditional fishing camp on the Yukon River near Mayo, due to the closure of the chinook fishery (Linklater, 2014). They harvest chinook and chum downstream of Fraser Falls. The area between Fraser Falls and the McQuesten River confluence is considered to be the most frequented fishing area of the Na-Cho Nyäk Dun First Nation (DFO, 2015*a*). In addition, the Horseshoe Slough Habitat Protection Area, which encompasses the No-Gold settlement of the Na-Cho Nyäk Dun First Nation, is located near the outlet of No-Gold Creek.

6.1.2.3 *Wildlife and Wildlife Habitat*

The Fraser Falls reservoir almost entirely floods the Horseshoe Slough Habitat Protection Area (HPA), which was created as part of the Na-Cho Nyäk Dun Final Agreement and approved by the Yukon Government in 2001. This 8,770 ha area 10 km upstream of Fraser Falls contains an abandoned U-shaped channel connected to Stewart River, and the lower portion of No-Gold Creek. There are several hundred small ponds in the valley bottom, ranging in size from a tenth of a hectare to 32.5 hectares. The Horseshoe Slough HPA is recognized as a regionally significant waterfowl area, providing nesting and moulting habitat for 12 species of duck, trumpeter swans, Canada geese, grebe species, Pacific loon, and American coot. Management objectives for the Horseshoe Slough HPA include conservation of wildlife and wildlife habitat, protection of the traditional and current uses of the area by the First Nation of Na-Cho Nyäk Dun, maintenance of current biodiversity levels, and encouragement of public awareness and appreciation of the natural resources of the area.

There are nine WKAs overlapping with the Fraser Falls project configuration:

- A duck WKA in Horseshoe Slough aimed at protecting breeding waterfowl. Based on a 1989 survey, there were 519 adults and 77 broods in the oxbows and ponds along this stretch of Stewart River;

- A goose WKA that overlaps the entire proposed reservoir at the average drawdown level has been established to protect the local moulting population (500 geese) prior to its southbound migration. Waterfowl undergo complete wing moults that render them flightless for three to five weeks after the breeding season;

- Five raptor WKAs that are given a management priority in the Yukon because of their vulnerability to disturbance (Environment Yukon, 2014). Disturbance within two kilometres of a raptor nest site is thought to impede reproductive success (Environment Yukon, 2014). The location of actual nest sites is kept confidential but can be available to assist with avoidance and other mitigation design. The raptor WKAs include:

    - Two bald eagle WKAs along Stewart River, west of Hess River. Bald eagles are not at risk in the Yukon or in Canada but summer nesting areas are mapped as key. As with all riparian raptors, bald eagles tend to use the same nest site every year, so disturbing a breeding pair would be more detrimental than for a species that builds a new nest each year. They nest in large trees on or near the shores of lakes or rivers. These sites are limited in the Yukon (Environment Yukon, 2014),
    - Two peregrine falcon WKAs; one east of Horseshoe Slough and one near the most northeastern limit of the proposed hydroelectric project. This species is vulnerable in BC, and
    - One golden eagle WKA in the northeast portion of the project, aimed at protecting an identified cliff nest site. This species is an alpine breeder, feeding mainly on rodents and birds;

- One woodland caribou WKA aimed at protecting the Ethel Lake herd population and its habitats. A hydroelectric project at Fraser Falls will not affect calving but may affect winter food supplies as this species feeds on ground lichens and moves to lower elevation forests as snow hardens and increases in depth. Approximately 40% of the herd's winter range burned during the 2004 fire season. The project overlaps with 4.5% of the herd's range (152 km^2); and

- A moose WKA occurs along Stewart River, northeast of the Fraser Falls reservoir. There is a minor amount of overlap with this WKA, which represents winter foraging habitat and was established based on anecdotal observations.

Other than the woodland caribou and peregrine falcon, other species at risk that may potentially occur in the Fraser Falls reservoir area include little brown myotis, rusty blackbird, sharp-tailed grouse, bank swallow, American kestrel, and possibly common nighthawk. The little brown myotis (bat) appears to be at the northern limit of its range near Stewart River; cliffs may contain crevices large enough to contain maternal colonies. Rusty blackbird may be present along the edges of the multiple ponds in the Horseshoe Slough HPA and along the edges of Stewart Lake. Sharp-tailed grouse could nest on river outwash meadows, though known WKAs for this species are primarily further west. There are confirmed bank swallow nest records along Stewart River though breeding is uncommon in central Yukon. There is a confirmed American kestrel breeding record near Stewart Crossing. Common nighthawks can nest in wetland areas (as well as open pine stands). There have been summer sightings of this species along Stewart River but no breeding records.

6.1.3 Socio-economic Setting

The Fraser Falls priority site is located along the Stewart River. The nearest communities to the site (within approximately 100 km) are the Village of Mayo and the small community of Stewart Crossing. Mayo is approximately 58 kilometres from the priority site by existing and new roads, and 410 kilometres north of Whitehorse by road. The Mayo airport is operated by the Yukon government.

In 2014, the population of Mayo was approximately 480 people, an increase of 27% since 2005. There are approximately 115 private occupied dwellings in Mayo with an additional 20 social housing units and 6 staff units provided by Yukon Housing Corporation (Yukon Government, 2014a). The community is served by an elementary school, a nursing station, ambulance and medivac services, a large community hall and recreational facilities (e.g., curling rink, hockey arena). Yukon College provides a local campus in Mayo with courses offered in house, as well as online and through tele-conferencing (Yukon Government, 2014a). Policing in the community is provided by an RCMP detachment.

Mayo's economic activity is centralized around government services. Mining, minerals exploration, construction, transportation, energy, tourism and service sectors contribute to the local and regional economy and support a labour force of approximately 150 persons (Yukon Government, 2014a). Mayo is the staging point for backcountry wilderness trips into the Peel River Watershed to the north (Yukon Government, 2014a). Tourist accommodation is provided by three campgrounds and three motels.

As part of the 2005 Village of Mayo's Official Plan, a number of socio-economic and community development goals were developed. These goals included maintaining Mayo as a healthy, sustainable and economically diverse regional service centre; and to pursue economic development initiatives that stabilize the regional economy, diversify local employment opportunities and enhance the quality of community life (Village of Mayo, 2005).

Stewart Crossing is located along the Stewart River downstream of Mayo, approximately 100 kilometres from the priority site by existing and new roads, and 357 kilometres north of Whitehorse by road. It is situated at the crossing of the Klondike Highway and the Silver Trail. The Yukon Bureau of Statistics does not maintain population statistics for Stewart Crossing. Temporary accommodation in provided by an RV Park and a campground (Google, 2015).

The priority site is located within the traditional territory of the First Nation of Na-Cho Nyäk Dun (NND) (AANDC, 2014a). In 2014, the population of the NND living in the Yukon was 602 people. As a self-governing First Nation, the NND has the ability to make laws on behalf of their citizens and their lands. Under the land claims agreement, the First Nation now owns 4,739.68 km^2 of settlement lands. The NND government provides a wide range of programs and services to its members. Key services include housing, education and training, social assistance, special needs support and community health. The First Nation works to preserve and promote its traditional knowledge and culture and contributes to the management of the land, water and natural resources within the Na-Cho Nyäk Dun territory (NNDFN, 2015).

The Na-Cho Nyäk Dun Development Corporation is mandated to develop economic and employment opportunities through investment and development in mining and reclamation projects, renewable energy initiatives and real estate (NNDFN, 2015).

6.1.4 Environmental Effects

Fraser Falls is expected to have a negative effect on fish and fish habitat for the following reasons:

- Hydroelectric development on the Stewart River will result in the flooding of approximately 31,200 ha of the mainstem Stewart River, the lower reach of the Hess River and mouth of the Pleasant Creek. This may result in loss of spawning and rearing habitats for Arctic grayling, chinook, chum and lamprey.
- Dam construction and reservoir creation may impede migration and access to spawning grounds by Arctic grayling in both the Stewart River and Hess River drainages. Some impacts to fish migration may be mitigated through the installation of fish passage structures.
- Changes to reservoir volumes may affect access by fish to tributary streams within the reservoir footprint, and Pleasant Creek access by chinook may be altered with fluctuating reservoir volumes.
- Off channel habitat both within the reservoir footprint as well as downstream in the mainstem Stewart River drainages are expected to be limited during periods of low flow/low discharge from the reservoir; and
- Changes to reservoir volumes are expected to impact shoreline habitat for lake-dwelling fish species and may result in stranding of fish eggs for shoal-spawning fish.

Further details of effects by species and life stage are provided in Appendix C.

Fraser Falls is expected to have a negative effect on wildlife for the following reasons:

- The federal policy on wetland conservation (Environment Canada, 1991) is for a no net loss to wetlands;

- The Fraser Falls reservoir at full service or average drawdown level would eliminate all waterfowl nesting and moulting habitat along the affected portion of Stewart River, including the Horseshoe Slough HPA. This in turn, could cause declines in regional waterfowl population levels;

- The Fraser Falls reservoir could result in the loss of some winter foraging habitat for the Ethel Lake caribou herd. There is no mitigating the loss of ground lichens. As noted in Section 5.4, a BMP applicable here could involve offsetting or securing suitable habitat within the herd's range;

- The Fraser Falls reservoir would permanently displace known to be used habitat used by bald eagles along Stewart River by flooding the productive shoreline. The reservoir would reduce (and possibly eliminate) the presence of large riparian trees over time (Polzin 2015; Herbison 2015);

- The peregrine falcon is a riparian cliff nester that uses ledges from 7 m to 400 m high. Nest sites may thus be affected by rising water levels in the reservoir during spring and summer given the 56 m dam height. The peregrine falcon feeds primarily on birds, which are most abundant in riparian zones. As such, the loss of riparian habitat from annual filling of the reservoir could cause a decline in bird prey availability for this species; and

- Other than the woodland caribou and peregrine falcon, there are no known species at risk occurrences in the project area, but the Fraser Falls reservoir could displace up to six additional species at risk by eliminating breeding and foraging habitat.

6.1.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the Fraser Falls project are identified on Table 8. The Fraser Falls reservoir is the largest among the six priority sites and will result in negative effects on a number of socio-economic attributes. The greatest potential for adverse effects is on:

- Renewable resource areas (i.e., special management and protected areas, trapping and outfitting concession lands, and timber harvest areas);
- Known heritage and cultural resources; and
- Areas potentially used for traditional Aboriginal activities within the reservoir area and downstream.

The ~ 40 km of new right-of-way for roads and ~ 48 kilometres of new transmission line will improve access to renewable and non-renewable resource areas and areas potentially used for traditional activities from Mayo. The new reservoir will also facilitate navigation and improve access to the land by boat. Improved access may be considered as a positive by some or a negative effect by others.

The Fraser Falls priority site has the potential to affect a fishing camp at Fraser Falls on the Stewart River, the known chinook and chum salmon downstream of Fraser Falls, and the area between Fraser Falls and the McQuesten River confluence (DFO 2015b). The Horseshoe Slough Habitat Protection Area, which encompasses the No-Gold settlement of the Na-Cho Nyäk Dun First Nation, is also located near the outlet of No-Gold Creek.

The Fraser Falls priority site has the potential to generate substantial employment opportunities and increased business activity during construction. The over 4,800 direct and indirect jobs potentially generated in the Yukon is moderate among the six priority sites. The potential for increased business activity associated with $553 Million of GDP during construction is considered substantial. Positive effects will likely occur during a single three year construction phase, and will tend to be captured by Whitehorse and Mayo to the greatest extent. Conversely, these communities will also experience increased competition for temporary accommodation, infrastructure and community services during construction that have the potential to adversely affect community well-being. Noticeable effects on community well-being are less likely in Whitehorse, due to its larger population and more diverse economic base. The numbers of jobs and the increased business activity created during operations is largely comparable to the other six priority sites. Overall the project will support the socio-economic development goals of Whitehorse and local communities.

Table 8: Fraser Falls - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions		• No direct effects on Interim Protected Areas	• Aboriginal Settlement Lands affected: o ~ 196 ha overlap with Category A Lands o ~ 3,100 ha overlap with Category B Lands • Other Land Tenure and Dispositions affected: o ~900 ha
Land Use Plans		• Project site is not located within the area of a draft or approved land use plan.	
Renewable Resources	• ~ 40 km of new right-of-way for roads and ~ 48 km transmission line will improve access to renewable resource areas from Mayo.	• No direct effects on: o Agricultural areas	• Renewable resource areas directly affected: o ~7,100 ha of special management or protected areas o ~ 31,200 ha of trapping concession lands o ~ 31,200 ha of outfitting concession lands o ~ 2,200 ha of Timber Harvest Area • Two outfitters affected • Ten trapline holders affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • ~ 40 km of new right-of-way for roads and ~ 48 km transmission line will improve access to renewable resource areas from Mayo.	• Non-renewable resource areas directly affected: o ~7,800 ha of Mineral and Metal Mining Resource Area

Table 8: Fraser Falls - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Heritage and Cultural Resources		• No systematic survey has been undertaken to date. Investigations focused on Lansing Post and locations on Stewart River.	• Three (3) known historic sites and three (3) known archaeological sites located within Project site area. • Project site is nearly entirely in zone of high archaeological potential.
Employment and Business Activity	• Potential for increased direct and indirect employment opportunities in the Yukon: o ~ 4,800 construction phase jobs over three years o ~ 34 operations phase jobs per year • Potential for increased business activity and potential for economic growth: o ~ $553 Million of direct and indirect GDP generated during construction o ~ $6.7 Million of direct and indirect GDP generated per year during operations.	• Economic leakage from Yukon economy: o $404 Million of GDP leakage during construction o $1.4 Million of GDP leakage per year during operations phase	
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Mayo and Stewart Crossing are in best position to supply local construction labour.		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.

Table 8: Fraser Falls - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Traditional Aboriginal activities		• Priority site located within Traditional Territories of Na-cho Nyäk Dun First Nation. • ~ 40 km of new right-of-way for roads and ~ 48 km transmission line will improve access to potential traditional use areas from Mayo. • New reservoir will facilitate navigation and improve access to the land by boat.	• Loss of areas used for hunting and other traditional activities in ~ 31,200 ha reservoir area, plus along ~ 40 km of new right-of-way for roads and ~ 48 km transmission line • Presence of an Aboriginal fishing camp at Fraser Falls and fishing sites downstream of Fraser Falls.
Community Well-Being	• Project is compatible with Whitehorse's Community Economic Development Strategy aimed at developing economic opportunities and will help achieve their targets for economic and population growth. • Project will serve to support Mayo's goals to be an economically diverse regional service centre. o Mayo likely to gain new residents during operations phase that will assist in stabilizing the local population, and help diversify local employment opportunities.	• No displacement of infrastructure. • Stewart Crossing not likely to attract temporary workers or experience substantial adverse boom-bust effects on community well-being due to community size and available infrastructure and services. • Reservoir not likely to provide new recreational opportunities due to distance from Mayo. • Reservoir will not likely be visible from Mayo, a major road or highway.	• Whitehorse and Mayo likely to experience greatest influx of temporary workers during construction. • Whitehorse and Mayo likely to be experience increased competition for temporary accommodation, infrastructure and community services during construction. • Increased use of Highway 11 to Mayo and Mayo airport to access the Project site. • Increased use of Whitehorse airport by Project workers.

6.1.6 Fraser Falls Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	Effect Rating
Fish and Fish Habitat	Higher
Wildlife and Wildlife Habitat	Higher
Socio-economics	Moderate

Effects on fish and fish habitat are rated ***Higher*** than some of the other priority sites due to:

- Flooding of 31,200 ha of the Stewart River, Hess River and mouth of the Pleasant Creek. The reservoir footprint will also flood Horseshoe Slough Habitat Protection Area;
- Potential loss of spawning and rearing habitats for chinook and chum salmon within and downstream of reservoir footprint. The dam may also act as a migration barrier to upstream habitats for chinook and chum salmon and may present challenges to out-migrating juveniles;
- Potential loss of spawning and rearing habitats for Arctic grayling due to change in habitat from riverine (lentic) to reservoir (lotic) habitat; and
- Changes in reservoir volumes that may affect access to tributary streams.

Effects on wildlife and wildlife habitat are rated ***Higher*** than some of the other priority sites due to:

- Overlap with Horseshoe Slough Habitat Protection area;
- Overlap of WKAs of duck, Canada goose, woodland caribou, peregrine falcon, bald eagle;
- Documented presence of 2 species at risk (peregrine falcon and woodland caribou); and
- Potential for presence of 6 other species at risk (little brown myotis, rusty blackbird, bank swallow, American kestrel, sharp-tailed grouse, common nighthawk).

Effects on socio-economic attributes are rated ***Moderate*** in relation to the other priority sites due to:

- Largest reservoir footprint area (31,200 ha) resulting in overlap area with Renewable Resource Areas (special management and protected areas, trapping and outfitting concessions, timber harvest area), and areas potentially used for Traditional Aboriginal Activities;
- Overlap with 3,300 ha of Na-Cho Nyäk Dun Settlement Land may pose a development constraint;
- Presence of an Aboriginal fishing camp at Fraser Falls and fishing sites downstream of Fraser Falls;
- The presence of known sites of heritage and cultural resources and the priority site is located in an area of high archaeological potential.

- Does not require displacement of infrastructure; and
- Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy and in comparison to other priority sites.

6.2 Two Mile Canyon

6.2.1 Site Development Overview

Two Mile Canyon is a hydroelectric project on the Hess River, located in the Yukon River basin and Stewart River watershed, approximately 100 km east of Mayo. The total drainage is estimated to be 14,200 km^2. The dam site and reservoir footprint area are shown in Figure 8.

The preliminary project layout includes the following components:

- Dam (height 62 m; 68 m with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse with two additional turbine and generator bays for post 2065 upgrades;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

The estimated full supply level of the water reservoir is 611 m above sea level, flooding a total area of approximately 10,300 ha. The average drawdown level of the water reservoir is 602 m ASL, resulting in the reservoir water level fluctuating by 9 m over an average year.

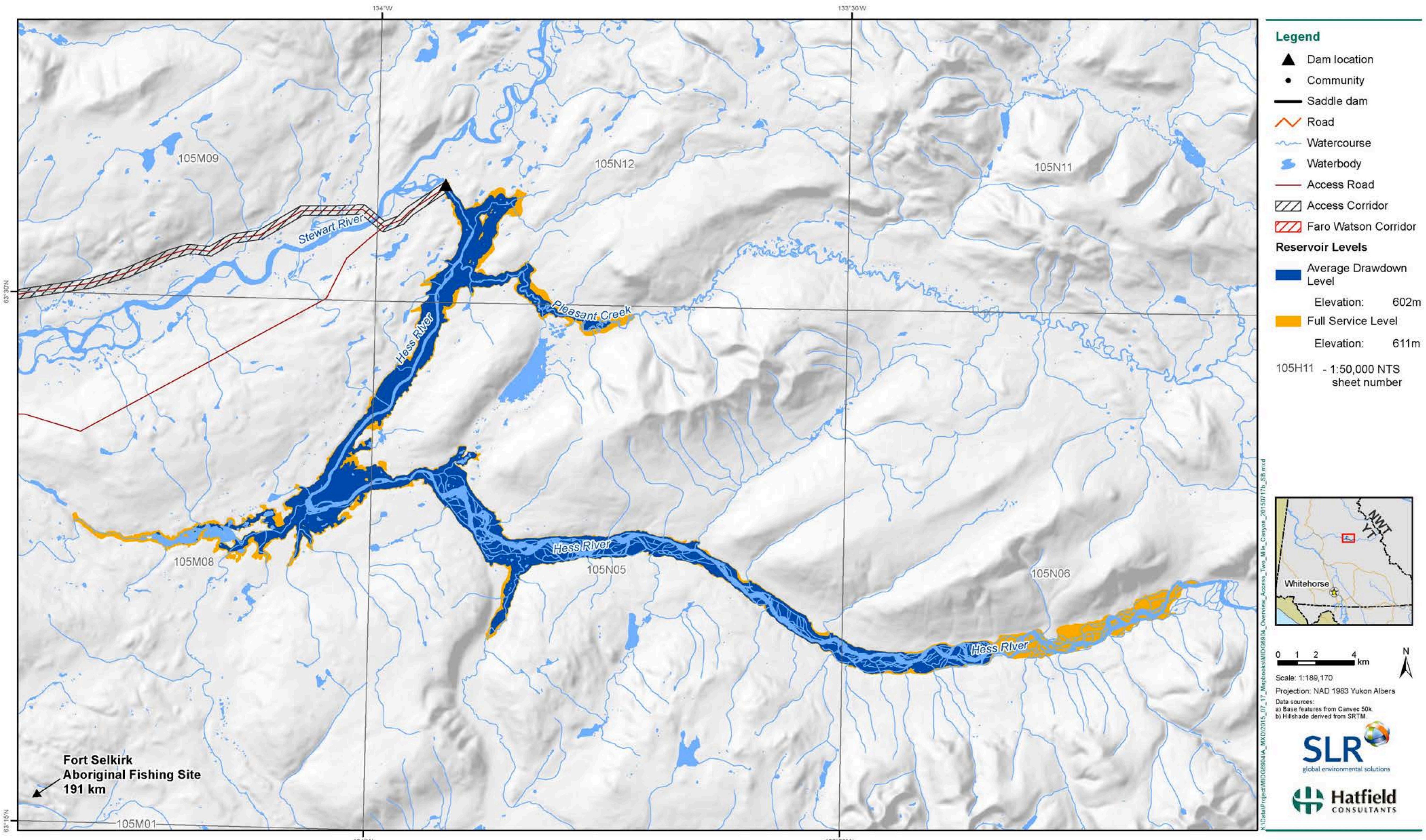
Approximately 110 km of new road and 113 km of new transmission line are required to access and interconnect the project.

Two Mile Canyon is able to meet 97 % forecasted Baseline 2065 energy demand and therefore has a predicted energy shortfall in the winter months of March and April. Meeting this shortfall will require other generation resource to fill the energy gap. This energy shortfall also implies that Two Mile Canyon is at its maximum storage reservoir size.

In addition to the spilled water (i.e. energy) and available energy in the months of May through October, there is “Must Run” energy from June to September which would require other Yukon facilities (e.g. Whitehorse) to restrict generation in the months from June to September to balance Yukon electrical load and demand.

A Class 5 cost estimate of its capital cost (i.e., 3 year construction phase) is approximately $919 Million, and operational costs are estimated at $8.5 Million per year over a 65 year lifespan.

Figure 8: Two Mile Canyon Priority Site and Reservoir Footprint



6.2.2 Environmental Setting

6.2.2.1 *Fish and Fish Habitat*

The Hess River supports populations of Arctic grayling, chinook, chum, lake trout, round whitefish, lake whitefish, northern pike, inconnu, lamprey, and slimy sculpin (DFO, 2015*b*), as well as least cisco (Elson, 1974). The Hess River is a glacier-fed system that is generally milky in appearance due to its high clay content. There are no documented barriers to fish passage in this system, and habitat values are rated as good to excellent for chinook, Arctic grayling and round whitefish (DFO, 2015*b*).

Pleasant Creek supports populations of chinook salmon, with salmon spawning as far upstream as the outlet of Pleasant Lake (DFO, 2015*b*).

6.2.2.2 *Aboriginal Fisheries Values*

The Hess River is part of the Na-Cho Nyäk Dun First Nation traditional territory and forms a part of the First Nation's chinook fishery.

6.2.2.3 *Wildlife and Wildlife Habitat*

There are no identified WKAs in the Two Mile Canyon priority site area, nor are there documented species at risk. Species at risk that may occur at that location (due to habitat and range overlap) include rusty blackbird, bank swallow, American kestrel, and possibly sharp-tailed grouse and common nighthawk. Rusty blackbird may be present along any ponds or side channels bordering the Hess River. There are confirmed bank swallow nest records along Stewart River, though breeding is uncommon in central Yukon. There is a confirmed American kestrel breeding record near Stewart Crossing. Sharp-tailed grouse could nest on river outwash meadows though known WKAs for this species are further west. Common nighthawks nest in wetland areas (as well as open pine stands). There have been summer sightings of this species nearby (along Stewart River) but no breeding records.

6.2.3 Socio-economic Setting

The Two Mile Canyon priority site is located along the Hess River. The nearest community to the site is the Village of Mayo. Mayo is approximately 130 kilometres from the priority site by existing and new roads, and 410 km north of Whitehorse by road. The Mayo airport is operated by the Yukon Government. The priority site is located within the traditional territory of the First Nation of Na-Cho Nyäk Dun (NND). Brief profiles of these communities were presented previously in Section 6.1.

6.2.4 Environmental Effects

Two Mile Canyon is expected to have a negative effect on fish and fish habitat for the following reasons:

- Hydroelectric development on the Hess River will result in the flooding of approximately 10,300 ha of the Hess River and lower reaches of Pleasant Creek, replacing riverine (lotic) habitat with reservoir (lentic) habitat. This may result in loss of spawning and rearing habitats for Arctic grayling, chinook and lamprey;

- Dam construction and reservoir creation may impede the migration of chinook and access to spawning grounds by Arctic grayling in the Hess River basin. Some impacts to fish migration may be mitigated through installation of fish passage structures;
- Changes to reservoir volumes may affect access by fish to tributary streams within the reservoir footprint;
- Off-channel habitat, both within the reservoir footprint as well as downstream in the Hess River and Stewart River drainages may be altered by changes to reservoir volumes; however impacts to the Stewart River may be relatively limited depending on the contribution of natural and altered flow regimes from the Hess River system; and
- Changes to reservoir volumes are expected to impact shoreline habitat for lake-dwelling fish species and may result in stranding of fish eggs for shoal-spawning fish.

Further details of effects by species and life stage are provided in Appendix C.

Two Mile Canyon is expected to have a neutral effect on wildlife. There are no known WKAs or species at risk occurrences overlapping with the proposed reservoir and therefore, no anticipated wildlife constraints. Species at risk that could breed within the reservoir footprint include the bank swallow, American kestrel and possibly the common nighthawk. The Two Mile Canyon reservoir is unlikely to affect the local rusty blackbird population based on the low abundance of wetlands along that section of Hess River compared to surrounding areas at the Hess River and Stewart River confluence.

6.2.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the Two Mile Canyon priority site are identified on Table 9. The Two Mile Canyon reservoir is the smallest among the six priority sites and will result in relatively small magnitude effects on the socio-economic attributes examined. It is likely to have no direct effects or the least adverse effects on:

- Special management and protected areas;
- Interim protected lands;
- Agricultural Areas;
- Trapping concession lands;
- Agricultural areas;
- Timber harvest areas;
- Oil and gas resource areas;
- Quarry permit area; and
- Areas potentially used for traditional activities by First Nations.

The up to 113 km of new right-of-way for roads and transmission line is the longest among the six property sites which will improve access to renewable and non-renewable resource areas and areas potentially used for traditional activities from Mayo. The new reservoir will facilitate navigation and access to land by boat. Improved access may be considered as a positive by some or a negative effect by others.

The Two Mile Canyon priority site has the potential to generate substantial employment opportunities and increased business activity during construction. The 3,600 direct and indirect jobs potentially generated in the Yukon is considered low in comparison to the other six priority sites. The increased business activity associated with $412 Million of GDP during construction is also lower than other priority sites. Positive effects will likely occur during a single three year construction phase, and will tend to be captured by Whitehorse and Mayo to the greatest extent. Conversely, these communities will also experience increased competition for temporary accommodation, infrastructure and community services during construction that have the potential to adversely affect community well-being. Noticeable effects on community well-being are less likely in Whitehorse, due to its larger population and more diverse economic base. Overall the project will support the socio-economic development goals of Whitehorse and local communities.

Table 9: Two Mile Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions		• No direct effects on: o Category A Settlement lands o Interim Protected Areas	• Aboriginal Settlement Lands affected: o ~ 2,000 ha overlap with Category B Lands • Other Land Tenure and Dispositions affected: o ~10,300 ha
Land Use Plans		• Project site is not located within the area of a draft or approved land use plan.	
Renewable Resources	• Up to ~ 113 km of new right-of-way for roads and transmission line will improve access to renewable resource areas from Mayo.	• No direct effects on: o Special management or protected areas o Agricultural areas o Timber Harvest Areas	• Renewable resource areas directly affected: o ~ 10,300 ha of trapping concession lands o ~ 10,300 ha of outfitting concession lands • Two outfitters affected • Six trapline holders affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • Up to ~ 113 km of new right-of-way for roads and transmission line will improve access to non-renewable resource areas from Mayo.	• Non-renewable resource areas directly affected: o ~380 ha of Mineral and Metal Mining Resource Area
Heritage and Cultural Resources		• No systematic survey has been undertaken to date.	• Priority site is nearly entirely in zone of high archaeological potential.

Table 9: Two Mile Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Employment and Business Activity	• Increased direct and indirect employment opportunities in the Yukon: o ~ 3,600 construction phase jobs over three years o ~ 33 operations phase jobs per year • Increased business activity and potential for economic growth: o ~ $412 Million of direct and indirect GDP generated during construction o ~ $6.6 Million of direct and indirect GDP generated per year during operations.	• Economic leakage from Yukon economy: o $301 Million of GDP leakage during construction o $1.4 Million of GDP leakage per year during operations phase	
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Mayo and Stewart Crossing in best position to supply local construction labour.		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.

Table 9: Two Mile Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Traditional Aboriginal Activities		• Project site located within Traditional Territories of Na-cho Nyäk Dun First Nation. • Up to ~ 113 km of new right-of-way for roads and transmission line will improve access to potential traditional use areas from Mayo. • New reservoir will facilitate navigation and improve access to the land by boat.	• Loss of areas used for hunting and other traditional activities in 10,300 ha reservoir area. • Located within the Na-Cho Nyäk Dun fishery.
Community Well-Being	• Project is compatible with Whitehorse's Community Economic Development Strategy aimed at developing economic opportunities and will help achieve their targets for economic and population growth. • Project will serve to support Mayo's goals to be an economically diverse regional service centre. o Mayo likely to gain new residents during operations phase that will assist in stabilizing the local population, and help diversify local employment opportunities.	• No displacement of infrastructure. • Stewart Crossing not likely to attract temporary workers or experience substantial adverse boom-bust effects on community well-being. • Reservoir not likely to provide new recreational opportunities due to distance from Mayo. • Reservoir will not likely be visible from Mayo, a major road or highway.	• Whitehorse and Mayo likely to experience greatest influx of temporary workers during construction. • Whitehorse and Mayo likely to be experience increased competition for temporary accommodation, infrastructure and community services during construction. • Increased use of Highway 11 to Mayo and Mayo airport to access the Project site. • Increased use of Whitehorse airport by Project workers.

6.2.6 Two Mile Canyon Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	Effect Rating
Fish and Fish Habitat	Higher
Wildlife and Wildlife Habitat	Lower
Socio-economics	Lower

Effects on fish and fish habitat are rated ***Higher*** than some of the other priority sites due to:

- Flooding of 10,300 ha of Hess River and Pleasant Creek which may result in loss of spawning and rearing habitats for chinook and chum salmon. The dam may also act as a migration barrier to upstream habitats for chinook and chum salmon and may present challenges to out-migrating juveniles.
- Potential loss of spawning and rearing habitats for Arctic grayling due to change in habitat from riverine (lentic) to reservoir (lotic) habitat.
- Changes in reservoir volumes that may affect access to tributary streams.
- Spawning and rearing habitat may be lost for species of unknown conservation status.

Effects on wildlife and wildlife habitat are rated ***Lower*** than some of the other priority sites due to:

- Absence of protected or conservation area;
- Absence of documented species at risk within the reservoir footprint area;
- Lack of reservoir footprint area overlap with any Wildlife Key Areas; and
- Potential for presence of 4 species at risk (rusty blackbird, bank swallow, American kestrel and common nighthawk).

Effects on socio-economic attributes are rated ***Lower*** that some of the other priority sites due to:

- Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy;
- Lowest reservoir footprint area of overlap with Renewable Resource Areas (trapping and outfitting concessions);
- Low reservoir footprint area of overlap with Non-Renewable Resource Areas (quartz claims, quartz mining land use permit area);
- Smallest reservoir footprint area overlap with areas used for Traditional Aboriginal Activities (10,300 ha);
- Does not require displacement of infrastructure; and
- Effects to community well-being are not expected to be widespread or noticeable.

It is noteworthy, that the overlap with 2,000 ha of Na-Cho Nyäk Dun Settlement Land and the fact that project site is located within an area of high archaeological potential may, however, pose a considerable development constraint.

6.3 Granite Canyon

6.3.1 Site Development Overview

Granite Canyon is a hydroelectric project on the Pelly River, located in the Yukon River Basin approximately 20 km east of Pelly Crossing. The total drainage is estimated to be 45,900 km^2. The dam site and reservoir footprint area are shown in Figure 9.

The preliminary project layout includes the following components:

- Dam (height 52 m; 60 m with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse with two additional turbine and generator bays for post 2065 upgrades;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

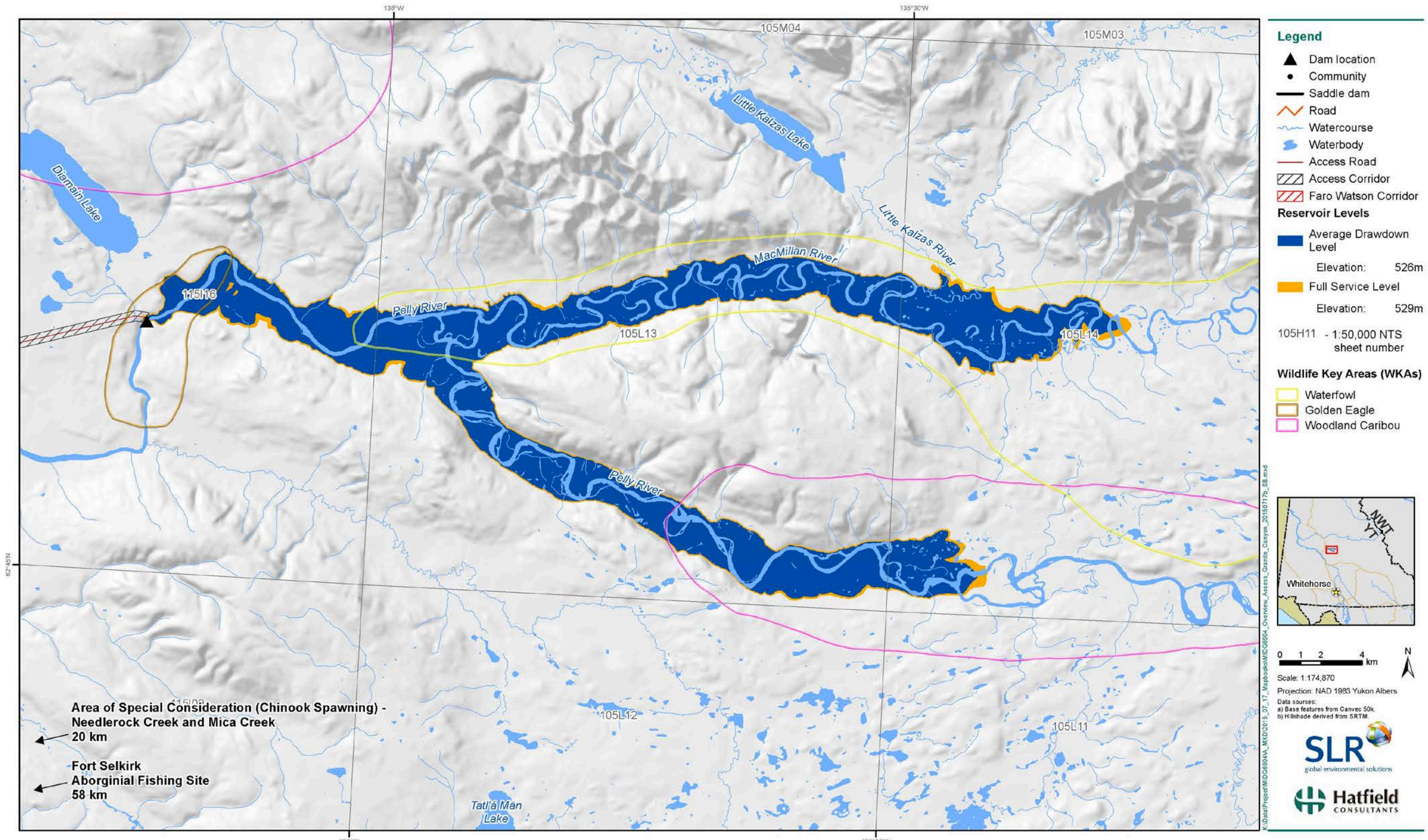
The estimated full supply level of the water reservoir is 529 m above sea level, flooding a total area of approximately 17,600 ha. The average drawdown level of the water reservoir is 526 m ASL, resulting in the reservoir water level fluctuating by 3 m over an average year.

Approximately 15 km of new road and 15 km of new transmission line are required to access and interconnect the project.

Granite Canyon is able to meet the forecasted Baseline 2065 energy demand for the Yukon. In addition to the spilled water (i.e. energy) in the months of May through December, there is “Must Run” energy from June to October which would require other Yukon facilities (e.g. Whitehorse) to restrict generation in the months from June to October to balance Yukon electrical load and demand.

A Class 5 cost estimate of its capital cost (i.e., 3 year construction phase) is approximately $847 Million, and operational costs are estimated at $7.2 Million per year over a 65 year lifespan.

Figure 9: Granite Canyon Priority Site and Reservoir Footprint



6.3.2 Environmental Setting

6.3.2.1 *Fish and Fish Habitat*

Fish species found in both the Pelly and South MacMillan River systems include chinook, Arctic grayling, lake trout, round whitefish, broad whitefish, lake whitefish, inconnu, northern pike, Arctic lamprey, slimy sculpin, lake chub, longnose sucker, burbot, and least cisco (Sparling 2003; DFO 2015lb).

During the summer, runs of chinook salmon ascend the Pelly River to spawning habitats widely distributed throughout the watershed. The Pelly River accounts for approximately 20% of the Canadian portion of the Yukon River basin chinook salmon populations (Osbourne, 2005). Chum salmon are also known to migrate into the drainage during the late fall, but spawning areas are not well known (Rodger Alfred, 2006 in Selkirk District Renewable Resource Council, 2006; Yukon Department of Tourism and Culture 2015*a*). Chinook also make use of the South MacMillan River (Elson 1974).

Downstream of the project site, Needlerock Creek is considered to be an important spawning tributary for chinook salmon and is listed on the Yukon Placer Fish Habitat Management System as an Area of Special Consideration, indicating it is an area containing fisheries or aquatic resources of ecological or cultural importance (Government of Yukon 2012; Yukon Placer Implementation Screening Committee and Yukon Placer Working Committee, 2005). The spawning populations in Mica and Needlerock Creeks contribute to a larger sub-drainage population that is thought to be genetically distinct and separate from populations in other sub-drainages of the Yukon River Basin (Beacham, in press. In SDRRC and Can-Nic-a-Nick Env. S. 2006).

6.3.2.2 *Aboriginal Fisheries Values*

The proposed dam site is located within the Selkirk First Nation traditional territory. The continued maintenance of Chinook salmon spawning populations, specifically in Mica and Needlerock Creeks near the community of Pelly Crossing, and access to local rearing streams by juvenile salmon, are important management objectives for the Selkirk First Nation (SFN), the Selkirk District Renewable Resource Council (SDRRC), the Department of Fisheries and Oceans Canada (DFO) and the people who live in the region (Selkirk District Renewable Res. Council and Can-Nic-a-Nick Env. S 2006).

Known Aboriginal fishing sites and traditional fish camps on the Pelly River include:

- Fort Selkirk just downstream of the Pelly River outlet (downstream of the priority site; Yukon Department of Tourism and Culture 2015*a*);
- Pelly River near the confluence with Little Kalzas River (within the reservoir footprint; DFO 2015*b*); and
- Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (downstream of the priority site; Yukon Department of Tourism and Culture 2015*b*).

6.3.2.3 *Wildlife and Wildlife Habitat*

Based on the Yukon WKA inventory there are three WKAs overlapping with the Granite Canyon priority site configuration:

- A swan and duck WKA overlaps with the north arm of the proposed Granite Canyon reservoir. Up to 14 trumpeter swans, 896 ducks, and 26 Canada Goose were observed in the wetlands associated with this river during June 2007 aerial surveys. The value of this WKA for spring and fall staging is unknown (there have been no spring staging surveys of the area and only one fall staging survey in 1988) but it is recognized for its value to nesting birds from June to August;

- A portion of a caribou WKA overlaps with the southern arm of the proposed reservoir. This WKA is based on anecdotal information regarding winter habitat use by an unknown herd (possibly part of the Tatchun herd). Winter range for caribou consists of mature, low elevation forests with abundant lichens. This habitat is utilized during the winter (October to April); and

- A golden eagle WKA is found at the western tip of the proposed reservoir at full service and average drawdown level aimed at protecting an identified cliff nest site. This species is an alpine breeder, feeding mainly on rodents and birds.

There are no known wildlife occurrences of species at risk, though rusty blackbird, bank swallow, American kestrel, and possibly common nighthawk could be present. Rusty blackbird may be present along the edges of MacMillan River. American kestrels have been sighted along the MacMillan River but there are no known breeding records for this species in the watershed (Sinclair et al. 2003). Common nighthawks nest in wetland areas (as well as open pine stands). There have been summer sightings of this species along MacMillan and Pelly Rivers but there are no known breeding records (Sinclair et al. 2003).

6.3.3 Socio-economic Setting

The Granite Canyon priority site is located along the Pelly River and the South MacMillan River. The nearest communities to the Project site (within approximately 100 kilometres) are the settlements of Pelly Crossing, Stewart Crossing and the Village of Carmacks. A brief profile of Stewart Crossing was provided previously.

Pelly Crossing is located along the Klondike Highway approximately 20 kilometres from the priority site by existing and new roads, and 285 kilometres north of Whitehorse by road. The community is served by a 916 m airstrip.

In 2014, the population was approximately 383 people, an increase of 36% since 2005. There are approximately 132 private occupied dwellings in Pelly Crossing with an additional 11 staff units provided by Yukon Housing Corporation (Yukon Government, 2014b). The community is served by a school (Kindergarten to Grade 12), a nursing station, ambulance and medivac services, a recreation centre with arena and curling rink, a youth centre, as well as a seasonal heritage centre and swimming pool (Yukon Government, 2014b). Yukon Collage provides a local campus in Pelly Crossing with courses offered online or through tele-conferencing facilities (Yukon Government, 2014b). Policing in the community is provided by an RCMP detachment.

Pelly Crossing's economic activity is largely based on government services and tourism. Fort Selkirk and the replica of Big Jonathan House are the key tourist attractions (Yukon Government, 2014b). In 2011, there was a total labour force of 190. Pelly Crossing's unemployment rate was at 22% in 2011 (Yukon Bureau of Statistics, 2015b).

The Project site is located within the traditional territory of the Selkirk First Nation (SFN). In 2014, the SFN had a population of approximately 672 members, approximately half of which live in or near Pelly Crossing. The unemployment rate for the Selkirk First Nation in Pelly Crossing was approximately 47% in 2011.

The 2007 Selkirk First Nation/Pelly Crossing Integrated Community Sustainability Plan's key economic development objective is to increase access to training and to allow for a broader range of employment choices for its members. The SFN Development Corporation is working on generating its own source revenue to enhance the First Nation's capacity to undertake or enhance services to their community. They work with Yukon College to ensure that the community campus facilities are meeting local needs. The SFN also works with the Government of Yukon to provide adequate housing options for all those that want to live in the community. Pelly Crossing and the SFN continue to improve health and social services that promote individual and community well-being (Selkirk First Nations, 2007).

The Village of Carmacks is located on the Yukon River, approximately 120 kilometres from the Granite Canyon priority site. It is located to the south of Pelly Crossing where the Klondike Highway and the Robert Campbell Highway intersect. The community is served by a 1524 m airstrip.

In 2014, the population of Carmacks was approximately 532 people, an increase of 41% since 2005. There are approximately 196 private occupied dwellings in Carmacks with an additional 16 social housing units and 14 staff units provided by Yukon Housing Corporation (Yukon Government, 2014c). The village is served by a school (Kindergarten to Grade 12), a nursing station, ambulance and medivac services, and a recreational complex. Policing in the community is provided by an RCMP detachment. Yukon College provides upgrading, GED, computer training and various occupation-related courses, as well as nightly internet access (Yukon Government, 2014c).

Carmacks' economic activity is driven largely by the provision of government services, mining and construction which support a labour force of approximately 350 persons (Yukon Government, 2014c). Tourism is a growing economic sector within the Village with tourists visiting Carmacks for Tagé Cho Hudän Interpretive Centre, a local museum, as well as a rest stop for those travelling on the Klondike and Robert Campbell Highway or along the Yukon River. The Village offers travellers a hotel, bed and breakfast and a campground (Yukon Government, 2014c).

6.3.4 Environmental Effects

The environmental effects of Granite Canyon on fish and fish habitat are considered to be negative for the following reasons:

- Hydroelectric development of the Granite Canyon site will result in the flooding of approximately 170 km^2 of the Pelly River and South MacMillan rivers, replacing riverine (lotic) habitat with reservoir (lentic) habitat. This may result in loss of spawning and rearing habitats for Arctic grayling, chinook, chum and lamprey within the reservoir footprint.
- Dam construction and reservoir creation may impede the migration of chinook and chum and may impede access to spawning grounds by Arctic grayling in the Pelly and South MacMillan Rivers and their tributaries upstream of the dam. Some effects to fish migration may be mitigated through installation of fish passage structures.

- Changes to reservoir volumes may affect access by fish to tributary streams and may alter off channel habitat within the reservoir footprint.
- Off-channel habitat may be altered due to changes in flow regimes downstream in the mainstem Pelly River drainage; and
- Changes in reservoir volumes are expected to impact shoreline habitat for lake-dwelling fish species and may result in stranding of fish eggs for shoal-spawning fish.

Further details regarding effects by species and life stage are provided in Appendix C.

The environmental effects of the Granite Canyon priority site on wildlife are considered to be negative for the following reasons:

- Trumpeter swans are likely to be displaced by the Granite Canyon reservoir (at full service and average drawdown levels) as it will eliminate the shallow wetlands that provide hummocky nesting substrates and productive littoral feeding zones (i.e., aquatic invertebrates and submerged/emergent plants will be harder to access and far less abundant). Cygnets would likely be subject to mortality from the initial flooding.

Although declines in waterfowl may occur, a duck WKA of greater value is situated approximately four kilometres south of the Granite Canyon site. It is known as the Needlerock Complex and consists of a large cluster of boreal ponds with stable water levels and vegetated littoral zones (containing sedges, pond lilies and some bulrushes). There are an estimated 12,500 breeding birds in the WKA at Needlerock, including 11 species of duck. Breeding waterfowl density was appraised at 4.5 broods per occupied pond.

The reservoir overlaps with a caribou range, but the caribou in the WKA is anecdotal and the herd present needs to be confirmed.

There are no known wildlife species at risk occurrences in the priority site area, but the Granite Canyon reservoir could displace up to five species at risk by eliminating breeding and foraging habitat.

6.3.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the Granite Canyon priority site are identified on Table 10. The Granite Canyon reservoir is moderately sized among the six priority sites. The greatest potential for adverse effects is on:

- First Nation settlement lands (Category A and Category B lands); and,
- Known heritage and cultural resources.

It is likely to have no direct effects or the least adverse effects on:

- Special management and protected areas;
- Interim protected lands;
- Agricultural areas;
- Timber harvest areas;
- Oil and gas resource areas;
- Mineral and metal mining resource areas; and
- Quarry permit areas.

The ~ 15 km of new right-of-way for roads and transmission line is relatively short among the six priority sites and is not expected to substantially improve access to renewable and non-renewable resource areas or areas potentially used for traditional activities from Pelly Crossing. However, the new reservoir itself will facilitate navigation and improve access to the land by boat. Improved access may be considered as a positive by some or a negative effect by others.

The Granite Canyon priority site may affect several known Aboriginal fishing sites and traditional fish camps on the Pelly River (i.e., at Fort Selkirk just downstream of the Pelly River outlet; on the Pelly River near the confluence with Little Kalzas River (within the reservoir footprint); and on Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing downstream of the project site. The Granite Canyon project has the potential to generate substantial employment opportunities and increased business activity during construction. Nevertheless, the approximately 3,300 direct and indirect jobs potentially generated in the Yukon is the smallest among the six priority sites. Similarly, the increased business activity associated with $380 Million of GDP during construction is also the smallest. Positive effects will likely occur during a single three year construction phase, and will tend to be captured by Whitehorse to the greatest extent.

Despite current limitations, Pelly Crossing, Carmacks and Stewart Crossing are best position to supply local construction labour given travel distance by road (~ 100 km). However, given the priority site location, Pelly Crossing, Carmacks and Stewart Crossing are not likely to attract temporary workers or experience substantial adverse boom-bust effects on community well-being.

Whitehorse will likely experience increased competition for temporary accommodation, infrastructure and community services during construction, but noticeable effects on community well-being are not considered likely, due to its larger population and more diverse economic base. The numbers of jobs and the increased business activity created during operations is smaller than the other six priority sites. Overall the project will support the socio-economic development goals of Whitehorse, the Selkirk First Nation and Pelly Crossing.

Table 10: Granite Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions		• No direct effects on Interim Protected Areas	• Aboriginal Settlement Lands affected: o ~ 3,400 ha overlap with Category A Lands o ~ 5,400 ha overlap with Category B Lands • Other Land Tenure and Dispositions affected: o ~4,600 ha
Land Use Plans		• Project site is not located within the area of a draft or approved land use plan.	
Renewable Resources		• No direct effects on: o Special management or protected areas o Agricultural areas o Timber Harvest Areas • ~ 15 km of new right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Pelly Crossing.	• Renewable resource areas directly affected: o ~ 17,500 ha of trapping concession lands o ~ 15,000 ha of outfitting concession lands • Two outfitters affected • Three trapline holders affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • ~ 15 km of new right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Pelly Crossing.	• Non-renewable resource areas directly affected: o ~35 ha of Mineral and Metal Mining Resource Area
Heritage and Cultural Resources		• Preliminary inventories and surveys undertaken on the Pelly River in the Granite Canyon area carried out in 1977 and 1981.	• Several 20th century cabins, a graveyard and six (6) known archaeological sites located within Project site area. • Project site is nearly entirely in zone of high archaeological potential.

Table 10: Granite Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Employment and Business Activity	• Increased direct and indirect employment opportunities in the Yukon: o ~ 3,300 construction phase jobs over three years o ~ 28 operations phase jobs per year • Increased business activity and potential for economic growth: o ~ $380 Million of direct and indirect GDP generated during construction o ~ $5.6 Million of direct and indirect GDP generated per year during operations.	• Economic leakage from Yukon economy: o $277 Million of GDP leakage during construction o $1.2 Million of GDP leakage per year during operations phase	
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Pelly Crossing, Carmacks and Stewart Crossing are best position to supply local construction labour given travel distance by road (~ 100 km)		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.
Traditional Aboriginal Activities		• Project site located within Traditional Territory of the Selkirk First Nation and on the edge of the Traditional Territory of Na-cho Nyäk Dun First Nation. • ~ 15 km of new right-of-way for roads and transmission line will not improve access to potential	• Loss of areas used for hunting and other traditional activities in 17,600 ha reservoir area. • Presence of an Aboriginal fishing sites within the reservoir footprint (i.e., Pelly River near the confluence with Little Kalzas River);

Table 10: Granite Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
		traditional use areas from Pelly Crossing. • New reservoir will facilitate navigation and improve access to the land by boat.	• Presence of Aboriginal fishing sites downstream: Fort Selkirk downstream of the Pelly River outlet; and Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing.
Community Well-Being	• Project is compatible with Whitehorse's Community Economic Development Strategy aimed at developing economic opportunities and will help achieve their targets for economic and population growth. • Project will serve to support the goals of the Selkirk First Nation/Pelly Crossing Integrated Community Sustainability Plan (2007) regarding improved access to training and a range of employment choices. o Local communities likely to gain new residents during operations phase that will assist in stabilizing the local population, and help diversify local employment opportunities. • Reservoir may provide new recreational opportunities due to proximity to Pelly Crossing.	• No displacement of infrastructure. • Pelly Crossing, Carmacks and Stewart Crossing not likely to attract temporary workers or experience substantial adverse boom-bust effects on community well-being. • Reservoir will not likely be visible from Pelly Crossing, a major road or highway.	• Whitehorse likely to experience greatest influx of temporary workers during construction. • Increased use of the Klondike Highway to Pelly Crossing and Pelly Crossing airport to access the Project site. • Increased use of Whitehorse airport by Project workers.

6.3.6 Granite Canyon Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	**Effect Rating**
Fish and Fish Habitat	Higher
Wildlife and Wildlife Habitat	Moderate
Socio-economics	Higher

Effects on fish and fish habitat are rated ***Higher*** than some of the other priority sites due to:

- Flooding of 170 km^2 of the Pelly River mainstem and a portion of the South Macmillan River;
- Downstream effects on Mica and Needlerock Creek Areas of Special Cultural Consideration;
- Potential loss of spawning and rearing habitats for chinook and chum salmon. The dam may also act as a migration barrier to upstream habitats for chinook and chum salmon and may present challenges to out-migrating juveniles;
- Downstream effects on Mica and Needlerock Creek Areas of Special Cultural Consideration;
- Potential loss of spawning and rearing habitats for Arctic grayling and due to change in habitat from riverine (lentic) to reservoir (lotic) habitat;
- Changes in reservoir volumes that may affect access to tributary streams; and
- Spawning and rearing habitat may be lost for species of unknown conservation status.

Effects on wildlife and wildlife habitat are rated ***Moderate*** in relation to the other priority sites due to:

- Absence of protected or conservation area;
- Overlap of WKAs for waterfowl and woodland caribou (possibly Tatchun herd);
- Presence of two documented species at risk within the reservoir footprint area (woodland caribou and trumpeter swan); and
- Potential for presence of 5 other species at risk (rusty blackbird, bank swallow, sharp-tailed grouse, American kestrel, common nighthawk).

Effects on socio-economic attributes are rated ***Higher*** that some of the other priority sites due to:

- Economic benefits (i.e., jobs and business activity) are considered moderate but substantial in the context of the Yukon economy;
- Presence of Aboriginal fishing sites within the reservoir footprint (Pelly River near the confluence with Little Kalzas River) and downstream: Fort Selkirk downstream of the Pelly River outlet; and Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing.
- High area of reservoir footprint overlap with Selkirk First Nation Settlement Land;
- Known sites of heritage and cultural resources; and
- Project site is located within an area of high archaeological potential.

6.4 Detour Canyon

6.4.1 Site Development Overview

Detour Canyon is a hydroelectric project on the Pelly River, located in the Yukon River Basin approximately 80 km downstream (northwest) of Faro. The total drainage area is estimated to be 28,500 km^2. The dam site and reservoir footprint area are shown in Figure 10.

The preliminary project layout includes the following components:

- Dam (height 57 m; 72 m with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse with two additional turbine and generator bays for post 2065 upgrades;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

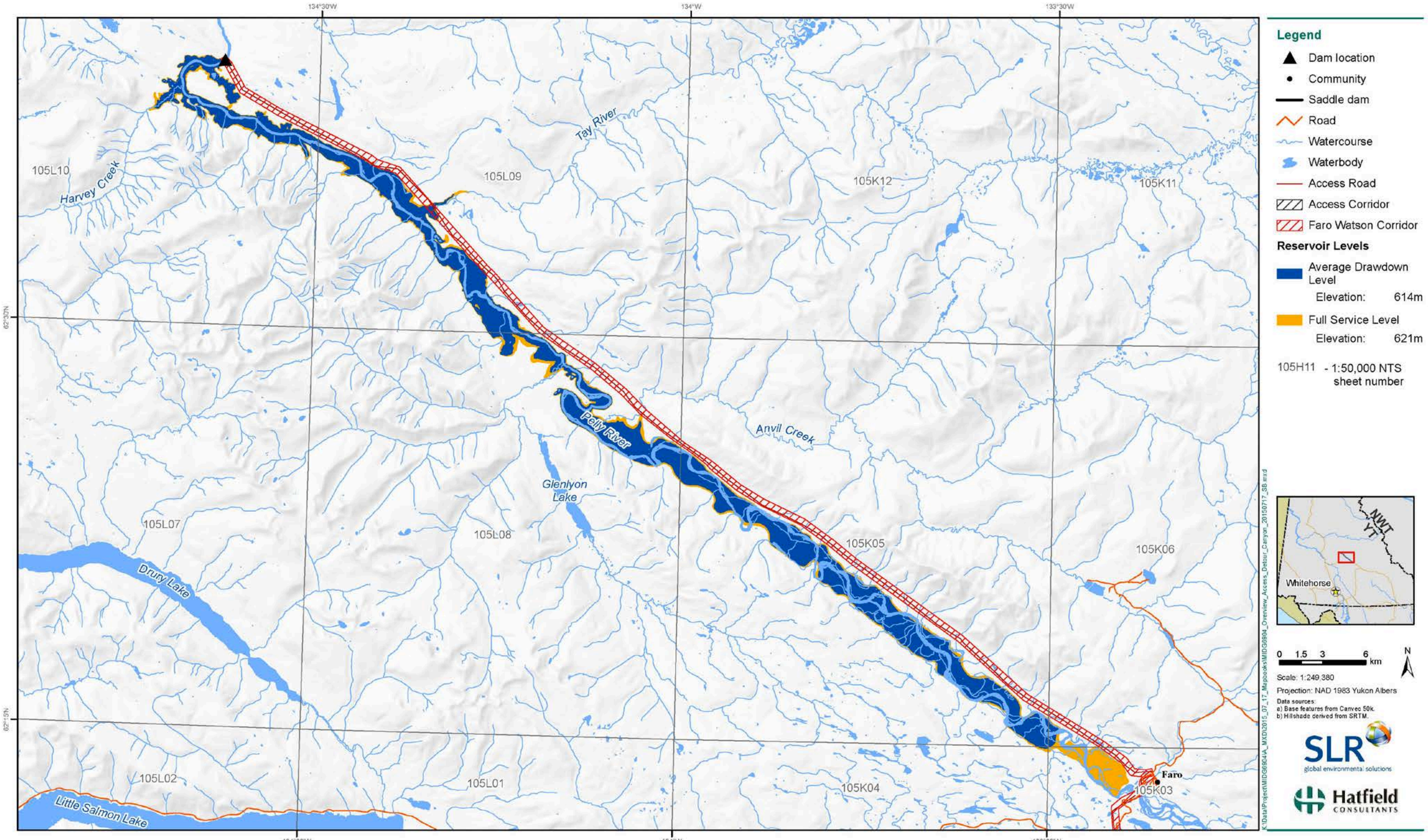
The estimated full supply level of the water reservoir is 621 m above sea level, flooding a total area of approximately 13,000 ha. The average drawdown level of the water reservoir is 614 m ASL, resulting in the reservoir water level fluctuating by 7 m over an average year.

Approximately 90 kilometres of new road and 83 kilometres of new transmission line are required to access and interconnect the project.

Detour Canyon is able to meet the forecasted Baseline 2065 energy demand for the Yukon. In addition to the spilled water (i.e. energy) in the months of May through November, there is "Must Run" energy from June to October which would require other Yukon facilities (e.g. Whitehorse) to restrict generation in the months from June to October to balance Yukon electrical load and demand.

A Class 5 cost estimate of its capital cost (i.e., 3 year construction phase) is approximately $1,413 Million, and operational costs are estimated at $9.5 Million per year over a 65 year lifespan.

Figure 10: Detour Canyon Priority Site and Reservoir Footprint



6.4.2 Environmental Setting

6.4.2.1 *Fish and Fish Habitat*

Fish species found in the Pelly River include chinook, chum (Rodger Alfred. 2006 in Selkirk District Renewable Resource Council, 2006; Yukon Department of Tourism and Culture 2015*a*), Arctic grayling, lake trout, round whitefish, broad whitefish, lake whitefish, inconnu, northern pike, Arctic lamprey, slimy sculpin, lake chub, longnose sucker, burbot, and least cisco (Sparling 2003; DFO 2015*b*). The Pelly River accounts for approximately 20% of the Canadian portion of the Yukon River basin chinook salmon populations (Osbourne, 2005). Very high numbers of chinook species have been recorded in Harvey Creek near the dam site. Arctic grayling and slimy sculpin have also been recorded in this tributary (DFO 2015*b*). Adult chinook have been documented in most Pelly River tributaries. In 2004, chinook were documented in Anvil Creek, Big Campbell River, Blind Creek, Glenlyon River, Hoole River, Kalzas River, North Macmillan River, Pelly Lakes outlet, Pelly River, Prevost Creek, Ross River, and the South Macmillan River. Mark-recapture studies conducted in the Pelly River yielded the highest number of tags in the Pelly River mainstem and the Ross River, while highest densities of chinook were recorded on Blind Creek and the Ross River. Previous years have also documented spawning in Earn River, Little Kalzas Creek, Laforce Creek, and Otter Creek (Mercer, 2005).

6.4.2.2 *Aboriginal Fisheries Values*

The proposed dam site is located within the Selkirk First Nation traditional territory. The continued maintenance of chinook salmon spawning populations, specifically in Mica and Needlerock Creeks near the community of Pelly Crossing, and access to local rearing streams by juvenile salmon, are important management objectives for the Selkirk First Nation (SFN), the Selkirk District Renewable Resource Council (SDRRC), the Department of Fisheries and Oceans Canada (DFO) and the people who live in the region (Selkirk District Renewable Res. Council and Can-Nic-a-Nick Env. S 2006).

Known Aboriginal fishing sites and traditional fish camps on the Pelly River include:

- Fort Selkirk just downstream of the Pelly River outlet (downstream of the project site; Yukon Department of Tourism and Culture 2015*a*);
- Pelly River near the confluence with Little Kalzas River (downstream of the project site; DFO 2015*b*); and
- Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Downstream of the project site; Yukon Department of Tourism and Culture 2015*b*).

6.4.2.3 *Wildlife and Wildlife Habitat*

Detour Canyon reservoir would overlap with none of the WKAs identified to date. The area is not recognized as being of notable value for waterfowl including swans; likely because there are few ponds associated with this section of the Pelly River except near Faro (i.e., near the southeastern tip at full service level). Nor have WKAs been identified for raptors, ungulates, mid-sized and large carnivores, or woodland caribou. There are no known species at risk occurrences in the project area, though habitat may exist for species nesting in banks (little brown myotis (bats) and bank swallows), gravel outwashes (sharp-tailed grouse), or open habitats (American kestrel, and possibly common nighthawk). Breeding records for bank swallows do exist further to the southeast on the Pelly River.

6.4.3 Socio-economic Setting

The Detour Canyon priority site is located along the Pelly River. The nearest community to the Project site (within approximately 100 kilometres) is the Town of Faro. The Village of Ross River is located 53 kilometres further south along the Robert Campbell Highway.

Faro is located approximately 83 kilometres from the priority site by existing and new roads, and 357 kilometres north of Whitehorse by road. The Faro airport is operated by the Yukon Government.

In 2014, the population of Faro was approximately 374 people, similar to that in 2005 (i.e., 381), but considerably lower than its peak of over 2,100 in 1982. There are approximately 170 private occupied dwellings in Faro with an additional 10 social housing units and 14 staff units provided by Yukon Housing Corporation (Yukon Government, 2014d).

The community is served by a school (Kindergarten to Grade 12), a nursing station, ambulance and medivac services. Faro residents have access to a wide range of community recreational facilities, including: a golf course and driving range, a seniors complex, a large recreational complex, swimming pool and sports fields (Yukon Government, 2014d). Policing in the community is provided by an RCMP detachment. Yukon College provides a local campus in Faro with courses offered online or through tele-conferencing facilities (Yukon Government, 2014c).

Faro’s economic activity is driven largely by the provision of government services, mining and construction which support a labour force of approximately 195 persons (Yukon Government, 2014d). Faro’s unemployment rate was at 16% in 2011. Faro was formerly the home of one of the largest open pit lead zinc mines in Canada that has since closed. Since 2003, planning for remediation and closure of the “Faro Mine Complex” has been a major undertaking, involving years of planning, technical studies and community consultations. The overall goal is to bring the Faro Mine complex to final closure and reclamation in a manner that maximizes benefits for Yukoners through employment and business opportunities.

Tourists visit Faro for the wildlife viewing. It hosts the Crane and Sheep Viewing Festival and the Campbell Regional Interpretive Centre. Faro offers visitors three motels, two bed and breakfasts and one campground (Yukon Government, 2014d).

The Faro Official Community Plan (2003) indicates that the town desires to make the economic transition from mining to new opportunities such as wilderness tourism, and to promote itself as retirement community and artistic community. Other goals include government decentralization, encouraging home-based businesses and developing its potential for mining history tourism (Town of Faro, 2003).

The Detour Canyon Project site is located in the traditional territories of both the Selkirk First Nation and the Kaska Dena Nation (Ross River Dena and Liard First Nations). A brief profile of the Selkirk First Nation was provided previously. In 2013, approximately 85% of Ross River’s population were of Kaska descent and members of the Ross River Dena. The Ross River Dena Council provides health and social services to its members and utilizes the community facilities and services in the community of Ross River. In 2011, the labour force of the Ross River Dena First Nation was 280, an increase of 18% since 2006. The unemployment rate was approximately 30% in 2011 (AANDC, 2014b).

6.4.4 Environmental Effects

The environmental effects of the Detour Canyon priority site on fish and fish habitat are considered to be negative for the following reasons:

- The proposed dam site will result in the flooding of approximately 13,100 ha of the Pelly River mainstem and its tributaries. The reservoir footprint includes the lower reaches of Anvil Creek, which has historically been impacted by mining operations, resulting in the introduction of mine tailings, cyanide, and major sediment releases (DFO 2015b);
- Creation of the Detour Canyon reservoir will result in alterations to several highly productive tributary outlets for chinook within the reservoir footprint;
- Fluctuations in water levels downstream of the dam site may impact spawning and rearing habitats;
- Migration of anadromous fish species will be impacted by the dam site; and
- The reduction or loss of highly productive spawning habitats within and upstream of the reservoir footprint.

Further details regarding effects by species and life stage are provided in Appendix C.

The Detour Canyon priority site is expected to have a low effect on wildlife. There are no known WKAs or species at risk occurrences overlapping with the proposed Detour Canyon reservoir and, therefore, no anticipated wildlife constraints.

6.4.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the Detour Canyon priority site are identified on Table 11. The Detour Canyon reservoir is relatively small in size in comparison to the other six priority sites. It is likely to have no direct effects or the least adverse effects on:

- Category A Settlement Lands;
- Special management and protected areas;
- Agricultural areas;
- Oil and gas resource areas;
- Quarry permit areas; and
- Other land tenure and dispositions

The ~ 83 kilometres of new right-of-way for roads and transmission line is relatively long among the six priority sites and, as such, is expected to improve access to renewable and non-renewable resource areas or areas potentially used for traditional activities from Faro. Similarly, the new reservoir itself will facilitate navigation and improve access to the land by boat. Improved access may be considered as a positive by some or a negative effect by others.

The Detour Canyon priority site has the potential to affect several known Aboriginal fishing sites and traditional fish camps on the Pelly River (i.e., at Fort Selkirk just downstream of the Pelly River outlet; on the Pelly River near the confluence with Little Kalzas River; and on Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing downstream of the priority site). Although the distance of this priority site to known Aboriginal fishing sites and camp locations downstream is far, there remains some potential for the reduction or loss of highly productive spawning habitats within and upstream of the reservoir footprint to negatively affect areas downstream.

The reservoir may also provide new recreational opportunities from Faro, but this may be limited due the 7 m water fluctuation over an average year.

The Detour Canyon project has the potential to generate substantial employment opportunities and increased business activity during construction. The approximately 5,500 direct and indirect jobs potentially generated in the Yukon is considered to be moderate to high relative to the other the six priority sites. Similarly, the increased business activity associated with $634 Million of GDP during construction is also moderate to high. Positive effects will likely occur during a single three year construction phase, and will tend to be captured by Whitehorse and Faro to the greatest extent.

Despite current limitations, Faro is in the best position to supply local construction labour given travel distance by road (~ 100 km). Whitehorse and Faro will likely experience increased competition for temporary accommodation, infrastructure and community services during construction. Noticeable effects on community well-being in Whitehorse are not considered likely, due to its larger population and more diverse economic base. The numbers of jobs and the increased business activity created during operations is largely comparable with the other six priority sites. Overall the project has the potential to support the socio-economic development goals of Whitehorse, Faro, the Ross River Dena Council and the Selkirk First Nation.

Table 11: Detour Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions			• Aboriginal Settlement Lands of the Selkirk First Nation affected: o ~ 3 ha overlap with Category B Lands • Interim Protected Lands affected: o ~ 2,300 ha • Other Land Tenure and Dispositions affected: o ~ 6 ha
Land Use Plans		• Project site is not located within the area of a draft or approved land use plan.	
Renewable Resources		• No special management or protected areas directly affected • No agricultural areas directly affected • ~ 83 km of new right-of-way for roads and transmission line will improve access to renewable resource areas from Faro. No access roads currently exist.	• Renewable resource areas directly affected: o ~ 13,000 ha of trapping and outfitting concession lands o ~ 1000 ha of Timber Harvest Area • Four outfitters affected • Two trapline holders affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • ~ 83 km of new right-of-way for roads and transmission line will improve access to non-renewable resource areas from Faro.	• Non-renewable resource areas directly affected: o ~10,800 ha of Mineral and Metal Mining Resource Areas (e.g., Quartz claims and leases)
Heritage and Cultural Resources		• No archaeological or historic sites documented in the Detour Canyon area. No systematic survey has been undertaken to date.	• Project site is nearly entirely in zone of high archaeological potential.

Table 11: Detour Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Employment and Business Activity	• Increased direct and indirect employment opportunities in the Yukon: o ~ 5,500 construction phase jobs over three years o ~ 37 operations phase jobs per year • Increased business activity and potential for economic growth: o ~ $634 Million of direct and indirect GDP generated during construction o ~ $7,3 Million of direct and indirect GDP generated per year during operations.	• Economic leakage from Yukon economy: o $463 Million of GDP leakage during construction o $1.6 Million of GDP leakage per year during operations phase	
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Faro in best position to supply local construction labour.		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.
Traditional Aboriginal Activities		• Project site located within Traditional Territories of Kaska Dene Nation and Selkirk First Nation. • ~ 83 km of new right-of-way for roads and transmission line will improve access to potential traditional use areas from Faro. No access roads currently exist. • New reservoir will facilitate navigation and improve access to the land by boat from	• Loss of areas used for hunting and other traditional activities in ~ 13,000 ha reservoir area. • Presence of Aboriginal fishing sites downstream at Fort Selkirk downstream of the Pelly River outlet; on the Pelly River near the confluence with Little Kalzas River; and on Tatl'á Män Lake at the head

Table 11: Detour Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
		Faro.	of Mica Creek near Pelly Crossing.
Community Well-Being	• Project may assist in achieving Faro's goal for economic transition from mining to new opportunities • Faro likely to gain new residents during operations phase. • Reservoir may provide new navigation and recreational opportunities from Faro. • Project may provide employment and business opportunities for Pelly Crossing and Ross River.	• No displacement of infrastructure	• Whitehorse and Faro likely to experience greatest influx of temporary workers during construction. • Whitehorse and Faro likely to experience increased competition for temporary accommodation, infrastructure and community services during construction. • Increased use of the Robert Campbell Highway to Faro and Faro airport to access the Project site. • Increased use of Whitehorse airport by Project workers.

6.4.6 Detour Canyon Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	**Effect Rating**
Fish and Fish Habitat	Higher
Wildlife and Wildlife Habitat	Lower
Socio-economics	Lower

Effects on fish and fish habitat are rated ***Higher*** than some of the other priority sites due to:

- Flooding of 13,000 ha of the Pelly River mainstem and its tributaries;
- Overlap with lower Anvil Creek Area of Special Cultural Consideration;
- Downstream effects on Mica and Needlerock Creek Areas of Special Cultural Consideration;
- Potential loss of spawning and rearing habitats for chinook and chum salmon. The dam may also act as a migration barrier to upstream habitats for chinook and chum salmon and may present challenges to out-migrating juveniles;
- Potential loss of spawning and rearing habitats for Arctic grayling and due to change in habitat from riverine (lentic) to reservoir (lotic) habitat;
- Changes in reservoir volumes that may affect access to tributary streams; and
- Spawning and rearing habitat may be lost for species of unknown conservation status.

Effects on wildlife and wildlife habitat are rated ***Lower*** than some of the other priority sites due to:

- Absence of protected or conservation areas;
- Lack of reservoir footprint area overlap with any Wildlife Key Areas;
- Absence of documented species at risk within the reservoir footprint area; and
- Potential for presence of 5 other species at risk (little brown myotis (bats), bank swallow, sharp-tailed grouse, American kestrel, common nighthawk).

Effects on socio-economic attributes are rated ***Lower*** than some of the other priority sites due to:

- Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy;
- Small reservoir footprint area (13,000 ha);
- Small area of reservoir footprint overlap with Liard First Nation/Ross River Dena Interim Protected Land;

- Low reservoir footprint overlap area with areas potentially used for Traditional Aboriginal Activities;
- Low reservoir footprint area overlap with Renewable Resource Areas;
- Lowest overlap with Other Land Tenures and Dispositions;
- Moderate overlap with Non-Renewable Resource Areas (e.g., quartz claim, quartz lease, quartz mining land use permit, placer claim);
- Does not require displacement of infrastructure; and
- No overlap with known Heritage and Cultural Resource sites (although the project site is located within an area of high archaeological potential).

6.5 Slate Rapids & Hoole Canyon

6.5.1 Site Development Overview

Slate Rapids and Hoole Canyon run-of river (ROR) is a cascade of two sites with Slate Rapids located upstream on the Pelly River providing water storage and generation, and Hoole Canyon ROR located downstream operating as a run-of-river facility with no substantial water storage (but a large headpond is needed to create head for generation purposes). The Slate Rapids dam site and reservoir footprint area are shown in Figure 11. The site of the Hoole Canyon ROR is shown in Figure 12.

A Class 5 cost estimate of the combined capital cost (i.e., over two three year construction phases) is approximately $2,962 Million, and operational costs are estimated at $15.9 Million per year over a 65 year lifespan. This assumes that there is no pre-existing Faro to Watson Lake transmission line.

6.5.1.1 *Slate Rapids*

Slate Rapids is a hydroelectric project on the Pelly River, located in the Yukon River Basin approximately 75 kilometres east of the community of Ross River. The total drainage is estimated to be 5,400 km^2.

The preliminary project layout includes the following components:

- Dam (height 37 m; 57 with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 2-unit powerhouse;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

The estimated full supply level of the water reservoir is 892 m above sea level, flooding the existing Fortin and Pelly Lakes. The average drawdown level of the water reservoir is 887 m ASL, resulting in the reservoir water level fluctuating by 5 m over an average year.

Assuming a future transmission line between Faro and Watson Lake, less than 10 kilometres of new road and less than 10 kilometres of new transmission line are required to access and interconnect the project. Without a future transmission line, approximately 145 kilometres of transmission line is required.

Slate Rapids is not able to supply all of the forecasted Baseline 2065 energy demand on a standalone basis, but based on a targeted 5 m average drawdown[2] it closes much of the forecast gap, with energy shortfalls in December through May.

6.5.1.2 *Hoole Canyon*

As the downstream project in the cascade, Hoole Canyon is a ROR hydroelectric project on the Pelly River, located in the Yukon River Basin approximately 30 km upstream of the community of Ross River. The total drainage is estimated to be 9,900 km^2.

The preliminary project layout includes the following components:

- Weir;
- Fish passage structures;
- Water intake;
- Conveyance;
- 2-unit powerhouse;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

The Hoole Canyon site is considered to be a run of river (ROR) facility with a large headpond of approximately 23 km^2 resulting in an estimated full supply level at 807 m above sea level.

Assuming a future transmission line between Faro and Watson Lake, 2 km of new road and 2 km of new transmission line are required to access and interconnect the project.

While Slate Rapids alone is not able to supply all of the forecasted Baseline 2065 energy demand, the cascaded layout of Slate Rapids and Hoole Canyon ROR is able to provide more energy than the forecasted Baseline 2065 energy need.

[2] Maximum drawdowns will be larger but the actual maximum drawdown will need to be determined after further study is performed in the future (post 2015).

Figure 11: Slate Rapids Priority Site and Reservoir Footprint

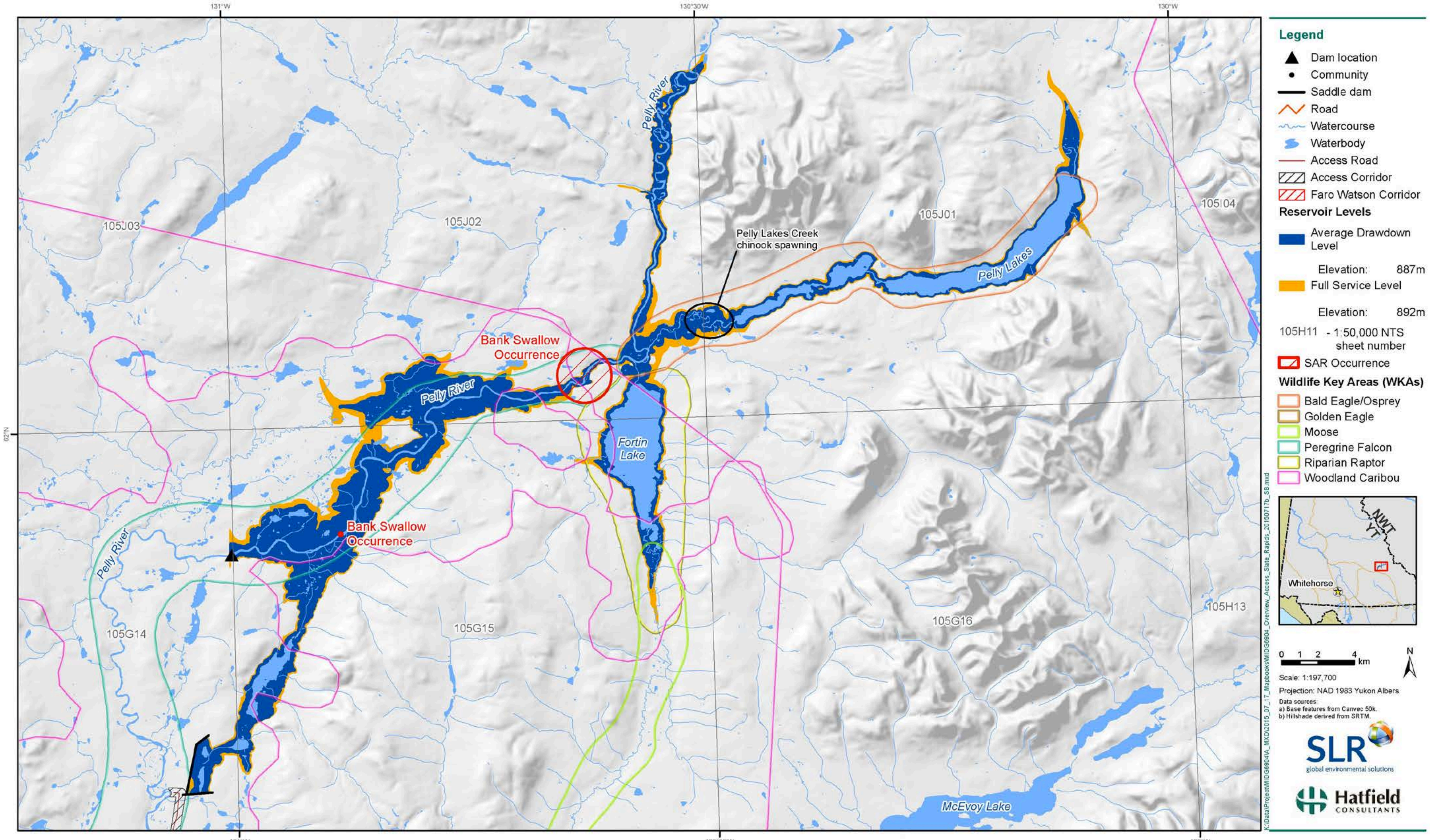
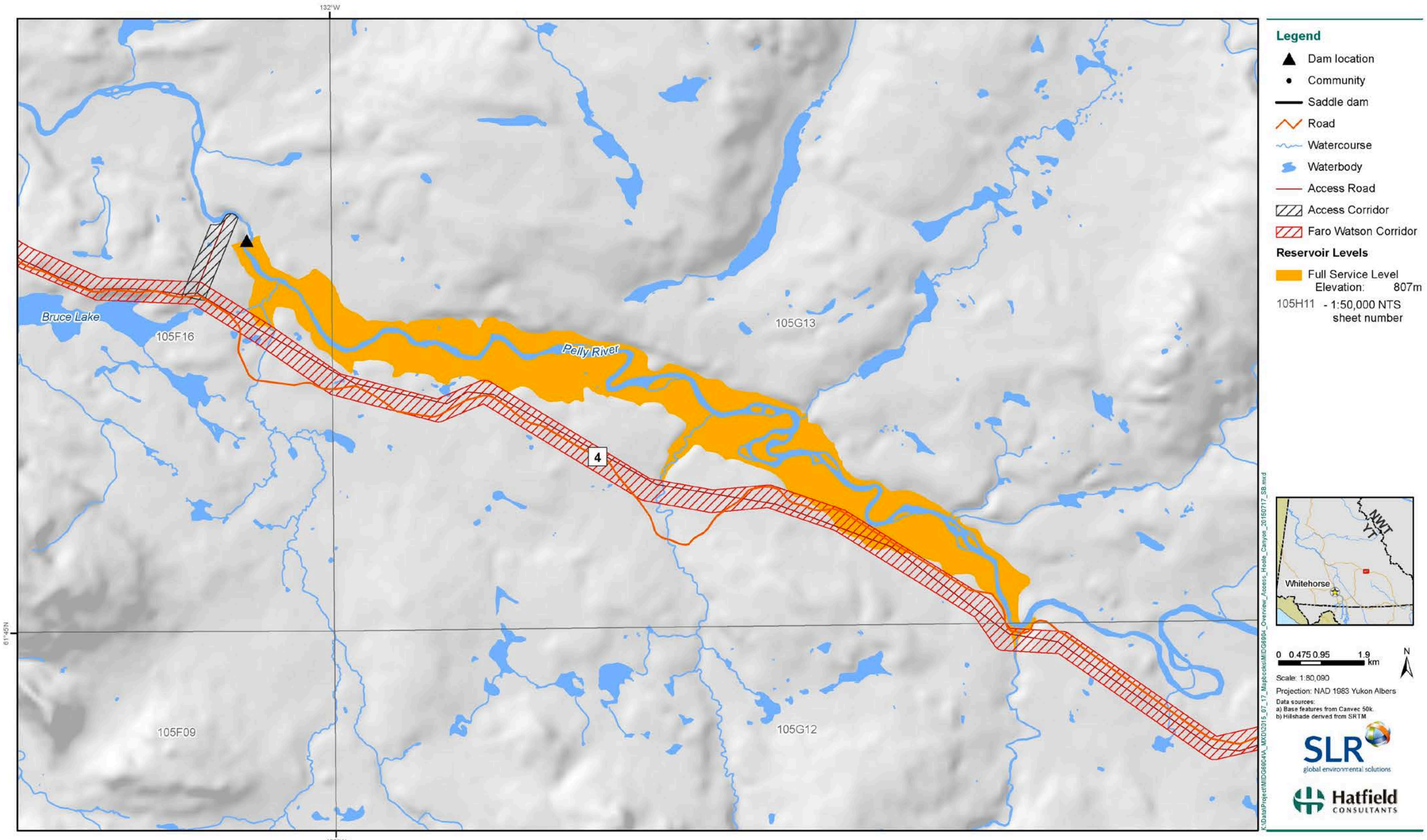


Figure 12: Hoole Canyon Run-of River Priority Site



6.5.2 Environmental Setting

6.5.2.1 *Fish and Fish Habitat*

Species present in the Pelly Lakes area of the Pelly watershed include chinook, chum (Rodger Alfred. 2006 in Selkirk District Renewable Resource Council, 2006; Yukon Department of Tourism and Culture 2015*a*), Arctic grayling, lake trout, round whitefish, broad whitefish, lake whitefish, inconnu, northern pike, Arctic lamprey, slimy sculpin, lake chub, longnose sucker, burbot, and least cisco (Sparling 2003; DFO, 2015a). Chinook salmon have been documented in the Pelly Lakes Creek, and a 2 km-long chinook spawning area is documented from the Pelly Lake outlet extending downstream. Species documented in Fortin Lake include Arctic grayling, broad whitefish, inconnu, lake trout, lake whitefish, round whitefish, and northern pike (DFO, 2015a).

6.5.2.2 *Aboriginal Fisheries Values*

No Aboriginal fishing sites or camps are known to exist in this portion of the Pelly River drainage. Farther downstream in the Pelly drainage, Aboriginal fishing sites and traditional fish camps on the Pelly River are documented for the Selkirk First Nation and include:

- Fort Selkirk just downstream of the Pelly River outlet (downstream of the project site; Yukon Department of Tourism and Culture 2015*a*);
- Pelly River near the confluence with Little Kalzas River (downstream of the project site; DFO, 2015*a*); and
- Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Downstream of the project site; Yukon Department of Tourism and Culture 2015*b*).

6.5.2.3 *Wildlife and Wildlife Habitat*

Based on the Yukon WKA inventory there are four WKAs overlapping with the Slate Rapids project configuration:

- Slate Rapids reservoir would be wholly encompassed within the Finlayson caribou herd WKA, as would the Hoole Canyon Run-of-River (ROR). This WKA is known to contain upland habitat for rutting and courtship and is large enough to likely contain other seasonal habitats including low elevation foraging habitat;

- A riparian raptor WKA occurs along Pelly River from the centre of the reservoir (immediately northeast of Fortin Lake) eastward to the Ross Lake community. Suitable nesting cliffs occur along this section of the river for peregrine falcon, and for golden eagles at higher elevations. This WKA extends across the proposed Hoole Canyon Run-of-River project;

- A bald eagle and osprey WKA would overlap almost entirely with the east arm of the Slate Rapids reservoir. The WKA represents summer (June to August) breeding habitat for these species, which suggests that large riparian trees are present along this section of Pelly River. The shoreline and riparian zone of Fortin Lake has also been identified as a riparian raptor WKA, likely because of its habitat potential for ospreys, bald eagles, and/or rough-legged hawks; and,

- A moose WKA overlaps with the southern tip of the Slate Rapids reservoir at Fortin Lake. This area is recognized as a late winter (February to April) range for the species when it is constrained by snow depth (mobility and food availability). The moose WKA extends approximately 19 km southwards. Eleven moose were observed in this WKA during a March 1994 survey.

There are two documented bank swallow colonies along the Pelly River, one is located two to three kilometres northeast of Fortin Lake, and the other approximately 15 km further southwest; both overlap with the proposed Slate Rapids reservoir.

No other species at risk have been identified in the vicinity of the Slate Rapids reservoir, or in the Hoole Canyon ROR project footprint. Rusty blackbirds have been observed in the surrounding area but there are no known breeding records for this species in eastern Yukon (Sinclair et al. 2003). Little brown myotis (bats) colonies could occur along the banks of the Pelly as it is within this species' range and there appears to be an abundance of cliffs and large trees with potential crevices/cracks for maternal hibernating colonies. There are no American kestrel sightings in the project area, but this could be a function of the area's remote location. American kestrels are found throughout the Yukon. The project may be within the range of the western jumping mouse.

6.5.3 Socio-economic Setting

The Slate Rapids and Hoole Canyon Project sites are located along the Pelly River, including Fortin Lake and Pelly Lakes. The Hoole Canyon site is located downstream of the Slate Rapids site. The nearest communities to the Project sites (within approximately 100 km) are Ross River (an unincorporated settlement) and the Town of Faro. A brief profile of the Town of Faro was provided previously. The Project sites are located in the traditional territory of the Kaska Dena Nation and more specifically the Ross River Dena Council. A brief profile of the Ross River Dena was provided previously.

Ross River is located at confluence of the Ross and Pelly Rivers, approximately 410 kilometres northeast of Whitehorse. Ross River is approximately 30 kilometres from the Hoole Canyon priority site by existing and new roads, and 90 kilometres from the Slate Rapids priority site. Ross River is served by a 1558 m airstrip.

In 2014, the population of Ross River was approximately 374 persons, an increase of 8.5% since 2005 of which 294 people identified themselves as Aboriginal, from the Ross River Dena. There are approximately 130 private occupied dwellings in Ross River with an addition 14 social housing units and 12 staff units provided by Yukon Housing Corporation (Yukon Government, 2014e).

Ross River has one school (Kindergarten to Grade 12). A new recreation centre was built in 2013 including a hockey rink and multi-sport areas (Yukon Government, 2014e). The community is served by a nursing station, ambulance and medivac services located in the Town of Faro. Policing in the community is provided by a local RCMP detachment. Yukon College provides a local campus in Ross River with courses offered online or through tele-conferencing facilities (Yukon Government, 2014e).

Ross River's economic activity is driven largely by the provision of government services and tourism which support a labour force of approximately 215 persons (Yukon Government, 2014e). Ross River's unemployment rate was 30% in 2011 (Yukon Bureau of Statistics, 2015c).

6.5.4 Environmental Effects

The environmental effects of Slate Rapids and Hoole Canyon on fish and fish habitat are considered to be negative for the following reasons:

- The hydroelectric project would result in the flooding of approximately 19,100 ha and would encompass the existing footprints of Fortin Lake, Pelly Lakes, as well as a number of smaller lakes, in addition to portions of the Pelly River mainstem. Although the footprints of Pelly and Fortin lakes would only be increased marginally from their present size, shoreline habitats are expected to be modified substantially due to the difference in elevation between full crest and reservoir drawdown;
- Portions of the mainstem Pelly River including identified spawning reaches for chinook salmon will be inundated within the reservoir footprint;
- Migration of anadromous fish is expected to be impeded by the presence of the project dam. Some impacts to fish migration may be mitigated through installation of fish passage structures; and
- Downstream habitats may be impacted by altered flow regimes, reduced inputs of sediment and woody debris, and changes to water quality.

Further details regarding effects by species and life stage is provided in Appendix C.

The environmental effects of Slate Rapids on wildlife are considered to be negative for the following reasons:

- The Slate Rapids reservoir has a proposed dam height of 37 m and could flood two swallow colonies at average drawn down and full service levels. More specifically, filling of the reservoir in summer could cause direct mortality to swallow eggs and nestlings on an annual basis. The magnitude of project effects would depend on the size of the colonies.

- The project may eliminate riparian raptor breeding habitat through all but the north arm of the reservoir. More specifically, flooding would likely cause the loss of large riparian trees by decreasing the nutrient levels they require for survival (Polzin 2015; Herbison 2015), thereby displacing nesting bald eagles. Flooding could eliminate nesting cliff ledges and cause direct mortality to peregrine falcon chicks along the west arm of the reservoir during the summer filling period. The project would have indirect effects as well, by reducing local food (fish and bird) availability as a result of decreased aquatic and riparian productivity. Productivity levels can affect both species abundance and diversity (Bunnell and Dupuis 1993; Banner and MacKenzie 1998).

- The project could eliminate bat hibernation sites if reservoir are at average or full service levels at the end of the active season (late September/early October) when little brown myotis (bats) are seeking winter refuge; the reservoir could also eliminate breeding habitat for this species and cause direct mortality of pups during the summer rearing season (July, August). Maternity colonies can contain several females and their young.

- The project could eliminate wetland habitat for rusty blackbirds. This is a riparian obligate that is vulnerable to becoming endangered in Canada but is relatively common in wetlands of southern Yukon (Sinclair et al. 2003). American kestrel potentially breeding in open wetland areas and although the reservoir may cause the fatality of nestlings or the displacement of breeding pairs, it likely will not cause notable declines in the regional population.

- The project would flood a small portion of a recognized moose winter range but the project overlap is small (4%) and there is a second identified moose winter range five kilometres to the east that fulfills the same function. The moose population is not at risk in the Yukon.

6.5.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the Slate Rapids and Hoole Canyon projects are identified on Table 12. The upstream project reservoir is moderately sized among the six priority sites. The greatest potential for adverse effects is on:

- Interim protected lands;
- Non-renewable resource areas;
- Known heritage and cultural resources; and
- Community well-being due to project phasing and the disruption caused by the potential diversion of the Robert Campbell Highway for the Hoole Canyon project.

It is likely to have no direct effects or the least adverse effects on:

- First Nation settlement lands;
- Special management and protected areas;
- Agricultural areas;
- Timber harvest areas;
- Oil and gas resource areas; and
- Quarry permit areas.

The ~ 10 kilometres of new right-of-way for roads and transmission line (Slate Rapids) and the ~ 50 kilometres of new right-of-way for roads and 2 kilometres for transmission line (Hoole Canyon) are relatively short among the six priority sites which and, as such, are not expected to substantially improve access to renewable and non-renewable resource areas or areas potentially used for traditional activities. However, the new reservoir itself will facilitate navigation and improve access to the land by boat. Improved access may be considered as a positive by some or a negative effect by others.

The Slate Rapids and Hoole Canyon projects have some potential to affect several known Aboriginal fishing sites and traditional fish camps on the Pelly River (i.e., at Fort Selkirk just downstream of the Pelly River outlet; on the Pelly River near the confluence with Little Kalzas River; and on Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing downstream of the project site). Although the distance of this priority site to known Aboriginal fishing sites and camp locations downstream is far, there remains some potential for the reduction or loss of highly productive spawning habitats within and upstream of the reservoir footprint to negatively affect areas downstream.

These projects have the potential to generate substantial employment opportunities and increased business activity during construction. The approximately 11,600 direct and indirect jobs potentially generated in the Yukon is the largest among the six priority sites. Similarly, the increased business activity associated with $1,329 Million of GDP during construction is also the largest. Nevertheless, these positive effects will likely occur during the two distinct construction phases approximately 15 years apart, and will tend to be captured by Whitehorse to the greatest extent.

Despite current limitations, Ross River and Faro are best positioned to supply local construction labour given travel distance by road (~ 100 km). Whitehorse and Faro will likely experience increased competition for temporary accommodation, infrastructure and community services during construction, but noticeable adverse effects on the community well-being of Whitehorse are not considered likely, due to its larger population and more diverse economic base.

The numbers of jobs and the increased business activity created during operations is the largest among the six priority sites. Overall the project will support the socio-economic development goals of Faro.

Table 12: Slate Rapids and Hoole Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions		• No Aboriginal Settlement Lands affected.	• Interim Protected Lands affected: o ~ 4,900 ha • Other Land Tenure and Dispositions affected: o ~ 130 ha
Land Use Plans		• Project site is not located within area of a draft or approved land use plan.	
Renewable Resources		• No direct effects on: o Special management or protected areas o Agricultural areas o Timber Harvest Areas • New right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Ross River. Hoole Canyon Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas.	• Renewable resource areas directly affected: o ~ 19,100 ha of trapping concession lands o ~ 19,100 ha of outfitting concession lands • Two outfitters affected • One trapline holder affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • New right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Ross River. Hoole Canyon Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas.	• Non-renewable resource areas directly affected: o ~19,100 ha of Mineral and Metal Mining Resource Area

Table 12: Slate Rapids and Hoole Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Heritage and Cultural Resources		• A preliminary survey of historic and archaeological sites was completed in 1981, however, no systematic survey has been conducted elsewhere in the Hoole Canyon Project area • No archaeological or historic sites documented in the Slate Rapids area. No systematic survey has been undertaken to date.	• Direct effects on: o One known (1) archaeological site. • Project site is nearly entirely in zone of high archaeological potential.
Employment and Business Activity	• Increased direct and indirect employment opportunities in the Yukon: o ~ 11,600 construction phase jobs over two three year periods due to phasing o ~ 61 operations phase jobs per year once both facilities are operational • Increased business activity and potential for economic growth: o ~ $1,329 Million of direct and indirect GDP generated during construction for both projects o ~ $12.3 Million of direct and indirect GDP generated per year once both facilities are operational	• Economic leakage from Yukon economy: o $1,970 Million of GDP leakage during construction o $2.6 Million of GDP leakage per year during operations phase	

Table 12: Slate Rapids and Hoole Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Ross River and Faro are in best position to supply local construction labour.		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.
Traditional Aboriginal Activities		• Project site located within Traditional Territory of Kaska Dene Nation • New right-of-way for roads and transmission line will not substantially improve access to Traditional activity areas from Ross River. Hoole Canyon Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas. • New Slate Rapids reservoir will facilitate navigation and improve access to the land by boat.	• Loss of areas used for hunting and other traditional activities in 19,100 ha reservoir area. • Presence of Aboriginal fishing sites downstream at Fort Selkirk downstream of the Pelly River outlet; on the Pelly River near the confluence with Little Kalzas River; and on Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing.

Table 12: Slate Rapids and Hoole Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Community Well-Being	• Ross River and Faro are likely to gain new residents during operations phase.		• Staged project development will result in disruption at two separate time intervals approximately 15 years apart. • Whitehorse likely to experience greatest influx of temporary workers during construction. • The nearest communities to the Project site, Ross River and Faro are most likely to experience increased competition for temporary accommodation, infrastructure and community services during construction. • Hoole Canyon Project may require diversion of a portion of the Robert Campbell Highway. This will likely result in disruption to traffic and transportation along this corridor. • Increased use of the Robert Campbell Highway from Ross River and community airports to access the Project site from Whitehorse. • Increased use of Whitehorse airport by Project workers.

6.5.6 Slate Rapids and Hoole Canyon Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	**Effect Rating**
Fish and Fish Habitat	Higher
Wildlife and Wildlife Habitat	Moderate
Socio-economics	Moderate

Effects on fish and fish habitat are rated ***Higher*** than some of the other priority sites due to:

- Flooding of 19,100 ha encompassing Fortin Lake, Pelly Lakes, portions of the Pelly River mainstem and a number of smaller lakes; Downstream effects on Mica and Needlerock Creek Areas of Special Cultural Consideration;
- Fluctuation of levels of Pelly Lakes and Fortin Lake (effects on shoreline habitat);
- Potential loss of spawning and rearing habitats for chinook and chum salmon. The dam may also act as a migration barrier to upstream habitats for chinook and chum salmon and may present challenges to out-migrating juveniles;
- Potential loss of spawning and rearing habitats for arctic grayling and due to change in habitat from riverine (lentic) to reservoir (lotic) habitat;
- Changes in reservoir volumes that may affect access to tributary streams; and
- Spawning and rearing habitat may be lost for species of unknown conservation status.

Effects on wildlife and wildlife habitat are rated ***Moderate*** in relation to the other priority sites due to:

- Absence of protected or conservation area;
- Overlap of WKAs for woodland caribou (Finlayson herd), moose and riparian raptors;
- Documented presence of 1 species at risk (bank swallows); and
- Potential for presence of 4 other species at risk (little brown myotis (bats), American kestrel, western jumping mouse, rusty blackbird).

Effects on socio-economic attributes are rated ***Moderate*** in relation to the other priority sites due to:

- Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy. This project offers the potential for the highest economic benefits relative to the other six priority sites.
- Highest area of reservoir footprint overlap with Liard First Nation/Ross River Dena Interim Protected Land;
- High reservoir footprint overlap area with areas potentially used for Traditional Aboriginal Activities;

- Presence of Aboriginal fishing sites downstream: Fort Selkirk downstream of the Pelly River outlet; Pelly River near the confluence with Little Kalzas River; and Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing;
- Highest area of reservoir footprint overlap with Non-Renewable Resource Areas (coal exploration licence, coal licence, quartz claim, quartz mining land use permit;
- Known sites of heritage and cultural resources;
- The project site is located within an area of high archaeological potential; and
- Potential displacement of Robert Campbell highway and associated community disruption is largely mitigable through highway diversion prior to site development.

6.6 False Canyon and Middle Canyon

6.6.1 Site Development Overview

False Canyon and Middle Canyon ROR is a cascade of two sites with False Canyon located upstream on the France River providing water storage and generation, and Middle Canyon ROR located downstream operating as a run-of-river facility with no water storage (but a headpond needed to create head for generation purposes). The False Canyon dam site and reservoir footprint area are shown in Figure 13. The site of the Middle Canyon ROR is shown in Figure 14.

A Class 5 cost estimate of the combined project capital cost (i.e., over two 3 year construction phases) is approximately $1,959 Million, and operational costs are estimated at $12.5 Million per year over a 65 year lifespan. This assumes that there is no pre-existing Faro to Watson Lake transmission line.

6.6.1.1 *False Canyon*

False Canyon is a hydroelectric project on the Frances River, located in the Liard River Basin approximately 75 km north of Watson Lake. The total drainage is estimated to be 12,200 km^2.

The preliminary project layout includes the following components:

- Dam (height 56 m; 65 with excavation) with a spillway control structure;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

The estimated full supply level of the water reservoir is 742 m above sea level, flooding a total area of approximately 26,100 ha (including raising Frances Lake level by 8 m). The average drawdown level of the water reservoir is 737 m ASL, resulting in the reservoir water level fluctuating by 5 m over an average year. That means Frances Lake will typically change elevation from +8 m in the summer to +3 m at the end of winter on an annual basis[3].

[3] The maximum drawdown will be larger than 5 m with the potential to draw the reservoir level down to +0 m or the natural lake level.

Assuming a future transmission line between Faro and Watson Lake, less than 10 km of new road and less than 10 km of new transmission line are required to access and interconnect the project. Without a Faro to Watson Lake transmission line, approximately 310 km of transmission line is required to connect the project to the substation near Faro.

While False Canyon is not able to supply all of the forecasted Baseline 2065 energy demand on a standalone basis, based on a targeted 5 m average drawdown it closes a considerable portion of the forecast gap, with energy shortfalls in March, April and May.

6.6.1.2 *Middle Canyon*

As the downstream project in the cascade, Middle Canyon is a ROR hydroelectric project on the Frances River, located in the Liard River Basin approximately 40 km northwest of Watson Lake. The total drainage is estimated to be 13,000 km^2.

The preliminary project layout includes the following components:

- Weir;
- Fish passage structures;
- Water intake;
- Conveyance;
- 3-unit powerhouse;
- Tailrace structures; and
- Diversions to facilitate de-watering of the dam site during construction.

The estimated full supply level of the water reservoir is 672 m above sea level, flooding a total area of approximately 1 km^2 just downstream of the Robert Campbell Highway.

Assuming a future transmission line between Faro and Watson Lake, less than 10 km of new road and less than 10 km of new transmission line are required to access and interconnect the project.

While False Canyon was not able to supply all of the forecasted Baseline 2065 energy demand, the cascaded layout of False Canyon and Middle Canyon ROR is able to provide more energy than the forecasted Baseline 2065 energy need. As a cascade, False Canyon and Middle Canyon ROR has unutilized energy throughout the year. It is recognized that the average drawdown for the False Canyon reservoir could be reduced to less than 5 m, but this could be viewed as not fully utilizing the river resources once a decision is made to impact the river system and build the cascade.

Figure 13: False Canyon Priority Site and Reservoir Footprint

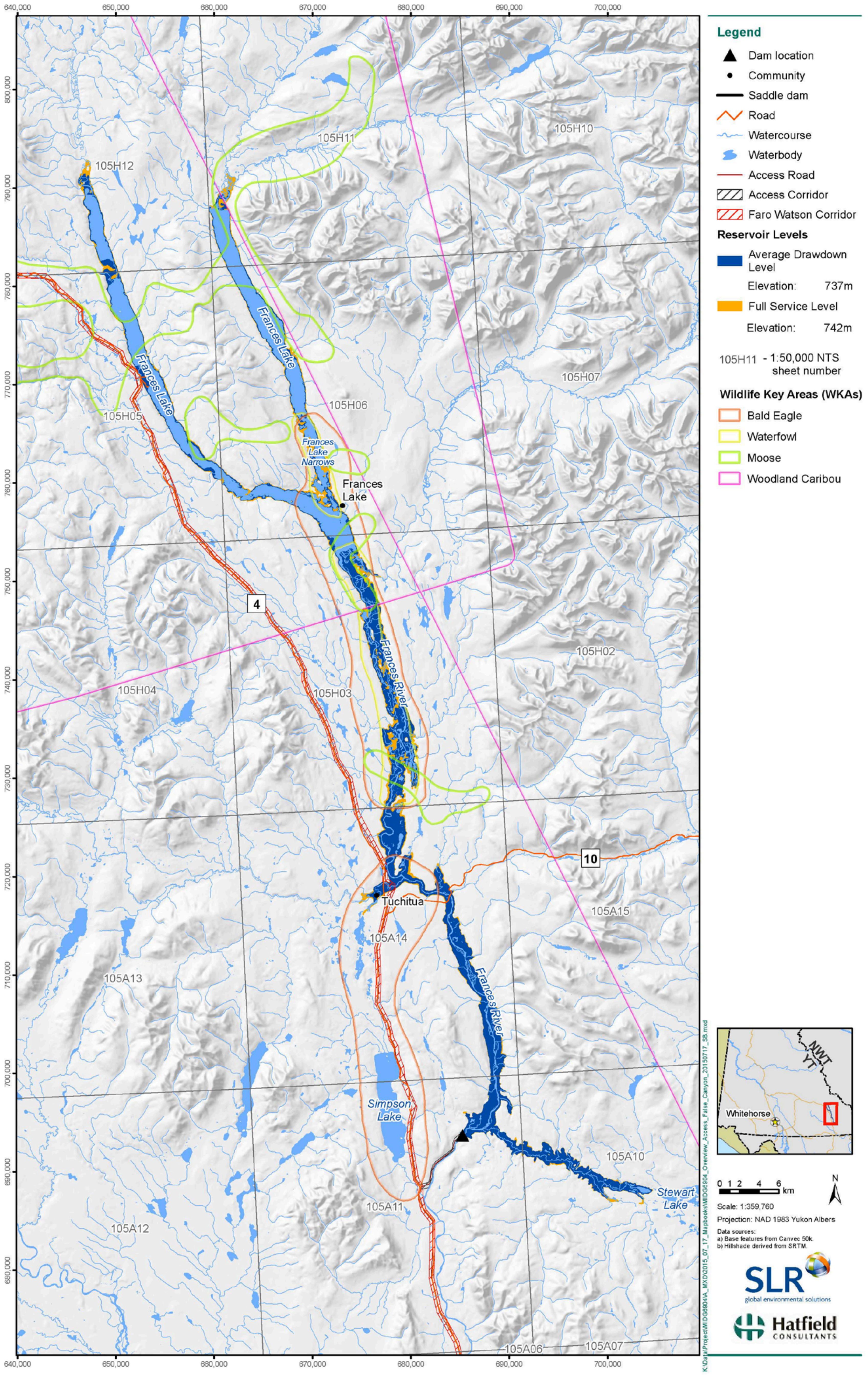


Figure 14: Middle Canyon Run-of-River Priority Site

6.6.2 Environmental Setting

6.6.2.1 *Fish and Fish Habitat*

Fish species documented in the Frances River system include slimy sculpin, Arctic grayling, bull trout, round whitefish, mountain whitefish, and longnose sucker (DFO, 2015*a*). False Canyon Creek supports populations of Arctic grayling, slimy sculpin mountain whitefish, and burbot. Stream files maintained at a lodge operated at Stewart Lake from 1959 indicate the presence lake trout, round whitefish, Arctic grayling, northern pike, and bull trout (DFO, 2015*a*).

Upstream of the proposed reservoir site, Frances Lake is home to Arctic grayling, northern pike, lake trout, and whitefish (DFO, 2015a). The lake has historically supported a commercial fishery but is currently classified as a Conservation Water under the Yukon fishing regulations due to a depressed stock (Environment Yukon, 2014).

The overwintering capacity in Frances Lake is presumed to be excellent with good quality rearing habitat. In 2009, angler harvest results reported lake trout, northern pike, Arctic grayling and bull trout in Frances Lake. Other species present in Frances Lake include burbot, lake whitefish and round whitefish (DFO, 2015*a*).

6.6.2.2 *Aboriginal Fisheries Values*

The Kaska Dena/Liard First Nation historically inhabited the narrows of Frances Lake by the Tu Cho people. The Frances Lake Village was traditionally used as a fishing and hunting site. Several burial sites also exist in and around this area Frances Lake (Kaska Dena/Liard First Nation; Mulder et al. 2000; Millar et al. 2012).

6.6.2.3 *Wildlife and Wildlife Habitat*

There are no WKAs overlapping with the Middle Canyon ROR project footprint but nine WKAs overlap with the False Canyon reservoir, including:

- Two bald eagle WKAs representing high quality breeding habitat from June to August, likely due to the presence of large, riparian trees. The first extends from the east arm of Frances Lake to the south end of a large Frances River wetland complex. The second bald eagle WKA is approximately five kilometres south of the first WKA; it overlaps with Frances River and a tributary flowing into Frances River just north of Tuchitua;

- Two waterfowl WKAs representing spring staging habitat from April to June. The northern WKA is situated on the lower portion of the east arm of Frances Lake. The second WKA coincides with the Frances River wetland complex just south of Frances Lake. A total of 800 ducks were observed in these WKAs in early May during an aerial survey. A total of 75 Canada geese and 15 trumpeter swans were also observed during an early May aerial survey, on the more southern WKA;

- A large caribou WKA is present in the northern third of the False Canyon reservoir. The project overlaps 162 ha (0.003%) of it. This WKA protects portions of the South Nahanni herd's range. A fall survey confirmed the presence of rutting and courtship habitat at this location (Environment Yukon, 2011a) though the WKA likely fulfills other seasonal life requisites. The reservoir likely coincides with some low elevation winter foraging habitat for this herd; and

- Four WKAs representing patches of moose winter range (February to April) are present in the top two-thirds of the False Canyon reservoir. These patches were identified during a December 2012 aerial survey. A total of 144 moose were observed in the most northern patch which intercepts the centre of both arms of Frances Lake. Less than a dozen individuals were observed at each of the three remaining winter habitat patches. The project overlaps with 7% of all four WKAs combined including the open water portion not utilized by moose.

There are no documented species at risk in the Middle Canyon ROR footprint but there are three documented species at risk at, or near the False Canyon reservoir including:

- A colony of barn swallows on a rounded peninsula towards the centre of the west arm of Frances Lake; the colony occupies an area 7 ha in size;

- A rusty blackbird nesting site approximately two kilometres northeast of the reservoir along Highway 10 (Nahanni Range Road); and

- A breeding (oviposition) site for the oscillated emerald was identified near Highway 10, approximately 800 m northwest of the Tuchituan community. The oscillated emerald is a species of dragonfly considered at risk in the Yukon but globally and nationally secure (NatureServe, 2015b). Emeralds are river-breeding dragonflies capable of commuting flights greater than one kilometre (NatureServe, 2015b) and as such the species could occur within the reservoir footprint.

Other species at risk that may occur in the False Canyon reservoir area include common nighthawk, American kestrel, and western jumping mouse. The common nighthawk and American kestrel are regularly found in southern Yukon and both can occupy open wetland habitats. There appears to be less wetland habitat along the upper Frances River section where the Middle Canyon ROR is proposed. The project may be within the range of the western jumping mouse.

6.6.3 Socio-economic Setting

The False Canyon and Middle Canyon Project sites are located along the Frances River and Frances Lake. The Middle Canyon site is located downstream of the False Canyon site. The nearest communities to the Project sites (within approximately 100 km) are Ross River and the Town of Watson Lake. A brief profile of Ross River was provided previously.

The Town of Watson Lake along with the adjoining settlements of the Liard First Nation, including Upper Liard, Two-Mile Village and Two and a Half Mile Village make up what us referred to as Watson Lake. The Town of Watson Lake itself is located along the Alaska Highway, approximately 12 km north of the territorial border with British Columbia and 454 km southeast of Whitehorse. In 2014, the population was approximately 1,489 people, a decline of 2% since 2005. Approximately 41% of the population identify themselves as Aboriginal, mostly from the Liard First Nation. There are approximately 350 private occupied dwellings in Watson Lake with an additional 34 social housing units and 46 staff units provided by Yukon Housing Corporation (Yukon Government, 2014f).

Watson Lake is served by an elementary and secondary school, a health centre, ambulance and medivac service. Policing in the community is provided by an RCMP detachment. Yukon College in Watson Lake is located in a separate wing of the secondary school, and provides the community with courses in academic upgrading, computer skills, and first aid. It is well equipped with a computer lab and high-speed Internet access (Yukon Government, 2014f). Watson Lake residents have access to a variety of community recreational facilities including a swimming pool, curling rink, hockey rink, youth centre, and community hall (Yukon Government, 2014f).

Watson Lake's economy is driven by its role as a key communication and logistics hub serving the mining, logging and tourism industries. Tourists visit area attractions such as the town's Signpost Forest, Northern Lights Space and Science Centre, the Liard Hot Springs and the local Visitor Interpretive Centre. Watson Lake offers travelers six motel/hotels, two bed and breakfasts and two campgrounds (Yukon Government, 2014f). In 2011, the community had a labour force of 890. Watson Lake's unemployment rate was 14% in 2011.

Watson Lake's Strategic Plan for revitalization states that the Town's objectives for development includes capturing increased employment and business opportunities from expanding mining and transportation activity in the region, while fostering sustainable development (Town of Watson Lake, ND). In addition, the objectives of the economic development plan for the Liard First Nation Council are largely focused on the mining industry and efforts to create environmental capacity and joint ventures with local contractors and mining corporations that ensure responsible and environmentally sound mining. The Liard First Nation aims to negotiate Socio-Economic Participation Agreements or Impact Benefit Agreements with mining companies that provide for direct participation in the economic and social benefits of mine development and operation in Kaska Traditional Territory. The First Nation plans to work with the Yukon Mine Training Association, Yukon Education, Yukon College, and resource development companies to provide training for its members (Liard First Nation, ND).

6.6.4 Environmental Effects

The environmental effects of False Canyon and Middle Canyon on fish and fish habitat are considered to be negative for the following reasons:

- Construction of the False Canyon hydroelectric site would result in the creation of a 26,100 ha reservoir encompassing Frances lakes and portions of the Frances River downstream, as well as False Canyon Creek extending to Stewart Lake. Changes to reservoir elevations between drawdown and full crest volumes will result in major dewatering in the approximately 20 km of Frances River downstream of the Frances Lakes system within the reservoir footprint. Changes to connectivity between tributary streams in the Frances Lake systems and mainstem Frances River within the reservoir footprint are expected to affect access to and utilization of tributary habitat by bull trout, which are federally listed as a species of Special Concern under COSEWIC;
- Reservoir creation is expected to result in inundation of shoal habitats surrounding the Frances Lake system, which are potentially utilized by lake trout, whitefish and burbot for spawning; and
- Construction of the dam may affect seasonal migration movements by some fish species, and habitats within and downstream of the reservoir are expected to experience changes to flow regimes resulting from project operations.

Further details regarding effects by species and life stage is provided in Appendix C.

The environmental effects of False Canyon on wildlife are considered to be negative for the following reasons:

- The False Canyon reservoir may eliminate waterfowl spring staging habitat at Frances Lake and in the Frances River wetland complex over time, by eliminating access to shallow water plants and invertebrates if these aquatic species do not survive deep water conditions through the summer period during operations. It should be noted however, that the two waterfowl WKAs at the False Canyon project site are east of a major migration route and thus do not represent a major staging area (Environment Yukon, 2011a);

- The bald eagles nesting at Frances Lake and in the Frances River wetland complex may be displaced if large riparian trees are lost over time, as a result of a decrease in nutrients. The project would likely have an indirect effect as well, by reducing local food (fish and bird) availability as a result of decreased aquatic and riparian productivity. Productivity is linked to species abundance and diversity. The loss of a few nesting pairs is unlikely to affect bald eagle regional population levels;

- The False Canyon reservoir has a proposed dam height of 56 m and a proposed drawdown level of 5 m. This project could flood the mid-sized barn swallow colony at average drawdown levels (a drawdown level of 50 m proposed). Filling of the reservoir in summer could cause direct mortality to swallow eggs and nestlings from flooding on an annual basis. The magnitude of project effects would depend on the size of the colony;

- Given the extent of the wetland complex associated with Frances River south of Frances Lake, there is a high probability that rusty blackbirds breed in the reservoir area. Eggs and nestlings of this species may be subject to direct mortality from flooding during the spring and summer reservoir filling period. Loss of productivity will likely eliminate the wetlands over time as a result of annual flooding;

- The False Canyon reservoir could displace the bald eagle pairs nesting near Frances Lake and along the Frances River tributary near Tuchitua by eliminating large riparian trees that could serve as nesting sites, and reducing the local food supply. Loss of large riparian trees from flooding is linked to decreased nutrient levels (Polzin 2015; Herbison 2015). Fish and bird species (prey) abundance would decline dramatically with the loss if wetland productivity; and

- There are no documented oscillated emerald oviposition sites in the False Canyon reservoir area though this dragonfly species' breeding sites along Frances River would likely be eliminated by the creation of the reservoir. Invertebrates are not protected under the *Yukon Wildlife Act* but protection of all species at risk is encouraged as a matter of due diligence.

The project is likely to have a negligible effect on caribou as it would overlap with 0.003% of the local WKA, which likely delineates the herd's range in the area. Similarly, the project would overlap with a minor amount of moose winter range habitat (less than < 7%) and this species is not at risk in the Yukon.

6.6.5 Socio-economic Effects

For the purposes of this study, the positive, neutral and negative socio-economic effects of the False Canyon and Middle Canyon projects are identified on Table 13. The upstream project reservoir is the second largest among the six priority sites. The greatest potential for adverse effects is on:

- Known heritage and cultural resources;
- Traditional Aboriginal activities within the reservoir area;
- Potential for displacement of current traditional activities at Frances Lake and Tuchitua. The Kaska Dena/Liard First Nation historically inhabited the narrows of Frances Lake by the Tu Cho people. The Frances Lake settlement was traditionally used as a fishing and hunting site, but its current use and the use of the Tuchitua area is not known; and
- Community well-being due to project phasing, the disruption caused by the potential diversion of the Robert Campbell Highway and Nahanni Range Road.

It is likely to have no direct effects or the least adverse effects on:

- First Nation settlement lands;
- Special management and protected areas;
- Agricultural areas;
- Oil and gas resource areas; and
- Quarry permit areas.

The ~ 10 km of new right-of-way for roads and transmission line is relatively short among the six priority sites which and, as such, is not expected to substantially improve access to renewable and non-renewable resource areas or areas potentially used for traditional activities. However, the new reservoir itself will facilitate navigation and improve access to the land by boat. Improved access may be considered as a positive by some or a negative effect by others.

These projects have the potential to generate substantial employment opportunities and increased business activity during construction. The approximately 7,700 direct and indirect jobs potentially generated in the Yukon is the second largest among the six priority sites. Similarly, the potential for increased business activity associated with $879 Million of GDP during construction is also the second largest. Nevertheless, these positive effects will likely occur during the two distinct construction phases approximately 25 years apart, and will tend to be captured by Whitehorse to the greatest extent.

Despite current limitations, Ross River and Watson Lake are in the best position to supply local construction labour given travel distance by road (~ 100 km). Whitehorse and Watson Lake will likely experience increased competition for temporary accommodation, infrastructure and community services during construction, but noticeable adverse effects on the community well-being of Whitehorse are not considered likely, due to its larger population and more diverse economic base.

The numbers of jobs and the increased business activity created during operations considered to be moderate among the six priority sites. Overall the project will support the socio-economic development goals of Whitehorse and Faro.

Table 13: False Canyon and Middle Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
First Nation Settlement Lands and Other Dispositions		• No Aboriginal Settlement Lands affected.	• Interim Protected Lands affected: o ~ 1,500 ha • Other Land Tenure and Dispositions affected: o ~ 30,000 ha
Land Use Plans		• Project site is not located within area of a draft or approved land use plan.	
Renewable Resources		• No special management or protected areas directly affected • No agricultural areas directly affected • ~ 10 km of new right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Ross River. Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas.	• Renewable resource areas directly affected: o ~ 26,100 ha of trapping concession lands o ~ 5,000 ha of outfitting concession lands o ~ 320 ha of Timber Harvest Area • One outfitter affected • Fifteen (15) trapline holders affected
Non-renewable Resources		• No oil and gas resource areas directly affected • No quarry permit areas affected • ~ 10 km of new right-of-way for roads and transmission line will not substantially improve access to renewable resource areas from Ross River. Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas.	• Non-renewable resource areas directly affected: o ~3,000 ha of Mineral and Metal Mining Resource Area (e.g., Quartz claims or leases)

Table 13: False Canyon and Middle Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Heritage and Cultural Resources		• A preliminary survey of historic and archaeological sites on Frances Lake was completed in 1992, however, no systematic survey has been conducted elsewhere in the False Canyon Project area • No archaeological or historic sites documented in the Middle Canyon area. No systematic survey has been undertaken to date.	• Direct effects on: o Several historic sites, seven (7) known archaeological sites and related historic camps and a First Nation Graveyard. • Project site is nearly entirely in zone of high archaeological potential.
Employment and Business Activity	• Increased direct and indirect employment opportunities in the Yukon: o ~ 7,700 construction phase jobs over two three year periods due to phasing o ~ 48 operations phase jobs per year once both facilities are operational • Increased business activity and potential for economic growth: o ~ $879 Million of direct and indirect GDP generated during construction for both projects o ~ $9.6 Million of direct and indirect GDP generated per year once both facilities are operational	• Economic leakage from Yukon economy: o $642 Million of GDP leakage during construction o $2.1 Million of GDP leakage per year during operations phase	

Table 13: False Canyon and Middle Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Local Labour and Skills Supply	• Employment opportunities will increase participation in labour market by Aboriginal and non-Aboriginal persons across Yukon. • Despite current limitations, Ross River and Watson Lake are in best position to supply local construction labour.		• Local labour and skill supply is currently very limited. • Increased competition for skilled labour across Yukon.
Traditional Aboriginal Activities		• Project site located within Traditional Territory of Kaska Dene Nation • ~ 10 km of new right-of-way for roads and transmission line will not substantially improve access to Traditional activity areas from Ross River. Project site is adjacent to the Robert Campbell Highway which provides major access to resource areas. • New reservoir will facilitate navigation and improve access to the land by boat between Lake Frances and Stewart Lake area to the south. • The potential inundation of the narrows of Frances Lake historically used by the Tu Cho people and the Frances Lake settlement that was traditionally used as a fishing and hunting site. Their current use and the use of the Tuchitua area is not known.	• Loss of areas used for hunting and other traditional activities in 26,100 ha reservoir area.

Table 13: False Canyon and Middle Canyon - Socio-economic Evaluation

Factors	Positive Effects	Neutral / Uncertain Effects	Negative Effects
Community Well-Being	• Ross River and Watson Lake are likely to gain new residents during operations phase. • Reservoir may provide new navigation and recreational opportunities from along the Robert Campbell Highway and Highway 10.		• Staged project development will result in disruption at two separate time intervals approximately 25 years apart. • Whitehorse likely to experience greatest influx of temporary workers during construction. • The nearest communities to the Project site, Ross River and Watson Lake are most likely to experience increased competition for temporary accommodation, infrastructure and community services during construction. • Portions of the Robert Campbell Highway and Highway 10 may require relocation, resulting in disruption to travel between Ross River and Watson Lake, and along Highway 10 to the NWT. • Increased use of the Robert Campbell Highway from Ross River and Watson Lake and community airports to access the Project site from Whitehorse. • Increased use of Whitehorse airport by Project workers. • Reservoir will likely be visible from the Robert Campbell Highway.

6.6.6 False Canyon and Middle Canyon Site Scorecard

Based on the available data, the analysis presented above and professional judgement, a score has been assigned for an overall ***effect rating*** of this site. The rating provides a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. Details on the methodology used to assign these ratings are provided in Appendix C (Fish and Fish Habitat), Appendix D (Wildlife and Wildlife Habitat) and Appendix E (Socio-economics).

Effect Category	**Effect Rating**
Fish and Fish Habitat	Moderate
Wildlife and Wildlife Habitat	Higher
Socio-economics	Higher

Effects on fish and fish habitat are rated ***Moderate*** in relation to other priority sites due to:

- Flooding of 26,100 ha encompassing Frances Lake (level raised by 8 m), portions of the Frances River, and False Canyon Creek;
- Potential loss of spawning and rearing habitat for arctic grayling and bull trout (i.e., species at risk); and
- The dam may act as a migration barrier to upstream habitats for arctic grayling and may present challenges to out-migrating juveniles.

Effects on wildlife and wildlife habitat are rated ***Higher*** than some of the other priority sites due to:

- Substantial overlap of WKAs for waterfowl, moose, bald eagle;
- Presence of 2 documented species at risk (barn swallow, trumpeter swan); and
- Potential for occurrence of 4 other species at risk (American kestrel, common nighthawk, western jumping mouse, oscillated emerald dragon fly).

Effects on socio-economic attributes are rated ***Higher*** than some of the other priority sites due to:

- High reservoir footprint area;
- High area of reservoir footprint overlap with other Land Tenures and Dispositions;
- Potential displacement of Robert Campbell Highway and Nahanni Range Road and associated community disruption. These effects are largely mitigable through highway diversion prior to site development;
- Overlaps with known Heritage and Cultural Resource sites; and
- The project is located within an area of high archaeological potential.

Nevertheless, this site offers substantial economic benefits (i.e., jobs and business activity) in the context of the Yukon economy.

7.0 REGULATORY CONSIDERATIONS

7.1 Federal Legislation

The following sections summarize the key federal legislation that will require consideration in the development of the Yukon Next Generation Hydro Project.

7.1.1 Fisheries Act

The federal *Fisheries Act* (Section 35) (amended June 2012) is the primary piece of legislation in Canada governing the protection, conservation and management of fish and fish habitat. This Act is enforced by Fisheries and Oceans Canada. The Act prohibits serious harm to fish that are part of or support a commercial, recreational, or Aboriginal (CRA) fishery. Harm can be caused by proposed works, undertakings or activities that affect fish habitat, passage of fish or modify flow in watercourses. If serious harm to fish that are part of or support commercial, recreational or Aboriginal fisheries will occur as the result of a proposed undertaking, the proponent is required to prepare a habitat off-set plan and obtain an Authorization under the *Fisheries Act* 35(2)(b), prior to commencing works. If a project cannot avoid *serious harm* to fish and, through the application of Fisheries and Oceans Canada's Self-Assessment process, has been identified as a project which requires review, a Request for Project Review is required by Fisheries and Oceans Canada.

7.1.2 Navigation Protection Act

Administered by Transport Canada, *the Navigation Protection Act*, formally known as the *Navigable Waters Protection Act* was created to protect navigation and marine safety on navigable waters in Canada from any work being completed on or near the navigable water that will create an obstruction that may risk interfering with the navigation in the body of water. A schedule that supports the Act, lists navigable waters for which regulatory approval is required for such works. Under the new Act, legislative protection is restricted to 97 lakes, 62 rivers, and three oceans. Additional bodies of water may be added by regulation where the Minister of Transport is of the opinion that it is in the national or regional economic interest or the public interest to do so, or where a province or municipality so requests. The Yukon and Mackenzie Rivers are included on the list of Navigable Waters.

7.1.3 Species at Risk Act

The *Species at Risk Act* (SARA) was created as means to conserve and protect biological diversity in Canada. The Act is administered by Environment Canada. The *SARA* is intended to prevent wildlife species becoming extinct or extirpated; help recover extirpated, endangered or threatened species; and, ensure that species of special concern do not become endangered or threatened. Currently there are over 300 wild plant and animal species protected under *SARA*.

Aquatic species and migratory birds are protected under *SARA* regardless of where they are located in Canada. For the remaining species, the protection under *SARA* only applies to species on federal lands including National Parks and First Nations Reserves. *SARA* also contains a prohibition against destroying any part of critical habitat for the listed species, which is habitat necessary for the survival of a species at risk. Pursuant to Section 79(1) of *SARA*, Environment Canada is obliged to ensure that effective protection is provided of listed species and a project proponent may be required to obtain a permit and develop a management plan.

7.1.4 Canada Water Act

The *Canada Water Act*, proclaimed in 1970, provides the framework for joint federal-provincial-territorial management of water resources and facilitates the implementation of the Federal Water Policy. The Act is administered by Environment Canada. The *Canada Water Act* enables Environment Canada to enter into agreements with other jurisdictions and to carry out research, planning, and implement programs for the conservation, development, and use of water resources. It allows for the establishment of advisory committees and for undertaking public information programs (Environment Canada, 2015). The Act also sets out a framework for joint federal-provincial management of boundary waters or inter-jurisdictional waters. Apart from federal legislation regarding large-scale diversions or the export of water, the allocation of water quantity is governed by the provinces. Under the *Canada Water Act*, Environment Canada continues to work on collecting data on water quality.

7.1.5 Canada Wildlife Act

The *Canada Wildlife Act* facilitates the protection of significant wildlife habitat throughout Canada primarily through the establishment of National Wildlife Areas. The Act is administered by Environment Canada, and authorizes the federal government to enter into a broad range of wildlife conservation partnerships. The Committee On the Status of Endangered Wildlife in Canada (COSEWIC) was established under the Act in 1977 to co-ordinate national wildlife conservation efforts related to threatened or endangered species. As such, the *Canada Wildlife Act* is the primary federal law pertaining to the protection and management of wildlife and aims to increase the awareness of the importance of Canada's biodiversity. The Act covers all wild animals, plants, and other organisms. It establishes National Wildlife Areas, in which activities that could harm wildlife are restricted, and requires the development of management plans for all National Wildlife Areas. The *Wildlife Area Regulations*, identifies activities that are prohibited within such areas because they may harm a protected species or its habitat. In some circumstances, land-use permits may be granted to individuals, organizations, or companies if the intended use is compatible with conservation of the area. Engaging in commercial/industrial activity is expressly prohibited by the *Act (s. 3(1) (k)).* Other elements of the Act include:

- A mandate to conduct public programs, convene conferences, conduct research, and establish related facilities;
- management and control of lands either belonging to the Government of Canada, or over which the government has powers of disposal of the purposes of the Act;
- a mandate to establish agreements with other governments for wildlife research and conservation, administration of lands, and provision of physical facilities for the purposes of the Act;
- the implementation of co-operative measures with other governments for the protection of a non-domestic animal in danger of extinction; and
- a mandate for acquisition of lands or an interest therein for research, conservation and interpretation with respect to migratory birds.

7.1.6 Dominion Water Power Act

The *Dominion Water Power Act* applies to all water power projects located on public land, public lands required in the development or working of Dominion water powers, to lands and properties to may be acquired for Dominion water power and to the power and energy produced from the waters. It states that any property within the Dominion water-powers will remain the rights of the Crown as well any public land that is with water power, required for the protection of waterpower or required for any purpose. Where there is public land required to be submerged, the Minister may dispose of the parcel but reserves the right to raise the water surface to such elevation as may be required in connection with the project. The government also has the power under this act to expropriate land, with compensation, required for the development of the water-power. This Act states that any land required to the Yukon Dam projects may be expropriated at the appropriate cost for the use of the water-power (Government of Canada, 2015b).

7.1.7 Migratory Birds Convention Act

The purpose of the *Migratory Birds Convention Act 1994 (MBCA)* is to implement the "Convention for the Protection of Migratory Birds in Canada and the United States" by protecting and conserving migratory birds, as populations and individual birds, their habitat and nests. The Regulations (*Migratory Bird Sanctuary Regulations (C.R.C., c. 1036*)) under the *MBCA* prohibit depositing, or permitting the deposit, of a substance that is harmful to migratory birds in waters or an area frequented by migratory birds or in a place from which the substance may enter such waters or such an area. A prohibition against the disturbance, destruction, or taking of a nest, egg or nest shelter of a migratory bird without a permit is also set out in the Regulations.

7.2 Yukon Legislation

The following sections summarize the key Yukon legislation that will require consideration in the development of the Yukon Next Generation Hydro Project.

7.2.1 Quartz and Placer Mining Act

The *Quartz and Placer Mining Act* describes the process and requirements for the acquisition of mining claims. It permits an individual to enter onto Yukon Territory lands to locate, prospect and mine for quartz, gold or other precious minerals or stones. There are several exceptions to these permissions such as, where the land:

- is required for a harbour, airfield, road, bridge, or other public work;
- is being used as a cemetery or burial ground;
- is lawfully occupied for placer mining purposes;
- is set apart to enable the Government to fulfil its obligations under land claims settlements; and
- Is within the boundaries of a city, town or village or if the land has been occupied by a building or within the curtilage of a dwelling-house.

Once a mining claim is in place, compensation is required to the owner for any person who lawfully occupies the land for any loss or damage caused. The process of compensation is undertaken in accordance with the *Yukon Surface Rights Board Act*.

7.2.2 Yukon Waters Act

The *Yukon Waters Act* empowers the Yukon Commissioner to administer and control rights in respect to water in the Yukon Territory, with the exception of water in a federal conservation area as defined in the *Yukon Act*. It also allows for the establishment of agreements among federal, provincial or territorial governments.

The Act establishes the Yukon Water Board to provide for the conservation, development, and utilization of waters in a manner that will provide the optimum benefit from them for all Canadians and for the residents of the Yukon in particular. The Act states that the use of water must be in accordance with the conditions of a license (Yukon Government, 2003). As such, the Board may issue Type A licenses or Type B licenses. In general, Type A licenses apply to projects that have a greater potential for adverse effects on water resources. Public hearings are mandatory for Type A applications and optional for Type B. A license issued by the Board generally contains terms and conditions which reflect a balance between protection of the water resources and their exploitation as proposed by the applicant.

7.2.3 Yukon Environmental and Socio-economic Assessment Act

The *Yukon Environmental and Socio-economic Assessment Act* (YESAA) provides a comprehensive and neutral environmental assessment (EA) for proposed projects in Yukon Territory. The Act ensures that before projects are undertaken, their environmental and socio-economic effects are considered. An assessment under YESAA is required when a proposed project is listed in the regulations and requires a permit or authorization, a transfer of land, or utilizes federal funding. The assessment process is initiated when *project proponent* submits a proposal to *the Yukon Environmental and Socio-economic Assessment Board (*YESAB*)*. Depending on the proposed project activities an assessment can take place at three different levels:

- Designated Office evaluation: where assessments are conducted in the six community-based Designated Offices located in Dawson City, Haines Junction, Mayo, Teslin, Watson Lake and Whitehorse;
- Executive Committee screening: assessing larger projects that are submitted to it directly or are referred by a Designated Office; and
- Panel of the Board reviews: where an undertaking is anticipated to have potential significant adverse effects, is likely to cause significant public concern, or involve the use of controversial technology.

Once the appropriate information has been collected and considered, the assessor recommends whether the project should proceed, proceed with terms and conditions, or not proceed. Alternatively, a Designated Office may refer a project under evaluation to an Executive Committee screening, or the Executive Committee may refer a project under screening to a review by a Panel of the Board. When an assessment is complete, the recommendation is sent to the relevant federal, territorial and First Nation government Decision Bodies. The Decision Body(s) will then decide whether to accept, reject or vary the recommendation of YESAB and issue a Decision Document.

7.2.4 Other Yukon Legislation, Permits and Approvals

Table 14 summarizes other Yukon legislation, permits and approvals that will require consideration in the development of the Yukon Next Generation Hydro Project.

Table 14: Other Yukon Legislation, Permits and Approvals

Yukon Legislation	Purpose	Relevant Approvals, Permits, Licences	Regulatory Agency (Ministry or other, where indicated)
Lands Act	• Regulation of Yukon Lands • Authorizes the acquisition of rights-of-way.	• Land Use Permit(s)	• Department of Energy, Mines and Resources
Territorial Lands Act	• Regulation of Lands administered by the Canadian Department of Aboriginal Affairs and North Development Canada • Authorizes the acquisition of rights-of-way.	• Land Use Permit(s)	• Department of Energy, Mines and Resources
Wildlife Act	• Protection of virtually all vertebrate animals from direct harm • Includes protection for endangered species.	• Permission for activities in a Habitat Protection/Wildlife Area • Permit(s) for field work, research and/or removals during construction	• Department of Environment
Forest Resources Act	• Governs the clearing of forest resources.	• Forest Resources Permit(s) for clearing related to construction	• Department of Energy, Mines and Resources – Forest Management Branch
Highways Act	• Regulates the construction of roadways.	• Permit(s) under Section 7(2) for construction of access roads	• Department of Highways and Public Works
Scientists and Explorers Act	• Regulates scientific and social scientific research, including studies connected with EA's.	• Scientists and Explorers Permit(s) required for non-resident researchers	• Tourism and Culture
Historic Resources Act	• Regulates the identification, protection and conservation of archaeological and paleontological resources.	• Archaeological Sites Regulations Permit	• Tourism and Culture

8.0 TRANSBOUNDARY CONSIDERATIONS

There are three transboundary agreements that require consideration in developing hydroelectric power generation facilities in the Yukon. These are the:

- Boundary Waters Treaty,
- Mackenzie River Basin Transboundary Waters Master Agreement, and
- Canada – United States Pacific Salmon Treaty

8.1 The Boundary Waters Treaty

The Boundary Waters Treaty was originally established to resolve disputes over irrigation and other uses of the waters shared by Canada and the United States, particularly those along the border, and as a preventative measure against future water disputes. The treaty was signed in January 1909, creating a body, the International Joint Commission (IJC), who would mediate and oversee the operation of the mechanisms developed for preventing and resolving disputes, taking into account the various needs for water including water use for hydroelectric power generation (IJC, 2015). The IJC is primarily responsible for regulating water levels, but also monitors water quality in water bodies shared between Canada and the United States. It reviews applications for projects such as dams and diversions, which will potentially affect the water level and flow of water across the boundary. If the project is approved by the IJC, there still may be conditions placed on the project design and/or operation to protect the interests of both Canada and the United States (IJC, 2015).

8.2 Mackenzie River Basin Transboundary Waters Master Agreement

Signed in 1997 by the Governments of Alberta, Saskatchewan, British Columbia, Yukon Territory, NWT and Canada, the Mackenzie River Basin Transboundary Waters Master Agreement commits all six governments to work together to manage water and ecosystems of the Mackenzie River Basin (MRBB, 2010a). The Agreement commits the Governments to the following principles:

- To manage water resources to maintain the ecological integrity of the aquatic ecosystem
- Manage water resources to sustain for present and future generations.
- Each Government is allowed to manage water resources in their jurisdiction provided that it does not harm the ecological integrity in another jurisdiction in an unreasonable way.
- If there is a development or activity that may affect the ecological integrity of the aquatic ecosystem in another jurisdiction, then there must be consultation, notification and sharing of information (MRBB, 2010a).

The agreement also allows for the governments to develop bilateral water management agreements to address water issues at jurisdictional boundaries. The Yukon-Northwest Territories Transboundary Water Management Agreement was the first bilateral Agreement completed in 2002 (MRBB, 2010a).

This Agreement is intended to protect, manage and conserve the ecological integrity of the aquatic ecosystem of the Mackenzie River Basin common to the Yukon and the Northwest Territories (MRBB, 2010b). The objectives of the Agreement are as follows:

- Develop and implement objectives to protect the aquatic ecosystem in Peel River Watershed and other water resources;

- Ensure that transboundary waters are safe to drink and the aquatic species are safe to eat;
- Prevent, control and minimize point and non-point sources of persistent toxic substances;
- Provide opportunities for all jurisdictions which may be affected to participate in the development planning processes;
- Encourage scientific research and use of traditional knowledge for water issues;
- Identify potential effects and mitigation measures from potential development projects on the aquatic ecosystem; and
- Keep the public and stakeholders informed on activities and provide consultation processes for the public and stakeholders to provide input (MRBB, 2010b).

Currently, there is no bilateral agreement between Yukon and British Columbia. In this case, the Master Agreement applies. There are two priority sites located upstream of the British Columbia and Yukon border. False Canyon site is located 132 km from the border along the Frances River; while Middle/Lower Canyon is 100 km north of the BC border on the Frances River.

8.3 Canada-United States Pacific Salmon Treaty

The Canada-United States Pacific Salmon Treaty (1985) outlines how fisheries will be managed by the United States and Canada, with a goal of rebuilding and conserving salmon stocks. There is a commitment to maintain viable fisheries on the Yukon River in both countries, with a particular focus on chinook, chum and coho salmon, including an agreement that salmon should be afforded unobstructed access to and from, and use of, existing migration, spawning and rearing habitats. Management of salmon fisheries is assigned to the Yukon River Panel, which makes recommendations for managing the harvest of salmon on the Yukon River. In cases where access is obstructed or productive capacity is diminished to a degree that affects the objectives of the Treaty, the Yukon River Panel may make recommendations for adjusting harvest methods and objectives to continue to meet the Treaty objectives.

9.0 SITUATIONAL ANALYSIS

9.1 Summary Analysis

Section 5 of this report indicated that hydroelectric power generation is a well-established technology that is regarded as a reliable, renewable and clean energy source. After many decades of experience with hydroelectric projects across Canada and internationally, the key environmental and socio-economic issues and Best Management Practices (BMPs) regarding facility design, construction and operations are known and understood.

Section 6 of this report identified the key positive and negative effects of each priority site and summarized the analysis in terms of a site scorecard, using a ***Higher, Moderate and Lower*** effect rating scheme. A rationale for the individual ratings in the scorecards was also provided. To illustrate the overall study findings with respect to the six priority sites, Table 15 compiles these site scorecards into a summary comparative scorecard. This scorecard is also presented using the "Higher", "Moderate" and "Lower" rating scheme applied in Section 6. The ratings provide a preliminary indication of the level of constraint, relative to other priority sites, that is likely to be associated with the proposed development. In general, a "Higher" rating means:

- the priority site may result in negative environmental and socio-economic effects and/or offers the least potential for positive socio-economic effects. In some cases, the "Higher" rating means the effects are of greater magnitude relative to other sites.
- the analysis shows there is greater certainty that an adverse effect may occur due to factors such as the known presence of key fish species (e.g., salmon), environmental features (e.g., WKA, species at risk) or important socio-economic attributes (e.g., Category A Settlement Lands, areas with subsurface rights for minerals) within the project footprint.
- the site will likely require a greater level of investigation through more detailed, complex and site specific environmental analyses.
- the site may require special site-specific design features to address technical, environmental and socio-economic constraints; and,
- a greater effort will likely be required in the design of mitigation, compensation and enhancement measures to manage adverse effects and maximize benefits.

A "Moderate" rating means that the priority site offers a mix of positive and negative environmental and socio-economic effects.

A "Lower" rating means that the priority site has less potential for negative environmental and socio-economic effects and/or offers greater potential for positive socio-economic effects than other sites. A "Lower" rating does not mean that the site is constraint free or will require less attention through further assessment, design and mitigation.

Table 15: Summary Comparative Scorecard

Site Name	Site ID	Fish and Fish Habitat Effects	Wildlife and Wildlife Habitat Effects	Socio-economic Effects
Fraser Falls	STEWA-STEWA-0519-B	Higher	Higher	Moderate
Two Mile Canyon	STEWA-HESS-0552	Higher	Lower	Lower
Granite Canyon	PELLY-PELLY-0480-B	Higher	Moderate	Higher
Detour Canyon	PELLY-PELLY-0567-B	Higher	Lower	Lower
Slate Rapids + Hoole Canyon ROR	PELLY-PELLY-0847-B + PELLY-PELLY-0760-A	Higher	Moderate	Moderate
False Canyon + Middle Canyon ROR	LIARD-FRANC-0696 + LIARD-FRANC-0670-B	Moderate	Higher	Higher

Table 16 provides an overall summary of the key advantages and disadvantages of each priority site. On the basis of the evaluation of the six priority sites at this stage in project planning, the following two sites appear offer some key advantages with respect to wildlife and wildlife habitat and potential socio-economic effects relative to the other priority sites:

- Two Mile Canyon
- Detour Canyon

The following site offers a mix of advantages and disadvantages with respect to effects on wildlife and wildlife habitat and socio-economics, but is considered to have substantial constraints with respect to fish and fish habitat:

- Slate Rapids + Hoole Canyon ROR

The following three sites have their own unique mix of advantages and disadvantages, but there are key constraints identified with each that will likely need to be mitigated for the sites to be more acceptable.

- Fraser Falls' key constraints are with respect to effects on fish and fish habitat, wildlife and wildlife habitat;
- Granite Canyon's key constraints are with respect to effects on fish and fish habitat and socio-economics; and
- False Canyon + Middle Canyon ROR's key constraints are with respect to effects on wildlife and wildlife habitat and socio-economics.

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages

Fraser Falls	STEWA-STEWA-0519-B	**Environmental**
		• Low fluctuation of reservoir level (3 m over an average year)
		
		Socio-economic
		• Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy:
		    o High amount of construction jobs (4,800); moderate amount of operations jobs (34)
		• Low overlap with other Land Tenures and Dispositions (900 ha)
		• High construction GDP (553 million); moderate operations GDP (6.7 million)
		• No displacement of infrastructure
		• Adverse effects on community well-being in local communities is expected to be low
			Environmental
			• Overlap with Horseshoe Slough Habitat Protection Area and No-Gold settlement
			• Overlap with chinook, chum salmon and arctic grayling habitat (all three are species of high priority for a National status assessment by COSEWIC). Other fish species will also be affected
			• Overlap with breeding habitat of documented species at risk (woodland caribou, peregrine falcon), and possibly with winter foraging habitat for woodland caribou.
			• Overlap with key nesting habitat for waterfowl and with goose moulting habitat.
			
			Socio-economic
			• Overlap with 3,300 ha of Na-Cho Nyäk Dun Settlement Land
			• Overlap with highest area of Renewable Resource Areas (71,800 ha); largest flooded area (311 km^2)
			• Overlap with Non-Renewable Resource Areas (7,800 ha)
			• Overlap with highest area of Traditional Aboriginal Activity use (31,200 ha)
			• Documented Aboriginal fishing sites:
			    o At Fraser Falls and downstream of Fraser Falls (Linklater 2014; DFO 2015b)
			    o Between Fraser Falls and the confluence with the McQuesten River (DFO, 2015b)

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
			• Overlaps known Heritage and Cultural Resource sites. • Project located in area of high archaeological potential.

Two Mile Canyon	STEWA-HESS-0552	**Environmental**
		• Smallest flooded area (10,300 ha)
		• Reservoir located outside of mainstem of Stewart River
		• Relatively lower effects on wildlife and wildlife habitat
		
		Socio-economic
		• Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy.
		  o Rated in the mid-range for Construction jobs (3,600) Operations jobs (33); and,
		  o Construction GDP (412 million), Operations GDP (6.6 million)
		• The Two Mile site is identified in the Na-Cho Nyäk Dun Settlement Agreement as set out for expropriation for hydroelectric or water storage projects with compensation at a maximum of 3% of the construction cost
		• Relatively low overlap with Renewable Resource Areas (20,700 ha);
		• Low overlap with Non-Renewable Resource Areas (380 ha)
			Environmental
			• Overlap with chinook, chum salmon and arctic grayling habitat. Other fish species will also be affected.
			• High fluctuation of reservoir level (9 m over an average year)
			
			Socio-economic
			• Overlap with 2,000 ha of Na-Cho Nyäk Dun Settlement Land;
			• Moderate overlap with other Land Tenures and Dispositions (10,300 ha)
			• Project located in area of high archaeological potential.

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
		• Relatively low overlap with areas used for Traditional Aboriginal Activities (10,300 ha) • Area is part of Na-Cho Nyäk Dun chinook fishery but no documented Aboriginal fishing sites • No displacement of infrastructure • Adverse effects on community well-being in local communities is expected to be low • No overlap known Heritage and Cultural Resource sites	
Granite Canyon	PELLY-PELLY-0480-B	**Environmental** • Low fluctuation of reservoir level (3 m over an average year) **Socio-economic** • The amount of construction jobs (3,300) and operations jobs (28) and construction GDP (380 million) and	**Environmental** • Downstream effects on Mica and Needlerock Creek Area of Special Consideration (Yukon Placer Fish Habitat Management System) which support genetically distinct populations of chinook salmon. Other fish species will also be affected • Overlap with chinook, chum salmon and arctic grayling habitat. Other fish species will also be affected. • Overlap with species at risk habitat (trumpeter swan) and potential overlap with wintering habitat of woodland caribou. • Overlap with important nesting habitat for waterfowl. **Socio-economic** • Overlap with 8,800 ha of Selkirk First Nation settlement land (highest amount)

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
		operations GDP (5.6 million) are lowest among the six priority sites, but considered substantial in the context of the Yukon economy. • The Granite Canyon site is identified in the Selkirk First Nation Settlement Agreement as set out for expropriation for hydroelectric or water storage projects with compensation at a maximum of 3% of the construction cost • Low overlap with Non-Renewable Resources Areas (35 ha); • No displacement of infrastructure • Adverse effects on community well-being in local communities is expected to be low	• Moderate overlap with Renewable Resources Area (32,400 ha); moderate flooded area (173 km^2) • Moderate overlap with other Land Tenures and Dispositions (4,600 ha) • Moderate overlap with Traditional Aboriginal Activities (17,600 ha) • Documented Aboriginal fishing site within the reservoir footprint (i.e., at Pelly River near the confluence with Little Kalzas River (DFO 2015b)); • Documented Aboriginal fishing sites downstream: o Fort Selkirk just downstream of the Pelly River outlet (downstream of the project site; Yukon Department of Tourism and Culture 2015a); and o Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Downstream of the project site; Yukon Department of Tourism and Culture 2015b). • Overlaps known Heritage and Cultural Resource sites • Project located in area of high archaeological potential.
Detour Canyon	PELLY-PELLY-0567-B	**Environmental** • Substantially lower effects on wildlife and wildlife habitat	**Environmental** • Downstream effects on Mica and Needlerock Creek Area of Special Consideration (Yukon Placer Fish Habitat Management System) which support genetically distinct populations of chinook salmon. Other fish species will also be affected. • Overlap with lower Anvil Creek Area of Ecological and Cultural Special Consideration

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages

		Socio-economic
		• Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy:
		  o Construction Jobs (5,500) and Operations Jobs (37);
		  o Construction GDP (634 million) and Operations GDP (7.3 million)
		• Relatively low overlap with Renewable Resource Areas (27,000 ha); relatively low flooded area (130 km^2)
		• Lowest overlap with other Land Tenures and Dispositions (6 ha)
		• No displacement of infrastructure
		• Relatively low overlap with Traditional Aboriginal Activity land use (13,000 ha)
		• No overlap with known Heritage and Cultural Resource sites
		• Adverse effects on community well-being in local communities is expected to be low
			(Yukon Placer Fish Habitat Management System);
			• Overlap with chinook, chum salmon and arctic grayling habitat. Other fish species will also be affected
			• High fluctuation of reservoir level (7 m over an average year)
			Socio-economic
			• Overlap with 2,300 ha of Liard First Nation/Ross River Dena Council Interim Protected Land
			• Overlap with 3 ha of Selkirk First Nation Settlement Land
			• Moderate overlap with Non-Renewable Resource Areas (10,800 ha)
			• Documented Aboriginal fishing sites downstream:
			  o Fort Selkirk just downstream of the Pelly River outlet (downstream of the project site; Yukon Department of Tourism and Culture 2015a);
			  o Pelly River near the confluence with Little Kalzas River (downstream of the project site; DFO 2015b); and
			  o Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Downstream of the project site; Yukon Department of Tourism and Culture 2015b).
			• Project located in area of high archaeological potential.

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
Slate Rapids + Hoole Canyon ROR	PELLY-PELLY-0847-B PELLY-PELLY-0760-A	**Socio-economic** • Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy: o Highest amount of construction jobs (11,600), highest amount of operations jobs (61) o Highest construction GDP (1,329 million), highest operations GDP (12.3 million)	**Environmental** • Fluctuation of levels of Pelly Lakes and Fortin Lake (effects on shoreline habitat) • Downstream effects on Mica and Needlerock Creek Area of Special Consideration (Yukon Placer Fish Habitat Management System) which support genetically distinct populations of chinook salmon. Other fish species will also be affected • Documented chinook salmon in Pelly Lakes Creek, documented spawning area Pelly lake outlet to 2 km downstream. Effects on spawning reaches, migration, and downstream habitats. Other fish species will also be affected • Overlap with arctic grayling habitat. • Moderate fluctuation of reservoir level (5 m over an average year) • Project is fully within Finlayson caribou herd overwintering range. • Documented bank swallow breeding site; colony-nesting species are at greater risk of local population declines. **Socio-economic** • Overlap with Liard First Nation/Ross River Dena Council Interim Protected Land 4,900 ha • Highest overlap with Non-Renewable Resource areas (19,100 ha); • Moderately high overlap of Renewable Resource Area; • Moderately high overlap with Traditional Aboriginal Activities area (19,100 ha); • Documented Aboriginal fishing sites downstream:

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
		• Low overlap with other Land Tenures and Dispositions (135 ha)	o Fort Selkirk just downstream of the Pelly River outlet (downstream of the project site; Yukon Department of Tourism and Culture 2015a); o Pelly River near the confluence with Little Kalzas River (downstream of the project site; DFO 2015b); and o Tatl'á Män Lake at the head of Mica Creek near Pelly Crossing (Downstream of the project site; Yukon Department of Tourism and Culture 2015b). • Overlaps known Heritage and Cultural Resource sites • Project located in area of high archaeological potential. • Potential displacement of Robert Campbell highway and associated community disruption
False Canyon + Middle Canyon ROR	LIARD-FRANC-0696 + LIARD-FRANC-0670-B	**Environmental** • Effects to fish are limited to non-anadromous fish species and therefore more localized than other priority sites • There is greater potential for moderating effects from Frances Lake complex on mercury accumulation in the reservoir.	**Environmental** • Frances Lake level will be raised by 8 m • Moderate fluctuation of reservoir level (5 m over an average year) • Loss of habitats (spawning, rearing, fluvial) for bull trout (species at risk) • Loss of habitat for arctic grayling. • Documented barn swallow breeding site; colony nesting species at greater risk of local population decline • Overlap with secondary waterfowl staging area and riparian raptor breeding area. • Overlap with caribou WKA (Nahanni herd) and potential encroachment on wintering habitat.

Table 16: Summary of Advantages and Disadvantages

Site Name	Site ID	Key Advantages	Key Disadvantages
		Socio-economic • Economic benefits (i.e., jobs and business activity) are considered substantial in the context of the Yukon economy: o High amount of construction jobs (7,700) o High construction GDP (879 million) o Moderate amount of operations jobs (48) o Moderate amount of operations GDP (9.6 million)	**Socio-economic** • Overlap with 1,500 ha of Liard First Nation/Ross River Dena Council Interim Protected Land • Overlaps with area of potential Traditional Aboriginal Activities • Moderately high overlap with Renewable Resource Areas; second highest flooded area (26,100 ha) • Moderately high overlap with Non-Renewable Resource Areas (3,000) • Highest overlap with other Land Tenures and Dispositions (30,000 ha) • Potential displacement of Robert Campbell Hwy and Nahanni Range Road • Overlaps known Heritage and Cultural Resource sites. Several burial sites are known to exist. • Project located in area of high archaeological potential. • Adverse effects on community well-being in local communities are expected to be moderate.

10.0 CONCLUSIONS AND RECOMMENDATIONS

At this stage in planning, each of the six priority sites remain viable locations for a new hydroelectric project. However, the site-specific advantages or disadvantages highlighted in this study, represent those potential positive effects that could occur and might need to be enhanced; and, those negative effects that will likely require attention through design, mitigation and adaptive management planning. To identify any one of these six priority sites as the preferred location for a new hydroelectric project, more detailed studies, and First Nations, public and stakeholder consultation is recommended. Further environmental and socio-economic baseline studies would need to be undertaken in consultation with First Nations, Yukon stakeholders and within the context of Yukon's environmental and socio-economic assessment process under the *Yukon Environmental and Socio-economic Assessment Act.*

In the absence of an overall preference for any specific site, greater certainty could be achieved to verify these conclusions through:

- Acquisition of more site specific data available in previous survey reports and publications;
- Conceptual level engineering design to better understand project layout and design;
- Discussions with First Nations, federal and territorial government agencies, municipal governments, community leaders, resource development companies (e.g., mining and exploration companies), outfitters, trappers, naturalists, and relevant stakeholders;
- Field surveys to obtain site-specific, baseline information on fish and wildlife species and their habitats; particularly species at risk or those of economic/cultural importance;
- Habitat suitability mapping for valued species;
- Historic and archaeological surveys,
- Traditional knowledge (TK) and traditional land use (TLU) studies;
- Community profiling and community-well-being studies; and
- Economic modelling.

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APPENDIX A
Background Information on Listed Fish Species and Candidate Fish Species in the Yukon

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

Background Information on Listed Fish Species and High Priority Fish Species in the Yukon

CRITICALLY IMPERILLED FISH SPECIES

Arctic Char (Salvelinus alpinus)

Both anadromous and freshwater resident populations of Arctic char occur in the Yukon. Arctic char do not venture far inland from the ocean, except in very large river systems (Roberge et al. 2002). In the Yukon, native populations are only known from two lakes on the north slope; all other populations were introduced in pothole lakes (Environment Yukon, 2010).

Arctic char usually spawn between September and October. Males spawn with more than one female. Once mature, females spawn every two to three years. Spawning occurs on rocky lake shores or in slow pools of rivers at depths ranging between 1.0 to 4.5 m when temperatures are near 4°C. Males are territorial and will defend a redd, which they make in the substrate. Lethal temperature for Arctic char eggs is 7.8°C. Eggs hatch after ice-break up (Roberge et al. 2002).

Anadromous Arctic char migrate to the ocean during the fall when the juveniles are aged five to seven years (size range from 152 to 203 mm). These fish usually stay within the estuary; however, some populations overwinter in lakes (Scott and Crossman, 1973). Adult Arctic char can range from 250 to 800 mm (Environment Yukon, 2010). Arctic char can reach ages greater than 24 years. Juveniles and adults feed on invertebrates and small fish (Roberge et al. 2002).

IMPERILLED FISH SPECIES

White Sucker (Catostomus commersoni)

In the Yukon, white suckers are present in some southern streams that flow into the Mackenzie River. They are commonly found in warm, shallow water in small lakes; bays of large lakes, and in tributary streams of lakes.

White suckers spawn in spring between May and June in inlet or outlet streams of lakes when water temperatures reach at least 10 to 12 °C. Some individuals spawn along lake margins. In some areas, part of the population will spawn in the lake, and the other part in the tributaries. Spawning is usually in flowing water over gravel substrate, often near pools 0.6 to 1.2 m deep. Adults form schools of one female to several males and travel close to the bottom (0.2 to 2.0 m above the bottom) during spawning. The eggs are scattered over and adhere to the gravel substrate or drift to slower water. Eggs hatch in one to two weeks, and the young remain in the stream for one to two weeks more before migrating downstream to the lake. Young white suckers range in size from 12 to 179 mm in length. Upon entering the lake, the young remain in shallow water along the shore during the day where they form schools and feed on plankton and move to deeper water at night, or when water temperatures reach 30 °C. By late summer, young white suckers move to the bottom (Scott and Crossman, 1973).

Juveniles inhabit shallow waters, where they feed near the surface on plankton but move to deeper areas once they reach 16 to 18 mm in length. Adults typically are benthic feeders, yet occasionally eat detritus. Adult white suckers associate with submerged woody debris.

Young white suckers grow rapidly during their first year, and growth slows as the fish grow older. Sexual maturity is between five to eight years of age (Scott and Crossman, 1973). Maximum age seems is 17 years of age, with adults ranging from 300 to 500 mm in size (Environment Yukon 2010a). The maximum size recorded is 635 mm in length.

Sockeye Salmon (Oncorhynchus nerka)

Sockeye salmon occur in two forms, the anadromous sockeye salmon and the freshwater lake-resident kokanee (Burgner 1991 in Roberge et al. 2002). Sockeye are found in the Alsek River system, with the Klukshu River being the most productive portion of the watershed. A commercial fishery exists in the US portion of the Alsek River (DFO 2011). There is a population of sockeye salmon in the Yukon River; however this population is limited to the Alaskan portion of the drainage (Scott and Crossman 1973).

Juvenile sockeye salmon rear lakes rather than streams, although some stream-rearing populations do occur (Woods et al. 1987 in Roberge et al. 2002).

Sockeye lay their eggs in gravel redds in rivers or lakes (Rand, 2011). Female sockeye salmon select the redd site and will defend the redd until near death (Burgner 1991 in Roberge et al. 2002). Spawning occurs at temperatures ranging from 3 to 7 °C (Scott and Crossman 1973) in late summer and autumn, in lake outlet or lake tributary streams, or along lake beaches in finer sediments. River-type sockeye spawn in river channels not associated with lakes (Rand, 2011).

Sockeye usually emerge from the spawning gravel when there is a peak in plankton abundance, allowing the young to optimize feeding (Goodlad et al. 1974; Burgner 1991 in Roberge et al. 2002). Juvenile sockeye salmon use aquatic vegetation as cover against possible predators (Gregory and Levings 1996 in Roberge et al. 2002). Young sockeye are generally <106 mm in length (Scott and Crossman 1973). In lakes, young sockeye frequent the near-shore area soon after emergence in spring and migrate into the limnetic zone later in the summer (Heard 1965; Dawson et al. 1973; Scarsbrook and McDonald 1973; 1975; Nunnallee and Mathisen 1974; Beauchamp et al. 1995 in Roberge et al, 2002).

Juveniles remain for one to three years in fresh water before migrating to the ocean. Some sockeye rear in river channels; however, most rear in a lake environment. Juveniles feed primarily on zooplankton and stream invertebrates. Some anadromous populations migrate within one to three months following emergence, and these make extensive use of estuaries (Rand, 2011). Downstream migration takes place between April and July. Larger, older sockeye salmon migrate earlier than younger, smaller sockeye salmon (Burgner 1991 in Roberge et al. 2002). Most adult sockeye spend one to three years in offshore feeding areas where they grow to maturity (approximately 50 to 60 cm total length and 2.5 to 3.0 kg weight) before returning to spawn. Adult sockeye feed primarily of zooplankton (copepods and euphausiids), but their diet also includes squids and fish (Rand, 2011).

At maturity, sockeye salmon migrate back toward their natal freshwater habitat where they spawn and die (Rand, 2011). The maximum sockeye age is 8 years old (Scott and Crossman 1973).

Chinook Salmon (Oncorhynhus tshawytscha)

Chinook salmon naturally occur in the Yukon and typically inhabit large river systems. Key drainages in the Yukon supporting chinook include the Porcupine River, Yukon River (north, mid and south mainstem), Stewart River, Pelly River, White River, and Teslin River. There are two main forms of chinook salmon: stream-type and ocean-type. Stream-type chinook salmon spend a larger portion of their life within freshwater, both before migrating to the ocean (one to three years) and during migration to spawning grounds (several months). Ocean-type chinook salmon spend less than a year rearing in freshwater and will enter freshwater only days or weeks before spawning (Healey 1991 in Roberge et al, 2002).

In the Yukon, migration to the spawning grounds generally begins in mid-late May through early July, and Chinook enter the Canadian portion of the Yukon River system around mid-July, with spawning occurring from late July through early September (Yukon River Panel 2015*a*). Chinook salmon will spawn within 100 m of the estuary or up to 2000 km upstream in the Yukon River. Female chinook salmon select the redd site. Redds are built on gravel (Chapman 1943; Scott and Crossman 1973) and cobble substrates (Dauble et al. 1999 in Roberge et al. 2002) often associated with gravel bars and islands (Geist and Dauble 1998). The fertilized eggs develop during the winter and hatch in late winter or early spring, depending on the time of spawning and water temperature (Yukon River Panel, 2008).

The young emerge from the gravel as fry after several weeks. Most Yukon River chinook salmon spend one to two years rearing in fresh water before their out-migration to the ocean. Chinook salmon from the Yukon River spend, on average, four years at sea (ranging between 1 to 6 years). Salmon do not feed during their spawning migration, so their condition deteriorates gradually during their migration as they use stored body reserves for energy. As female salmon travel to spawning grounds, their eggs gradually mature, becoming larger in preparation for spawning (Yukon River Panel, 2008).

Preferred water temperature ranges from 12 to 14°C (Scott and Crossman 1973). In streams and rivers, juvenile chinook salmon associate with cobble and boulder substrates, in fairly fast flowing water < 1.0 m deep along stream margins and near the confluence of tributary streams (Bravender and Shirvell 1990; Porter and Rosenfeld 1999; Yukon River Panel 2015*a*). Young and juvenile chinook salmon will use aquatic vegetation as cover (Gregory and Levings 1996 in Roberge et al. 2002). Young chinook salmon feed on zooplankton and aquatic invertebrates (Sommer et al. 2001 in Roberge et al. 2002), and adults feed on fish (Scott and Crossman 1973). Chinook salmon generally live between two to three years in the ocean before returning to their natal stream to spawn (Scott and Crossman 1973). Maximum possible age is 9 years, and the maximum length has been recorded as 149 cm (Roberge et al. 2002).

Ninespine Stickleback (Pungitius pungitius)

In the Yukon, the ninespine stickleback is found in the Mackenzie River drainage. Ninespine stickleback inhabit fresh and saline waters along the coast from the Aleutian Islands in Alaska to the Mackenzie River delta. Ninespine stickleback inhabit shallow bays in lakes, tundra ponds and slow streams. In lakes, ninespine stickleback associate with densely vegetated areas, but are also found in open water areas offshore, and to great depths. Populations that reside mostly in estuaries will move into streams to spawn. During the summer, estuarine populations are sometimes confined to the lower reaches of rivers.

Spawning occurs in lakes from May to July. During spawning, males build a nest on the stems of plants, most often in shallow water. The nest is made up of fragments of algae and other aquatic vegetation held together by kidney secretions. Males entice a female to swim through and deposit eggs within the nest. More than one female will deposit eggs into a single nest. Males aerate the eggs within the nest by fanning their pectoral fin over the nest entrance. Males guard the nest until the eggs have hatched and the young are free-swimming.

Sexual maturity of lake populations is thought to be reached within the first year, and life span is about three years. Individuals from this species have been found to reach five years of age. Because sexual maturity is reached within the first year, there is no true juvenile stage for this species (Roberge et al. 2002). Adults associate with shallow vegetated areas of lakes, ponds, and slow areas in streams and feed on fish eggs, benthic invertebrates, molluscs, and aquatic insects. Adult fish range in size from 4 to 7 cm (Environment Yukon, 2010).

VULNERABLE FISH SPECIES

Bering Cisco (Coregonus laurettae)

The Bering cisco is anadromous, migrating from salt water to fresh water to spawn in fast-flowing water near beds of loose gravel where eggs are broadcast over the substrate. Whether they spawn more than once in their life is unknown, but Bering ciscoes reach sexual maturity between four and nine years of age. Fry do not appear to spend much time rearing in fresh water prior to outmigration (COSEWIC 2004).

In the Yukon River, primary spawning areas occur along the mainstem between Circle and Fort Yukon in Alaska. However some Bering cisco migrate up the Yukon River and reach Canadian waters with sporadic observations as far upstream as Dawson City. Migrating fish have been observed in the lower Porcupine River but thus far have not been documented in the Canadian portion of the Porcupine River. Traditional knowledge suggests that the distribution in the upper Yukon River is more widespread than currently documented. In the Yukon River, spawning migrations span from late spring or early summer through fall with peak spawning activity occurring in October. It is possible that the Bering cisco may be found along the Yukon Territory portion of the Beaufort Sea coastline, but its presence there has not been documented or confirmed (COSEWIC 2004).

During the summer, Bering ciscoes are the most abundant whitefish species in the lower Yukon River in Alaska. Bering cisco migrate at the same time as Yukon chinook and chum salmon. Their occurrence over long distances in the Yukon River and along the Bering coastline, suggest they could be an important food source to a number of predators in coastal and riverine environments (COSEWIC 2004).

The migratory behaviour of Bering cisco makes the species potentially susceptible to watercourse obstructions. Alterations to stream flows or changes in the water quality in those areas where they spawn could also potentially have adverse effects. It is possible that Bering cisco found in the Canadian portion of the Yukon River represent the fringe of a much larger spawning population centered in the upper portions of the Yukon River in Alaska that spills over into Canada in some years. It is not known if spawning occurs in Canada (COSEWIC 2004).

The Bering cisco is known to battle against currents for over 2100 kilometres in its migratory upriver path from the Bering Sea through the Yukon River. Bering cisco found in the Yukon River average about 34 cm (males) to 38 cm (females) in length (DFO, 2007).

Squanga Whitefish (Coregonus sp.)

Squanga whitefish exist only in four Yukon lakes: the Dezadeash Lake in the Alsek River drainage, and Squanga Lake, Little Teslin Lake, and Teenah Lake in South-Central Yukon (Bodaly et al. 1988). A population also existed in Hanson Lake in the Yukon River drainage, however that lake was poisoned in 1963 in preparation for stocking rainbow trout.

Squanga whitefish live in sympatry with lake whitefish, and are distinguished by their higher gill raker number. The two forms of whitefish are genetically and morphologically distinct, and likely reproductively isolated in these lakes. The four populations of Squanga whitefish are not monophyletically unique, and each has a rare status rating from COSEWIC. Squanga whitefish are found at all depths. In the summer, they are most often found in the pelagic zone.

Squanga whitefish mature between two to six years of age, depending on the lake. They probably spawn each year after maturation, and live up to a maximum of seven years. Like other whitefish species, Squanga whitefish are broadcast spawners and offer no parental care to the eggs. It is unclear if this form spawns within inlet or outlet streams, or if spawning is within the lake (Roberge et al. 2002).

This species is unable to coexist with ciscoes as they are more competitive and occupy a similar niche. Therefore the Squanga whitefish is highly susceptible to introductions of ciscoes as well as piscivorous (fish eating) species of fish (Ferguson and Tobler, 2004).

Bull Trout (Salvelinus confluentus)

The current distribution of bull trout in Canada extends from the southern portion of Yukon and the south-western corner of Northwest Territories, into parts of western Alberta. Bull trout are found in the Liard River drainage in the Yukon (Roberge et al. 2002). Bull trout prefer cold, high gradient, unproductive waters (Baxter 1997, in Roberge et al. 2002). Typically, bull trout do not inhabit waters that are warmer than 15 °C. Bull trout exhibit four life history strategies: stream resident, fluvial-adfluvial, lacustrine-adfluvial, and possibly anadromous (Cannings and Ptolemy 1998, in Roberge et al. 2002)

There are three types of life history strategies used by bull trout in the Yukon, including:

- Resident - spends its life in small rivers or streams, isolated by physical, chemical or other forms of barriers;
- Fluvial - completes its life cycle in small rivers and streams, migrating between natal streams and larger streams; and
- Adfluvial – similar to fluvial, but matures in lakes rather than streams and rivers.

Sexual maturity occurs between five and seven years of age. Spawning occurs in the fall, when water temperatures fall below 10 °C. Preferred spawning areas are cold, unpolluted moving streams with cobble or loose gravel substrates. The female digs a redd in the center of the channel, and is accompanied by a dominant male, who defends her from other males competing for fertilization. Eggs hatch in the spring (COSEWIC 2013). Young emerge from gravel between April and May (Ratliff 1992, in Roberge et al., 2002). In rivers, they use shallow (< 0.5 m), low velocity areas that have ample cobble and boulder substrates, making use of root wads and woody debris as overhead cover (Baxter 1997, in Roberge et al., 2002).

Juveniles inhabit pool habitat during the summer and run habitat during the fall (McPhail and Baxter 1996, in Roberge et al., 2002), emerging from cover at night to more open, deeper and faster water over silt substrates (Baxter and McPhail 1997, in Roberge et al., 2002). Most juveniles remain in streams for up to four years before migrating to the mainstem, lake or the ocean (Roberge et al. 2002).

Bull trout are opportunistic foragers with a wide diversity of prey sources. Juveniles tend to prefer aquatic insects and invertebrates. While adults continue to eat a wide variety of invertebrates, they are voracious predators and prey upon other fish species as opportunities present (DFO, 2014). Bull trout specimens of up to 24 years in age have been recorded (COSEWIC, 2013). The average length of resident adults is 250 mm (maximum 410 mm fluvial; maximum 900 mm adfluvial) (DFO, 2014).

Dolly Varden (Salvelinus malma)

Dolly Varden are found in all coastal waters of British Columbia, including Vancouver Island and the Queen Charlotte Islands (Scott and Crossman 1973). Dolly Varden are also found farther inland in the headwater streams of the Liard and Peace rivers, which span into Yukon (Scott and Crossman 1973; Haas 1998 in Roberge et al. 2002). The Western Arctic a population of Dolly Varden occurs in drainages that flow into the Beaufort Sea. Approximately 5 to 10% of the global population exists within Canadian waters. Population sizes are largely unknown, with information limited to selected sites (DFO, 2012).

Several different life history types of Western Arctic Dolly Varden populations exist:

- anadromous (sea-run) types that reside in their natal drainage for approximately three years, before migrating out to sea to feed for the summer;
- non-anadromous (freshwater) males that live alongside anadromous fish in the fall and winter and reproduce by "sneaking" into redds to spawn with anadromous females. The non-anadromous types remain in freshwater environments throughout their lives; and
- other non-anadromous types that are found above falls, a long distance from the sea, or in lakes. Both anadromous and non-anadromous types spend the fall and winter in freshwater environments that are well oxygenated and offer abundant shoreline cover and vegetation (DFO, 2012).

Dolly Varden return to their natal streams from September to early November to spawn. The females dig redds and bury their eggs in medium-to-large sized gravel, in moderate velocity water. Spawning takes place at water temperatures of approximately 8 °C. The males defend the redds (Scott and Crossman, 1973). The fry emerge from the gravel in May or June (DFO, 2012).

Juveniles rear in low velocity water and can be found along stream margins, small pools, back eddies, undercut banks, and side channels. As juveniles age (age 3+), they may move to mainstem channels where they can be found primarily in riffles (Griffith 1979).

Adults will spawn each year, sometimes up to four consecutive years (Armstrong 1974 in Roberge et al. 2002). Sexual maturity is reached between three to six years of age, with males usually maturing a year earlier than females (Scott and Crossman 1973). Maximum age of Dolly Varden is approximately 10 to 12 years on average (Bjornn 1961 in Roberge et al. 2002); however, fish up to 20 years in age have been recorded (Scott and Crossman 1973). Sea-run adults reach over 350 mm in length, while non-anadromous adults are generally 300 mm or less in size (Environment Yukon, 2010).

Coho Salmon (Oncorhynchus kisutch)

Coho salmon naturally occur in rivers along the coast of BC and the Yukon. In the Yukon, coho are found in the Alsek and Klukshu river systems, with a US fishery in the lower reaches of the Alsek and a Canadian recreational and traditional First Nations fishery in the Canadian portion of the drainage. In the Yukon River system, coho are limited to the Porcupine River system and the upper Yukon mainstem (Johannes 2012). Coho salmon spawn and rear in streams; however, lake-rearing (Swain and Holtby 1989), pond-rearing (Dolloff 1993) and lake-resident (Foerster and Ricker 1953) populations do exist in BC and Alaska.

Spawning migration normally occurs in tandem with high runoff periods, with timing ranging from July to November in the Yukon; however, run timing for each stock is adapted to the environment to which the adults return. For example, in rivers where salmon must migrate past falls, run timing occurs during low water when falls are passable. In addition, in rivers with lower temperatures, run timing occurs earlier to allow for longer incubation time of eggs (Yukon River Panel 2015*d*). Early migrating coho salmon populations may spawn immediately upon reaching their spawning grounds or wait several months before spawning, while late migrating coho salmon populations spawn soon after arriving at their spawning grounds (Sandercock 1991 in Roberge et al. 2002). Lake-resident populations spawn in tributary streams to the lake (Foerster and Ricker 1953 in Roberge et al. 2002).

Coho salmon may spawn along the whole length of small streams but do not usually venture farther than 250 km from the mouth of large rivers (Scott and Crossman 1973). Coho salmon typically spawn in channels that are characterized by pool-riffle habitat at a slope of 1-3% (Montgomery et al. 1999 in Roberge et al. 2002); however, coho salmon redds have also been observed in slightly steeper habitat. Females select the redd sites (Sandercock 1991 in Roberge et al. 2002) which are usually built in shallow areas over medium to small gravel (Scott and Crossman 1973).

Emergence from the gravel depends on the water temperature. At 2.2 °C, eggs take 137 days to hatch (Sandercock 1991 in Roberge et al. 2002). Newly emerged coho salmon move to slower areas within the stream, such as side channels, near cover structures and stream banks (Tschaplinski and Hartman 1983; Bisson et al. 1988 in Roberge et al, 2002). They may migrate directly to the ocean, but often they remain within fresh water for up to two years (Scott and Crossman 1973). Coho salmon residency time in fresh water is dependent on temperature, with warmer stream temperatures leading to earlier migration to the ocean (Hartman et al. 1982; Holtby 1988). Young and juvenile coho salmon feed on insects and young fish (Scott and Crossman 1973). Young are usually < 100 mm in size.

Newly emerged fry find refuge in shallow stream margins (Yukon River Panel 2015d) and slower areas within the stream, such as side channels, near cover structures and stream banks (Tschaplinski and Hartman 1983; Bisson et al. 1988 in Roberge et al, 2002). Fry migrate to ponds, lakes and low velocity river pools as they grow (Yukon River Panel 2015*d*). They associate with deep, slow water and use cover structures such as undercut banks and large woody debris (Roberge et al. 2002). Juvenile coho migrate to off-channel habitat during the fall to overwinter (Yukon River Panel 2015*d*) and make both large- and small-scale movements during the winter (Roni and Quinn 2001 in Roberge et al. 2002), likely in search of suitable overwintering habitat. Movement into off-channel habitat or tributaries also coincides with the first freshet (Tschaplinski and Hartman 1983; Bell et al. 2001 in Roberge et al. 2002).

Coho salmon migrate downstream after one or two years between April and August (Scott and Crossman 1973; Johnston et al. 1987 in Roberge et al. 2002). Adult coho spend either one or two years at sea before returning to spawn in their natal streams (Scott and Crossman 1973). Adults feed on fish, molluscs and invertebrates. Maximum age is reached at 5 years, and size of adults ranges from 267-762 mm. Water temperatures become lethal for coho salmon at around 25.1 °C.

Rainbow Trout (Oncorhynchus mykiss)

British Columbia and parts of Alberta and the Yukon are the only areas of Canada that support native rainbow trout. Rainbow trout distribution across North America is widespread due to introductions beyond their natural range (McPhail and Lindsey 1970 in Roberge et al. 2002).

Rainbow trout may be resident to fresh water or present as anadromous steelhead (Scott and Crossman 1973).

Resident rainbow trout inhabit either lakes or streams. Lake-dwelling rainbow trout are most commonly found in deep, cold oligotrophic lakes that have inlet and outlet streams with adequate spawning habitat. Adult rainbow trout from large lakes are primarily piscivorous, and grow to a large size. In smaller lakes, adults feed primarily on invertebrates, and are typically much smaller in size (Ford et al. 1995 in Roberge et al. 2002).

Spawning takes place in small tributary streams that feed into lakes and in larger streams from mid-March to late-June (Lindsey et al. 1959; Hartman et al. 1962; Scott and Crossman 1973), when water temperatures are between 10.0 to 15.5 °C (Scott and Crossman 1973). Redds are built in clear, silt-free cold water streams near vegetated banks (Ford et al. 1995) over fine gravel, typically in riffles above pools (Scott and Crossman 1973).

Emergence from the redd takes four to seven weeks (mid-June to mid-August, Scott and Crossman 1973; Ford et al. 1995 in Roberge et al. 2002). Lethal temperature for resident rainbow trout is 24 °C (Black 1953 in Roberge et al. 2002). The maximum age of stream resident rainbow trout is three to four years (Scott and Crossman 1973).

Spoonhead Sculpin (Cottus ricei)

Spoonhead sculpin are found across North America. In BC and the Yukon, they are limited to the Peace River and Mackenzie River. Their abundance within any one location is often low, despite their large range and variable habitat use.

Spoonhead sculpin habitat varies from cool fast streams with clear water to deep lakes to muddy, turbid rivers (Roberge et al. 2002). Their preferred water temperature is <15°C. They can reach a maximum length of 135 mm and live up to six years. Spawning is believed to occur in the spring (April to May) at water temperatures around 6°C. Courted females attach adhesive eggs (280 – 1,200 eggs) to the underside of a rock, and the eggs are guarded and fanned by the male until hatch (2-3 weeks) (Roberts. 1988).

Adults feed on aquatic insects, crustaceans, aquatic worms and range in size from 50 to 80 mm (Environment Yukon, 2010).

Mountain Whitefish (Prosopium williamsoni)

Mountain whitefish typically live in cool lakes and clear or silty rivers and tend to prefer large rivers over small streams (average bank-full width of 28.5 m). Preferred rivers have an average maximum summer temperature of 20.5 °C, and an average watershed gradient of 1.0% (Roberge et al. 2002 and Environment Yukon, 2010). In the Yukon, mountain whitefish can be found in the Liard River system, including Frances River (DFO 2015*b*). Mountain whitefish do not inhabit water deeper than 20 m. They are most commonly found in water 4-6 m deep (Scott and Crossman, 1973 in Roberge et. Al, 2002).

Mountain Whitefish spawn in mid-October to November over gravel or cobble in river or stream riffles or along lake shores (Environment Yukon, 2010). Peak spawning temperatures range between 3 – 5 °C. Mountain whitefish congregate into small groups (2 - 5 individuals) at dusk to spawn. In lakes, spawning occurs in shallow water, and eggs are abandoned by the adults after spawning.

Hatching occurs after 36 days at 16.6 °C. Young that were spawned in river/lake systems typically move to the lake by the end of the summer. They move to deeper offshore areas when water temperatures increase. Young may also undergo upstream movement to overwintering grounds. Length of young ranges from 66 to 185 mm. Juveniles and adults use aquatic vegetation and submerged cover as refuge. In lakes, mountain whitefish do not inhabit waters deeper than 20 m and are most commonly found in water 4 to 6 m deep.

Mountain whitefish are typically bottom feeders and feed on benthic invertebrates and insects. The maximum size recorded is 572 mm. The maximum recorded age is 18 years. Mountain whitefish reach sexual maturity between three to four years of age; however, maturity can occur as early as two year of age (Roberge et al. 2002 and Environment Yukon, 2010).

COSEWIC HIGH PRIORITY CANDIDATE SPECIES

Arctic Grayling (Thymallus arcticus)

In the Yukon, Arctic grayling are found in the Yukon River drainage. They occur primarily in headwaters and upstream of major barriers and typically inhabit clear water of large, cold rivers; smaller, rocky tributary streams, and lakes. They tend to be highly adapted to local environmental conditions and are therefore highly susceptible to anthropogenic changes in their environment.

All life stages migrate between summer and overwintering habitats. Generally, adult Arctic grayling inhabit mainstem reaches during the fall and winter months and move into tributary streams to spawn. Adults have been found to use mainstem pools, riffles, runs and side- and back-channel habitats in the summer and fall. In pools, they can be associated with small boulders and gravel, or bedrock and boulders. In the fall, young Arctic grayling move upstream, and in the spring when runoff peaks near 16.8 m^3/s, they move downstream.

Spawning occurs immediately after ice break-up in small tributary streams of large rivers and lakes. In the Yukon, this happens between April and June when temperatures range from 7 to 10 °C. Spawning takes place over gravel and rock in small tributary streams. When no appropriate spawning habitat is available, spawning may occur over gravel and rock or sometimes over muddy vegetated areas in pools of large rivers. No redd or nest is made during spawning and no parental care is given to the eggs. Eggs hatch relatively quickly (8 to 32 days) depending on water temperature during incubation, and young grow rapidly during their first year of life.

Young inhabit side-channel pools and riffles with water temperatures ranging from 11 to 14 °C and are associated with sand, gravel, cobble, boulder, and silt substrates. Juvenile Arctic grayling usually stay within the nursery tributary streams during summer and may overwinter in lakes with adults. Young juveniles may be found in pool, riffle and run habitat of the mainstem and side channels, while older juveniles are found almost exclusively in pool habitat. Arctic grayling inhabit deeper water as they get older, with young individuals inhabiting water 0 to 25 cm deep, and age 3+ individuals found in pools > 2 m deep. Arctic grayling are territorial, with the larger fish inhabiting the optimal locations. Decreasing temperatures trigger movement downstream to overwintering areas in mainstem rivers or lakes. In rivers, adults can be found in water < 30 cm and velocities 0.21 to 0.8 m/s.

In the Yukon, sexual maturity is reached at seven to nine years. After maturity, spawning may occur each year. Maximum age is reached near 11 to 12 years. Arctic grayling prey on plankton and insects (Roberge et al. 2002). Adults typically range in length from 250 to 400 mm, with a maximum recorded size of 757 mm (Environment Yukon 2010a).

APPENDIX B
Background Information on Wildlife Species of Concern in the Yukon

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

Background Information on Wildlife Species of Concern in the Yukon

SPECIALLY PROTECTED WILDLIFE IN YUKON

Trumpeter Swan

Trumpeter swan populations declined dramatically as a result of overhunting in the 1900s. No bag limit was in place until 1938 and when regulations were introduced in 1916, they were weak and ineffective particularly in the Yukon and Alaska (Lundberg 2011). The North American population decreased to a critical 734 birds in 1935 though it is now stable at approximately 110,000 birds. Aerial surveys in 1995 estimated 1,260 $\pm$ 517 swans in the Yukon (Sinclair et al. 2003). The species is not considered at risk in the Yukon (Yukon Environment 2015) but it receives special protection under the territorial *Wildlife Act*. More specifically, it cannot be hunted except be Inuvialuit and only then if the Minister has established a total allowable harvest and Inuvialuit have been allocated an opportunity to harvest the species. The species is likely protected in the Yukon because it contains breeding habitat, and critical staging areas where swans recover from their long distance migration before accessing their breeding grounds.

Trumpeter swans are seen regularly in the southern Yukon during spring migration and in smaller concentrations during fall migration. Fall migration routes follow spring routes in reverse. Migration is typically in short segments with long layovers and few very long flights. They arrive in the Yukon in early to mid-March (Sinclair et al. 2003) as soon as the first patches of open water become available, usually in the ice-free, shallow lake outlets but also in marshes and slow-moving rivers (McKelvey et al. 1983). Staging peaks in mid-April and declines rapidly in May. Trumpeter swans stage on ice-free waters until breeding habitats are accessible.

The trumpeter swan breeds in southern and central Yukon, in two fairly distinct groups: swans from the Rocky Mountain population nest in the southeast and north of the Stewart River area whereas those from the Pacific coast population nest in the southwest. They tend to nest in shallow wetlands of river floodplains (Sinclair et al. 2003). Breeding habitats are characterized by irregular shorelines, abundant, elevated nest sites, a high volume and diversity of aquatic invertebrates and/or submerged and emergent plants, a stable water level, at least 100 m of unobstructed runway for takeoff, and an early ice-free date (Boreal Songbird Initiative 2014). A low level of human disturbance is also characteristic of trumpeter swan breeding sites (Boreal Songbird Initiative 2014). Many of the wetlands used by trumpeter swans are created or maintained by beaver dams (Sinclair et al. 2003). Breeding pairs are usually dispersed and rarely tolerate other pairs on the same wetland (Sinclair et al. 2003).

The public image of swans in the Yukon is notable as is reflected in Yukon Environment's Interpretive Centre on Marsh Lake, M'Clintock Bay, where visitors can view the species and participate in daily counts. It is also reflected in the strategic plan prepared by the Trumpeter Swan Society (TSS), which was established in 1968 in response to the species' near extinction. The TSS task is to "assure that wild populations of trumpeter swan attain numbers and distributions that will keep them strong and resilient as habitats are increasingly modified by the impacts of human population growth". The TSS aims to achieve this through the sharing of knowledge and by organizing forums in which to discuss swan issues. Their goal is to maintain numbers above the minimum population goals in approved management plans, promote/restore suitable habitat, identify and secure winter and nesting distributions. Part of their mandate is to ensure that the needs of this species are adequately addressed in agency management plans, actions and decision processes.

CRITICALLY IMPERILLED WILDLIFE

Little Brown Myotis

The little brown myotis (*Myotis lucifugus*) is listed as critically imperilled in Yukon Territory. It has also been designated as "endangered" federally by the Committee on Species of Endangered Wildlife in Canada (COSEWIC), and was recently listed under SARA. Both the provincial and federal designations mean that the species is at risk of extirpation or extinction. Populations are stable across western Canada, but have been declining in eastern Canada since 2010 due to white-nose syndrome (WNS), which is a disease caused by a cold-loving fungus Pseudogymnoascus destructans (Pd; COSEWIC 2013a). To date, WNS has spread from the northeastern United States (epicentre) across all of the eastern provinces to Manitoba. This is the primary threat facing this species; however, there have been no records of WNS in the Yukon. Little brown bats are also susceptible to regional declines if maternal colonies are eliminated during the breeding season. Depending on site conditions and the locations of maternal colonies, a newly established reservoir could eliminate a roosting site.

Little brown myotis are a colonial species of bat that exploit a wide variety of habitats including mixed forests, shrub lands, grasslands and urban areas. During the summer months maternal colonies are located in sheltered and spacious areas that provide hot (33 to 55°C) and stable temperatures (COSEWIC 2013a). Attics are typically used but natural environments with suitable conditions will also be used. In the Yukon, colonies have been documented in buildings, bat houses and rock crevices (Slough and Jung 2008); the hollows of large trees would also be suitable. Maternal roosts are composed of breeding females and young with numbers ranging from a few hundred to a few thousand individuals, and maternal roosts may be used annually. The males roost alone or in small colonies in smaller refuge sites away from maternal colonies (e.g., underneath the bark of a tree).

Bats are summer residents in the Yukon, south of the 64th parallel. They migrate to areas with moister air, such as the British Columbia coast for the hibernation period. As such, mitigation in the Yukon is restricted to the breeding period of April 1 – September 30 (Yukon Environment 2015a). During this time, harm to large segments of the population might be mitigated by locating maternal roosts, and protecting females and pups by managing water levels during the summer reservoir filling period.

IMPERILLED WILDLIFE

Swallows

Barn swallows (*Hirundo rustica*) and bank swallows (*Riparia riparia*) are listed as imperilled in Yukon Territory. They have also been designated as 'Threatened' federally by COSEWIC and are listed as such under SARA. Both of these designations mean that the species is threatened with becoming endangered if reasons for population declines are not diminished or eliminated. Swallows are protected under the federal *Migratory Bird Convention Act*, which prohibits harm, disturbance or destruction to birds or their nests eggs, nestlings, or fledglings.

Bank swallows nest in colonies on vertical banks found along rivers, lakes, roads, and aggregate pits. Sand-silt substrates are most favourable to the species as they are easier to excavate nest burrows in. Embankments of gravel or clay are also used (Sinclair et al. 2003). Breeding sites are often near open terrestrial habitats such as meadows, where the species is known to forage on insects. Colonies can range in size from several pairs to a few thousand. The Canadian population has decreased by approximately 98% over the last 41 years, and 31% of this loss has been over the last ten years (COSEWIC 2013b). There does not appear to be a single threat to the species, and as such declines may be the result of cumulative effects from several sources including loss of breeding habitat from erosion at project sites such as flood control (dams) and aggregate management activities. Loss of foraging habitat is not likely an issue in the Yukon, where agricultural conversion and deforestation are not prevalent in the landscape. This species occurs on many Yukon River embankments, with confirmed colonies being noted at numerous locations along major rivers including Yukon, Pelly, Teslin, Hyland, Liard, and Coal Rivers (Sinclair et al. 2003).

Barn swallows also nest in colonies, but their breeding sites often consist of human-made structures such as barns and outbuildings. Prior to European colonization, barn swallows nested mostly in caves and in the holes, crevices and ledges of cliff faces. Breeding sites are typically near open foraging habitats such as wetlands, river and lake shorelines, fields and meadows. There has been a 76% decline on barn swallows in Canada over the past 40 years (COSEWIC 2011). Threats are attributed to loss of habitat, insect declines, exposure to pesticides, and severe weather events on breeding grounds (COSEWIC 2011). They are however, regularly found across southern Yukon.

As with all colonial nesters, swallows are susceptible to notable regional declines if adults and young are eliminated during the breeding season. Depending on site conditions, a newly established reservoir could eliminate a colony’s nesting site, or cause a swallow species to relocate its breeding area higher on the vertical bank being affected. Harm to all life stages can be mitigated for by managing water levels during the summer reservoir filling period.

Common Nighthawk

The common nighthawk is considered threatened nationally and imperilled in the Yukon largely as a result of habitat loss and alteration (COSEWIC 2007), though pesticide use (insect declines) and increased predation on nests may also be contributing factors (NatureServe 2015a). This species has experienced a 50% reduction in its overall population size based on Breeding Bird Surveys from 1966 to 2007 (NatureServe 2015a). It is protected under the federal *Migratory Bird Convention Act*, which prohibits harm, disturbance or destruction to birds or their nests eggs, nestlings, or fledglings.

In the summer, common nighthawks are found in open lodgepole pine forest, old burned areas, open mixed forests, and near wetlands. Large groups of these birds may congregate near lakes and rivers to feed on insects during migration (Sinclair et al. 2003). Common nighthawks are rare in central Yukon although mating flight displays have been heard in the Dawson area and the species has been sighted frequently in spring and summer along Stewart River and as far north as Forty Mile. The species is fairly common in southern Yukon, with breeding records from Kluane Lake in the west to La Biche River in the east.

Common nighthawks are known to have territories of 4 ha to 28 ha depending on location and habitat. They are intolerant of human activity and as such require large no-disturbance setbacks (≥ 150 m) during disturbance activities. This species nests on the ground and may be displaced from nest sites in wetland areas during the summer reservoir filling period. Mitigation at priority sites would involve timing restrictions during the construction period, and water level management during operations to prevent flooding of ground nests within the reservoir footprint.

Olive-sided Flycatcher

The olive-sided flycatcher (*Contopus cooperi*) is listed federally by COSEWIC, and on Schedule 1 of SARA, as “Threatened”, and is listed as “Imperiled/Vulnerable” (S2S3B) in the Yukon. It breeds throughout most of the forested regions of Canada. It is found throughout most of the Yukon, and common in the southern Yukon from Beaver Creek east to La Biche river, and into central Yukon where it is abundant in the Tintina Trench area (Sinclair et al. 2003). The Olive-sided flycatcher is an early post-disturbance specialist, highly associated with forest edges and early successional habitats. As such, it is typically associated with the edges and openings of mature coniferous forests, and in particular forested edges near aquatic habitat (e.g., wetlands), but will also use human-induced edges such as recent clearcuts. It will also use early successional forests, however the presence of tall live or dead perch trees is an essential habitat requirement.

The olive-sided flycatcher is a migratory species, and arrives on breeding grounds in Canada between April and June, with most individuals arriving in May. Fall migration begins in late July to early August, when it returns to wintering grounds in South and Central America. It is considered threatened within Canada because of a precipitous population decline across its range in recent decades. The reason for the decline in olive-sided flycatcher numbers is not clear.

American Kestrel

The American kestrel is found in areas that provide a combination of nest sites and abundant food. Habitats for this species include open spruce or mixed forests, burn areas, meadows, wetlands, and alpine and tundra areas. Although this species is globally and nationally secure, it is endangered in Alaska and imperilled in the Yukon (Smallwood et al. 2009). It was relatively widespread in previous years, but numbers have been steadily declining and detections have been scarce recently (CBC News 2007).

The American kestrel arrives in central Yukon by mid- to late April and migrates south during August and September (Sinclair et al. 2003). The species feeds on terrestrial arthropods and small vertebrates including voles, mice, shrews, bats, and passerines. Nest sites are typically located in old woodpecker cavities, usually in dead spruce trees and occasionally in deciduous trees. Suitable nest trees and perches are necessary for its survival (Smallwood and Bird 2002). Nest boxes are a mitigation strategy for this species.

Fisher

The fisher is currently listed federally as “Imperilled/Apparently Secure” (S2S4) in the Yukon, and is not listed federally by COSEWIC or on Schedule 1 of SARA. This species is a secretive animal that usually seeks cover habitats and is seldom directly observed in the wild. In the Yukon, it is associated with densely packed conifers (Yukon Environment 2015b). It relies on mature and old-growth forests with multi-storied, continuous overhead canopies, large deciduous trees, and ground floor structural complexity in the form of coarse woody debris and snags (Hatler et al. 2008). These forest attributes are critical to the fisher’s survival because they make available an abundance of security and thermal refugia, which are particularly important in cold winter months and during the rearing season. Females have specific denning requirements, namely the presence of mature deciduous or mixed forests - often associated with riparian zones and lower slopes that contain large, decadent deciduous trees with large boles (aspens > 40 cm in diameter-at-breast-height; poplars > 52 cm). Such old trees are atypical and uncommon across the landscape (Weir 2003). Female home ranges, which are a mean of 32 km^2 in size (compared to 199 km^2 for males), typically contain a large proportion of high quality denning habitat (e.g., a mean of 30% of a home range in boreal black and white spruce forests; Weir 2003). Fisher density in northeast BC is estimated to be 11.4 to 23.1 individuals per 1000 km^2 and is expected to be similar in the southern portion of the Yukon.

The establishment of a hydroelectric project reservoir could cause the direct mortality of pups if the initial summer filling occurs before the young are mobile. In subsequent years, females are unlikely to den within the drawdown zone as shrub cover would likely be reduced. Trees are known to disappear from riparian areas surrounding reservoirs due to the lack of nutrients in oligotrophic environments. Denning trees typically have > 45% cover surrounding them for security (Fisher Habitat and Forest Management Web Module).

Western Jumping Mouse

The western jumping mouse (*Zapus princeps*) is found in southern Yukon, and is at the northern limit of its distribution. This species is apparently secure through the remainder of its range in western North America. This jumping mouse is associated with tall grass, often near streams that may have shrubs or trees (Eder and Kennedy 2011). It ranges from valley bottom to tree line. The species hibernates 30 cm to 60 cm below the surface, in a burrow 1 m to 3 m long. Females breed soon after they emerge from hibernation and typically nests above ground (BC Conservation Data Centre 2015). They appear to have one litter per year, of two to eight pups (Eder and Kennedy 2011; BC Conservation Data Centre 2015).

Although adults are known to swim well, diving as deep as 1 m (Eder and Kennedy 2011), pups in nests next to low-lying streams could be subject to direct mortality from flooding during reservoir filling in the summer. The species would likely experience habitat loss from reservoir establishment. The effect of a hydroelectric project would be difficult to manage given the need for winter drawdown and spring/summer filling. However, the western jumping mouse is not a valley bottom specialist and the population as a whole would survive at higher elevations.

VULNERABLE WILDLIFE

Woodland Caribou (*Rangifer tarandus caribou*)

The Finlayson Caribou Herd (FCH) and Ethel Lake Caribou Herd (ELCH) are within the “Northern Mountain Population” (NMP) of woodland caribou (Rangifer tarandus caribou) identified by Environment Canada (2012). The annual range of the FCH is a 23,000-km^2 area located in east-central Yukon near Finlayson Lake (412049/6841587, UTM zone 9v). The ELCH is a 3,400-km^2 area located in central Yukon near Ethel Lake (446056/7027607; UTM zone 9v). A 2007 survey estimated the FCH at 3,100 caribou, and it is considered to be a “declining” population; the ELCH – last inventoried in 1993 – was estimated at 300 caribou, and is considered to be a “stable” population (Environment Canada 2012).

Like most NMP caribou, the FCH caribou display a seasonal elevational migration pattern of wintering within concentrated forested lowlands with shallow snow depths and abundant terrestrial lichen, followed by dispersal to high-elevation areas, often in alpine habitats, for spring (calving) and summer foraging (Reid et al. 2013). The FCH's summer and fall ranges are primarily on alpine plateaus south of Finlayson Lake. However, approximately one-third of the herd uses scattered alpine areas north of the Campbell Highway. Calving sites are dispersed and limited to high elevation presumably to reduce predation rates during this vulnerable life stage. Breeding is highly synchronized with 80-90% of calves born within a 10-day period, typically peaking at the end of May (Yukon Environment, nd).

Winter range is considered a fundamental concern for NMP caribou (Florkiewicz et al. 2006) because although herds forage on a variety of plants during the growing season (from spring green-up to fall abscission), they feed primarily on terrestrial lichens in winter. Access to lichens can be limited by deep and/or crusted snow that is difficult to crater through. As lichens are typically very slow growing, they tend to be associated with mature and old forests (Sulyma 2001). They are also associated with dry, nutrient-poor growing sites where productivity of other plants is low (Sulyma 2001). In winter, NMP caribou typically inhabit lowland areas dominated by open, mature to old (> 80 yrs), coniferous (lodgepole pine [*Pinus contorta*] or mixed spruce [*Picea glauca*]/pine) forest as these have well-developed canopies that intercept snow (i.e., have lower snow depths) and provide abundant terrestrial lichens (Florkiewicz et al. 2006, Farnell 2009, Reid et al. 2013). The FCH winter range is a lowland forested area east of Ross River, where there are abundant ground lichens under relatively open black spruce, white spruce, and lodgepole pine forests. This winter range is located north of the Pelly Mountains, which create a rain-shadow effect by intercepting the predominant weather systems from the southwest. The low snow depths and abundant ground lichens in the main Finlayson winter range are typical of Yukon woodland caribou winter ranges (Adamczewski et al. 2010).

The FCH is subject to one of four intensive caribou recovery and maintenance programs in the Yukon geared towards increasing and stabilizing NMP herds. The program has involved a combination of measures since the early 1980s including increased monitoring, reduced or suspended harvesting, and wolf control (Environment Canada 2012). The Robert Campbell Highway – constructed in the early 1960s – drastically increased human access to the FCH, with a resulting increase in harvest pressure and subsequent population decline (Adamczewski et al. 2010). The FCH was the subject of a large-scale, high-profile wolf removal project from 1983 to 1989 (Farnell 2009, Adamczewski et al. 2010, Yukon Environment 2011). Hunting quotas and limits have been in effect for resident hunters and outfitters since 1998. There are a number of substantial mineral exploration projects in the herd's range, including the Wolverine Mine and access road which recently began operation in 2011. It is expected that the FCH will require ongoing harvest management into the foreseeable future (Environment Canada 2011).

The ELCH has had persistently low recruitment in past decades and is a relatively small herd (~300 caribou). For these reasons the herd has had a voluntary hunting closure supported by the local community since the early 2000s (NNFWPT 2014). A large part of the winter range was affected by fire in 2005, with an associated loss of forage and winter habitat. It is expected to be many decades before caribou use these burned areas in winter, and has therefore raised concerns over herd movements and future health (Environment Canada 2012, NNFWPT 2014).

<u>Sharp-tailed Grouse</u>

The Yukon Territory subspecies of sharp-tailed grouse (*Pedioecetes phasianellus caurus*) is considered vulnerable to becoming endangered in the Yukon but is not federally listed as a species at risk. The Yukon government has identified some critical habitat areas for sharp-tailed grouse (i.e., referred to as Wildlife Key Areas) as this species is considered an immediate management concern because of its limited distribution in the Yukon, unique habitat requirements, restricted movements, and intense social behaviours that make it particularly vulnerable to disturbance (Yukon Environment 2014).

As with all grouse, the sharp-tailed grouse is a lekking species. That is, up to 20 males will display in open areas with good horizontal visibility (a lek) during the spring courtship period (March to July), with peak attendance in late April and early May (Conelly et al. 1998). Leks are found in open aspen stands or shrubby forest clearings. During this time, females will mate with the most dominant males at the centre of the lek then leave to nest and raise their young solitarily. Nesting habitat is generally comprised of dense shrubby vegetation where there is good cover from predators. As sharp-tailed grouse are a precocial species (the young are self-reliant as soon as they hatch), the chicks and their mother quickly leave the nest site in search of cover and food. As such, brood habitat consists of edge habitat that offers both shrubby vegetation for concealment and short vegetation for foraging, particularly in the form of forbs. Sharp-tailed grouse eat seeds, berries, forbs, leaves, and insects. They also need a source of gravel for their crop, which aids in the digestion of food. They forage for seeds, berries and forbs and leaves on the ground in summer but shift to denser deciduous and shrub cover in winter for browse opportunities and thermal insulation (Mossop 1979).

In summary*, P. p. caurus* is associated with aspen stands or shrubby forest clearings with open areas for lekking, meadows for brood foraging, deciduous trees and shrubs for browsing especially in winter, and a gravel source for crop maintenance (food digestion). Such habitat mosaics tend to be associated either with gravel outwashes, which produce fairly stable aspen parkland habitat, or wet sedge-hummock meadows that have been subject to fire (Mossop 1979). According to a study of active and inactive leks in northwestern Alberta, lek sites are more likely to be utilized if there is natural habitat cover in the surrounding landscape and a low level of habitat disturbance (Stavne 2006). Fire causes the typical, mature white spruce to be replaced by an aspen-willow tree cover. Sand dunes appear to provide especially good lekking sites when they are present in parkland habitats as they are slightly raised and covered by sparse ground vegetation and an open balsam poplar tree layer.

Sharp-tailed grouse populations have been declining throughout North America (Leupin 2003, Schroeder et al. 2000; Yukon Environment 2014). In the Yukon, the availability of post-fire sedge meadows are limited by the natural process of succession, which causes the deciduous canopy to be replaced by a coniferous one over a certain period of time (Mossop 1979). The interval between fires has declined dramatically as a result of forest fire management. That is, the mean interval between fires appears to have dropped from 100 years in the 1940s to 500 years as early as the 1970s (Kelleyhouse 1979). Consequently, suitable (early succession) sedge meadows have become more limited in their availability. Populations on gravel outwashes are susceptible to mortality during flood events. They are also more susceptible to hunting and displacement from developments (e.g., roads) due to their easy access by humans (Mossop 1979). Increased mortality rates also appear to coincide with spring and fall dancing periods, when a large number of individuals from a population are at risk from predators and hunters, and as a result of winter severity (Leupin 2003).

Sharp-tailed grouse may be displaced as a result of reservoir flooding, if outwash parkland habitat is eliminated. Other project effects include increased hunting from access road development, and habitat loss from project infrastructure. Some mitigation is possible through design planning (e.g., avoidance of aspen and willow-dominated sedge meadows), and temporal/spatial constraints near identified sharp-tailed grouse sites during the breeding season (e.g., no-disturbance buffers, work window limitations).

Peregrine Falcon

The peregrine falcon (*Falco peregrinus anatum*) receives special protection under the Yukon *Wildlife Act*; WKAs have been identified for this species to protect its breeding habitats. It was designated by COSEWIC as “special concern” in 2002 and is now listed under SARA as such. This “American” peregrine falcon subspecies is a summer resident that occupies most major river valleys in the Territory, with healthy populations in the Yukon, Peel and Porcupine River drainages (Sinclair et al 2003). The largest of these populations is the one occurring in the Yukon River valley, where density between the Pelly River and the Alaska border ranges from 5 km to 120 km (Sinclair et al 2003). The second largest population is in the Peel River Valley, with a mean density of approximately 23.5 km between nests. The Porcupine River Valley population is the smallest, with approximately 35 known nests spaced an average of 15.2 km apart (Sinclair et al 2003). Peregrine falcons suffered a drastic decline in the late 1970s and early 1980s but appear to be recovering to healthy levels in the Yukon (Sinclair et al. 2003).

Nests of this species are established on steep cliff faces adjacent to or near water bodies, most frequently along major rivers. The nesting cliff is the most important feature of its breeding habitat, and the same cliff may be occupied for decades (refer to Sinclair et al. 2003). A breeding pair will select a group of potential ledges on which to nest each summer, before selecting the final egg-laying site. Peregrine falcons are very strong fliers that hunt and capture medium-sized birds in flight. As wetlands tend to have high concentrations of birds, they are an important foraging habitat feature.

Impacts to this species as a result of hydroelectric development may occur from blasting cliff faces for construction, or from flooding nest sites during reservoir development and operations. As peregrine falcons are summer residents, mitigation measures would target the breeding period (May to August) and would involve the implementation of timing windows for construction activities and the management of reservoir water levels (i.e., summer filling rates).

Rusty Blackbird

Rusty blackbirds are of special concern federally (listed under SARA) primarily because of the loss of wetlands on the species wintering grounds to the south. The creation of hydroelectric reservoirs could lead to further habitat loss within the species’ breeding range (COSEWIC 2006). Bird control programs designed to manage bird species that ravage crops are likely an additional threat. These programs, aimed at controlling cowbird, starling, red-winged blackbird, and grackle populations, have been ongoing in southeastern US since the 1970s. The rusty blackbird is inadvertently affected as it mingles with these species during migration (COSEWIC 2006). In the Yukon, the rusty blackbird is also considered as being of special concern as a result of population declines. The rusty blackbird receives some public attention as evidenced by the annual Rusty Blackbird Migration Blitz organized by the Yukon Bird Club; part of an international effort to monitor the species progress along migration routes (Yukon Research Centre 2014).

Rusty blackbirds nest in pristine, shrubby wetland habitat at the edge of ponds and lakes of boreal forests. Nesting has been confirmed at scattered locations throughout the Yukon (Sinclair et al. 2003). The species first appears in the Yukon during the second half of April, and departs in September (Sinclair et al. 2003). Large flocks can be seen at this time, as the species congregates to in productive areas prior to their southward migration. Fall feeding grounds include productive wetland complexes as well as landfills (Sinclair undated).

APPENDIX C
Fish and Fish Habitat Site Scorecards

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

Scorecard Rating Methodology –
Fish and Fish Habitat

Appendix C, Tables C1-C6 present the ratings of the effects of each hydroelectric project on identified fish species with populations distributed in and around the reservoir footprints of the Next Generation priority sites. These tables also rate the potential effects of each site on known Aboriginal fish camps, fishing locations, fisheries and fisheries values. Effects to fish habitat were also evaluated and rated.

The fish and fish habitat evaluation methodology is provided in section 2.1.1.1 of this report. In summary, potentially affected species were identified using Fisheries and Oceans Canada *Fisheries Information Summary System*. Species life histories were then assessed to determine potential interaction with each priority site and an evaluation of potential effects during different life stages were developed for each species.

Both federally and provincially/territorially listed fish Species at Risk were identified. These species were rated according to listed status (i.e. listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), by Canada's *Species at Risk Act* (SARA) or by the Yukon Conservation Data Centre. Section 3.6.3 provides the federal and provincial/territorial rankings for fish Species at Risk evaluated in this report.

Effects of each hydroelectric project were assigned a rank of 0.5-5, with 5 representing the highest potential for an adverse effect. Overall site ratings were assigned based on the highest ranking assigned for any given parameter. For example, a site with ranking of 5 for chinook salmon, 1 for whitefish, and 3 for northern pike would be assigned an overall rating of 5. Sites are expected to have a notable (higher) effect on fish and fish habitat values if they are assigned a rating of 5; a moderate effect for a rating of 3-4, and a low or neutral effect for a rating of 1-2. Given the importance of salmon in the Yukon and for Aboriginal peoples, this approach to rating the effects is considered to be precautionary rather than an absolute conclusion regarding the significance of the effect.

Overall Site Rating	Rating	Effects on Fish and Fish Habitat
Lower **(most preferred)**	0.5	• Effects limited to fish species that are not territorially or federally listed (i.e., no effects to species at risk) • Habitat gains expected to result from reservoir creation • Effects are limited to a few life stages
	1	• Effects limited to fish species that are not territorially or federally listed (i.e., no effects to species at risk) • Habitat gains expected to result from reservoir creation • Effects to several life stages
	2	• Effects limited to fish species that are not territorially or federally listed (i.e., no effects to species at risk) • No habitat gains are expected to result from reservoir creation
Moderate	3	• Effect on non-migratory fish species on the YCDC Watch list but for which an S4 (apparently secure), or higher rating is assigned by YCDC, (i.e., non-migratory fish species that are potentially at risk).
	4	• Effect on fish species at risk in the following categories: o territorially (YCDC) listed non-migratory species with S3 (vulnerable) rank for which habitat impacts are expected to be confined to the reservoir footprint; and/or o territorially (YCDC) listed migratory species with S4 (apparently secure) rank
Higher **(least preferred)**	5	• Effect on fish species at risk in the following categories: o federally listed (COSEWIC/SARA) designation of special concern or higher; and/or o territorially (YCDC) listed species ranked as S1 (critically imperiled) or S2 (imperiled) • Effect on upstream and downstream habitats of migratory species

Table C-1: Fraser Falls Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Chinook salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site	Potential dewatering of stream margins; stranding potential downstream of reservoir;			5
Chum salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site				5
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; Loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations		Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Burbot			Potential hardening of gravel bars downstream of reservoir				1
Northern pike			Loss of low-gradient stream habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint			3
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins; potential stranding/loss of habitat in backwaters and mainstem side channels	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Inconnu	Potential changes to run timing associated with changes in ice-up and break-up; freshet		Loss of habitat within reservoir footprint	Loss of habitat within reservoir footprint			2
Longnose sucker			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of vegetated lake margins within reservoir footprint	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Least cisco			Loss of habitat within reservoir footprint	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		0.5
Slimy sculpin						Loss of habitat within reservoir footprint	0.5
Overall Fisheries Rating							5 (Higher)

Table C-2: Two Mile Canyon Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Chinook salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site	Potential dewatering of stream margins; stranding potential downstream of reservoir;			5
Chum salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site				5
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; Loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations		Potential increase in pelagic habitat for adult life stages within reservoir footprint		
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Arctic lamprey		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles		Potential dewatering of ammocoete burrows in reservoir tributaries and downstream of reservoir; potential hardening of stream margins d/s			0.5
Northern pike			Potential dewatering of low-gradient spawning habitat downstream of reservoir; loss of low-gradient habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint; stranding potential at some flow regimes			3
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins;	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Inconnu	Potential changes to run timing (changes in ice-up and freshet)		Loss of habitat within reservoir footprint	Loss of habitat within reservoir footprint			2
Least cisco			Loss of habitat within reservoir footprint; potential loss of deep pool habitat downstream of reservoir if flooding magnitude/frequency is reduced	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		0.5
Slimy sculpin					Potential loss of cover (logs and rocks) downstream of reservoir	Loss of habitat within reservoir footprint	1
Overall Fisheries Rating							5 (Higher)

Table C-3: Granite Canyon Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Chinook salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site	Potential dewatering of stream margins; stranding potential downstream of reservoir;			5
Chum salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site				5
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential for stranding; loss of shoal habitat in reservoir at some water elevations			1
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Arctic lamprey		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles		Potential dewatering of ammocoete burrows in reservoir tributaries and downstream of reservoir; potential hardening of stream margins downstream of reservoir			4
Northern pike			Potential dewatering of low-gradient spawning habitat downstream of reservoir; loss of low-gradient habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint; stranding potential at some flow regimes			3
Burbot			Potential dewatering of spawning habitat within reservoir margins; potential access issues to tributary spawning streams	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins; potential stranding/loss of habitat in backwaters and mainstem side channels	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Inconnu	Potential changes to run timing associated with changes in ice-up and break-up; freshet		Loss of habitat within reservoir footprint	Loss of habitat within reservoir footprint			2
Least cisco			Loss of habitat within reservoir footprint; potential loss of deep pool habitat downstream of reservoir if flooding magnitude/frequency is reduced	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		0.5
Slimy sculpin					Potential loss of cover (logs and rocks) downstream of reservoir	Loss of habitat within reservoir footprint	1
Lake chub			Potential for access limitation to tributary streams due to reservoir fluctuations; potential dewatering of spawning sites downstream of reservoir		Potential loss of suitable habitat in reservoir footprint; moderate to poor replacement habitat in reservoir due to need for high cover values		1
Overall Fisheries Rating							5 (Higher)

Table C-4: Detour Canyon Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Chinook salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site	Potential dewatering of stream margins; stranding potential downstream of reservoir			5
Chum salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site				5
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Arctic lamprey		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles		Potential dewatering of ammocoete burrows in reservoir tributaries and downstream of reservoir; potential hardening of stream margins downstream of reservoir			4
Burbot			Potential dewatering of spawning habitat within reservoir margins; potential access issues to tributary spawning streams	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Northern pike			Potential dewatering of low-gradient spawning habitat downstream of reservoir; loss of low-gradient habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint; stranding potential at some flow regimes			3
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins; potential stranding/loss of habitat in backwaters and mainstem side channels	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Inconnu	Potential changes to run timing associated with changes in ice-up and break-up; freshet		Loss of habitat within reservoir footprint	Loss of habitat within reservoir footprint			2
Least cisco			Loss of habitat within reservoir footprint; potential loss of deep pool habitat downstream of reservoir if flooding magnitude/frequency is reduced	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		0.5
Slimy sculpin					Potential loss of cover (logs and rocks) downstream of reservoir	Loss of habitat within reservoir footprint	1
Lake chub			Potential for access limitation to tributary streams due to reservoir fluctuations; potential dewatering of spawning sites downstream of reservoir		Potential loss of suitable habitat in reservoir footprint; moderate to poor replacement habitat in reservoir due to need for high cover values		1
Broad whitefish				Potential loss of shallow water habitat in reservoir margins;	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Longnose sucker			Potential dewatering of spawning habitat within reservoir margins; potential access issues to tributary spawning streams	Potential loss of vegetated lake margins within reservoir footprint	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
All species	Potential contamination of reservoir and downstream habitats due to historic mine wastes draining from Anvil Creek.						2
Overall Fisheries Rating							5 (Higher)

Table C-5: Slate Rapids and Hoole Canyon Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Chinook salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site	Potential dewatering of stream margins; stranding potential downstream of reservoir;			5
Chum salmon		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; restriction or loss of migration route to areas upstream of dam site				5
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Burbot			Potential dewatering of spawning habitat within reservoir margins; potential access issues to tributary spawning streams	Potential loss of shallow water habitat in reservoir margins		Potential increase in pelagic habitat for adult life stages within reservoir footprint	1
Arctic lamprey		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles		Potential dewatering of ammocoete burrows in reservoir tributaries and downstream of reservoir; potential hardening of stream margins downstream of reservoir			4
Northern pike			Potential dewatering of low-gradient spawning habitat downstream of reservoir; loss of low-gradient habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint; stranding potential at some flow regimes			3
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins;			1
Inconnu	Potential changes to run timing associated with changes in ice-up and break-up; freshet		Loss of habitat within reservoir footprint	Loss of habitat within reservoir footprint			2
Least cisco			Loss of habitat within reservoir footprint; potential loss of deep pool habitat downstream of reservoir if flooding magnitude/frequency is reduced	Potential loss of shallow water habitat in reservoir margins	Potential increase in pelagic habitat for adult life stages within reservoir footprint		0.5
Slimy sculpin					Potential loss of cover (logs and rocks) downstream of reservoir	Loss of habitat within reservoir footprint	1
Lake chub			Potential for access limitation to tributary streams due to reservoir fluctuations; potential dewatering of spawning sites downstream of reservoir				1
Broad whitefish				Potential loss of shallow water habitat in reservoir margins;	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Longnose sucker			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of vegetated lake margins within reservoir footprint	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Overall Fisheries Rating							5 (Higher)

Table C-6: False Canyon and Middle Canyon Fish and Fish Habitat Site Scorecard

Fish and Fish Habitat							
Fish Species	Migration Timing	Migration	Spawning	Rearing	Adult life stage	All life stages	Rating
Arctic grayling		Migration barrier at dam site could result in loss of access to upstream habitats; may present challenge to out-migrating juveniles	Limited access to reservoir tributaries; loss of spawning habitat in reservoir footprint	Potential loss of side channel access downstream of reservoir; loss of lotic habitat within reservoir footprint			4
Lake trout			Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential for stranding; loss of shoal habitat in reservoir at some water elevations	Potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Bull trout			Loss of spawning habitat within reservoir footprint; potential loss or hardening of gravel bars downstream of reservoir; adverse changes to water temperature and quality may reduce quality of spawning habitat	Potential loss of gravel and cobble substrates downstream of reservoir; loss of rearing habitat within reservoir footprint	Loss of fluvial habitat within reservoir footprint; potential loss of cold, fast water habitat downstream of reservoir		4
Lake whitefish				Potential dewatering of shoals during reservoir fluctuations	Limited increase in pelagic habitat for adult life stages within reservoir footprint		1
Burbot			Potential dewatering of spawning habitat within reservoir margins; potential access issues to tributary spawning streams	Potential loss of shallow water habitat in reservoir margins	Limited potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Northern pike			Potential dewatering of low-gradient spawning habitat downstream of Frances Lake; loss of low-gradient habitat within reservoir footprint	Potential loss of marshes and backwaters within reservoir footprint; stranding potential at some flow regimes			3
Round whitefish			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of shallow water habitat in reservoir margins; potential stranding/loss of habitat in backwaters and mainstem side channels	Limited potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Slimy sculpin					Potential loss of cover (logs and rocks) downstream of reservoir	Loss of habitat within reservoir footprint	1
Broad whitefish				Potential loss of shallow water habitat in reservoir margins	Limited increase in pelagic habitat for adult life stages within reservoir footprint		1
Longnose sucker			Potential loss of suitable spawning habitat (lake outlet and river mouths) within reservoir footprint due to fluctuating water levels	Potential loss of vegetated lake margins within reservoir footprint	Limited potential increase in pelagic habitat for adult life stages within reservoir footprint		1
Overall Fisheries Rating							4 (Moderate)

APPENDIX D
Wildlife and Wildlife Habitat Scorecards

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

Scorecard Rating Methodology – Wildlife and Wildlife Habitat

Appendix D, Tables D1-D6 present the ratings of the potential effects of each hydroelectric project on wildlife and wildlife habitat. The wildlife and wildlife habitat evaluation methodology is provided in section 2.1.2 of this report. In summary, each priority site was evaluated based on:

- the presence of a protected or conservation area;
- species at risk with a documented occurrence within the proposed reservoir footprint;
- the potential occurrence of additional species at risk; and
- Environment Yukon's Wildlife Key Areas (WKA) representing a large aggregation of individuals (i.e., staging, nesting, moulting areas for water birds).

Consideration was also given to:

- WKAs for species not at risk; and
- project overlaps with a caribou range (reservoirs may overlap with winter foraging caribou habitat).

Effects of each hydroelectric project were assigned a rank of 0 or 1 with 0 indicating no potential for effect, and 1 indicating a potential for effect to the identified priority site wildlife and wildlife habitat attribute. The overall site ratings were assigned based on the cumulative score for the site.

Overall Site Rating	Cumulative Score
Lower (most preferred)	**1-2**
Moderate	**3-4**
Higher (least preferred)	**5 and above**

Table D-1: Fraser Falls Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area	Horseshoe Slough Habitat Protection Area	Part of Na-Cho Nyäk Dun Final Agreement approved by Yukon Government in 2001	1
WKA[1] - Breeding (summer)	Duck	1989 survey yielded > 500 adult ducks with 77 broods in summer	1
WKA - Moulting (fall)	Canada Goose	1989 survey yielded > 500 Canada geese prior to southward migration	1
WKA - Staging (spring)	__	__	0
WKA - Overwintering	Woodland Caribou - Ethel Herd	Project overlaps with 4.5% of WKA; there is potential for low elevation winter habitat within this area of overlap	0.5
WKA - Raptors	Peregrine Falcon Bald Eagle	Two pairs of each species	0.5
Species At Risk[2] - Documented	Woodland caribou Peregrine Falcon	Federally listed as vulnerable	2
Species at Risk - Number of Additional, Potential	Six species	Little brown myotis Rusty blackbird Bank swallow American kestrel Sharp-tailed grouse Common nighthawk	1
Overall Environmental Effect Rating			7 (Higher)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

Table D-2: Two Mile Canyon Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area	—	—	0
WKA[1] - Breeding (summer)	—	—	0
WKA - Moulting (fall)	—	—	0
WKA - Staging (spring)	—	—	0
WKA - Overwintering	—	—	0
WKA - Raptors	—	—	0
Species At Risk[2] - Documented	—	—	0
Species at Risk - Number of Additional, Potential	Four species	Rusty blackbird Bank swallow American kestrel Common nighthawk	1
Overall Environmental Effect Rating			1 (Lower)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

Table D-3: Granite Canyon Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area			0
WKA[1] - Breeding (summer)	Duck Swan Goose	A duck WKA of greater value is situated approximately four kilometres south of the project. A June 2007 survey yielded 14 trumpeter swans, 896 ducks, and 26 geese.	1
WKA - Moulting (fall)	—	Value of this WKA as staging habitat undetermined.	—
WKA - Staging (spring)	—	Value of this WKA as staging habitat undetermined.	—
WKA - Overwintering	Unknown caribou herd, possibly Tatchun	Anecdotal WKA	0.5
WKA - Raptors	Golden Eagle	High elevation (no project interaction)	0
Species At Risk[2] - Documented	Trumpeter Swan Woodland caribou	Federally listed as vulnerable	2
Species at Risk - Number of Additional, Potential	Five species	Rusty blackbird Bank swallow American kestrel Common nighthawk Sharp-tailed grouse	1
Overall Environmental Effect Rating			4.5 (Moderate)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

Table D-4: Detour Canyon Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area	—	—	0
WKA[1] - Breeding (summer)	—	—	0
WKA - Moulting (fall)	—	—	0
WKA - Staging (spring)	—	—	0
WKA - Overwintering	—	—	0
WKA - Raptors	—	—	0
Species At Risk[2] - Documented	—	—	0
Species at Risk - Number of Additional, Potential	Five species	Little brown myotis Bank swallow Sharp-tailed grouse American kestrel Common nighthawk	1
Overall Environmental Effect Rating			1 (Lower)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

Table D-5: Slate Rapids and Hoole Canyon Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area	__	__	0
WKA[1] - Breeding (summer)	__	__	0
WKA - Moulting (fall)	__	__	0
WKA - Staging (spring)	__	__	0
WKA - Overwintering	Finlayson caribou herd Moose	Project wholly encompassed within WKA (4% of it); aimed at protecting rutting/calving ground but may contain winter habitat; moose WKA extends 19 km southwards.	0.5
WKA - Raptors	Suitable nesting cliffs for riparian raptors including peregrine falcon. Bald eagle and osprey pairs.		0.5
Species At Risk[2] - Documented	Bank swallows	Two swallow colonies: one is 700 ha; the other 3 ha	2
Species at Risk - Number of Additional, Potential	Four species	Little brown myotis American kestrel Rusty blackbird Western jumping mouse	1
Overall Environmental Effect Rating			4 (Moderate)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

Table D-6: False Canyon and Middle Canyon Wildlife and Wildlife Habitat Site Scorecard

Evaluation Attribute	Description	Comment	Rating
Protected Area	—	—	0
WKA[1] - Breeding (summer)	—	—	0
WKA - Moulting (fall)	—	—	0
WKA - Staging (spring)	Duck Goose Swan	800 ducks, 75 geese, 15 trumpeter swans observed in spring during an May aerial survey (year unknown)	1
WKA - Overwintering	South Nahanni caribou herd Moose	Project overlaps 162 ha (0.003%) of caribou WKA; four WKAs for moose - 144 moose observed in most northern one and < 12 in the remainder	1
WKA - Raptors	Bald Eagle	Two pairs	0.5
Species At Risk[2] - Documented	Barn swallow Trumpeter swan	Swallow colony is estimated to be 7 ha; rusty blackbird breeding documented two kilometres from project	2
Species at Risk - Number of Additional, Potential	Five species	American kestrel Common nighthawk Wester jumping mouse Oscillated emerald dragonfly	1
Overall Environmental Effect Rating			5.5 (HIgher)

[1] Wildlife Key Areas (WKAs) are recognized by the Yukon Territory as being significant for specific wildlife groups.

[2] Species at risk provincially (i.e., vulnerable, imperilled or critically imperilled according to the Yukon Conservation Data. Centre) or federally (i.e., listed as endangered or special concern under the *Species at Risk Act*).

APPENDIX E
Socio-economic Scorecards

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

Scorecard Rating Methodology – Socio-economics

Appendix E, Tables E1-E6 present the ratings of the potential effects of each hydroelectric project on local and regional socio-economic attributes. The socio-economics evaluation methodology is provided in section 2.2.2 of this report. Each priority site was evaluated based on:

- Reservoir overlap with *First Nation Settlement Lands*, *Interim Protected Land* and *other Land Tenures and Dispositions.* The greater the area of overlap the higher the rating. Sites with similar areas of overlap were grouped together and were assigned a similar rating.

- Presence or absence of regional *Land Use Plans*. As there are no priority sites within areas of an approved or draft regional land use plan, this indicator was not used in the evaluation.

- Reservoir overlap with *Renewable Resources* (e.g. parcels of land that are protected or otherwise managed for their renewable resources and/or environmental values.) The greater the area of overlap the higher the rating. Sites with similar areas of overlap were grouped together and were assigned a similar rating.

- Reservoir overlap with *Non-Renewable Resources* (e.g. land that is used or proposed for use for mining, oil and gas extraction). The greater the area of overlap the higher the rating. Sites with similar areas of overlap were grouped together and were assigned a similar rating.

- Reservoir overlap with *Historic and Archaeological Resources* (e.g. presence or absence of known historic or archaeological sites and the likelihood for the project sites to be located within areas of high archaeological potential). All projects were rated as Moderate unless they were associated with known historic or archaeological sites. These sites were rated as least preferred (Higher)

- *Employment and Business Activity* (estimate of direct and indirect jobs created and the GDP generated by each project for the construction and operations phases). Given the substantial employment and business opportunities likely to be generated by any hydroelectric project in the Yukon, none of the priority sites were rated as least preferred (Higher). Rather, the projects generating lower amount of jobs and GDP were rated as Moderate. Projects generating a higher amount of jobs and GDP were rated as most preferred (Lower). Sites with similar numbers of jobs and GDP were grouped together and were assigned a similar rating.

- *Labour Force and Skills Supply* (communities nearest the six priority sites that have some potential to supply local labour for construction). Generally, these communities are within approximately 100 km of a Project site by road). Because all local communities have some but limited potential to supply the project with labour during construction, each priority site were rated as least preferred (Higher).

- Reservoir overlap with areas of *Traditional Aboriginal Activities* (e.g. direct loss of areas available for traditional activities due to flooding of reservoir areas). The greater the area of overlap the higher the rating. Sites with similar areas of overlap were grouped together and were assigned a similar rating. Consideration was also given to the potential changes in access to land that might be afforded by the development of each Project site. Because improved access may be considered as a positive by some or a negative effect by others, all sites were rated as Moderate. Consideration was also given to the presence of known Aboriginal fishing sites or camp locations at the project sites and known locations downstream. Priority sites with no known or documented sites/camp locations potentially affected were rated as most preferred (Lower), sites with known sites/camp locations potentially affected downstream were rated as Moderate; and priority sites with known fishing sites/camps within the reservoir footprint were rated as least preferred (Higher).

- *Community Well-Being* – Considers the potential for in-migration of workers to the Yukon and communities nearest the Project sites that might experience growth and consequently adverse effects on community well-being. Consideration is given to project phasing that may increase the potential for community disruption and the potential displacement of infrastructure (i.e., highways). Priority sites that involved two construction phases were rated lower than those with a single construction phase. Given the likelihood that any highways displaced would be replaced / diverted, these effects were rated as Moderate.

Potential positive, neutral or adverse socio-economic effects of each hydroelectric project were assigned a rank of 1 - 3 with 1 indicating a high adverse or low positive effect, 2 indicating a moderate effect and 3 indicating a low adverse or high positive effect. The overall site ratings were assigned based on the cumulative score for the site.

Overall Site Rating	**Cumulative Score**
Lower (most preferred)	**37 and 39**
Moderate	**33 and 34**
Higher (least preferred)	**31 and 32**

Table E-1: Fraser Falls Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	3,300 ha	2
Interim Protected Lands	0	3
Renewable Resource Areas	71,800 ha	1
Non-Renewable Resource Areas	7,800 ha	2
Other Land Tenures and Dispositions	900 ha	3
Construction Jobs	4,800	3
Operations Jobs	34	2
Construction GDP	553 million	3
Operations GDP	6.7 million	2
Labour and Skills Supply	Limited local supply of labour	1
Traditional Aboriginal Activities – Reservoir Area	31,200 ha	1
Traditional Aboriginal Activities – Improved Access	Yes, by land and water	2
Traditional Aboriginal Activities – Known Fishing Sites or Camp Locations	Yes, at Fraser Falls and downstream sites. Complete inundation of No-Gold settlement and Horseshoe Slough Habitat Protection Area	1
Heritage and Cultural Resources	Known Sites and High Potential	1
Community Well- Being – Displacement of Infrastructure	No displacement of infrastructure	3
Community Well- Being –Local Adverse Effects	Some adverse effects in local communities	3
Overall Socio-economic Effect Rating		33 (Moderate)

Table E-2: Two Mile Canyon Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	2,000 ha	2
Interim Protected Lands	0	3
Renewable Resource Areas	20,700 ha	3
Non-Renewable Resource Areas	380 ha	3
Other Land Tenures and Dispositions	10,300 ha	2
Construction Jobs	3,600	2
Operations Jobs	33	2
Construction GDP	412 million	2
Operations GDP	6.6 million	2
Traditional Aboriginal Activities – Reservoir Area	10,300 ha	3
Traditional Aboriginal Activities – Improved Access	Yes, by land and water	2
Traditional Aboriginal Activities – Known Fishing Sites or Camp Locations	Yes, within Na-Cho Nyäk Dun fishery. No documented sites or locations	3
Heritage and Cultural Resources	High Potential	2
Labour and Skills Supply	Limited local supply of labour	1
Community Well- Being – Displacement of Infrastructure	No displacement of infrastructure	3
Community Well- Being –Local Adverse Effects	Some adverse effects in local communities	3
Overall Socio-economic Effect Rating		38 (Lower)

Table E-3: Granite Canyon Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	8,800 ha	1
Interim Protected Lands	0	3
Renewable Resource Areas	32,400 ha	2
Non-Renewable Resource Areas	35 ha	3
Other Land Tenures and Dispositions	4,600 ha	2
Construction Jobs	3,300	2
Operations Jobs	28	2
Construction GDP	380 million	2
Operations GDP	5.6 million	2
Traditional Aboriginal Activities – Reservoir Area	17,600 ha	2
Traditional Aboriginal Activities – Improved Access	Yes, by water	2
Traditional Aboriginal Activities – Fishing Sites or Camp Locations	Yes, potential effects at downstream sites. Inundation of Little Kalzas River fishing camp by reservoir footprint.	1
Heritage and Cultural Resources	Known Sites and High Potential	1
Labour and Skills Supply	Limited local supply of labour	1
Community Well- Being – Displacement of Infrastructure	No displacement of infrastructure	3
Community Well- Being –Local Adverse Effects	Some adverse effects in local communities	3
Overall Socio-economic Effect Rating		32 (Higher)

Table E-4: Detour Canyon Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	3 ha	3
Interim Protected Lands	2,300 ha	2
Renewable Resource Areas	27,000 ha	3
Non-Renewable Resource Areas	10,800 ha	2
Other Land Tenures and Dispositions	6 ha	3
Construction Jobs	5,500	3
Operations Jobs	37	2
Construction GDP	634 million	3
Operations GDP	7.3 million	2
Traditional Aboriginal Activities – Reservoir Area	13,000 ha	3
Traditional Aboriginal Activities – Improved Access	Yes, by land and water	2
Traditional Aboriginal Activities – Fishing Sites or Camp Locations	Yes, potential effects at downstream sites.	2
Heritage and Cultural Resources	High Potential	2
Labour and Skills Supply	Limited local supply of labour	1
Community Well- Being – Displacement of Infrastructure	No displacement of infrastructure	3
Community Well- Being – Local Adverse Effects	Some adverse effects in local communities	3
Overall Socio-economic Effect Rating		39 (Lower)

Table E-5: Slate Rapids and Hoole Canyon Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	0 ha	3
Interim Protected Lands	4,900 ha	1
Renewable Resource Areas	38,200 ha	2
Non-Renewable Resource Areas	19,200 ha	1
Other Land Tenures and Dispositions	135 ha	3
Construction Jobs	11,600	3
Operations Jobs	61	3
Construction GDP	1,329 million	3
Operations GDP	12.3 million	3
Traditional Aboriginal Activities – Reservoir Area	19,100 ha	2
Traditional Aboriginal Activities – Improved Access	Yes, by water	2
Traditional Aboriginal Activities – Fishing Sites or Camp Locations	Yes, potential effects at downstream sites.	2
Heritage and Cultural Resources	Known Sites and High Potential	1
Labour and Skills Supply	Limited local supply of labour	1
Community Well- Being – Displacement of Infrastructure	Potential for diversion of the Robert Campbell Hwy. Effects are largely mitigable.	2
Community Well- Being –Local Adverse Effects	Some adverse effects on CWB in local communities. Staged development increases potential for community disruption.	2
Overall Socio-economic Effect Rating		34 (Moderate)

Table E-6: False Canyon and Middle Canyon Socio-economics Site Scorecard

Evaluation Attribute	Area Affected and/or Effect	Rating
Settlement Lands	0 ha	3
Interim Protected Lands	1,500 ha	2
Renewable Resource Areas	31,400 ha	2
Non-Renewable Resource Areas	3,000 ha	2
Other Land Tenures and Dispositions	30,000 ha	1
Construction Jobs	7,700	3
Operations Jobs	48	2
Construction GDP	879 million	3
Operations GDP	9.6 million	2
Traditional Aboriginal Activities – Reservoir Area	26,100 ha	1
Traditional Aboriginal Activities – Improved Access	Yes, by water	2
Traditional Aboriginal Activities – Fishing Sites or Camp Locations	Yes, within Kaska Dena/Laird First Nation fishery. No documented sites or locations. However, current use of historic Frances Lake settlement and Tuchitua area is not known.	2
Heritage and Cultural Resources	Known Sites and High Potential	1
Labour and Skills Supply	Limited local supply of labour	1
Community Well- Being – Displacement of Infrastructure	Potential for diversion of Robert Campbell Hwy. and the Nahanni Range Road. Effects are largely mitigable.	2
Community Well- Being –Local Adverse Effects	Some adverse effects on CWB in local communities. Staged development increases potential for community disruption.	2
Overall Socio-economic Effect Rating		31 (Higher)

APPENDIX F
Yukon Next Generation Hydro:
Climate Change and Hydrology Report

Yukon Development Corporation
Positive and Negative Environmental and Socio-economic Effects
- Technical Paper
SLR Project No.: 234.01009.00000

global environmental solutions

Yukon Next Generation Hydro: Climate Change and Hydrology

Midgard Consulting Inc.

May 2015
SLR Project No.: 234.01009.00000

YUKON NEXT GENERATION HYDRO:

CLIMATE CHANGE AND HYDROLOGY

SLR Project No.: 234.01009.00000

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1.0 INTRODUCTION

> Water is linked inextricably with climate. The warming trend recorded over the past decades shows up in changing precipitation patterns, widespread melting of snow and ice, increases in atmospheric water vapour through increasing evaporation, and changes in soil moisture and runoff. However, it is difficult to pinpoint exactly how climate change is affecting the hydrologic cycle at the Yukon scale, among all the other variables that affect climate or water or both. While there is broad agreement that changes affecting Yukon water resources will occur as a result of climate change, they will vary from region to region.
>
> *—Yukon Water: A Summary of Climate Change Vulnerabilities (Environment Yukon 2011), p. 12*

It is not possible to predict and quantify how climate change will affect streamflow and water balances at the scale of individual hydroelectric projects. However, climate trends and projections for the Yukon Next Generation project area are available, and results from research and monitoring provide general guidance on hydrological changes that should be considered for future Yukon hydro development. This paper summarizes and discusses trends in climate and hydrological parameters for the project region, based on long-term reference climate and streamflow records, and on results of research on climate and hydrology. Major hydrological parameters potentially affected by climate change are then considered in relation to the Next Generation hydro options.

1.1 Climate Change Projections

It is clear that humans are influencing the climate system, mainly through emissions of greenhouse gases (IPCC 2013). General circulation models run under a range of assumptions about greenhouse gas emissions consistently predict that the current warming trend will continue and likely increase in magnitude over the next century (IPCC 2013). Model predictions for the Yukon show continued warming trends, especially in winter, and increases in precipitation (IPCC 2013; Werner et al. 2009). Projected increases in temperature for west-central Yukon are some of the largest for western North America. The projected increases in precipitation are much more uncertain, and would be expected to vary more within the region (Werner et al. 2009).

1.2 Climate Change and Hydroelectricity

There is a growing body of work, both at the international scale and for Canada and Alaska, on the hydroelectricity sector and climate change, focusing on planning and adaptation (Cherry et al. 2010; Mukheibir 2013; OURANOS 2008; Schaefli 2015). Hydro is susceptible to both positive and negative impacts from climate change, both as long-term trends and as short-term variability due to increases in extreme events. Impacts can be direct, through changes in hydrology, or indirect, such as through changes in demand and competition for supply. Adaptive responses include 1) improving information related to understanding and prediction of changes in climate and hydrology in the context of impacts on hydroelectric production (in general and at site-specific scales), and 2) incorporating flexibility into planning and operations.

Of particular relevance to the Yukon Next Generation Hydro project are the projections and planning framework developed for British Columbia, where modelling predicts that changes in streamflow by 2050 are likely to increase BC’s annual hydropower potential by more than 10%, with a concurrent decrease in electricity demand of 2% due to warmer temperatures. A key point made is that uncertainties around projections are high and it is important to build in capacity for flexibility (Parkinson & Djilali 2015).

2.0 TRENDS AND VARIABILITY IN CLIMATE AND HYDROLOGY

This section presents information on climate and streamflow variability and trends relevant to planning hydroelectric developments in the Yukon. For reference, Table 1 lists the hydro sites under consideration, their locations within watersheds and permafrost zones, and most relevant climate and hydrometric monitoring stations.

Table 17. Hydro Sites and Climate and Hydrometric Stations

Sites	Watershed description	Permafrost zone for catchment area*	Climate stations	Active hydrometric stations
Two Mile Canyon, Fraser Falls	Fraser Falls is on the Stewart R., which joins the Yukon R. near Dawson, and Two Mile Canyon is on the Hess R., a tributary of the Stewart R.	Extensive discontinuous	Mayo	Stewart R. near Mayo; Stewart R. at the Mouth
Detour Canyon, Granite Canyon	On the mid to lower reaches of the Pelly R. which joins the Yukon R. downstream of Pelly Crossing	Extensive discontinuous for most of the Pelly watershed; the middle reaches are at the northern edge of the sporadic discontinuous zone	Mayo, Pelly Ranch	Pelly R. at Pelly Crossing;** Pelly R. below Vangorda Cr.
Hoole Canyon, Slate Rapids	On upper reaches of the Pelly River	Extensive discontinuous	Watson Lake, Whitehorse ***	Pelly R. below Fortin Cr.; Pelly R. at Ross River
Middle and False Canyons	On the Frances River, which flows to the Liard R. upstream of Watson Lake (Mackenzie R. basin)	Extensive discontinuous in upper part of watershed; sporadic discontinuous around Middle Canyon	Watson Lake	Frances R. near Watson Lake; Liard R. at Upper Crossing

* Permafrost zones: sporadic discontinuous 10-50% cover; extensive discontinuous 50-90% cover (Goulding 2011).
**Pelly R. at Pelly Crossing is the only hydrometric station that is part of the Reference Hydrometric Basin Network.
***While the Faro meteorological station is closer, it is not included in the national datasets used for climate trend analysis.

2.1 Climate Variability

Climate change is not a steady progression. Temperature and precipitation vary naturally from year to year, and broad-scale oscillations of the atmospheric system in the Pacific Ocean influence the Yukon climate over a range of timeframes. These climate oscillations include El Niño-Southern Oscillation (ENSO) events that tend to occur on average every two to seven years and the Pacific Decadal Oscillation (PDO), an El Niño-like phenomenon where sea-surface temperatures, surface currents, and winds in the Pacific Ocean abruptly and unpredictably shift between contrasting “phases” every 20–30 years (Bonsal & Shabbar 2011).

These and other climate oscillations directly influence precipitation and temperature patterns across the Yukon and elsewhere. The PDO has a strong association with the hydrology of western North America (Brabets & Walvoord 2009; Monk et al. 2011). These climate oscillations themselves may be affected by climate change, with more prolonged and intense El Niño events in recent years. The PDO shifted to a warm phase in the late 1970s, coinciding with a shift toward more frequent El Niño events (Bonsal & Shabbar 2011). A shift to a cool phase of the PDO may have occurred around the late 1990s (Werner et al. 2009).

2.2 Temperature and Precipitation Trends

The national and Yukon analyses in this section all use the same datasets and statistical methods. Data are Environment Canada's homogenized Canadian monthly surface air temperatures (Environment Canada 2014; Vincent et al. 2012) and precipitation amounts (Mekis & Vincent 2011). The datasets include climate station records of length, continuity and quality suitable for analysis of climate trends, and they have been checked and adjusted to remove variations not related to climate (for example, methodological changes). Mayo and Watson Lake are the main stations of relevance to this assessment of options for Yukon hydro development, along with Pelly Ranch, which has a shorter record of consistent data. Whitehorse and Dawson trends are also presented to provide a more complete regional picture. Analyses are based on departures from 1961–1990 means. Linear trends were estimated using a non-parametric method (Sens slope estimates), and Mann-Kendall tests were used to test for significance. More in-depth discussion of Canadian trends, based on analysis of these datasets, can be found in Bush et al. (2014).

2.2.1 Temperature

Spatial patterns of trends in annual mean (Figure 1) and seasonal mean temperature changes for Canada (not shown) indicate that the magnitude of warming is comparatively high in the Yukon, and that this is largely due to the winter trends. Warming has been stronger in the north and west of Canada than in the east, and is weakest along the Atlantic coast (Bush et al. 2014). This is a North American pattern, considered to be linked to shifts in atmospheric-ocean circulation patterns (see the section on climate variability, above). Warming trends in winter and spring are strongest in western Canada. Fall warming is most noticeable across the Arctic (including west to Inuvik), while summer warming is more evenly distributed across the country (Bush et al. 2014).

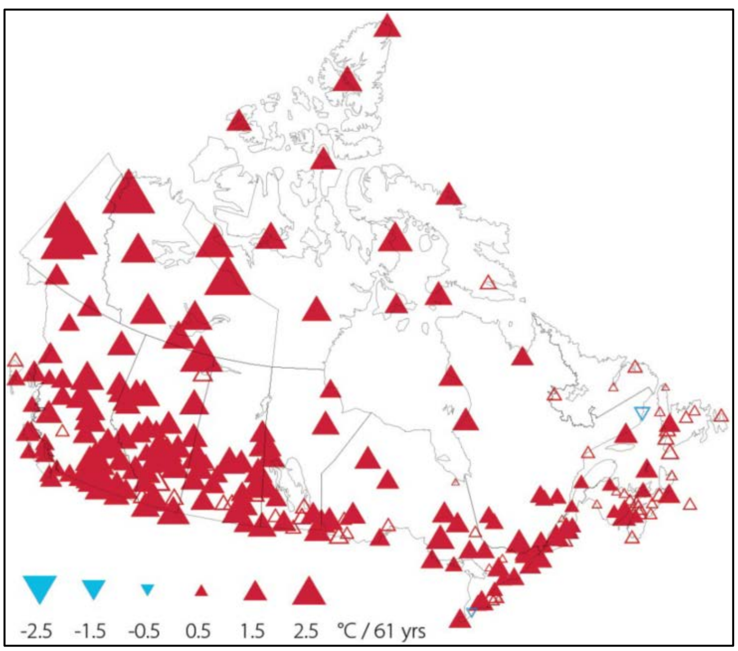


Figure 15. Trends in annual mean temperature across Canada, 1950–2010
Filled triangles indicate magnitude and direction of significant trends (P ≤ 0.05). From Bush et al. (2014) based on Vincent et al. (2012).

The seasonal pattern and average rate of warming at selected Yukon climate station locations since 1950 is shown in Figure 2. The rate of temperature increase was consistently greatest in winter. All locations also warmed significantly in the spring. There were no significant trends in the fall. The most noticeable broad-scale pattern within the Yukon is the trend to warmer summers in central Yukon (Dawson, Pelly Ranch and Mayo) concurrent with a lack of summer trends in the southern Yukon (Watson Lake and Whitehorse). Annual and seasonal mean temperature increases since 1950 for these Yukon climate stations are presented Figure 3, along with the comparable temperature means for the country as a whole.

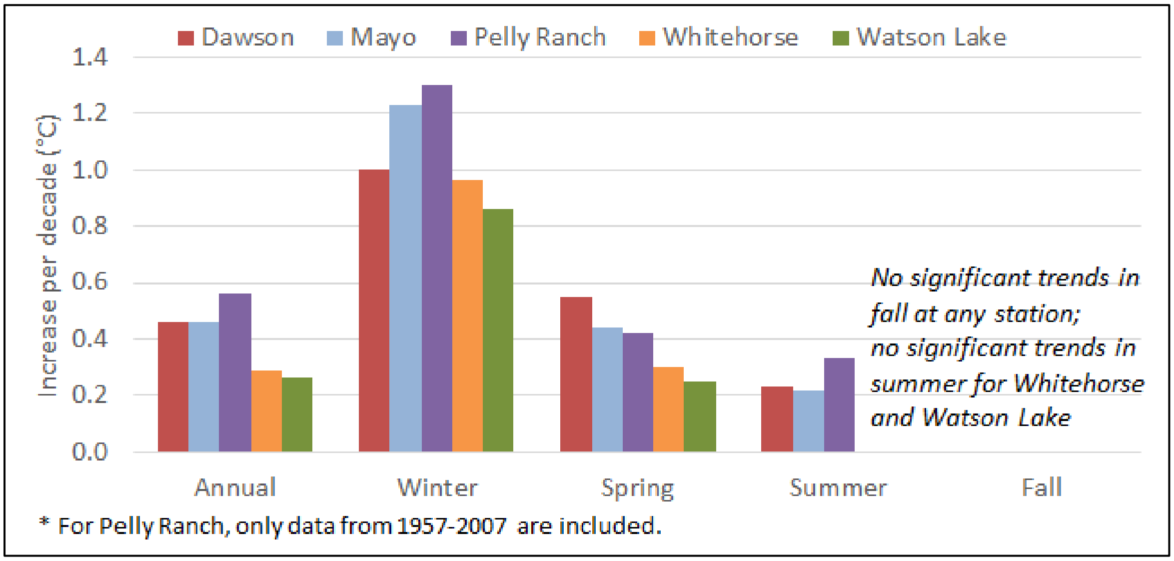
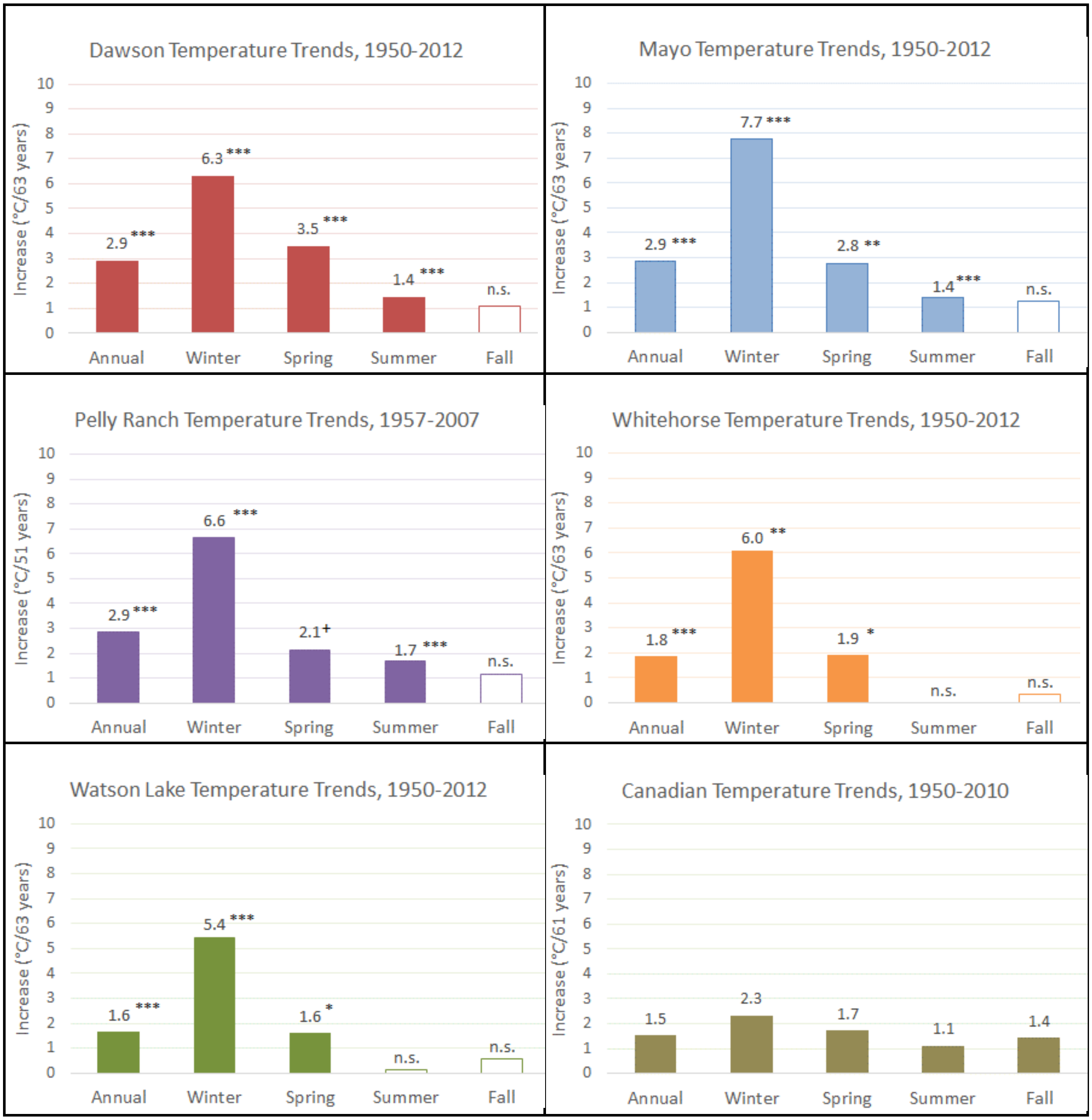


Figure 16. Rate of annual and seasonal warming in degrees per decade over the period 1950–2012 at selected Yukon stations
Season breakdown by months: winter Dec-Feb; spring Mar-May; summer June-Aug; fall Sept-Nov. Temperature increases over the period of record and statistical probabilities are in Figure 3. Data from Environment Canada (2014); methods after Vincent et al. (2012).



Statistical significance: n.s. = P > 0.10; + = P ≤ 0.10; * = P ≤ 0.05; ** = P ≤ 0.01; *** = P ≤ 0.001

Figure 17. Annual and seasonal temperature trends since 1950 at selected Yukon stations and Canadian means

Yukon trends calculated from Adjusted and Homogenized Canadian Climate Data (Environment Canada 2014); statistical methodology and Canadian temperature trends from Vincent et al. (2012).

2.2.2 Precipitation

Annual rainfall in Canada increased by 12.5% from 1950 to 2009, and snowfall also increased slightly. As precipitation varies a lot from year to year, the trends are often not significant for individual stations. Seasonally, the biggest and most consistent increase across Canada is in spring rainfall (Mekis & Vincent 2011). Variability in winter precipitation, especially in western Canada, is strongly influenced by climate oscillations such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (Bonsal & Shabbar 2011; Bush et al. 2014) (see section on climate variability, above).

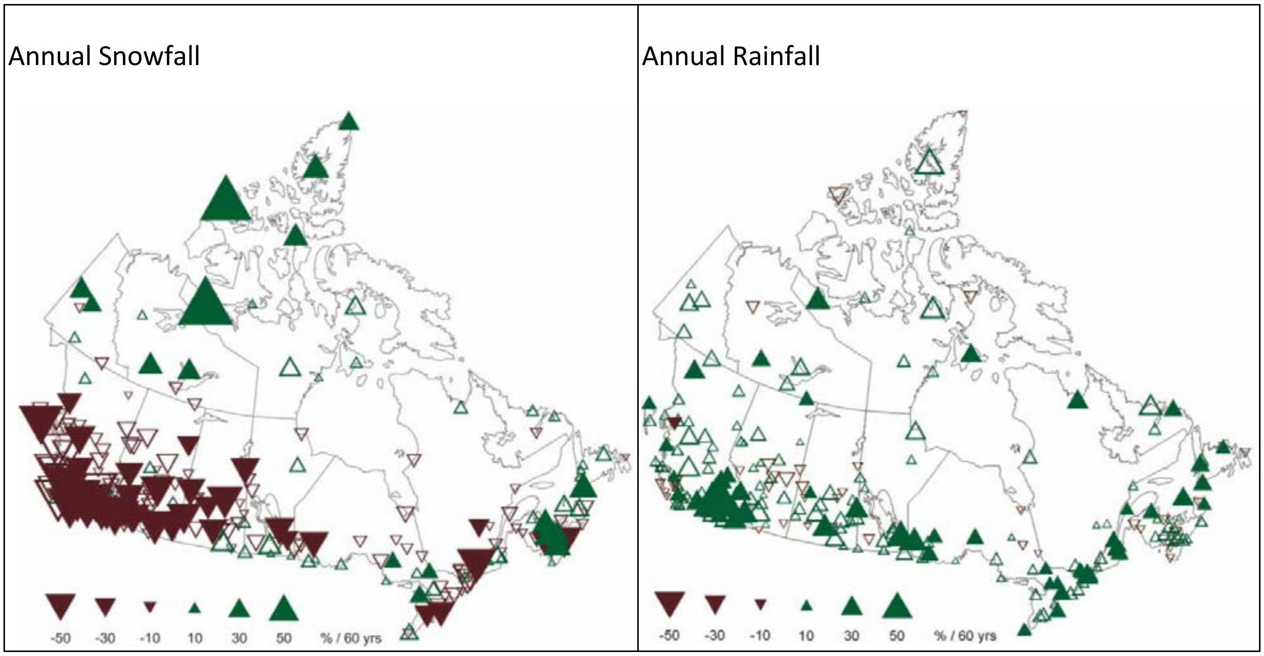


Figure 18. Trends in annual mean snowfall and rainfall across Canada, 1950–2009
Percent changes in annual mean snowfall and rainfall, based on deviations from 1961–1990 means (Mekis & Vincent 2011).

Changes in total annual mean precipitation since 1950 at selected Yukon stations are shown in Figure 5. Trends are not consistent, with only Mayo and Whitehorse showing significant increases over this period.

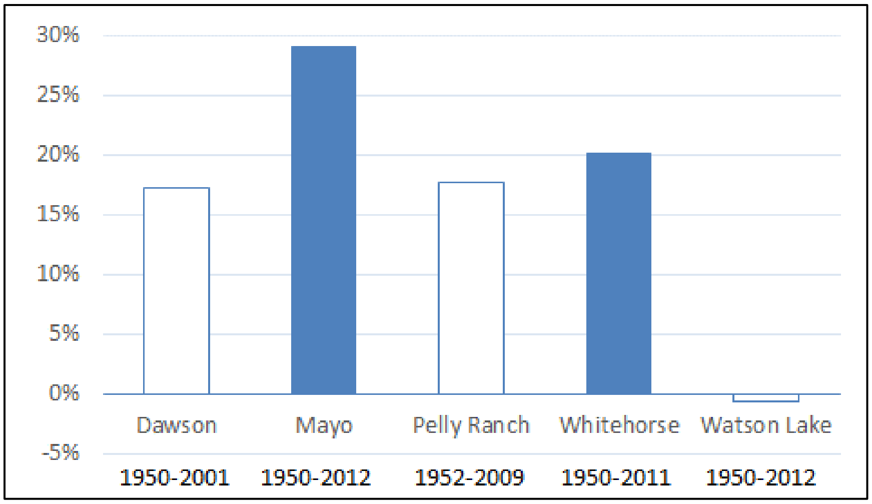


Figure 19. Changes in total annual mean precipitation at selected Yukon stations (various periods from 1950 to 2012)
Percent changes in annual precipitation, based on deviations from 1961–1990 means. Coloured bars (Mayo and Whitehorse) are the only statistically significant changes ($P \leq 0.05$). Data from Adjusted and Homogenized Canadian Climate Data (Environment Canada 2014).

Heavy rainfall events are also of significance for design and management of dams and reservoirs. As more frequent and severe extreme weather events are expected to accompany climate warming (IPCC 2013), the Yukon will likely experience increasing frequency and intensity of heavy rainfall events. Extreme precipitation events are currently projected to become about twice as frequent by mid-century over most of Canada (Bush et al. 2014). This pattern has not been detected in the climate records for Canada. Occurrence of heavy rainfall events across Canada in the 20th century did not increase or fluctuate on a decadal basis—increases in precipitation were instead related to increased numbers of small-to-moderate precipitation events (Vincent & Mekis 2006; Zhang et al. 2001). An analysis for 1950–2010 showed trends for heavy precipitation events (rainfall and snow) for some stations, but no trends in the Yukon (Figure 6).

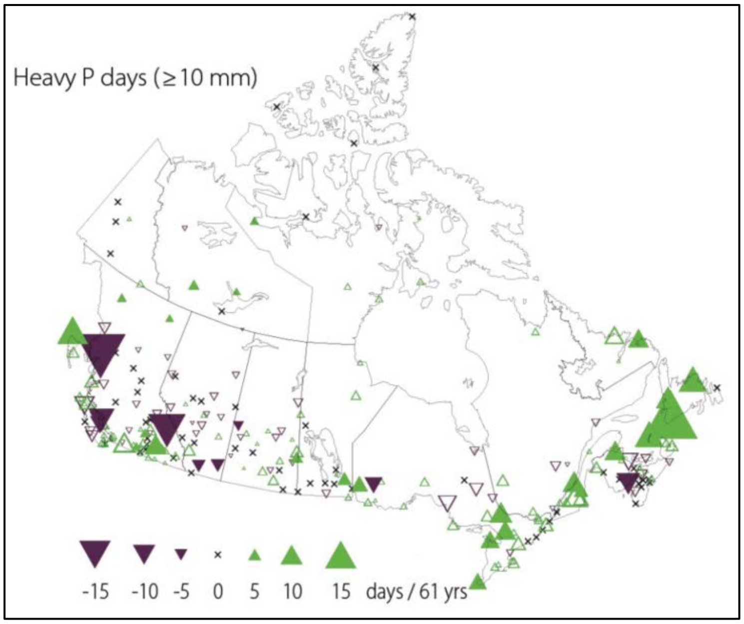


Figure 20. Trends in frequency of extreme precipitation events, 1950-2010
The trend analysis shows no change for Yukon sites (Bush et al. 2014).

2.3 Trends in Permafrost, Glaciers and Snow

2.3.1 Permafrost

Increases in winter air temperatures are the main driver behind the widespread warming of permafrost in northern Canada (Derksen et al. 2012). Changes in permafrost are also related to snow cover, as snow provides insulation. Sites with significant snow cover show less of a warming trend in ground temperatures. Permafrost temperatures measured in boreholes at numerous sites across Canada have all increased over the past two to three decades, but there is little information on ground temperature trends in central and southern Yukon (Smith 2011).

A recent repeat of a 1964 permafrost survey indicates that permafrost in the sporadic permafrost zone of southern Yukon and northern BC is thawing. This survey of permafrost conditions along the Alaska Highway corridor was redone in 2007/08 (James et al. 2013). Permafrost had thawed or was degrading at more than half of the 55 sites from Fort St. John to Whitehorse. In 1964, permafrost was present at 10 of the 18 sites between Watson Lake and Whitehorse, and in 2007/08 it was present at 6 sites. Where permafrost persisted, it was patchy, thin and warm (at or near 0°C). The researchers concluded that the southern limit of permafrost in BC and Yukon has shifted northward by 25 to 75 km since the 1960s.

The Next Generation hydro sites are in the extensive discontinuous permafrost zone or along the northern edge of the sporadic discontinuous zone (Table 1), zones that are vulnerable to permafrost degradation due to climate change (Hinzman et al. 2005). Permafrost conditions in the entire catchment area for each potential hydro site will have an impact on hydrology, including on base flows (see hydrology trends section below).

2.3.2 Glaciers

Increased melting of glaciers can also affect base flows. The Yukon has lost 22% of its glacial cover in the past 50 years, and the estimated average rate of thinning is 0.9 m per year water equivalent, a rate only exceeded in Alaska and Patagonia (Barrand & Sharp 2010). Increases in glacial melt rates are enhancing flows upstream of the Whitehorse hydro dam, and studies are underway to improve information that can be used to predict changes in Yukon R. flow related to glacier melt rates (Yukon Energy 2014). Initial results indicate that increased rates of melting of headwater glaciers will continue to enhance runoff for decades in the future and that the most likely response of Yukon River flow is an average increase in annual runoff, with higher flows in early spring and late fall (Northern Climate ExChange 2012). This response to climate change would extend the period of hydroelectric production from the Whitehorse dam. Although none of the Next Generation hydro sites are influenced by glaciers, future changes in Yukon River headwater glaciers are relevant to the projections of overall and seasonal hydroelectric generating capacity for the Yukon.

2.3.3 Snowpack

Snowmelt is the dominant hydrological event in the watersheds of all the potential hydro sites under consideration (see section on hydrology trends, below). Winter snow storage and subsequent melt are strongly related to timing and magnitude of spring flows (Dyer 2008).

Snowfall has increased since 1950 at some Yukon locations (Figure 4), and an overall increase in winter precipitation is projected for this region. However, at the same time, winter and spring temperatures are increasing, leading to more winter melting and earlier springs (Zhang et al. 2011). The net effect of these two trends can be anticipated to vary from site to site and over time.

There is a broad-scale trend to a strong decrease in the extent of snow cover in spring. The area covered by snow in the Northern Hemisphere, measured by satellite and ground observations, declined over the period 1967–2008 by 14% in May and by 46% in June (Brown et al. 2010). Spring snow cover duration was reduced by 10 days on average across Canada and Alaska over this time period (Brown et al. 2010).

Snow cover extent can be used to predict runoff patterns, but it needs to be augmented with additional information to estimate the amount of snow storage (Dyer 2008). Snow depths and snow water equivalent, which together provide information on water storage in the snowpack, are measured in March, April and May at 56 locations in the Yukon and are used each year to provide peak flow estimates for the Pelly, Stewart and Liard river basins (among others) (Environment Yukon 2015). Research has also been carried out in the Pelly and Stewart basins to improve understanding of the relationships between basin-level snow characteristics that can be detected through remote sensing and snowmelt hydrology (Ramage & Semmens 2012).

2.4 Hydrology Trends

Trends in temperature are marked and significant and follow similar patterns on a broad scale, while trends in precipitation are more variable and more specific to locations. Trends in hydrology are ultimately determined by changes in temperature and precipitation, but it is not a simple relationship. The effects of climate drivers interact, and streamflow is influenced by secondary drivers that are related to climate change—such as changes in permafrost and snowpack. Table 2 shows results from some relevant analyses of changes in hydrology in relation to climate change.

Table 18. Overview of Findings from Selected Hydrology Studies

Study scope	Years	Findings	Reference
Average, peak and low flows, Yukon hydrometric stations	Previous 3 decades	▪ Slight increases in annual mean flows and decreases in annual peak flows ▪ Significant increases in low flows, especially in the continuous permafrost zone, with greater variability in change in the discontinuous zones.	Janowicz (2008)
Low flows, Yukon and western NWT stations	Period of record (min. 25 years)	▪ The following sites relevant to this project were included in the analysis. All had increased annual low flows ($p<0.1$): o Pelly R. at Pelly Crossing; Pelly R. below Vangorda Cr.; Stewart R. at Mouth; Liard R. at Upper Crossing	Janowicz (2007)
Streamflow trends, Yukon River Basin (Yukon and Alaska)	1944–2005	▪ Annual discharge remained relatively unchanged except for glacier-fed rivers, where it increased ▪ Average winter flows increased at 15 of 21 sites ($p<0.1$), attributed to permafrost thaw	Brabets and Walvoord (2009)
Mackenzie River Basin (54 stations including Frances R.)	Various periods up to 2000	▪ General trends across the basin: o Increasing flows December-April o Increasing annual minimum flows o Weak decreasing trend in annual, early summer and late fall flows o Earlier onset of freshet	Abdul Aziz and Burn (2006)

A study based on results from research at the Wolf Creek Research Basin near Whitehorse used modeling to predict the impacts of future changes in temperature and precipitation on hydrology (Rasouli et al. 2014). The authors concluded that hydrology in mountain streams is very sensitive to warming, with increased temperatures leading to reductions in snow accumulation, annual runoff and peak streamflow, and to lengthening of the snow-free period. Changes in precipitation partly modulate these responses to warmer temperatures—increased precipitation somewhat offsets the warming, while decreased precipitation greatly enhances the effects of warming.

Changes in hydrology in the Arctic tend to be greater than predicted from changes in temperature and precipitation. This indicates that changes are not just related to changes in runoff, but also to changes in infiltration (Bring & Destouni 2011). Research on large northern rivers, including the Yukon and Mackenzie, suggests that, as permafrost thaws, deeper groundwater flow paths develop, leading to greater base flows and hydrological regimes dominated more by groundwater and less by surface flow. This change in regime is accompanied by changes in water chemistry, as well as changes in timing and magnitude of streamflow (Carey et al. 2013; Smith 2011).

Where a layer of permafrost is present, streamflow responds rapidly to rainfall and snowmelt because the permafrost acts as a barrier to water infiltration. Most water travels as overland flow to streams. This results in the type of annual streamflow pattern seen for the Frances River (Figure 7), with very low base flows in winter and a steep snow-melt peak and a rapid decline. The Pelly and Stewart rivers follow similar patterns (Figure 8). In areas where permafrost continues to degrade and active layers deepen, groundwater flow will become more significant, leading to more gradual responses to snowfall and rain, and a more uniform distribution of flow over the year (Hinzman et al. 2005). This is a pattern that is likely to develop to varying degrees at the candidate hydro sites.

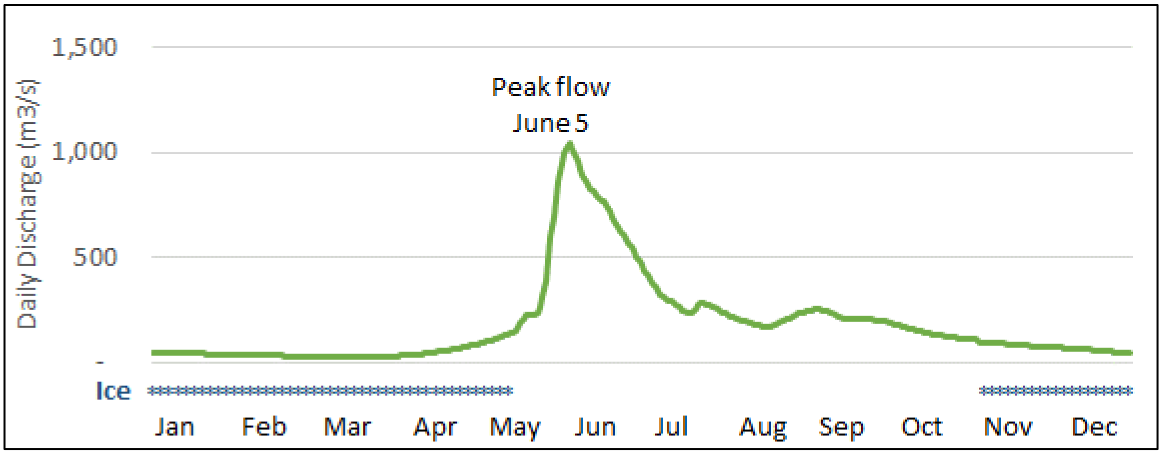


Figure 21. Daily discharge over 2013, Frances R. near Watson Lake
Data from Wateroffice (Government of Canada 2015).

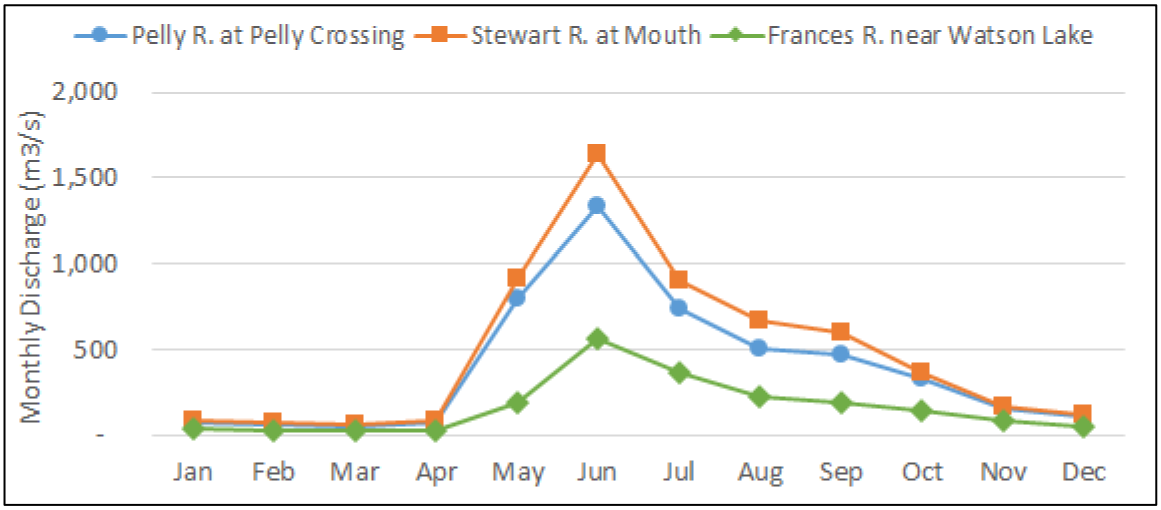


Figure 22. Monthly mean discharge, Pelly, Stewart and Frances rivers
Averaged over the following periods: Pelly R. 1951-2013; Stewart R. 1963-2013; Frances R. 1962-2013. Watershed areas for gauging stations (km^2): Pelly R. 48,900; Stewart R. 51,000; Frances R. 12,800. Data from Wateroffice (Government of Canada 2015).

Another factor that affects water balance, especially for lakes and reservoirs, and especially in the arid Yukon climate, is evaporation. Changes in evaporation rates can have a substantive impact on a water body—studies in the Experimental Lakes Area in Ontario showed that an increase in average air temperature from 14 to 16°C led to an increase in evaporation of 30% (Schindler & Smol 2006). Rates of evapotranspiration (evaporation plus plant transpiration) can increase with warmer temperatures, but are also related to other meteorological and ecological factors, such as the degree of cloudiness, aspect, and type of vegetation. Global-scale projections for future changes in evapotranspiration show an increase for northern latitudes (Goulding 2011). A study based on remote sensing data and modeling of trends over the entire Yukon River Basin (Yuan et al. 2012) found a significant increase in evapotranspiration over the 1982–2009 time period, offset in some areas by an increase in annual precipitation, and with a net drying trend in other areas. Both evapotranspiration and precipitation vary considerably from site to site.

3.0 HYDROLOGICAL PARAMETERS AND THEIR RELEVANCE TO YUKON NEXT GENERATION HYDRO SITES

This section is restricted to discussion of the hydrological parameters that affect the engineering design of the projects:

- Timing of peak inflows
- Peak flows
- Average flows

Current trends and future changes in these parameters reflect the trends and changes in climate and hydrology that are discussed in the previous sections.

Table 3 presents an overview of these three design parameters and their impact on project planning. Other parameters related to climate change impacts on the hydrological cycle, including sedimentation and water quality, are not considered in the design of the dams at this stage and will be studied in the future (A. Le and P. Helland, Midgard Consulting Inc., personal communication).

Table 19. Changes in Hydrological Parameters (Observed or Potential) and Relationship to Hydrological Modeling for Yukon Next Generation Hydro
In the Yukon, energy demand is higher in the winter, which makes winter energy more valuable. Summer energy demand is comparatively low and all the potential dams spill water from May to November.

Parameter	Expected or Potential Change	Action	Reason
Timing of peak inflow	Earlier freshet	No modification to hydrological models	An earlier freshet does not affect the height of the dams because water is spilled from May to November.
Peak flows	Changes in annual freshet peak flow (direction of change uncertain, but may decrease)	No modification to hydrological models	Peak flows are used to size the dams' freeboard and spillway and are not considered in the normal operation of the dams. The peak flows will be studied in detail in the future.
	Increased spring and summer peaks in flow from heavy rainfall events		
Average flows	Increased winter flows	No modification to hydrological models	Increased winter flows would provide more valuable energy. It is more conservative to size the dams with no adjustment to the hydrological model.
	Changes to annual and summer flows (direction of change uncertain)		Decreased or increased summer flows will not affect the dams' energy generation as water is spilled during the summer.

Input on dam design parameters from A. Le and P. Helland, Midgard Consulting Inc.

4.0 CONCLUSIONS

Future effects of climate change on hydrology cannot be quantified for this planning stage of the Yukon Next Generation Hydro project. There is no consistent trend in future average and peak runoff patterns that can be expected with a high degree of certainty. A review of the literature indicates that effects of climate change on hydrology may be favorable to winter energy generation in the Yukon through increases in base flows. To remain conservative, and because of the uncertainty attached to projections, the hydrological models used at this planning stage were not altered to reflect these potential effects.

Climate projections are in the form of a range of probable future conditions, based on models run under a range of emission scenarios and assumptions. The hydrological response to climate change in the water basins upstream of the Next Generation hydro sites will depend on the effectiveness of global greenhouse gas emissions reduction, the manner in which the various drivers and impacts on streamflow interact, and on how broad-scale patterns of directional change and variability will be manifested at the smaller spatial scales of these river basins. This paper summarizes the general trends that are occurring and likely to occur.

As work on the Next Generation hydro progresses towards the design phase, site-specific information on climate, permafrost, snow conditions and hydrology will be needed so that hydrological projections and construction and operational plans can be adapted to take climate change into account.

Both climate stations and hydrological stations should be installed at proposed hydroelectric sites to improve the understanding of relations between climate and hydrological parameters and to improve predictive capacity. Survey and monitoring of snowpack (such as snow depth, snow water equivalent and snow cover extent) and permafrost conditions and trends in the project watersheds are also important for forecasting hydrological response to changes in climate. Down-scaled climate model projections are needed for the catchment areas of proposed sites. Cherry et al. (2010) provides a useful template for information needs and climate change projections studies related to hydro development, based on work in Southeast Alaska.

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