12 FISH AND FISH HABITAT

12.1 Approach

This section of the EIS presents the assessment of the potential effects of the Project on the fish and fish habitat VC. As discussed below, fish and fish habitat would potentially be affected by the construction and operation of the Project. Fish and fish habitat is of concern to Aboriginal groups, the public, and stakeholders for a variety of reasons outlined below. Effects on fish and fish habitat are regulated both federally and provincially, including through the *Fisheries Act.*

The approach to the effects assessment takes into account the regulatory and policy setting for fish and fish habitat, and the results of consultation with the general public, regulators, stakeholders, community members, Aboriginal groups, and governments. In particular, BC Hydro has considered information from Traditional Land Use Studies (TLUS) provided by Aboriginal groups. The TLUS information indicates that Aboriginal groups use fish in the Peace River and its tributaries. The results of consultation and the TLUS have been incorporated into the baseline information for fish and fish habitat described below. The use of fish for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19, and potential impacts of the Project on the exercise of asserted or established Aboriginal and treaty rights are discussed in Volume 5 Section 34 Asserted or Established Aboriginal Rights and Treaty Rights, Aboriginal Interests and Information.

The effects assessment of fish and fish habitat uses a first principles approach that includes computer modelling of water quality, water temperature and ice regime, fluvial geomorphology, sediment transport, aquatic productivity, and fish population dynamics. Modelling was used as a tool to inform and support information collected by baseline studies. This combined approach was used to support the prediction of potential effects to fish and fish habitat caused by the Project.

12.1.1 Regulatory and Policy Setting

Both federal and provincial agencies have mandates relevant to the protection and management of fish and fish habitat.

The federal legislation that has guided the assessment of the potential for the Project to adversely affect fish and fish habitat is the *Fisheries Act* (R.S.C., 1985, c.F-14) and the *Species at Risk Act (S.C., 2002, c. 29).*

British Columbia is responsible for regulation of non-salmon freshwater fisheries, including management, conservation, and recreation. The province’s Freshwater Fisheries Program Plan has the stated aim of “A naturally rich and sustainable freshwater fish resource supporting diverse uses for all British Columbians.” (B.C. Government 2007).

The Draft Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011) provides guidance for the Site C EIS based on the province’s mandate to protect and manage fish and fish habitat.

The stated purpose of the document is to “Identify and recommend valued environmental components (VECs) and management objectives for fish, wildlife and ecosystem resources for consideration in assessing the proposed Site C project and its possible development.” The document defines a VEC as “characteristics or attributes that, if degraded, would compromise the integrity of the key values”. The document further identifies key values as “Environmental elements that are important in maintaining environmental sustainability and ecological integrity.”. The document and the VECs were taken into account in the identification of species for consideration in this assessment.

The assessment of potential effects on fish and fish habitat was designed by taking into account the draft Fish, Wildlife and Ecosystem Resources and Objectives for the Lower Peace River Watershed Site C Project Area (B.C. Government 2011).

12.1.2 Key Issues and Identification of Potential Effects

The key issues raised by the public, Aboriginal groups, and government agencies guided the scope of the fish and fish habitat assessment (refer to Volume 1 Section 9 Information Distribution and Consultation). Key issues raised included the following:

- Integration of traditional knowledge
- Fish populations and habitats on which they rely that could be potentially affected by the Project
- Opportunities to mitigate or enhance fish outcomes with project design

The key issues and the approach used to address the issues are presented in Table 12.1.

Table 12.1 Key Issues: Fish and Fish Habitat

Key Issues	Approach to Addressing Key Issues
Integration of traditional knowledge	Integration of traditional knowledge is addressed in Section 12.2.2 and 12.3 Baseline Conditions.
Fish populations and habitats on which they rely that could be potentially affected by the Project	Potential effects on fish population and fish habitats are addressed in relevant effects assessment subsections below.
Opportunities to mitigate or enhance fish outcomes with project design	Opportunities to mitigate or enhance fish outcomes are addressed in relevant effects assessment sections and in Section 12.4 Mitigation Measures.

The key aspects identified in the EIS Guidelines included the following:

1. Habitat changes created by the reservoir in the mainstem and affected tributaries, as well as upstream and downstream of the dam due to flow alterations
    - Upstream and downstream fish migrations by species and life history stage and their potential to be affected by the Project
    - Fish mortality
    - Potential impacts on the genetic diversity of fish populations above and below the project site

- Potential impacts to predator-prey interactions and expected changes
- Potential impacts to food web composition and structure
- Potential impacts of gas pressure on fish resulting from water discharge over the structure

Because of the overlapping nature of these seven key aspects, for the purpose of this assessment, they have been grouped into three categories of potential effects:

Changes to fish habitat

Changes to fish health and fish survival

Changes to fish movement

This approach was used for the following reasons:

1. It permits a structured evaluation process
   - Each category represents major federal and/or provincial regulatory mandates
   - Each category represents an important component of fish population ecology

Each of these potential effects is described briefly below.

The Project has the potential to affect fish habitat in two ways. The Project may destroy fish habitat by placing a permanent physical structure on that habitat, or the Project may alter fish habitat by changing the physical or chemical characteristics of that habitat in such a way as to make it unusable by fish. Destruction or alteration of important habitats may be critical to the sustainability of a species population.

The Project may affect fish health and survival. It may cause direct mortality of fish or indirect mortality of fish by changing system productivity, food resource type and abundance, and environmental conditions on which fish depend (e.g., water temperature).

The Project may affect fish movement by physically blocking upstream and downstream migration of fish or by causing water velocities that exceed the swimming capabilities of fish, which results in hindered or blocked upstream migration of fish. Blocked or hindered fish movement has consequences to the species population. Fish may not be able to access important habitats in a timely manner or not at all (e.g., spawning habitats). Blocked fish movement may result in genetic fragmentation of the population.

Potential Project interactions with fish and fish habitat are summarized in Volume 2 Appendix A Project Interactions Matrix, Table 2. As defined in Volume 2 Section 10 Effects Assessment Methodology, a rank of “2” indicates that the effects of an interaction may not be fully avoided or mitigated through the application of standard mitigation measures, or are not well understood. Therefore, they were further analysed and evaluated in the effects assessment.

Project interactions with a ranking of “2” are summarized in Table 12.2 below.

Table 12.2 Interaction of the Project with Fish and Fish Habitat

Project Activities and Physical Works	Fish and Fish Habitat – Categories of Effects		
	Fish Habitat	**Fish Health and Survival**	**Fish Movement**
Construction Phase			
Dam & Generating Station Construction – Component Level Interactions			
Site clearing and preparation	✓	✓	✓
Temporary and permanent access roads	✓	✓	
Relocation of surplus excavated material	✓	✓	
Temporary construction access bridge across the Peace River	✓	✓	
Stage 1 channelization and diversion works (north bank)	✓	✓	
Stage 1 channelization works (south bank)	✓	✓	
Stage 2 – diversion	✓	✓	
Stage 2 – Diversion | Earthfill dam and north bank excavation	✓	✓	
Stage 2 – Diversion | South bank structures	✓	✓	
Reservoir Preparation and Filling – Component Level Interactions			
Hudson's Hope Shoreline Protection	✓	✓	
Water management during confinement	✓	✓	✓
Water management during diversion	✓	✓	✓
Water management during reservoir filling	✓	✓	✓
Highway 29 Realignment – Component Level Interactions			
Highway 29 Realignment	✓	✓	✓
Operations Phase			
Reservoir and Generating Station Operations – Component Level Interactions			
Operation of the powerhouse, substation, and reservoir; includes downstream water management	✓	✓	✓

NOTE:

Only Project interactions ranked as “2” in Volume 2 Appendix A Project Interactions Matrix, Table 2 are carried forward to this table. A ✓ indicates that a project component or activity is likely to interact with the VC.

12.1.3 Standard Mitigation Measures and Effects Addressed

Volume 2 Appendix A Project Interactions Matrix, Table 2 provides a ranking for each Project component, physical work, and associated activity by Project Phase (Construction and Operation) in relation to its potential effect on fish and fish habitat.

Rankings of “0” in Volume 2 Appendix A Project Interaction Matrix, Table 2 indicate that there is no interaction between the Project component and fish and fish habitat. Of the 67 items listed, 17 were rated as “0”. As these project activities have no interaction with fish and fish habitat, they are not considered further in the assessment.

Rankings of “1” in Volume 2 Appendix A Project Interactions Matrix, Table 2 mean that an interaction would occur but that it is well understood and can be avoided or mitigated through the application of standard mitigation measures and would be negligible. Of the 67 interactions listed, 34 were given a ranking of “1”. For these activities, such as worker accommodation, quarry operations, and right-of-way vegetation maintenance, standard mitigation measures will be implemented when activities are conducted adjacent to a watercourse. These are not considered further in the effects assessment.

12.1.4 Selection of Key Indicators

The key indicators for assessing the potential effects on fish and fish habitat, which encompass the terms listed above, and their rationale for selection are listed in Table 12.3.

Table 12.3 Key Indicators for Fish and Fish Habitat

Categories of Effect	Key Indicator	Rationale for Selection of the Key Indicators [a]
Change in fish habitat	Quality and quantity of fish habitats, habitat availability, water depth, velocity, water temperature, sedimentation, water quality, ice regime, aquatic productivity, and food resources, competition for food and habitat	Federal and/or provincial mandate for management
Change in fish health and survival	Species diversity; fish population distribution, fish population relative abundance, fish population biomass, sedimentation, stranding, fish entrainment, total dissolved gas	Incorporates traditional knowledge (harvesting); federal and/or provincial mandate for management
Change in fish movement	Fish species population, movement patterns and general life history parameters (i.e., access to habitats), swim speeds, entrainment	Federal and/or provincial mandate for management

NOTE:

[a] Includes input from consultation with the public, Aboriginal groups, and government agencies as well as regulatory guidelines, policies, and programs

12.1.5 Spatial and Temporal Boundaries

12.1.5.1 Spatial Boundaries

The spatial boundaries for assessing the potential effects on fish and fish habitat are listed in Table 12.4 and shown in Figure 12.1. The spatial boundaries were initially set based on information collected on resident fish populations in the Peace River and TLUS information was subsequently reviewed to confirm adequate boundaries.

The Local Assessment Area (LAA) is defined as the Peace River downstream from the Peace Canyon Dam to Many Islands, Alberta and its tributaries entering the proposed reservoir. In determining the LAA, consideration was given to the extent of potential changes to:

Surface water regime (i.e., minimum and maximum flow, seasonal flows, rate of flow, and stage change)

Water quality (i.e., nutrients available for trophic production, total dissolved gases)

Water temperature (magnitude of change, seasonal thermal regime)

Geomorphology and sediment transport (river channel morphology, bedload, and suspended sediment transport)

Downstream ice regime

The downstream limit of the LAA was set at a point where the physical changes in the river are expected to diminish to the point where the change could no longer have a measurable effect that would influence fish and fish habitat.

For the Regional Assessment Area (RAA), consideration was given to the geographic extent, or maximum distribution, of fish populations residing in the LAA and associated meta-populations in the Peace River and tributaries flowing into the future reservoir. In general, a fish population can be defined as a group of individuals of the same species that live at the same point in time in a geographically defined area (Wootton 1990). For a given species, the meta-population within the geographic boundary of the RAA consists of distinct groups or populations. For meta-populations residing in the Peace River, this geographic boundary can be defined as the Peace River downstream from the Peace Canyon Dam and upstream from Vermilion Chutes (Mill et al. 1997).

Table 12.4 Spatial Assessment Areas for Fish and Fish Habitat

Local Assessment Area	Regional Assessment Area
• Peace River in the proposed reservoir area • Tributaries entering the proposed reservoir • Peace River downstream of the proposed Site C Dam to the Many Islands Area, Alberta (207 km) • Watercourses and water bodies within the transmission line and roadway rights-of-way • Watercourses and water bodies within the Project activity zone (construction materials) • Riparian areas adjacent to identified watercourses and water bodies	• Peace River from Peace Canyon Dam, B.C. to Vermilion Chutes, Alberta

12.1.5.2 Temporal Boundaries

Project component and activities that could affect fish and fish habitat would occur during the construction and operations phases of the Project (see Volume 1 Section 4 Project Description).

The potential for construction activities to result in changes to key aspects have been assessed for Years 1 through 8 of the Project. Changes to key aspects resulting from the operations phase have been assessed on the basis that the operations would begin in Year 8 and would continue through the operating life of the Project.

12.2 Information Sources and Methodology

The description of the baseline conditions in the section below was compiled based on available literature, field studies, and traditional knowledge. Refer to Appendix O Fish And Fish Habitat Technical Data Report and Appendix P Aquatic Productivity Reports for detailed fish and fish habitat information.

12.2.1 Summary of Available Studies

Fisheries studies in the Peace River system have been conducted since the 1970s. Work has occurred in the Williston and Dinosaur reservoirs, mainstem Peace River, and many of its tributaries in B.C. and Alberta. The following provides a general overview of the fisheries studies conducted in the Peace River system.

A general investigation of fish and fish habitat was completed during the 1970s in preparation for the Site C development (Renewable Resources Ltd. 1978). After this initial investigation, structured large scale inventories occurred starting in the early 1990s when multi-year inventories were completed on the Peace River (Pattenden 1992; Pattenden et al. 1990, 1991) and its tributaries (ARL 1991a, 1991b), again in anticipation of development. This work focused primarily upstream of the Site C Dam site location and generally provided descriptive information. These studies were also the first attempt to examine fish movements using radio telemetry (Pattenden et al. 1990, 1991).

In 1994, the B.C. Government commissioned a fish fence study on the Chowade River (RL&L 1995) in order to establish the importance of this tributary to the Halfway River as sport fish habitat. A focus of the study was to characterize the spawning bull trout (*Salvelinus confluentus*) population, which was thought to originate, in part, from the Peace River. This work was followed by a study by the Province that examined movements of bull trout and Arctic grayling (*Thymallus arcticus*) in the upper Halfway River watershed (Burrows et al. 2001). The results of this study were reanalyzed and submitted in a report to BC Hydro (AMEC and LGL 2010b).

A study that encompassed the Peace River in British Columbia that focused on small fish habitat utilization was completed in 1999 and 2000 (RL&L 2001). This was the first attempt to characterize small fish use of near-shore habitats on the river, to map fish habitats, and to quantify availability of these habitats relative to flow regulation effects. Small fish were defined as small-fish species and younger age-classes of large-fish species.

In 2001, BC Hydro initiated a multi-year, annual Large River Fish Community Indexing Program on the Peace River (P&E 2002; Mainstream Aquatics Ltd. et al. 2012). The purpose was to quantify large-fish (i.e., ≥ 250 mm length) population characteristics (i.e., abundance, growth, and population structure) that were to be used to monitor effects of flow manipulations. The river was stratified into discrete sections located between the Peace Canyon Dam and the Pine River confluence and then sampled using structured and repeated fish collection methods. In 2009, the program became the Peace River Fish Index Project and was integrated into the Peace Water Use Plan administered by the Water Licence Requirements Program. Though this study has concentrated on three target species (bull trout, mountain whitefish [*Prosopium williamsoni*], and Arctic grayling), it provides yearly data describing abundance and distribution on all large-fish species in the Peace River.

In 2005, fish and fish habitat studies on the Peace River and its tributaries were initiated by BC Hydro in support of anticipated regulatory application for the Project. These studies have been multidisciplinary and have encompassed the LAA. They include the following:

Standardized fish investigations of the Peace River within British Columbia and downstream into Alberta (Mainstream Aquatics Ltd. 2009a, 2010a, 2012)

Standardized fish investigations of the Moberly and Halfway Rivers (Mainstream Aquatics Ltd. 2009a, 2009b, 2009c, 2010b, 2010c, 2011a, 2011b)

Fish habitat surveys in all minor and major tributaries affected by the Site C Clean Energy Project reservoir (AMEC and LGL 2008b; Mainstream Aquatics Ltd. 2009a, 2009b, 2009c)

Movement studies of sport fish using radio telemetry (AMEC and LGL 2008a, 2008b, 2008c, 2008d, 2010a, 2010b)

Fish fences to document spring and fall fish use of tributaries (AMEC and LGL 2008b; Mainstream Aquatics Ltd. 2009a, 2009b)

Rotary screw traps in the Peace River and major tributaries to monitor downstream movements of fish (Mainstream Aquatics Ltd. 2010d, 2011b)

Bull trout spawner and redd surveys of the Halfway River watershed (Diversified and Mainstream 2009, 2011b)

Examination of fish recruitment sources using the elemental signature method (Clarke et al. 2010; Earth Tone Environmental and Mainstream 2012)

Examination of genetic characteristics selected fish populations (Taylor and Yau 2012)

During the same general period, several Water Licence Requirement studies were completed under the Peace Water Use Plan. Three works of interest to this review include:

An evaluation of Peace River side channel characteristics and fish community structure (NHC et al. 2010)

A study designed to map and quantify fish habitats at five river flows (Mainstream Aquatics Ltd. et al. 2012)

A study that described Peace River riparian habitats (MacInnis et al. 2011)

A number of investigations also have been completed on Williston Reservoir and Dinosaur Reservoir. Most recent work includes fish surveys of Williston Reservoir (Sebastian et al. 2009) and Dinosaur Reservoir (Diversified and Mainstream 2011a).

An extensive amount of work has been completed on the Peace River downstream in Alberta. Two general inventories of the entire river (from the B.C. boundary to the Peace-Athabasca Delta) were completed – one in 1989 and 1990 (Hildebrand 1990), and the other in 1993 (Boag 1993). A comprehensive series of multi-year investigations of fish communities, fish habitats, and fish movements were completed between 1999 and 2009 for the Dunvegan Hydroelectric Project, which is located 125 km downstream of the B.C./Alberta boundary. Relevant investigations include RL&L (2000a) and Mainstream Aquatics Ltd. (2006a, 2006b, 2009d, 2009e, 2010e).

12.2.2 Traditional Knowledge

Traditional Land Use Studies (TLUS) provided information on the harvest of particular species of fish at particular locations on the Peace River and its tributaries by Aboriginal groups. TLUS were prepared for a number of First Nation communities and presented to BC Hydro for review. These included Blueberry River First Nation Traditional Land Use Study (Bouchard and Kennedy 2011); Duncan's First Nation Ethnohistorical Review (Bouchard and Kennedy 2012a); Horse Lake First Nation Ethnohistorical Overview

(Bouchard and Kennedy 2012b); Doig River First Nation, Prophet River First Nation, Halfway River First Nation, and West Moberly First Nation Traditional Land Use Study (Chandler 2012); Saulteau First Nation Culture and Traditions Study (NesooWatchie Resource Management Ltd. 2011), Kelly Late Métis Settlement Society Aboriginal Traditional Knowledge Assessment (KS Davidson & Associates & KCD Consulting Incorporated 2012), Dene Tha' Traditional Land Use with Respect to BC Hydro's Proposed Site C Dam (Stevenson 2012), and Fort Nelson First Nation Background and Rational for Involvement in the Site C Project (Wolfenden 2012). TLUS references are listed in Volume 5 Appendix A.

12.3 Baseline Conditions

The baseline conditions for fish and fish habitat are described in terms of the following:

Fish ecology, including description of fish communities, identification of species composition, distribution, relative abundance, migration and movement patterns, and general life history parameters

Fish habitats, including an evaluation of the quality and quantity of fish habitats in the LAA. These include critical or sensitive areas such as spawning, rearing, and overwintering habitats and migration routes.

Changes in environmental factors (e.g., food, water temperature, sediment transport)

12.3.1 Fish Species

In total, 32 fish species have been recorded in the LAA (Table 12.5). None of the species are officially listed as endangered, thoureatened, or a special concern under Schedule 1 of the *Species at Risk Act* (SARA), or are being considered for official listing under Schedule 2 or 3 of SARA.

In British Columbia, one species is listed as "red" (endangered or thoureatened): spottail shiner; and three are listed as "blue" (special concern): bull trout, goldeye, and pearl dace. The remaining species are designated as "yellow", described as secure and not at risk of extinction.

In Alberta, two species are identified as "may be at risk" -- pygmy whitefish and spoonhead sculpin. A total of ~~six~~five species have "sensitive" designations, including ~~bull trout,~~ Arctic grayling, lake trout, brook stickleback, northern pikeminnow, and northern redbelly dace. The bull trout is listed as a species of special concern. The rainbow trout designation as "at risk" refers to the Athabasca River population. The remaining fish species are "secure", "not assessed", or "not determined".

Table 12.5 Fish Species Recorded by Baseline Studies in the Local Assessment Area

Group	Species [a]		Provincial Status	
	Common Name	Latin Name	B.C.	AB
Sport fish	Arctic grayling	*Thymallus arcticus*	Yellow	Sensitive
	Bull trout	*Salvelinus confluentus*	Blue	Sensitive
	Brook trout	*Salvelinus fontinalis*	Exotic	Exotic
	Burbot	*Lota lota*	Yellow	Secure
	Goldeye	*Hiodon alosoides*	Blue	Secure
	Kokanee	*Oncorhynchus nerka*	Yellow	Not assessed
	Lake whitefish	*Coregonus clupeaformis*	Yellow	Secure
	Lake trout	*Salvelinus namaycush*	Yellow	Sensitive
	Mountain whitefish	*Prosopium williamsoni*	Yellow	Secure
	Northern pike	*Esox lucius*	Yellow	Secure
	Pygmy whitefish	*Prosopium coulteri*	Yellow	May be at risk
	Rainbow trout	*Oncorhynchus mykiss*	Yellow	At risk
	Yellow perch	*Perca flavescens*	Yellow	Secure
	Walleye	*Sander vitreus*	Yellow	Secure
Suckers	Largescale sucker	*Catostomus macrocheilus*	Yellow	Sensitive
	Longnose sucker	*Catostomus catostomus*	Yellow	Secure
	White sucker	*Catostomus commersoni*	Yellow	Secure
Minnows	Brook stickleback	*Culea inconstans*	Yellow	Secure
	Finescale dace	*Chourosomus neogaeus*	Unknown	Undetermined
	Flathead chub	*Platygobio gracilis*	Yellow	Secure
	Lake chub	*Couesius plumbeus*	Yellow	Secure
	Longnose dace	*Rhinichthys cataractae*	Yellow	Secure
	Northern pikeminnow	*Ptychocheilus oregonensis*	Yellow	Sensitive
	Northern redbelly dace	*Phoxinus eos*	Unknown	Sensitive
	Peamouth	*Mylcheilus caurinus*	Yellow	Not rated
	Pearl dace	*Margariscus margarita*	Blue	Undetermined
	Redside shiner	*Richardsonius balteatus*	Yellow	Secure
	Spottail shiner	*Notropis hudsonius*	Red	Secure
	Trout-perch	*Percopsis omiscomaycus*	Yellow	Secure
Sculpins	Prickly sculpin	*Cottus asper*	Yellow	Not assessed
	Slimy sculpin	*Cottus cognatus*	Yellow	Secure
	Spoonhead sculpin	*Cottus ricei*	Yellow	May be at risk

The B.C. Government considers bull trout as a species warranting special management (BCMOE 1994). A review of the status of bull trout populations in British Columbia ranked the conservation status in several core areas of the Lower Peace Ecological Drainage Unit (Hagen and Decker 2011).

The Halfway/Peace core area, which would be potentially affected by the Project, received a Rank of C2 – At Risk. "At Risk" is defined by Hagen and Decker (2011) as follows:

Core area at risk because of very limited and/or declining numbers, range, and/or habitat, making the bull trout in this core area vulnerable to extirpation

BChydro FOR GENERATIONS

The B.C. Government has identified seven~~six~~ fish species of interest in the Lower Peace River Watershed Site C Project Area (B.C. Government 2011). These species are Arctic grayling, bull trout, burbot, goldeye, mountain whitefish, rainbow trout, and walleye. Indicator species were identified to represent a variety of ecological communities, thermal regimes, trophic levels, and biogeographical origins, and intended to capture potential effects across a wide range of conditions and faunas that may be affected by the Project. Two species of conservation concern were not identified as suitable for this purpose. Spottail shiner (red listed) were excluded because this species, while present, is not native to the Project area. The northern pearl dace (blue listed) is identified as a species of concern due to its limited distribution in B.C. The species is not found in the mainstem Peace River but is present in some nearby watersheds (B.C. Government 2011).

Fish species listed in Table 12.5 may have traditional use, recreational use, or management value. All fish species listed in Table 12.5 have ecological function value (i.e., an integral part of fish community function) and have the potential to be affected by the Project. Table 12.6 provides a summary of traditional knowledge associated with fish and fish habitat provided in TLUS studies.

The use of fish for traditional purposes is considered in the assessment of the potential effects of the Project on Current Use of Lands and Resources for Traditional Purposes, which is found in Volume 3 Section 19.

Table 12.6 Summary of Traditional Knowledge Provided in Traditional Land Use Studies Reports

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
Blueberry	Beatton River		Suckers	Sucker species	
	Carbon Creek		Trout	Trout species	
	Charlie Lake		Suckers	Sucker species	
	Chinaman L.		Trout	Trout species	
	Farrell Creek		Grayling	Arctic grayling	
			Rainbow	Rainbow trout	
			Squawfish	Northern pikeminnow	
	Gwillim Lake		Walleye	Walleye	
	Halfway River	Cameron River	Dolly Varden	Bull trout	Winter
			Grayling	Arctic grayling	July, August
			Kokanee	Kokanee	
			Sucker	Sucker species	
		Cust Creek	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter
		Dunlevy Creek.	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter
		Gravel Creek	Dolly Varden	Bull trout	Winter
			Lake Trout	Lake trout	Winter

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
			Lake Trout	Bull trout	
			Grayling	Arctic grayling	July, August
			Jackfish	Northern pike	
			Kokanee	Kokanee	
			Ling cod	Burbot	June, July
			Pike	Northern pike	
			Rainbow	Rainbow trout	October
			Squawfish	Northern pikeminnow	
			Suckers	Sucker species	
	Jackfish Lake		Jackfish	Northern pike	
	Moberly Lake		Dolly Varden	Bull trout	September
			Pike	Northern pike	
			Rainbow	Rainbow trout	
			Trout	Trout species	
	Moberly River		Jackfish	Northern pike	
	Peace River	Bear Flats	Dolly Varden	Bull trout	
			Rainbow trout	Rainbow trout	
		Beatton River confluence	Walleye	Walleye	
		Halfway River confluence	Brown trout	Brown trout	
			Dolly Varden	Bull trout	
			Grayling	Arctic grayling	
			Jackfish	Northern pike	
			Kokanee	Kokanee	
			Pickerel	Walleye	
			Pike	Northern pike	
			Rainbow	Rainbow trout	
			Suckers	Sucker species	
			Trout	Trout species	
			Walleye	Walleye	
			Whitefish	Whitefish species	
		Lynx Creek Confluence	Dolly Varden	Bull trout	
			Grayling	Arctic grayling	
			Rainbow	Rainbow trout	
		Mainstem Peace River	Arctic grayling	Arctic grayling	Aug, Sep, Oct
			Dolly Varden	Bull trout	
			Pike	Northern pike	
			Rainbow	Rainbow trout	
			Trout	Trout species	
			Whitefish	Whitefish species	
	Pine River		Grayling	Arctic grayling	May
	Stuart Lake		Whitefish	Whitefish species	
	Upper Stoddart		Suckers	Sucker species	

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
	Williston Lake	Dunlevy Reach Upper Reach	Catfish Dolly Varden	Burbot Bull trout	Winter
			Lake Trout Ling cod	Lake trout Burbot	
Saulteau	Carbon Creek		Trout	Trout species	
	Moberly Lake		Grayling Ling cod Pike Suckers Trout Whitefish	Arctic grayling Burbot Northern pike Sucker species Trout species Whitefish species	
Kelly Lake Metis	Belcourt Lake		Dolly Varden	Bull trout	
	Onion Lake		Rainbow trout	Rainbow trout	
	Blue Lake Steep Rock Creek	Upper Lower	Bull trout Bull trout Walleye Suckers	Bull trout Bull trout Walleye Sucker species	
Dene Tha'	Peace River	East of Manning	Various species	Various species	
	Charlie Lake		Various species	Various species	
	Sulphur Lake		Various species	Various species	Late Summer
Fort Nelson	Various locations		Various species		
Treaty 8 (Doig River, Halfway River, Prophet River, and West Moberly)	Charlie Lake		Jackfish	Northern pike	
	Peace River	Farrell Creek confluence	Sucker Bull trout	Sucker species Bull trout	
		Halfway River confluence	Bull trout	Bull trout	
		Lynx Creek confluence	Sucker Whitefish	Sucker species Mountain whitefish	
		Downstream. of Halfway River	Jackfish Lake trout	Northern pike Lake trout	
		Upstream of Halfway River	Bull trout Jackfish Lake trout Whitefish	Bull trout Northern pike Lake trout Mountain whitefish	
		Peace Canyon Dam Tailrace	Bull trout	Bull trout	
		Williston Lake	Lake trout Fish	Lake trout Fish species	
Duncan	Beatton River		Various species	Fish species	
	Charlie Lake		Various species Jackfish	Fish species Northern Pike	

Group	Water Body	Area	Fish Harvested	Common Name	Harvest Month/ Season
	Peace River	Beatton River confluence	Various species	Fish species	
		Hudson's Hope	Jackfish Bull trout	Northern Pike Bull trout	
		Moberly River confluence	Various species Jackfish	Fish species Northern Pike	
		Upstream of. Halfway River	Walleye	Walleye	
	Pine River		Bull trout Various species Jackfish	Bull trout Fish species Northern Pike	
Horse Lake	Beatton River	Upper Beatton River	Various	Fish species	
	Charlie Lake		Various Jackfish Walleye	Fish species Northern Pike Walleye	
	Moberly Lake		Various Jackfish	Fish species Northern Pike	
	Peace River	Downstream of Halfway River	Walleye	Walleye	
		Pine River confluence Upstream of Halfway River	Various Jackfish Walleye	Fish species Northern Pike Walleye	
	Pine River		Various Jackfish	Fish species Northern Pike	

12.3.2 Fish Ecology

The fish community is composed of fish populations that use one or more ecological strategies. Factors that influence the ecology of a fish population include the species characteristics, environmental conditions, location and availability of important habitats, predation, competitors, and food resources. The following text discusses these factors of the ecology of fish populations recorded in the LAA. Table 12.7 presents a general summary of the ecology of fish species populations recorded in the LAA. More detailed summaries of fish population distribution, habitat use, movement strategies, and recruitment sources within the LAA are provided in Table 12.8 and Table 12.9.

12.3.2.1 Coldwater Versus Coolwater Fish Groups

There are two primary groups of sport fish observed in the LAA, and are categorized as coldwater and coolwater fish. As the name implies, coldwater species reside in coldwater habitats, and require large-textured sediments and clean, well-oxygenated water to complete their life requisites. These species spawn in summer or fall and have extended egg incubation periods.

Coolwater species are able to tolerate higher water temperatures and are better adapted to inhabit turbid water and cope with higher fine sediment loads than the coldwater species. Most of these species spawn in spring and have short egg incubation periods.

The transition zone for cool and coldwater fish is within the LAA. Coldwater species dominate the fish community primarily upstream of the Pine River confluence; however, coolwater fish also migrate or reside in the coldwater type habitat upstream of the Pine River. The abundance of the coolwater fish increases downstream of the Pine River confluence and becomes the dominant fish group at the B.C./Alberta boundary.

Table 12.7 Summary of the Ecology of Fish Populations Recorded in the Local Assessment Area

Group	Species [a]	Distribution [b] and Relative Abundance		Important Habitats [d]				Recruitment Source [e]			Movement Strategy [f]
		Upst.	Dwst.	Upst.		Dwst.		Type	Stream Resident Populations		
				Peace R.	Tribs.	Peace R.	Tribs.		Upst.	Dwst.	
Sport fish (coldwater)	Arctic grayling	S	S	F, W	**S**, **R**, F, W	F, W	S, R, F, W	N	x	x	E
	Bull trout	P	S	F, W	**S**, **R**, F, W	F, W	S, R, F, W	**N**, E	x	x	E
	Brook trout										
	Kokanee	S	I	F, W				E			D
	Lake whitefish	S	S	F, W		S, R, F, W		N, **E**			L
	Lake trout	S	I	F, W				E			L
	Mountain whitefish	**A**	A	S, R, F, W	**S,** R, F, W	S, R, F, W	S, R, F, W	N	x	x	L, E
	Pygmy whitefish										
	Rainbow trout	P	I	F, W	**S**, **R**, F, W			N, **E**	x		L
Sport fish (coolwater)	Burbot	S	P		S, R, F, W	F, W	**S**, **R**, F, W	N	x	x	L
	Goldeye	S	P	–		F, W	**S**, R, F, W	N			E
	Northern pike	S	P	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Yellow perch	S				Unique		N			L
	Walleye	S	P	F, W	F, W	F, W	**S**, **R**, F, W	N			E
Suckers	Largescale sucker	A	A	F, W	**S, R,** F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Longnose sucker	A	**A**	F, W	**S, R,** F, W	S, R, F, W	S, R, F, W	N	x	x	L
	White sucker	S	P	F, W	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L

Group	Species [a]	Distribution [b] and Relative Abundance		Important Habitats [d]				Recruitment Source [e]			Movement Strategy [f]
		Upst.	Dwst.	Upst.		Dwst.		Type	Stream Resident Populations		
				Peace R.	Tribs.	Peace R.	Tribs.		Upst.	Dwst.	
Minnows	*Brook stickleback*										
	Finescale dace										
	Flathead chub	S	P		S, R, F, W	F, W	**S, R,** F, W	N	x	x	E,L
	Lake chub	A	A	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Longnose dace	A	A	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Northern pikeminnow	P	A	F, W	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Northern redbelly dace										
	Peamouth										
	Pearl dace										
	Redside shiner	**A**	**A**	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Spottail shiner	S	P	U	S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
	Trout-perch	I	P		S, R, F, W	S, R, F, W	S, R, F, W	N	x	x	L
Sculpins	Prickly sculpin	A	A	F,W	S, R, F, W	F,W	S, R, F, W	N	x	x	L
	Slimy sculpin	A	A	F,W	S, R, F, W	F,W	S, R, F, W	N	x	x	L
	Spoonhead sculpin	I	S		S, R, F, W	F,W	S, R, F, W	N	x	x	L

NOTES:

[a] Species: Italics indicate incidental species recorded only rarely in the LAA

[b] Distribution: Upst. (Upstream of the Site C Dam site location); Dwst. (Downstream of Site C Dam site location); + (Present); – (Not present)

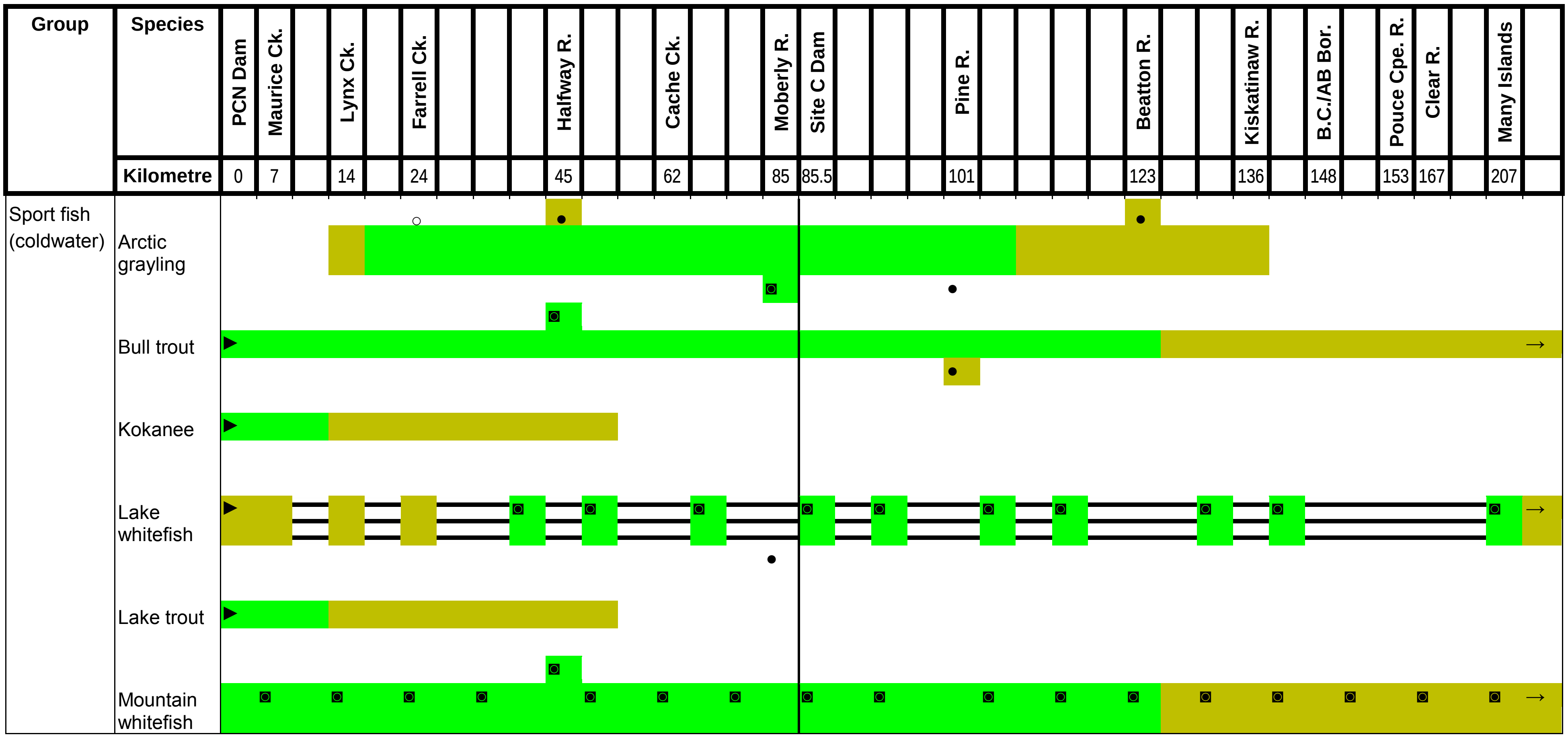
[c] Relative Abundance: A (Abundant); P (Present); S (Scarce); I (Incidental)

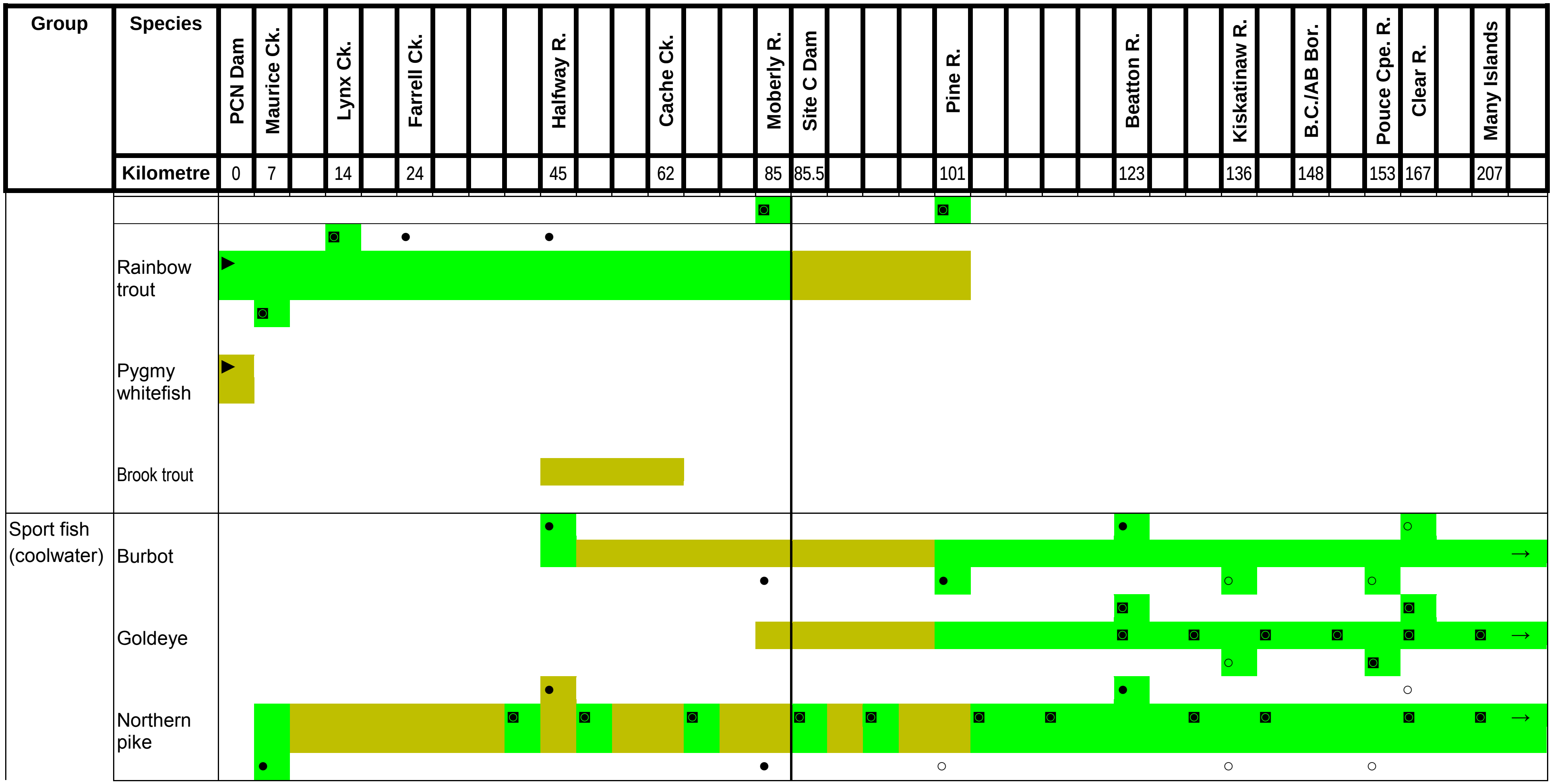
[d] Important Habitats: S (Spawning); R (Rearing); F (Feeding); W (Wintering); bold indicates required use of tributary habitat by Peace River population; "U" refers to a small number of side channels that provide all important habitats

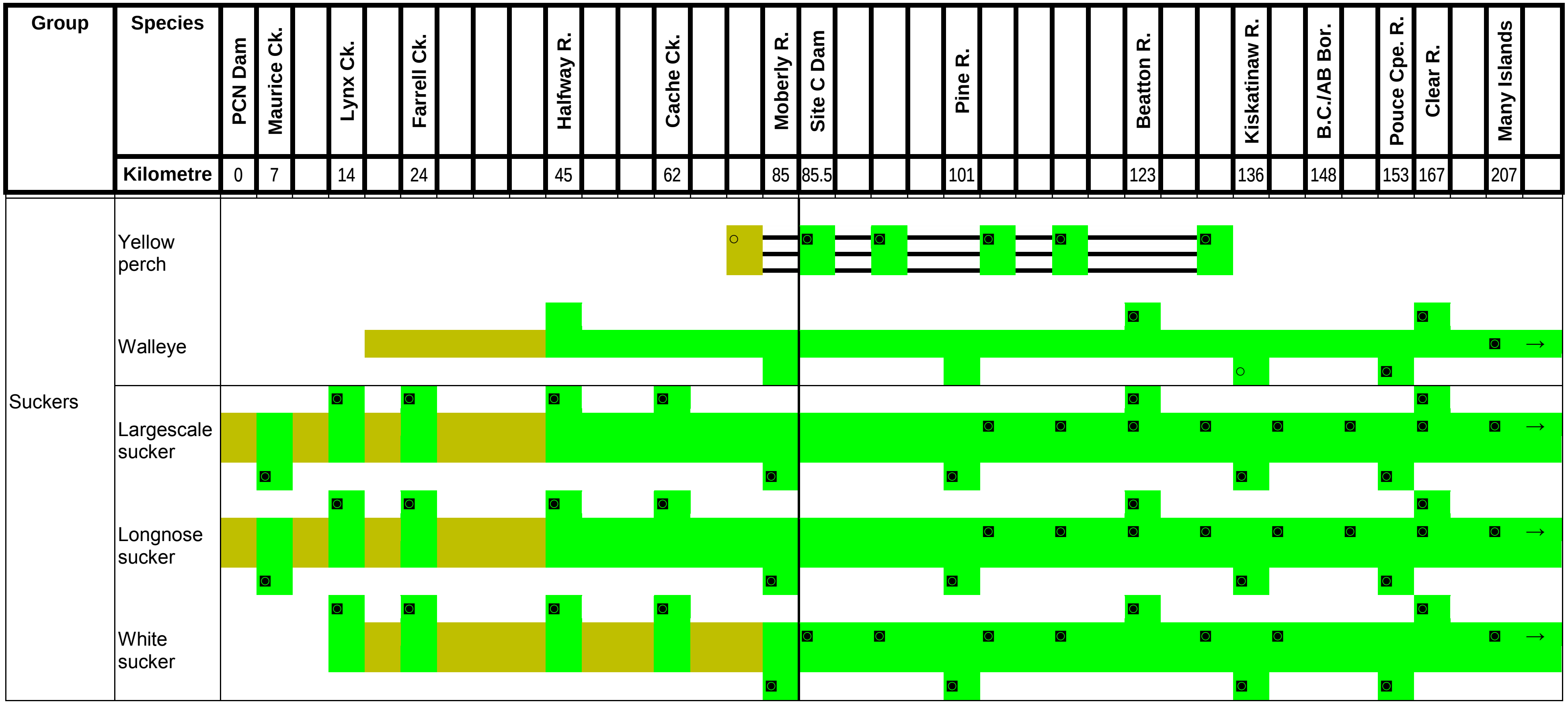
[e] Recruitment Source: N (Natural); E (Entrainment); bold indicates primary source

[f] Movement Strategy: E (Extended movements); L (Local movements); (D) Unidirectional downstream dispersal

Table 12.8 Summary of Large-Fish Population Distribution, Habitat Use, Movement Strategy, and Recruitment Sources in the Local Assessment Area




Group
Species
PCN Dam
Maurice Ck.
Lynx Ck.
Farrell Ck.
Halfway R.
Cache Ck.
Moberly R.
Site C Dam
Pine R.
Beatton R.
Kiskatinaw R.
B.C./AB Bor.
Pouce Cpe. R.
Clear R.
Many Islands
Kilometre
0
7
14
24
45
62
85
85.5
101
123
136
148
153
167
207
Rainbow trout
Pygmy whitefish
Brook trout
Sport fish (coolwater)
Burbot
Goldeye
Northern pike



NOTES:

Core population defined by area of frequent occurrence and high abundance relative to remainder of population in LAA.

Extended population defined as area of infrequent occurrence and low abundance relative to remainder of population in LAA.

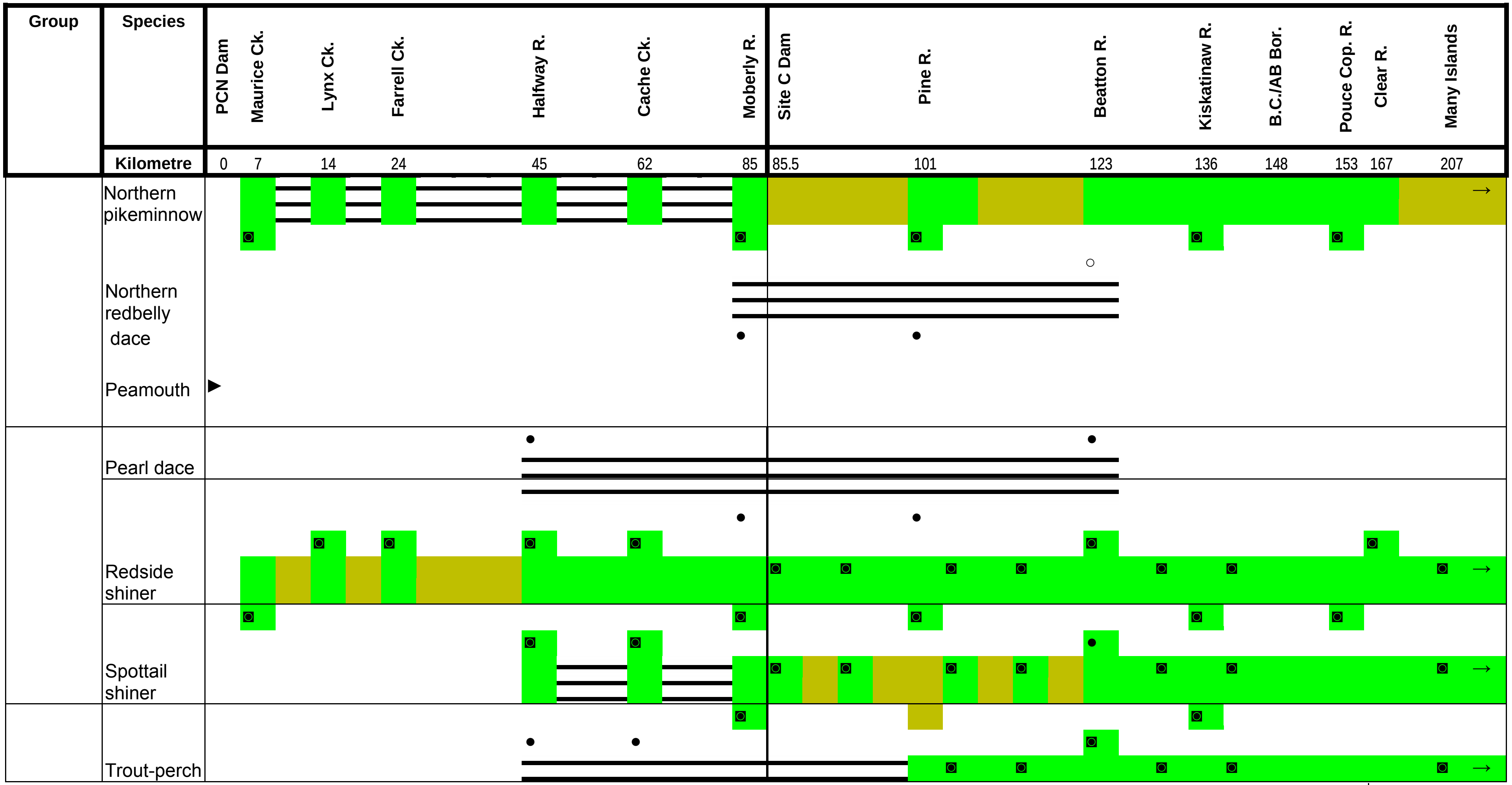
Area of population separation

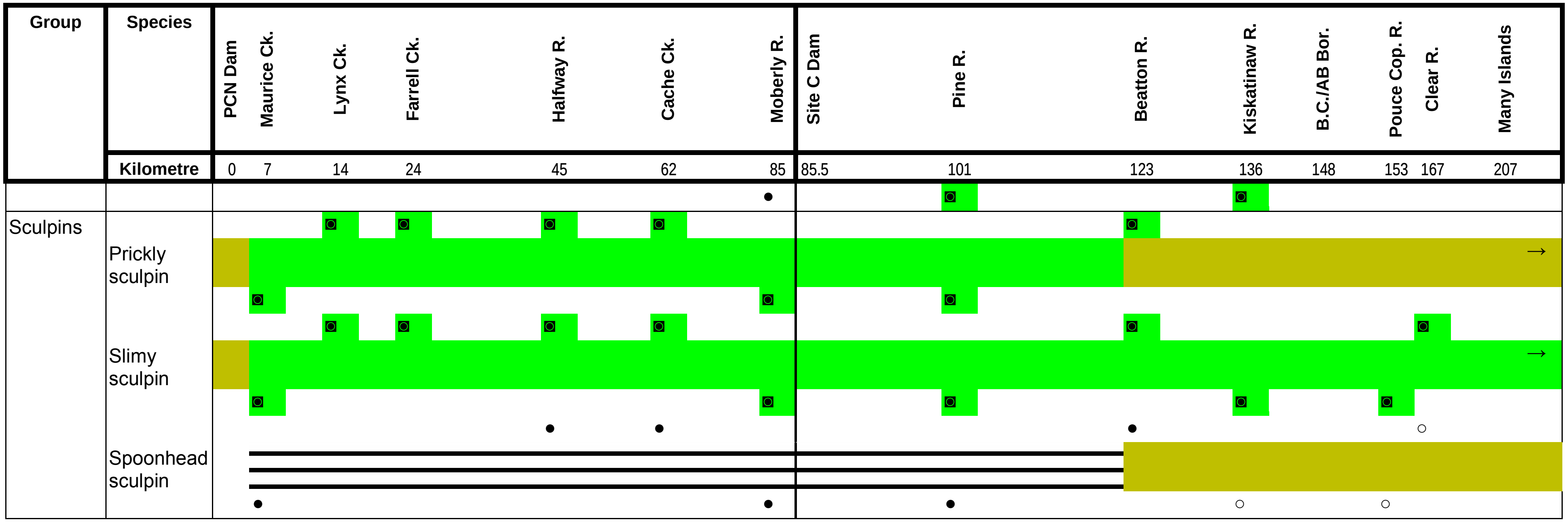
BC hydro FOR GENERATIONS

►	Recruitment by entrainment from upstream sources.
●	Tributary resident population that is a recruitment source for Peace River population.
○	Suspected recruitment source for Peace River population.
◙	Important spawning or rearing habitat and recruitment source for Peace River population.
→	Distribution extends downstream outside of LAA.

Table 12.9 Summary of Small-Fish Population Distribution, Habitat Use, Movement Strategy, and Recruitment Sources in the Local Assessment Area.

Group	Species	PCN Dam	Maurice Ck.	Lynx Ck.	Farrell Ck.	Halfway R.	Cache Ck.	Moberly R.	Site C Dam	Pine R.	Beatton R.	Kiskatinaw R.	B.C./AB Bor.	Pouce Cop. R.	Clear R.	Many Islands
	Kilometre	0	7	14	24	45	62	85	85.5	101	123	136	148	153	167	207
Minnows	Brook stickleback															
	Finescale dace															
	Flathead chub															
	Longnose dace															
	Lake chub															


Group
Species
PCN Dam
Maurice Ck.
Lynx Ck.
Farrell Ck.
Halfway R.
Cache Ck.
Moberly R.
Site C Dam
Pine R.
Beatton R.
Kiskatinaw R.
B.C./AB Bor.
Pouce Cop. R.
Clear R.
Many Islands
Kilometre
0
7
14
24
45
62
85
85.5
101
123
136
148
153
167
207
Northern pikeminnow
Northern redbelly dace
Peamouth
Pearl dace
Redside shiner
Spottail shiner
Trout-perch



NOTES:

- Core population defined by area of frequent occurrence and high abundance relative to remainder of population in LAA.
- Extended population defined as area of infrequent occurrence and low abundance relative to remainder of population in LAA.
- Area of population separation
- ► Recruitment by entrainment from upstream sources.
- ● Tributary resident population that is a recruitment source for Peace River population.
- ○ Suspected recruitment source for Peace River population.
- ◙ Important spawning and/or rearing habitat and recruitment source for Peace River population.
- → Distribution extends downstream outside of LAA.

Seven sport fish species that are part of the fish community belong to the coldwater group. They include Arctic grayling, bull trout, kokanee, lake whitefish, lake trout, mountain whitefish, and rainbow trout. Rainbow trout and Arctic grayling are the only species in the group that are a spring spawners. Rainbow trout is also a species whose population has limited natural recruitment within the LAA.

Five sport fish species belong in the coolwater group including walleye, goldeye, northern pike, burbot, and yellow perch.

Fish species that also occupy the coolwater habitats include the three sucker species and nine species listed in the minnow group. They include largescale sucker, longnose sucker, white sucker, flathead chub, lake chub, longnose dace, northern pikeminnow, redside shiner, spottail shiner, and trout-perch.

The three sculpin species occupy both types of environments. Slimy sculpin and prickly sculpin tend to do better in cold, clear water systems, while spoonhead sculpin do better in cool, turbid water systems.

A number of species recorded in the LAA are rare and are not considered part of the existing fish community. These include brook trout, pygmy whitefish, brook stickleback, finescale dace, northern redbelly dace, peamouth, and pearl dace. They are present, but individuals of these species represent transients from populations that reside outside the influence of the LAA.

12.3.2.2 Small Versus Large Fish

The LAA fish community was divided in two groups based on maximum fish size – large and small-fish species. Large-fish species generally attain a length of at least 200 mm at maturity, but are also represented by smaller age classes (i.e., young-of-the-year and juveniles). The large-fish category includes sport fish and suckers. In the small-fish group, all age classes are smaller than 200 mm. This category includes minnows and sculpins. The only exception to this length criterion is northern pikeminnow in the minnows group, which can attain a length in excess of 600 mm.

The rationale for the size distinction relates to the relative difference between large-fish species and small-fish species in their ability to move extended distances. In fluvial systems like the regulated Peace River, adults of large-fish species are capable of moving long distances upstream against the river current. Due to their small size, small-fish species undertake shorter upstream movements compared to large-fish species. Small-fish species and younger age classes of large-fish species can complete long distance movements during downstream dispersal.

12.3.2.3 Extended Versus Local Movements

Fish that reside in north temperate climates use migration (movement) as a strategy to cope with harsh and unpredictable environments. Migration is defined as movements resulting in alternating between two or more separate habitats occurring with regular periodicity (seasonal or annual) and involving a large fraction of the population (Northcote 1998). The patterns of movement can vary between species and even between groups within the same population (Northcote 1998). Fish residing in the Peace River use movement as a strategy to access important habitats (Nelson and Paetz 1992; Mill et al. 1997; McPhail 2007); however, certain species are known to undertake extensive movements (extended), whereas others undertake only local movements (local).

There are four movement strategies identified below. These movement strategies are not mutually exclusive as a given species, life stage, or distinct group may use one or more of these strategies.

Extended Movement Strategy: Several species demonstrate extended movements, including Arctic grayling, bull trout, mountain whitefish, goldeye, and walleye. Movements by adults involve long distance migrations to tributary spawning habitats and foraging areas.

- Arctic grayling migrate to the Moberly River, where they spawn 20 to 60 km upstream from the Peace River confluence
- Mountain whitefish migrate throughout the Peace River to the Moberly and Halfway rivers to spawn
- Bull trout travel as much as 300 km in order to access spawning habitats in upper Halfway River tributaries
- Walleye undertake post-spawning feeding movements in the Peace River from spawning areas in the Beatton River, Clear River, and Pouce Coupe River to as far upstream as the Halfway River, a distance of 100 km. Some of these walleye enter and move upstream into larger tributaries such as the Pine River, Moberly River, and Halfway River.
- Goldeye is a migratory species that can travel long distances from wintering habitats downstream to spawning and feeding habitats to as far upstream as the Moberly River. The goldeye population spawns in the Peace River and in several tributaries, primarily in Alberta.

Local Movement Strategies: Some fish species undertake local movements around focal areas. For example, all three sucker species and most species in the minnow group have populations in the Peace River that reside in the immediate vicinity of tributary confluences. During spring and early summer, large numbers of fish belonging to these populations are recorded moving upstream to spawning and feeding areas in the tributaries.

Combined Extended and Local Movement Strategies: Some species utilize both local and extended movement strategies, depending on the availability of important habitats. These include all three sucker species and mountain whitefish. For example, some mountain whitefish complete all life history actives within a 1 or 2 km section of the Peace River, while other mountain whitefish migrate more than 80 km in order to access tributary spawning habitats in the Pine River, Moberly River, and Halfway River.

Downstream Dispersal Movement Strategy: Downstream dispersal by small-fish species and younger age classes of large-fish species, which can be active or passive, has been recorded for most species present within the Peace River and from all tributaries. This movement strategy is a source of recruitment to the Peace River for some fish populations (e.g., Arctic grayling). For other populations, it represents a loss (e.g., kokanee). Examples are as follows:

- Juvenile Arctic grayling are recorded immediately downstream of major tributaries from the Halfway River to the Beatton River, indicating downstream dispersal from each system
- Large numbers of Age 0 mountain whitefish emigrate from rearing tributaries such as the Moberly River and Halfway River
- Kokanee in the Peace River recruit from the upstream Williston and Dinosaur reservoirs. These fish then disperse through the LAA to downstream areas.
- Recently emerged mountain whitefish fry in the upper Peace River disperse downstream in spring and by mid-summer are absent from upstream of the Halfway River confluence

12.3.2.4 Recruitment Sources – Natural Versus Entrainment

Natural recruitment of fish populations in the LAA originate from the mainstem Peace River and/or Peace River tributaries. Tributaries provide spawning and early rearing habitats for species populations that reside in the Peace River. In addition, some tributaries contain resident populations that provide recruitment to the Peace River via downstream dispersal. Baseline studies indicate that resident fish in Maurice Creek are a recruitment source for Peace River rainbow trout. The Halfway River, Pine River, and Beatton River are important sources for recruitment of Arctic grayling.

Few fish populations rely entirely on mainstem Peace River for recruitment. Spawning sculpin species, mountain whitefish, sucker species, and walleye occur in the mainstem Peace River. However, the contribution of mainstem spawning to recruitment is minimal, given the temperature, flow, and ice regime of the system and evidence of rapid downstream dispersal of recently emerged fry. Sculpin, mountain whitefish, sucker, and walleye populations utilize tributary spawning and early rearing habitats that are located outside of the influence of the Peace River.

An importance source of recruitment for some fish populations in the LAA is entrainment. Recruitment via entrainment maintains the rainbow trout, kokanee, and lake trout populations. Other species known to recruit from sources upstream of the Peace Canyon Dam include bull trout, lake whitefish, and peamouth.

12.3.2.5 Habitat Use: Peace River Habitats versus Tributary Habitats

The Peace River fish community is dominated by adults and older juveniles of large-fish species, with a paucity of younger fish in the large-fish species group and most small-fish species. This is most apparent upstream of the Halfway River confluence. The mechanism that drives this outcome is the absence of suitable habitats needed by small-sized fish in the Peace River (more detail on fish habitat characteristics is provided in Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). This is caused by the regulated flow regime of the Peace River and life history strategies that rely on tributary habitats for the life requisites spawning and early rearing. Downstream of the Halfway River, this pattern of large-fish versus small-fish diminishes, but still remains the primary feature of the Peace River fish community. Species populations that do not follow this pattern are rainbow trout and kokanee, which receive recruitment from upstream sources, and sculpins. Prickly sculpin and slimy sculpin are widely distributed in the Peace River in areas that contain large amounts of physical cover in the channel bed that is not dewatered by flow regulation.

In contrast to the Peace River, tributaries in the LAA support a diverse number of small- and large-fish species. The fish species populations that utilize tributaries depend on the environmental characteristics of the watercourse. Smaller tributaries and the lower sections of larger tributaries have limited coldwater fish habitats due to water flow regimes that are dominated by large spring freshets, low summer and winter flows, high summer water temperatures, and elevated suspended sediment loads caused by watercourse down-cutting through the Peace River valley wall. Areas such as Lynx Creek, Farrell Creek, lower Halfway River, and Cache Creek support populations of minnows and suckers, which use tributary confluence areas as population focal points.

In the upper watersheds of larger tributaries such as the Halfway River and Pine River, there is an abundance of habitat that support coldwater fish populations. These habitats are utilized by some Peace River fish populations (e.g., bull trout) and resident populations that may provide recruitment to Peace River populations by downstream dispersal (e.g., Arctic grayling).

12.3.2.6 Habitat Use: Main Channel Habitats versus Side Channel Habitats

The Peace River fish community utilizes two primary habitat areas – main channel and side channel. Fish populations use one or both habitat areas depending on species life stage requirements, the physical characteristics of the side channel area, and the Peace River flow regime. Side channels can be more protected than habitats in main channel areas (i.e., lower water velocities). Side channels are important habitats for smaller-sized fish species and younger age-classes of large-fish species. Side channel areas provide critical refuge during high river flows and during periods of fry emergence.

Some side channels provide fish habitats that exhibit specific physical characteristics. These side channels are sheltered from high water velocities (i.e., one inlet at the downstream end), have low water turbidity during much of the year, and support growth of aquatic vegetation. These side channel habitats are restricted in distribution and are few in number within the LAA. These side channel areas support five species populations including lake whitefish, northern pike, yellow perch, white sucker, and spottail shiner.

12.3.2.7 Fish Abundance and Distribution

In terms of overall abundance of large-fish and small-fish, fish numbers are much higher in the LAA compared to further downstream. Extensive work in the Dunvegan area of the Peace River, which is 120 km downstream of the LAA, recorded an order of magnitude lower abundance of large-fish and of small-fish.

Mountain whitefish is the dominant species in the LAA. In 2011 within the Peace River, there were an estimated 275,500 large-sized mountain whitefish (70,400 kg) upstream of the proposed Site C Dam site and an estimated 86,000 large-sized mountain whitefish (29,000 kg) downstream of the proposed Site C Dam site (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Longnose sucker replaces mountain whitefish as the dominant large-fish species downstream of the Beatton River confluence. Redside shiner is the numerically dominant small-fish species in the Peace River LAA upstream and downstream of the proposed Site C Dam site.

Smaller tributaries contain fish communities numerically dominated by suckers and minnows. Spring trapping studies recorded several thousands of fish belonging to these groups in monitored streams (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). These included Lynx Creek, Farrell Creek, and Cache Creek. Maurice Creek supports a rainbow trout population. The lower portions of larger tributaries contain fish communities dominated by suckers and minnows, but the upper watersheds also support coldwater sport fish such as Arctic grayling, bull trout, and rainbow trout.

12.3.2.8 Fish Age Structure

Population structure refers to the size and age distribution of a population. A balanced population structure would include all size or age groups in appropriate proportions necessary to sustain a fish population. The Peace River fish community is dominated by large-sized fish, particularly upstream of the Halfway River confluence. Younger fish of large-fish species (and most small-fish species) exhibit low abundance. The availability and quantity of small-fish habitats is limited by the Peace River flow regime. Small-fish species do occur upstream of the Halfway River, but are more abundant in protected backwaters and side channels away from the main influence of Peace River flows. The frequency of occurrence and abundance of small-sized fish increases downstream of the Halfway River.

12.3.3 Fish Habitats

Fish habitat is defined as any spawning ground and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes (Fisheries and Oceans Canada 1998). A distinction is made for important habitat, which is defined as habitat that is essential for the maintenance of a self-sustaining fish population. Removal of important habitat from production by alteration, destruction, or elimination of access might reduce the sustainability of the population.

Important habitats are present throughout the LAA (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Depending on the species, important habitats are located in the Peace River upstream and downstream of the Site C Dam site, and in Peace River tributaries within and outside of the inundation zone of the Site C reservoir. In general, the lower sections of Peace River tributaries provide important spawning and early rearing habitats for suckers and minnows. Important spawning and rearing habitats for sport fish have been recorded only in upstream areas of large tributaries.

The upper Halfway River watershed provides spawning and rearing habitats for the Peace River bull trout population. The Moberly River provides spawning and rearing habitats for the Peace River Arctic grayling population. Maurice Creek provides spawning and rearing habitats for the Peace River rainbow trout population. The Halfway River, Moberly River, and Pine River provide spawning habitats for the Peace River mountain whitefish population. The Beatton River provides spawning and rearing habitats for walleye and goldeye. All tributaries to the Peace River provide spawning and rearing habitats for suckers, minnows, and sculpins. The Peace River downstream of the Halfway River confluence provides rearing habitat for mountain whitefish. Side channels provide habitats for several fish species, in particular northern pike, yellow perch, and spottail shiner. Finally, the mainstem Peace River is a migration area for several species by providing an upstream and/or downstream movement corridor between habitats. Several species require the Peace River as a movement corridor including Arctic grayling, bull trout, mountain whitefish, burbot, goldeye, walleye, largescale sucker, and longnose sucker.

12.3.4 Environmental Factors

Physical and biological information used to describe baseline conditions for fish and fish habitat are described in more detail in other volumes and sections of the EIS as identified in Table 12.10. These environmental factors and their influence on fish habitat are described in detail in Volume 2 Appendix O Fish and Fish Habitat Technical Report.

Table 12.10 Environmental Factors Supporting Fish and Fish Habitat

Environmental Factors	Volume 2, Section Number	Volume 2 Appendices
Previous Development	Section 11.1 Previous Development	–
Geology, Terrain, and Soils	Section 11.2 Geology, Terrain, and Soils	Appendix B Geology, Terrain Stability, and Soil Reports
Surface Water	Section 11.4 Surface Water Regime	Appendix D Surface Water Regime Technical Memos
Water Quality	Section 11.5 Water Quality	Appendix E Water Quality Baseline Conditions in the Peace River
Thermal and Ice Regime	Section 11.7 Thermal and Ice Regime	Appendix G Downstream Ice Regime Technical Data Report Appendix H Reservoir Temperature and Ice Regime Technical Data Report
Fluvial Geomorphology and Sediment Transport	Section 11.8 Fluvial Geomorphology and Sediment Transport Regime	Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report
Methylmercury	Section 11.9 Methylmercury	Appendix J Mercury Technical Data Reports
Aquatic Productivity		Appendix P Aquatic Productivity Reports

12.4 Effects Assessment

The creation of the Site C reservoir will change the river ecosystem. Upstream of the dam, a new aquatic ecosystem, with a fish community, will develop in the reservoir created by the impoundment of the river. For a distance downstream of the dam, the operation of the dam and generating station would modify the surface water regime and other characteristics of the river aquatic ecosystem and influence aquatic habitat conditions, ecological productivity, and fish community composition. The dam would also impede upstream and downstream movement of migratory species and can directly affect survival of fish passing through it. The Project therefore has the potential to adversely affect fish and fish habitat.

The assessment of the potential for the Project to affect fish and fish habitat took into consideration the potential changes to the following key aspects:

1. Habitat changes created by the reservoir in the mainstem and affected tributaries, as well as upstream and downstream of the dam due to flow alterations

- Upstream and downstream fish migrations by species, their life history stage, and their potential to be affected by the Project
- Fish mortality
- Potential impacts on the genetic diversity of fish populations above and below the project site
- Potential impacts to predator-prey interactions and expected changes
- Potential impacts to food web composition and structure
- Potential impacts of gas pressure on fish resulting from water discharge over the structure

Because of the overlapping nature of these seven key aspects, for the purpose of this assessment, they have been grouped into three categories:

- Changes to fish habitat
- Changes to fish health and fish survival
- Changes to fish movement

This approach was used for the following reasons:

1. It permits a structured evaluation process
2. Each category represents major federal and/or provincial regulatory mandates
3. Each category represents an important component of fish population ecology

The following sections discuss each of the potential changes to fish habitat, fish health and survival, and fish movement resulting from effects of the construction and operation phases of the Project resulting from the key issues identified in Section 12.1.2 above and interactions summarized in Table 12.11 below.

Table 12.11 lists the interactions that may cause a change to one or more of the three categories of effects by Project phase and component. Some interactions are common to project components and phases (e.g., sediment inputs), while others are specific to a particular phase and component (e.g., entrainment of fish).

Table 12.11 Interaction of the Project by Phase, Project Component and Category of Effects

Interaction	Phase and Project Component														Category of Effects		
	Construction							Operation									
	Access Roads	Dam & Generating Station	Highway 29 Realignment and Hudson's Hope shoreline protection	Quarried & Excavated Materials	Reservoir Creation [a]	Transmission System	Worker Accommodation	Access Roads	Dam & Generating Station	Highway 29 Realignment	Quarried & Excavated Materials	Reservoir Operation	Transmission System	Worker Accommodation	Fish Habitat	Fish Health and Survival	Fish Movement
Sediment inputs		X	X		X										X	X	
Footprint of infrastructure		X	X												X		
Obstructed fish movement		X							X								X
Stranding of fish		X			X				X			X				X	
Entrainment of fish		X							X							X	
Altered total dissolved gas		X			X				X							X	
Altered depth and velocity					X							X			X		
Altered surface water regime		X							X						X		
Altered sediment regime		X			X				X			X			X		
Altered thermal regime									X			X			X		
Altered ice regime									X						X		

NOTE:
[a] Refers to channelization and diversion headpond and reservoir filling

12.4.1 Effects Assessment – Construction – Change in Fish Habitat

Fish habitat would be potentially be changed by the following Project components and activities during operations:

Construction of dam and generating station, Highway 29, and Hudson's Hope shoreline protection

Construction headpond and reservoir filling

12.4.1.1 Change in Habitat Due to Construction of the Dam and Generating Station, Highway 29, and Hudson's Hope Shoreline Protection

The construction of the dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection infrastructure footprint would potentially affect fish habitat. The surface area of these components and activities that would potentially affect fish habitat are provided in Table 12.12.

Table 12.12 Surface Area of the Project Components and Activities that Would Potentially Affect Fish Habitat

Project Component and Activities	Surface Area (ha)
Dam and Generating Station Construction Zone	**198.5**
Dam, generating station, and spillway	
L5 surplus excavated materials area	
Aggregates processing and stockpiles	
North bank haul road (2.95 km of Peace River shoreline)	
L6 relocated surplus excavated materials area	
Peace River construction bridge	
Moberly River construction bridge	
Highway 29 Realignment	**10.6**
Halfway River bridge	0.2
Lynx east (1.76 km of Peace R. shoreline)	10.4
Reservoir: Hudson's Hope Shoreline Protection	**6.1**
Berm (1.52 km)	4.6
Bank setback (0.77 km of Peace R. shoreline)	1.5
Total	**215.2**

Construction of the dam and generating station would result in the loss of 198.5 ha of fish habitat. Fish habitats affected are primarily in the Peace River, but habitats in the Moberly River would be affected by the construction bridge. Moberly River fish habitats that would be affected include spawning and rearing habitats for mountain whitefish, suckers, and minnows, and feeding habitats for all adult species, in particular for goldeye and walleye. Peace River fish habitats affected include a side channel area along the south bank that provides spawning, rearing, feeding, and wintering habitats for several species. Peace River mainstem channel areas that are affected include spawning, rearing, feeding, and wintering habitats for several fish species. Within the dam and generating station construction zone, there are two locations that contain high-quality fish habitats. High quality is defined as habitat that supports highest numbers of fish. The first includes the river channel located along the north bank of the Peace River, which provides high-quality rearing habitats for Arctic grayling and mountain whitefish. The second is the river channel located along the north bank of the Peace River that would be changed by the 2.95 km North Bank Haul Road. The area provides high-quality rearing habitats for Arctic grayling, bull trout, mountain whitefish, and rainbow trout. The area also provides high-quality feeding habitats for Arctic grayling, bull trout, rainbow trout, and walleye.

Construction of Highway 29 realignment would result in the loss of 10.6 ha of fish habitat. This includes 0.2 ha of habitat in the Halfway River and 10.4 ha along a 1.76 km shoreline of the Peace River. The Halfway River within the Highway 29 Realignment construction footprint provides spawning and rearing habitats for suckers and minnows and feeding habitats for bull trout. The shoreline located along the north bank of the Peace River provides several types of high-quality habitats. These include high-quality spawning habitats for mountain whitefish, high-quality rearing habitats for Arctic grayling, bull trout, mountain whitefish, and rainbow trout, and high-quality feeding habitats for Arctic grayling, bull trout, and mountain whitefish.

Construction of the Hudson’s Hope shoreline protection would result in the loss of approximately nine ha of fish habitat. This includes the berm, and fish habitat affected by construction activities associated with the shoreline setback. The Peace River in the area of the Hudson’s Hope shoreline protection provides several types of high-quality fish habitats. These include high-quality rearing habitats for bull trout and rainbow trout, and high-quality feeding habitats for bull trout, mountain whitefish, and rainbow trout. This section of the Peace River is used by lake trout for rearing and feeding. It also contains physical characteristics that provide high-quality spawning habitat for lake trout.

12.4.1.2 Change in Habitat Due to the Construction Headpond and Reservoir Filling

During channelization and diversion, a headpond would form upstream of the dam and generation station construction site. During the channelization period (approximately 36 months) the maximum upstream extent of the headpond would be approximately 10 km, and approximately 387 ha of the Peace River valley outside of the active channel would be inundated. During the diversion period (approximately 39 months), the maximum upstream extent of the headpond would be approximately 27 km and approximately 1,630 ha of the Peace River valley would be inundated.

The headpond would alter existing Peace River fish habitats by increasing water depth and decreasing water velocity. Sediment inputs from erosion of newly inundated areas outside of the active Peace River channel and sedimentation caused by deposition of suspended sediments would alter existing clean riverbed materials.

Both stages of construction (channelization and diversion) would lead to an increase in the water levels upstream of the construction site, which would provide additional fish habitat. During the channelization period, upstream water levels would be up to 1 m higher than under existing conditions at the upstream end of the river constriction; the difference would be less with increasing distance upstream. Although the daily range of water levels upstream of the construction site during channelization would be slightly higher than under existing conditions, the difference in the hourly rate of change would be negligible.

During diversion there would be a greater influence on upstream water levels than during the channelization period. Water levels adjacent to the cofferdam during diversion would be increased by 1.5 m or more (compared to existing conditions) 90% of the time, and water levels would be increased by 8.6 m or more 10% of the time. The difference would again be less with increasing distance upstream. Although the daily range of water levels in the construction headpond would be greater than under existing conditions, the difference in the hourly rate of change is minimal.

The increase in wetted surface area of the headpond would potentially provide additional fish habitats; however, water levels would fluctuate. This fluctuation would limit the ability of fish to utilize the newly formed habitats in the headpond.

Peace River fish habitats affected by the headpond include main channel and side channel areas that provide spawning, rearing, feeding, and or wintering habitats for most species recorded upstream of the Site C Dam (see Table 12.7).

Filling of the Site C reservoir would result in the loss of 28.0 km^2 of Peace River fish habitat area and 1.63 km^2 of tributary fish habitat area. The lotic habitat areas would be replaced by 9.42 km^2 of littoral area (defined as water depth < 6 m) and 83.57 km^2 of limnetic area. The different habitat types currently existing in the Peace River and Peace River tributaries, are described in Volume 2 Appendix O Fish and Fish Habitat Technical Data Report. A description of the timeline for reservoir filling and commissioning is presented in Volume 1 Appendix B Reservoir Filling Plan.

Based on the continual change from riverine habitat to reservoir habitat during headponding and reservoir filling, it is expected that the fish species that have critical riverine habitat requirements upstream of the Site C Dam, specifically the Moberly River Arctic grayling, mainstem spawning mountain whitefish, and perhaps migratory Halfway River bull trout would be most affected by the creation of the reservoir.

12.4.2 Effects Assessment – Operations – Change in Fish Habitat

Fish habitat would be potentially be changed by the following Project components and activities during operations:

Reservoir transformation during operations

Generating station operation effects on downstream Peace River

12.4.2.1 Transformation of Reservoir Habitat During Reservoir Operation

Following reservoir creation, the reservoir would undergo a dynamic ecosystem transformation, where there would be an initial surge of nutrients and productivity in the newly flooded reservoir over the short term, diminishing over time as the reservoir reaches equilibrium. The following section describes the changes that would occur during the reservoir transformation period. Predicted changes to the fish habitats during the transformation of the Site C reservoir are presented in Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River. Changes in fish habitat are based on calculations that quantify conversions of lotic habitats in the existing Peace River and its tributaries to lacustrine habitats in the Site C reservoir. Lacustrine habitats include littoral and pelagic habitats. The Site C reservoir would include 9.42 km^2 of littoral area and 83.57 km^2 of pelagic area.

Site C reservoir water levels would range between 460.0 m to 461.8 m elevations or 1.8 m (Section 4.3 in Volume 1 Section 4 Project Description). The daily range of Site C reservoir levels (i.e., the maximum daily reservoir level minus the minimum daily reservoir level) is expected to be 0.6 m or less 60% of the time (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

Most species that presently reside in the Peace River and its tributaries within the reservoir inundation zone would be present in the Site C reservoir after inundation. However, the relative abundance and biomass of fish species within the reservoir fish community would change during the transition of the reservoir. The short-term (10 years), medium-term (10 to 30 years), and long-term fish communities (> 30 years) would reflect the transition in ecological conditions of the Site C reservoir and tributaries flowing into the reservoir, including:

Physical environment (i.e., water depth and velocity, water temperature, water quality)

Availability of habitats needed to support the fish population

Aquatic productivity and food resources

Recruitment from sources outside of the reservoir (i.e., upstream and downstream)

Competition for food and space

Species that are able to reside within the new physical environment, that can exploit increases in aquatic productivity, food resources, and newly formed habitats, and that can outcompete other fish for food and space would dominate the Site C reservoir fish community.

A quantitative ecosystem approach was used to analyze the range of possible changes in fish and fish habitat, both upstream and downstream of the proposed Site C Dam, by considering changes to the ecological conditions listed above (Volume 2 Appendix P Aquatic Productivity Reports: Part 1 Baseline Aquatic Productivity in the Upper Peace River, Part 2 Hydrodynamic, Water Quality and Productivity Modelling for the Site C Project; Part 3 Future Conditions in the Peace River). The methods used are centred on a weight of evidence approach based on multiple performance measures and analyses to assess a range of possible changes in aquatic habitat productive capacity that may result from operation of the Project.

Fish populations depend on important habitats and on available food resources to meet their energy needs. Food requirements vary with fish species and life stages, and may include aquatic and terrestrial insects, zooplankton, or other fish. The food web that supports the fish community, in turn, is affected by many physical and chemical factors including the rate at which water moves through a river or reservoir, and the quality of that water, particularly its sediment and nutrient content, which affects primary production.

These flows of energy and interactions are schematically illustrated in Figure 12.2. The operation of Site C reservoir can potentially affect fish both directly (e.g., mortality during turbine passage), or indirectly through changes to their habitats, movements, and food resources. These interactions were examined and a range of possible future conditions following the creation of the Site C reservoir were explored. The following questions were used to define the metrics for evaluating possible changes in productive capacity. This study focuses on five sets of metrics:

1. Total habitat area before and after construction and operation of Site C

    Primary production (biomass and production of phytoplankton and periphyton)

    Secondary production (biomass and production of benthos and zooplankton)

    Fish production and biomass (total, as well as by species groups)

    Fish harvest

Table 12.13 provides an overview of the aquatic productivity evaluation structure, including the questions addressed, the specific linkages considered (with reference to Figure 12.2) and the set of methods used.

Table 12.13 Overview of the Aquatic Productivity Evaluation Structure

Question	Description	Methods [Links in Figure 12.2] [a]
1	What are the projected changes in the area of lotic, littoral, and pelagic/profundal habitat with the creation of the Site C reservoir?	GIS analysis of habitat maps (link 2)
2	What changes in water quality, lower trophic levels, and fisheries have been observed following the creation of other reservoirs, particularly within Western Canada?	Literature review (all links)
	What are the expected changes in phytoplankton and periphyton in both the Site C reservoir and downstream areas? How do the answers to the above question vary under different assumptions about flow, nutrients, and suspended sediment?	CE-QUAL-W2 simulation model applied to Dinosaur, Site C reservoir and Peace River (links 1a, 2, 4)
3	What covariates best explain observed variations in benthic production within the Peace River? What are the effects of water level fluctuations on benthos? What are the expected changes in benthic production downstream of Site C, relative to current conditions?	Multiple regression equations developed from 2010 and 2011 field data, and then applied to conditions following construction and operation of the Site C Dam (links 3a, 3b, 5)
	How would overall secondary production (zooplankton plus benthos) in Site C compare to current secondary production in the reaches of the Peace River and tributaries that would be flooded?	Estimates based on 2010 and 2011 field measurements of production and GIS analyses of areas (link 3b)
4 and 5	What are the expected changes in the biomass and production of different species groups and the structure of the food web following construction and operation of the Site C Dam? How do the answers to the above question change under a range of assumptions about the sensitivity of fish species to dam construction and operation, as well as assumptions about the factors affecting primary production scenarios?	Application of the Ecopath model based on field data, literature, CE-QUAL-W2 simulations (Section 3), habitat changes (Section 4), empirical models (Section 5) (all links considered either directly or indirectly)

NOTE:

[a] The linkages in square brackets in the second column refer to the pathways in Figure 12.2 (modified from Volume 2 Appendix P Aquatic Productivity Reports: Part 3) Future Conditions in the Peace River Table 1.1)

The following is a summary of the evaluation presented in Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River.

Question 1 – Habitat Area

Existing fluvial habitat types (i.e., riffles, pools, runs, side channels) used by fish would be lost through the inundation of the Peace River mainstem and lower tributary sections of the Site C reservoir, but new lacustrine habitat types (i.e., littoral and limnetic zones) would be created within the reservoir. Overall, the creation of the Site C reservoir would result in the loss of 28.0 km^2 of mainstem lotic area (predominantly deep run/glide habitat) and 1.63 km^2 of tributary lotic area (a mix of pool, riffles, runs, and other habitat types). The lotic areas would be replaced by 9.42 km^2 of littoral area (defined as < 6 m) and 83.57 km^2 of limnetic area. It is expected that littoral habitats within the inundated area would provide new spawning and juvenile rearing habitats, both for some riverine (but adaptable) fish species found in the Peace River, as well as for lake-adapted species that would become more common in the reservoir. The increased limnetic zone is expected to provide extensive deeper water habitat for use by foraging juveniles and adults of different fish species. The total area would increase by 3.3-fold as the river is converted to a reservoir, which should be recognized in the interpretation of before-after comparisons of total biomass (i.e., no change in total biomass is consistent with a one-third reduction in biomass per unit area).

Question 2 – Primary Production

Phytoplankton and periphyton biomasses were predicted for the Site C reservoir and Peace River under two time snapshots (i.e., early and longer-term stages of the reservoir operation). Phytoplankton and periphyton biomasses in both aquatic systems were predicted to be similar during the early and longer-term stages of operations, since nutrient contributions from shoreline erosion occurring in the reservoir do not differ substantially between the two stages.

In the reservoir, projected changes reflect a shift in primary production from periphyton to phytoplankton as the river becomes a reservoir. Phytoplankton biomass densities ($t•km^{-2}$ or $g•m^{-2}$) are expected to increase about 30X relative to current biomass densities, in both the early and long term. Average periphyton densities in the reservoir are expected to decrease to 5% of their current value in both the early and long term, as only the littoral zone of the Site C reservoir (10.1% of the area) would grow periphyton, and periphyton production per unit area is expected to be less than in the Peace River. When future conditions are compared to current conditions, it is expected that there would be about a 2.7-fold increase in algal biomass (tonnes of periphyton plus phytoplankton) and a 1.8-fold increase in primary production (t/year of primary production).

Question 3 – Secondary Production

Total secondary production in the Site C reservoir (i.e., littoral and profundal benthic production plus pelagic zooplankton production) is expected to be very similar to the total current rates of benthic production in both the mainstem Peace River and the area of tributaries that would be flooded when the reservoir is created. Overall reservoir secondary production is estimated to be 89% to 121% of current Peace River secondary production. The form of secondary production would change from being 100% benthic in the current system to a mix of benthic (74% to 81%) and zooplankton production (19% to 26%) in the reservoir.

Questions 4 and 5 – Fish Production and Harvest

Ecopath models were developed for the area upstream of Site C, under current conditions and two periods following completion of the Project (early term and longer term). Input assumptions to Ecopath blended five factors: information on fish and lower trophic level organisms; influence of species-specific habitat preferences and life history strategies; CE-QUAL-W2 estimates of changes in phytoplankton and periphyton; the results of single species passage models; and empirical models of expected changes in benthic biomass. Ecopath was used to determine if the input assumptions were ecologically feasible, given the diet preferences and productivities of each ecosystem component, and adjustments in biomass or diet were made where necessary to ensure mass balance, taking into account prey preferences. Sensitivity analyses were completed across a range of assumptions for both the reservoir fish community assemblage (maximum, most likely, minimum) and levels of primary production (low bookend, most likely, high bookend). The analysis used the extreme bookends of the 27 scenarios run in CE-QUAL-W2 to bracket the full range of productivity. The key findings (summarized for each group of ecosystem components, based on the most likely CE QUAL-W2 scenario) are as follows:

Results for the most likely fish community scenario indicate about a ~~3~~1.8-fold increase in total biomass of harvestable fish in the Site C reservoir relative to what currently exists in the Peace River, though with a very different species composition. Group 1 fish (burbot, lake trout, rainbow trout, walleye, northern pike) are expected to increase in their overall biomass, as increases in burbot, lake trout, northern pike, and rainbow trout offset decreases in walleye. The total biomass of group 2 passage-sensitive species (Arctic grayling, mountain whitefish, bull trout) is expected to decline, due to declines in the biomass of mountain whitefish and Arctic grayling. Bull trout are expected to increase in the reservoir over the longer term under two of the three fish community scenarios (maximum, most likely), and decline under the minimum scenario. The changes in overall biomass are driven most strongly by a substantial increase in group 3 planktivorous fish species (kokanee and lake whitefish) over both the near and long term.

The following changes are expected to other ecosystem components in the Site C reservoir relative to current conditions in the Peace River: a ~~100~~30-fold increase in phytoplankton biomass, an ~~40~~80% decrease in periphyton biomass, a ~~2.3-fold~~ 30% ~~increase~~ decrease in benthic biomass, and a 4 to 10-fold increase in the biomass of small fish, suckers, and northern pikeminnow (taken as a group, though, northern pikeminnow is expected to decrease).

The above outcomes are insensitive to the low and high bookend CE-QUAL-W2 scenarios, as there is little variation in phytoplankton production.

Conclusion

Based on the outcome of the aquatic productivity evaluation and examination of other factors that include availability of habitats needed to support reservoir fish populations, and recruitment from sources outside of the reservoir, the following is a prediction of the fish community as it would change through time as the reservoir transitions following operation of the facility:

Short Term (1 to 10 Years)

Over the short term, the Site C reservoir fish community would reflect a fish community undergoing rapid transition. Existing fish populations that are specifically adapted to river habitats would be affected. These include Arctic grayling and mountain whitefish, the sculpin species, and possibly bull trout. Bull trout are included in this list because the current adfluvial species is closely tied to mountain whitefish abundance, which is a primary food source, and at least a portion of the bull trout population would migrate downstream past the Site C Dam. These three riverine species abundance would be reduced in the lower section of the reservoir, but would still likely be found in the upper reservoir and tributaries where riverine characteristics would remain. Tributary resident populations would persist in the Halfway River.

Species that are able to rapidly exploit new habitats, that are tolerant of perturbations to the aquatic environment (e.g., elevated suspended sediment concentrations and sedimentation of clean bed materials), and that presently utilize tributary habitats would quickly dominate the system. These would include the sucker species largescale sucker, longnose sucker, and white sucker, and the minnow species lake chub, northern pikeminnow, redside shiner, and spottail shiner. If northern pikeminnow is able to fully exploit the new the environment, then this species may become the top pelagic predator.

In the existing Peace River, burbot are rarely encountered upstream of the dam and generating station construction zone, but it is the dominant predator in the Peace River in the lower portion of the LAA and farther downstream in Alberta. Formation of the Site C reservoir would provide habitat for burbot that recruit from the Halfway River and the Moberly River and that would be able to exploit newly formed reservoir habitat and abundant food resources originating from the tributaries. Depending on the reproductive capacity of the reservoir burbot population, it may become the top benthic predator in the reservoir.

Five species that recruit from upstream sources would enter the newly formed reservoir, including kokanee, lake whitefish, lake trout, rainbow trout, and peamouth. Rainbow trout and peamouth would be able to utilize tributary habitats for spawning and rearing and they have flexible food requirements; therefore, these populations should successfully colonize over the short term. This would be particularly true for peamouth, which has flexible food requirements being able to exploit both pelagic (zooplankton) and benthic food sources.

The abundance of kokanee and lake trout (a primary predator of kokanee) over the short term would depend on the ability of kokanee to exploit pelagic food resources (zooplankton) in the reservoir, annual recruitment from upstream sources, and entrainment rates through the Site C Dam. Zooplankton biomass production would depend on water quality (i.e., suspended sediment concentrations), primary productivity, zooplankton residence time, competition from other species, and entrainment rates through the Site C Dam. There would be limited or no kokanee spawning habitats in the reservoir and limited accessible spawning habitats in tributaries (i.e., kokanee spawning habitats are available in the Halfway River system starting at least 100 km upstream of the Site C reservoir).

<u>Medium Term (10 to 30 Years)</u>

Over the medium term, water quality should improve due to reduction of sediment inputs from valley wall erosion. Fish populations that were not able to utilize Site C reservoir habitats or that were not maintained by upstream recruitment sources would have been affected over the short term. Species belonging to the sucker and minnows group would still dominate the system. Species that have a lower reproductive capacity, but that can effectively exploit reservoir habitats may increase in importance during the medium term.

Lake whitefish would recruit from upstream sources. This species is able to exploit benthic and pelagic food resources; therefore, it would compete directly with kokanee. If there is sufficient recruitment from upstream sources, lake whitefish could become established and eventually exploit spawning habitats in the Site C reservoir and in tributaries such as the Moberly River and Halfway River. If the fish community in Williston Reservoir, which was dominated by lake whitefish (Volume 2 Appendix O Fish and Fish Habitat Technical Data Report) is assumed to be representative of the Site C reservoir fish community over the medium term, lake whitefish would be a dominant pelagic species. Lake whitefish would be a food source for bull trout and lake trout.

Northern pike is a piscivorous species that would be present in the Site C reservoir at the time of inundation. Northern pike currently recruit from several Peace River tributaries and from side channel areas of the Peace River. The abundance of northern pike in the reservoir would be largely dependent on recruitment from important spawning and early rearing habitats in the form of shallow water areas dominated by submergent or emergent aquatic vegetation. Shallow water areas are limited in surface area in the Site C reservoir. However, stable water elevations and an abundance of sand bed materials originating from valley wall erosion could promote development of aquatic vegetation in these areas, as has occurred in Dinosaur Reservoir. Northern pike would become an important top predator in these areas of the Site C reservoir over the medium term; however, its overall importance to the reservoir fish community would depend on availability of habitats.

It is uncertain whether walleye would reside in the reservoir. Walleye regularly occur in the Site C reservoir section of the Peace River. Walleye would be upstream of the dam and generating station construction zone at the time of scheduled closure of the Peace River in Year 4 of construction. The resulting construction headpond would allow walleye to remain upstream until creation of the Site C reservoir. If sufficient numbers of walleye are present at the time of reservoir formation, a population could become established. Walleye is a species that can exploit reservoir habitats, and there would be abundant food resources. In addition, historical spawning and rearing habitats traditionally utilized by the Peace River walleye population (i.e., Halfway River system) would be available.

Over the medium term, kokanee could become the dominant pelagic species in the reservoir. This would be based largely on the ability to out-compete lake whitefish for pelagic food resources, recruitment levels from upstream sources, and levels of secondary productivity (zooplankton biomass). If kokanee dominate, then lake trout and possible bull trout abundance in the reservoir would increase over the medium term.

<u>Long-term (> 30 Years)</u>

At the end of 30 years, fish species populations able to adapt to a reservoir environment and out-compete other species would be well established and reservoir conditions would have stabilized. This species assemblage would form the basis of the long-term fish community. Sucker populations would be the dominant group that exploits benthic production. Lake whitefish or kokanee would be the dominant group that exploits pelagic production. The top predators in the reservoir would include northern pikeminnow, burbot, and northern pike. Depending on kokanee biomass, lake trout or bull trout would be top predators if there was sufficient recruitment to sustain the population. Rainbow trout would also be present, but it would not become a dominant species in the Site C reservoir. It is uncertain whether a self-sustaining population of walleye will become established in the reservoir.

12.4.2.2 Downstream Habitat Changes

In contrast to the changes from creation of the reservoir, the downstream changes are incremental. Peace River surface water regime immediately downstream of the Site C Dam would be similar to conditions currently experienced immediately downstream of the Peace Canyon Dam (i.e., a regulated flow regime). Farther downstream, the effects of Site C Dam operations would be dampened by tributary inputs and flow attenuation.

Operations of the dam and generating station would interact with fish habitat downstream of the Site C Dam based on the following parameters:

Surface water regime

Sediment transport regime

Thermal and ice regime

Aquatic productivity

Surface Water Regime

As described in Volume 2 Appendix D Surface Water Regime Technical Memos, changes in the surface water regime result from the following factors:

A change in the location of flow regulation

A change in the generating capacity (or range of generating capacity) at the point of flow regulation

The capture of tributary inflows between Peace Canyon dam and the Site C Dam

In general, Site C discharges would follow the same general pattern as the provincial demand for electricity; higher during the winter and lower during the summer on a seasonal basis, higher during weekdays and lower during weekends on a weekly basis, and higher during daylight hours and lower during late night hours on a daily basis (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

In general, the limited amount of active storage (storage within the normal operating range) limits the degree to which the Project could change the downstream flow regime. The following discusses factors that would affect fish habitats and fish utilization of fish habitats downstream of Site C based on the surface water regime.

The timing of releases from Site C would be expected to follow the daily load pattern and would be similar to the timing of releases from Peace Canyon Dam today. Due to the travel time required for water to flow between the Peace Canyon outlet and the location of the proposed Site C tailrace, operational changes at points downstream of Site C would occur approximately 10 to 12 hours sooner with Site C. For example, if releases were increased from Peace Canyon at 6:00 a.m., the flow increase would be noticeable at the location of the proposed Site C Dam between 4:00 p.m. and 6:00 p.m. Under the existing conditions at the Site C Dam site, discharge is highest during hours of darkness (6:00 p.m. to 6:00 a.m.) and lowest during hours of daylight (6:00 a.m. to 6:00 p.m.). The reverse would occur with Site C operation.

The operational releases of the Peace Canyon Dam are bounded by the minimum flow requirement of 283 m^3/s and the maximum licensed discharge of 1,982 m^3/s. The proposed minimum flow for the Project is 390 m^3/s and the proposed maximum turbine discharge capacity is about 2,520 m^3/s. The range of operational releases is 1,699 m^3/s under existing conditions and would be approximately 2,130 m^3/s with the Project. Although the range of operational releases immediately downstream of the Site C Dam would be higher with the Project, the actual range of flows immediately downstream would be lower with the Project, due to tributary inputs between Peace Canyon Dam and the Site C Dam site. There would be no change in the range of flows experienced downstream of the Pine River confluence.

Under existing conditions, the greatest daily range in flows is experienced immediately downstream of the point of regulation (i.e., at the Peace Canyon Dam outlet). This daily range is reduced in the downstream direction due to natural attenuation and tributary inflows. Site C would shift the existing point of regulation by a distance of 85 km downstream and hence increase the daily range of flows at that location and for some distance downstream. As shown in Section 11.4.5.2 in Volume 2 Section 11 Environmental Background, the increase in the daily range of water levels due to the Project would be on the order of 0.5 m at the location of the Site C tailrace and reducing to approximately 0.3 m near the Alces River confluence.

The influence of the Project on the average rate of change of water levels from one hour to the next was analyzed as described in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D). Duration curves are provided in that appendix that indicate the percentage of time a particular rate of change of water level (whether increasing or decreasing) would be experienced with and without the Project, based on 10 years of simulated flows. At the Site C tailrace, results suggest that water level decreases of 0.25 m/hour or more would only occur 9% of the time with the Project, compared to never without the Project. At Taylor, the modelling suggests that water level decreases of 0.25 m/hour or more would occur only 3% of the time with the Project, compared to never without the Project.

In addition, the two-dimensional model described in Volume 2 Appendix D Surface Water Regime Technical Memos, Part 3 Downstream Flow Modelling (2D) was used to investigate the influence of the Project on the wetting and drying of side channels downstream. A worst-case scenario was simulated both with and without the Project where flows were increased from minimum to maximum over a short period of time. The rates of change in flows are presented in Table 12.14.

Table 12.14 Flow Comparisons at Site C Dam Tailrace During High Operations Period

Location	Rate of Change (m^3/15 min)	
	Increasing Flow	Decreasing Flow
Peace Canyon Dam tailrace	26.7	-51.7
Existing Site C Dam location	7.4	-3.2
Site C Dam tailrace	46.7	-54.0
Percentage difference from Peace Canyon Dam tailrace	75.0	4.5

The Site C Dam tailrace would have a predicted maximum rate of change for increasing flows of 46.7 m^3/15 min and a predicted maximum rate of change for decreasing flows of -54.0 m^3/15 min. These values are higher than maximum rates of change under existing conditions at the Site C Dam site (7.4 m^3/15 min for increasing and -3.2 m^3/15 min for decreasing). The predicted maximum rates of change for the Site C Dam tailrace would be higher than predicted maximum rates of change that presently occur at the Peace Canyon Dam tailrace (i.e., 75% higher for increasing and 4.5% higher for decreasing) based on this worst-case scenario.

Changes to the flow regime would affect the temporal and spatial availability of Peace River fish habitats. The effects would be highest in the 15.9 km section of Peace River between the Site C Dam and the Pine River confluence because there are no large tributary inputs that would attenuate the flows. During periods of low tributary flows (i.e., late summer, fall and winter) the changes would extend farther downstream. Under present conditions, habitat availability in the vicinity of the Site C Dam is greatest during hours of darkness when fish species require feeding habitats. Availability of habitats located in shallow water areas (i.e., main channel margins and side channels) would be most affected by flow changes. A portion of these habitats would not be available during hours of darkness, depending on Site C operations.

The change in range of daily flow caused by Site C operation would potentially alter habitat availability. Habitat availability was examined by comparing the wetted surface area at minimum and maximum operational flows under existing Peace Canyon Dam and predicted Site C operations (BC Hydro 2012). Wetted surface area for the Peace River from the Site C Dam site to the Pine River confluence was calculated using hydrodynamic modelling assuming steady state flow and 10 percentile tributary discharges for each scenario (Table 12.15).

Table 12.15 Comparison of Peace River Wetted Surface Areas from the Site C Dam to the Pine River Confluence Under Existing Peace Canyon Dam and Site C Dam Operations.

Scenario	Synthetic Discharge (m^3/s)	Wetted Surface Area (ha)	Difference	
			Hectares	Percent
Minimum Peace Canyon Dam	294	547.5	+29.7	5.4
Minimum Site C Dam	390	577.2		
Maximum Peace Canyon Dam	1,993	837.0	+115.0	13.7
Maximum Site C Dam	2,540	952.0		

With 10 percentile tributary inputs, the increase in the minimum flow from 294 m^3/s (existing) to 390 m^3/s (Site C operation) would improve habitat availability during low flow conditions. The increase in wetted surface area would be 29.7 ha or a 5.4% increase compared to existing conditions. There would also be an increase in wetted surface area at the upper range of flow: 1,993 m^3/s (existing) versus 2,540 m^3/s (Site C operation). The increase in wetted surface area would be 115.0 ha or a 13.7% increase compared to existing conditions. However, this potential positive effect could be effected by daily flow regulation (i.e., additional habitat surface would be subjected to dewatering).

The rate at which habitats become dewatered due to daily flow regulation would diminish downstream of the Site C Dam site during operations. Habitat types most affected by dewatering would be shallow-water rearing habitats used by large-fish species and shallow-water habitats used by small-fish species.

<u>Sediment Transport Regime</u>

The following changes to suspended sediments are expected downstream of the Site C Dam with respect to baseline conditions (Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report):

Suspended sediment concentrations are expected to decrease in the closest reach between the Site C Dam and the Pine River confluence during the spring freshet period

Timing of elevated freshet concentrations is expected to become longer due to reservoir attenuation (i.e., the concentrations in the outflows are not as 'spiky' as in the baseline)

Suspended sediment composition downstream of the Site C Dam would shift from dominant silt to dominant clay, with no sand in suspension

Suspended sediment concentrations consisting mostly of clay are expected to increase in the reservoir outflows in the fall/winter period due to increased shoreline sediment inputs into the reservoir

Lateral variability in turbidity that is present under current conditions would be replaced by full mixing in the reach from the dam to the Pine River confluence

Changes due to reservoir operations are expected to decrease with time as the shoreline sediment recruitment decreases and new equilibrium is reached between reservoir water levels and shorelines. Changes would become less apparent as a result of inputs from each tributary confluence downstream, where more water and sediment is contributed to the Peace River. The mean annual sediment transport load from the Project would be reduced by 54% due to the settling in the reservoir. Reductions would decrease to 21% at the Pine River confluence, 8% at the Alces River confluence, and 2% at the Smoky River confluence.

Expected median daily suspended sediment concentration immediately downstream of the Site C Dam site (baseline and operations phase) is shown in Table 12.16.

Table 12.16 Expected Median Daily Suspended Sediment Concentration Immediately Downstream of the Site C Dam Site (Baseline and Operations Phase)

Season	Baseline (mg/l)	Operations (mg/l)
Winter (January–March)	0.1	0.6
Spring (April–June)	39.6	14.3
Summer (July–September)	3.2	11.6
Autumn (October–December)	0.1	6.9

The following changes to bedload sediments would occur for the Peace River downstream of the Site C Dam with respect to the baseline conditions:

The Project would intercept the Moberly River bedload material that has been accumulating in the Peace River channel below the confluence since the onset of regulation in 1967

Elsewhere, the Project is not expected to result in any changes in channel erosion or deposition patterns, which are either natural (i.e., valley wall erosion and landslides along the river), or are driven by the ongoing response of the river channel to upstream flow regulation that started in 1967 (i.e., aggradation below tributary confluences, local bank erosion opposite from tributary confluences, and vegetative encroachment onto gravel bars and into secondary channels)

The sediment transport regime predicted for the operation of the Project would cause higher suspended sediment concentrations during the fall and winter periods and lower concentrations during the spring and freshet than presently occurs. Higher suspended sediment concentrations would consist of mainly clay and a small amount of silts, which are not expected to settle out prior to the Pine River confluence. Increased sediments would potentially affect clear water fish species including Arctic grayling, bull trout, mountain whitefish, and rainbow trout occupying the river downstream of the dam.

<u>Thermal and Ice Regime</u>

The thermal and ice regime of the Peace River would change due to the Project (Section 11.7 Thermal and Ice Regime in Volume 2 Section 11 Environmental Background). The following changes are expected to occur with respect to the baseline conditions:

Water temperatures in the Peace River at the outlet of the Site C Dam are expected to be warmer than existing conditions between July and January, with differences ranging between 0.3°C (July) and 1.5°C (October)

Water temperatures in the Peace River just downstream of the Site C Dam are expected to be between 0.4°C and 0.9°C cooler from March to June

In all months, a smaller daily range than the existing temperature regime is expected

Water temperatures 62 km downstream of the Site C Dam (i.e., the Alces River confluence) are expected to range from 0.9°C cooler in May to 0.7°C warmer in November

Operation of the Project would alter the Peace River water temperature regime at least to the Alces River, but the changes are within the annual range of water temperatures of fish habitats under existing conditions.

The ice regime of the Peace River would change due to the Project. The following changes would occur with respect to the baseline conditions:

The maximum extent of the ice front would move farther downstream compared to existing conditions

The change may improve existing wintering fish habitats. Wintering habitats used by large fish in the Peace River can be characterized by deep water, low velocity areas that provide protection from solid ice (surface ice and ice anchored to the channel bed) and frazil ice (Hildebrand 1990; Pattenden 1993; Power et al. 1993; Brown et al. 1994). Smaller fish, such as minnows and sculpins, also seek protection within interstitial spaces provided by rock substrates in areas that are not subjected to freezing or damage from ice (Cunjak and Power 1986). In general, wintering fish are closely associated with river edges and protected areas that provide refugia from high flows, as has been demonstrated by Whalen and Parrish (1999). Based on the characteristics described above, wintering habitats presently available to large and small fish are affected by the ice front that forms as far upstream as Taylor under existing conditions.

Operation of the Project would move the ice front downstream on average approximately 40 km, potentially resulting in an increase in fish wintering habitat and overwintering survival rate.

Aquatic productivity

A quantitative ecosystem approach used to analyze changes to aquatic productivity (Volume 2 Appendix P Aquatic Productivity Reports, Part 3 Future Conditions in the Peace River) concluded that the total biomass of fish would be expected to increase by 1.2-fold to 1.4-fold downstream of the Site C Dam. Details are as follows:

Total biomass of fish in the three focal groups of fish is expected to result in a net increase of 1.2-fold to 1.4-fold. This net increase in total biomass is accounted for by a 45% to 80% decrease in the biomass of group 1 fish (burbot, lake trout, rainbow trout, walleye, northern pike), counteracted by a 1.8-fold to 1.9-fold increase in the biomass of group 2 fish (Arctic grayling, mountain whitefish, bull trout). The increase in group 2 fish is due primarily to a doubling of mountain whitefish, which are assumed to benefit from increased water clarity (decrease in sediment inputs) downstream of the Site C Dam. Bull trout and Arctic grayling are expected to decline. Group 3 fish (kokanee and lake whitefish) contribute a negligible amount of biomass to the river.

The following changes are expected to other ecosystem components downstream of the Site C Dam relative to current conditions in the Peace River: a 3.7-fold increase in periphyton; a 3-fold decrease in benthic biomass, and a 50% decrease in the biomass of small fish, suckers, and northern pikeminnow (taken as a group), driven by a 50% decrease in suckers. Despite the reduction in benthic biomass, there was enough benthos to support all the fish species in the downstream model.

The above outcomes were sensitive to the low bookend CE-QUAL-W2 scenario, where a halving of periphyton biomass (relative to current conditions) is assumed to propagate up the food chain, resulting in a 40 to 50% decrease in total fish biomass relative to current conditions, driven by decreases in both fish groups 1 and 2

Conclusion

Based on the outcome of the aquatic productivity evaluation and examination of other factors that include changes in fish habitats needed to support downstream fish populations, and recruitment sources, the following is a prediction of the fish community downstream of the facility.

Species that presently reside in the Peace River downstream of the Site C Dam site would initially be present in the Peace River during operations. The relative abundance and biomass of a species within the downstream Peace River fish community would change. The fish community would reflect the ecological changes in fish habitat downstream of the dam. Ecological conditions considered for predicting the future fish community include the following:

Physical environment (i.e., flow regime, sediment regime, water temperature, and ice regime)

Aquatic productivity and food resources

Availability of habitats needed to support the fish population

Recruitment from sources (i.e., upstream, downstream)

Competition for food and space

The Peace River downstream of the Site C Dam would be characterized by a regulated flow regime similar to what presently occurs downstream of the Peace Canyon Dam. The fish community that utilizes those habitats of the Peace River downstream of the Site C Dam would be similar to what presently occurs downstream of the Peace Canyon Dam.

Recruitment sources of the Peace River fish community downstream of the Peace Canyon Dam include upstream reservoirs, tributaries, and the Peace River. The primary tributary recruitment source for Arctic grayling is the Moberly River, and for bull trout the primary tributary recruitment source is the Halfway River. Recruitment sources of the Peace River fish community downstream of Site C would include upstream reservoirs (Site C reservoir), tributaries, and the Peace River. The Pine River would be the only potential natural downstream tributary recruitment source for Arctic grayling, bull trout, and mountain whitefish (see Section 12.3).

Operations of the Project would result in ecological conditions that would allow Arctic grayling, bull trout, mountain whitefish, and rainbow trout populations to persist and potentially extend their distribution further downstream in Alberta. Other species such as kokanee and lake trout would establish distributions immediately downstream of the Site C Dam, similar to the pattern that presently exists downstream of the Peace Canyon Dam. Most of these populations would be maintained by recruitment from the Site C reservoir. There would be the potential for these populations to access spawning and rearing habitats in the Pine River system in order to generate natural recruitment; however, this outcome cannot be predicted with certainty. Some limited natural recruitment of mountain whitefish would occur directly from the Peace River.

Burbot, northern pike, walleye, and goldeye populations would remain downstream of the Pine River due to the regulated flow regime, cooler summer water temperatures, and the reduced sediment load during freshet. Burbot, northern pike, and walleye may not reside in the Peace River between the Site C Dam and the Pine River confluence, but still might forage upstream of the Pine when conditions are favorable. Goldeye would migrate as far upstream as the Beatton River. Similarly, the regulated flow regime caused by operations of the Project might limit sucker and minnow populations to at least downstream of the Pine River and as far downstream as the Beatton River.

The extent of the change on all fish populations downstream of the Pine River would be based primarily on the degree to which Pine River and other tributary inputs (i.e., Beatton River, Kiskatinaw River, Clear River, and Pouce Coupe River) would attenuate the flow and thermal and ice regime as a result of the operations of the Project.

12.4.3 Effects Assessment – Construction – Fish Health and Survival

Fish health and survival would potentially be changed by construction activities as follows:

Sediments inputs during in-stream activities, surface runoff from disturbed areas including transportation routes and surplus excavated material storage sites, and bank erosion caused by backwatering of river during channelization, diversion, and reservoir filling

Stranding of fish due to water level fluctuations

Fish entrainment through the diversion tunnels and spillways

Increased total dissolved gases concentrations during spillway commissioning

Each of these potential effects are described in more detail below.

12.4.3.1 Changes in Fish Health and Survival Due to Sediment Inputs

Sediment inputs may result in potential effects on fish health and survival during construction of the dam and generating station, formation of the construction headpond and reservoir filling, and from realignment of Highway 29.

Dam and Generating Station Construction Zone

Several activities associated with the dam and generating station construction zone have the potential to introduce sediments into the aquatic environment. Major sources include the following:

Surface runoff from disturbed locations

Transport of excavated materials across and adjacent to watercourses to storage areas (includes dust and slurry)

Drainage from excavated materials storage areas

In-stream works including:

- Excavation of the riverbed
- Placement of materials in the watercourse
- Pile driving cofferdam sheets and bridge piers
- Activation of the diversion tunnels
- Removal of in-stream materials (e.g., Stage 1 cofferdams)

Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report estimates sediment load resulting from construction activities at the dam and generating station construction zone. The list of construction activities, the type and amount of materials, and the timing are presented in Table 5.1 of that appendix. With mitigation, the simulated total suspended sediment (TSS) increases could be reduced to below 25 mg/l above background concentrations for the majority of dam construction activities listed in Table 5.1. Sediment input from construction activities examined that cannot be mitigated include flushing the diversion tunnels, tailrace, and discharge channels.

Table 12.17 summarizes background TSS concentrations of the Peace River (Table 5.2 of Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report). The 5%, 50% and 95% exceedance values for daily concentrations in each quarter are provided in the table below.

Table 12.17 Background Total Suspended Solids Concentrations in the Peace River

Quarter	Baseline Suspended Sediment Concentration (mg/L)		
	5%	50%	95%
1	0.0	0.1	1.6
2	1.1	40	383
3	0.3	3.2	210
4	1.0	0.1	1.4

The suspended sediment concentrations of the Peace River show a strong seasonal pattern. Highest concentrations occur in spring (40 mg/L at 50% exceedance during Quarter 2), whereas much lower concentrations occur in summer, fall and winter (≤ 3.2 mg/L at 50% exceedance).

Elevated suspended sediment concentrations are known to be harmful to fish (Newcombe 1994; Anderson et al. 1995). These effects include decreased health and reduced viability of eggs and larvae, irritation of gills, and smothering of food production areas, making habitats unsuitable for fish.

The potential for these concentrations to impair fish health and survival can be quantified using an empirical model developed by Newcombe and Jensen (1996). The model, which incorporates sediment concentration and duration of exposure, provides ratings of ill effects for fish life stages (e.g., adults or larvae). The calculated severity of ill effects (SEV) index is based on a 15-point scale that is used to categorize fish response as follows:

Nil effect (0)

Behavioural effect (1 to 3)

Sublethal effect (4 to 8)

Lethal effect (9 to 14)

The application of the model is limited to coldwater salmonids, such as Arctic grayling, bull trout, mountain whitefish, and rainbow trout. It is not directly applicable to coolwater species because they are more tolerant of sediment effects.

Using predicted TSS concentrations at 50% exceedance flows, severity of ill effects ratings indicate that adult and juvenile salmonid fish would be subjected to lethal concentrations of sediments for 11 of the 18 activities for which TSS concentrations were predicted (Table 12.18). The remaining seven activities would cause sublethal TSS concentrations for adult and juvenile salmonid fish. Severity of ill effects ratings indicate that salmonid fish eggs and fry would be subjected to lethal concentrations of sediments for 16 of the 18 activities for which TSS concentrations were predicted (Table 12.18). The remaining two activities would cause sublethal TSS concentrations.

Table 12.18 Severity of Ill Effects Based on Predicted Suspended Sediments [a] Caused by Construction Activities of the Dam and Generation Station

Activity	Predicted TSS (mg/L) at 50% Flow Exceedance	Duration (days)	Severity of Ill Effects Rating by Fish Life Stage	
			Eggs and Larvae	Juveniles and Adults
North Bank Haul Road	26.1	90	**13.2** [b]	**10.5**
Inlet Diversion Cofferdam	28.8	30	**12.3**	**10.0**
Outlet Diversion Cofferdam	28.8	90	**13.5**	**10.7**
L6 Disposal Dyke	20.6	90	**13.1**	**10.4**
L6 Disposal Dyke	19.5	90	**13.1**	**10.4**
North Bank Cofferdam	26.1	60	**12.7**	**10.2**
Excavate diversion inlet channel	0.5	30	**10.8**	8.6
Excavation berms	20.6	30	**11.9**	**9.6**
Place riprap in excavated channel	0.8	30	**10.9**	8.7
Excavate diversion outlet channel	0.5	60	**11.5**	**9.1**
Excavation berms	26.1	60	**12.7**	**10.2**
Place riprap in excavated channel	0.8	60	**11.7**	**9.2**
Remove diversion inlet cofferdam	0.1	30	**10.2**	8.1
Remove diversion outlet cofferdam	0.1	30	**10.2**	8.1
Flush diversion tunnel	420.0	0	5.6	5.8
In-stream excavation of tailrace	0.5	30	**11.4**	**9.1**
Place riprap in excavated areas	0.6	30	**11.4**	**9.1**
Flush tailrace and discharge channel	35.0	0	4.9	5.1

NOTE:

[a] Source: Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report

[b] Bold indicates values that represent lethal effects on fish life stage

It is assumed that the effect of elevated TSS concentrations caused by activities in the dam and generating station construction zone would extend to the Pine River confluence, or a distance of 15.9 km. This assumption is based on no major tributary inputs in the river section between the construction area and the Pine River that would dilute TSS concentrations. Based on the Site C Dam site construction schedule, the TSS effects would occur continuously or near continuously in Year 1 and continuously for four years from Years 4 to 7.

Adults and juveniles of salmonid populations that are present between the Site C Dam site and the Pine River confluence are Arctic grayling, bull trout, mountain whitefish, and rainbow trout. Mountain whitefish eggs and fry are also abundant and widely distributed in this river section.

Construction Headpond and Reservoir Filling

A construction headpond would form upstream of the dam and generation station construction zone during the channelization (approximately 36 months) and diversion (approximately 39 months) periods (subsequently referred to as construction headpond). Confinement of the channel would result in an increase in upstream water levels relative to current conditions due to the reduced ability to pass Peace River flows (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

During the channelization period, water levels would be up to 1 m higher than existing conditions. The maximum upstream extent of the construction headpond during channelization would be approximately 10 km (Figure 11.4.13 in Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

During the diversion period, water levels would be up to 8.6 m higher (in the 90^{th} percentile water levels) than existing conditions. The upstream extent of the construction headpond during the diversion period would be 27 km (Figure 11.4.13 in Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

The construction headpond water levels would vary (see Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background), which could result in bank instability and bank erosion, potentially resulting in sediment inputs. Shoreline erosion is expected to occur in an episodic manner, primarily during windstorm events when the headpond level is high (Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report). It is expected that shoreline erosion events of one-day duration would generate incremental increases in suspended sediment concentration on the order of 1 to 20 mg/L, as observed in fully mixed river flow downstream of the tunnel outlets. These events would be most common in the autumn and winter (averaging 12 and 15 daily events per season, per year), and least common in the spring and summer (averaging seven daily events per season, per year), due to seasonal differences in wind conditions and wave energy in the headpond.

Reservoir filling would occur at the end of the construction phase and would require approximately three months to complete. Water levels would be increased in a staged fashion to allow commissioning of the facility. Reservoir filling would increase water levels, resulting in bank instability and bank erosion, potentially resulting in sediment inputs.

Highway 29 Realignment and Hudson's Hope Shoreline Protection

Highway 29 realignment includes construction of new bridge crossings on four fish-bearing watercourses: Cache Creek, Halfway River, Farrell Creek, and Lynx Creek. Farrell Creek, Halfway River, Cache Creek, and Lynx Creek support primarily sucker and minnow species; however, sport fish species can be present. Life stages most affected would be adults, eggs, and fry during the spring period. During the summer, fall, and winter period, adults would be most affected.

The majority of construction activities would occur away from the current watercourses. The bridges would be clear span structures, with only the Halfway River bridge having piers in the current active river channel. In-stream activities such as pier placement and abutment work could generate sediment inputs. Depending on the crossing, bridge construction would require from two to two-and-a-half years to complete each highway section (see Table 4.15 in Volume 1 Section 4 Project Description).

The Hudson's Hope shoreline protection base case design consists of a 10 m high, 295,000 m³ shore protection berm 1,650 m long immediately below the residential areas of Hudson's Hope. The berm would be constructed of granular fill and protected with riprap. A majority of the construction works would be conducted adjacent to the Peace River, including river bank and in-stream works that could generate sediment inputs.

The Peace River in the vicinity of the construction activities provides several types of high-quality fish habitats. These include high-quality rearing habitats for bull trout and rainbow trout, and high-quality feeding habitats for bull trout, mountain whitefish, and rainbow trout. Lake trout also use this area for rearing and feeding.

12.4.3.2 Stranding of Fish

Flow changes during the construction of the Project may result in increased risk of stranding for fish species residing in the Peace River. A description of flow changes expected during construction (channelization and diversion) stage of the Project is provided in Section 11.4.3 Surface Water Conditions during Construction in Volume 2 Section 11 Environmental Background.

A construction headpond would form upstream of the dam and generation station construction zone during the channelization and diversion periods (subsequently referred to as construction headpond). Confinement of the channel would result in an increase in upstream water levels relative to current conditions, due to the reduced ability to pass Peace River flows (see Section 12.3.3.1 for description). The large surface area outside of the active river channel potentially subjected to frequent dewatering (approximately 387 ha during the channelization period and approximately 1,630 ha during the diversion period) and the large range in fluctuation (1.0 m during the channelization period and 8.6 m during the diversion period) could cause an increased risk of fish stranding.

Downstream of the dam and generating station construction zone, downstream flows (levels, and rates of stage change) would be unaffected during the channelization stage with the exception of small (average 20 cm) increase in water level at the downstream portion of the river constriction. During the diversion phase, the headpond would dampen changes to the rate of changes in flow, resulting in smaller, less abrupt changes in Peace River flows downstream of the constriction. Hydraulic changes would be negligible at Taylor and further downstream. There would be no increase in the risk of fish stranding downstream of the dam and generating station construction area.

12.4.3.3 Fish Entrainment

Entrainment occurs when a fish is drawn into a water intake and cannot escape (Fisheries and Oceans Canada 2007). For hydroelectric developments, entrainment commonly refers to any downstream movement of fish through the facility. Entrainment can also refer to the movement of fish into an intake for a water pump (Fisheries and Oceans Canada 1995).

Fish may be entrained during construction Stage 2, River Diversion: a) fish may be entrained in the diversion tunnel inlet and downstream through the diversion tunnels;

b) during reservoir filling (see Volume 1 Appendix B Reservoir Filling Plan), which occurs during the latter part of the river diversion stage, fish may be entrained through a modified diversion tunnel or the spillways.

Approach to Evaluate Fish Entrainment

The approach to evaluate the potential for entrainment is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. In general, the approach:

Adhered to **principles** used previously in regulatory discussions concerning entrainment at existing facilities (the BCH-DFO-MOE Fish-Hydro Management Committee's Working Principles for the BC Hydro Entrainment Strategy) (Fish-Hydro Management Committee 2011)

Followed established **methods** used to assess entrainment at existing BC Hydro facilities (e.g., the Entrainment Risk Screening and Evaluation Methodology; BC Hydro 2006)

Followed guidance from **regulatory guiding documents** relevant to managing entrainment and fish passage management [e.g., Practitioner's Guide to Fish Passage for DFO Habitat Management Staff (Fisheries and Oceans Canada, 2007)] and Practitioners Guide to the Risk Management Framework for DFO Habitat Management Staff (Fisheries and Oceans Canada No date)

Given this overall approach, the technical assessment broadly mirrored that used to assess and manage entrainment at existing BC Hydro facilities (e.g., Revelstoke, Mica, Hugh Keenleyside) and the approach used in the environmental assessment of other BC Hydro facilities (e.g., John Hart and Aberfeldie redevelopments).

Two main components are used to evaluate entrainment:

a) Entrainment rate: Entrainment rate is used to estimate the consequences to the upstream fish populations (i.e., those fish populations that inhabit the Peace River between Peace Canyon Dam and the Site C Dam site, including tributaries)

b) Survival rate of entrained fish: Survival of entrained fish is estimated for each entrainment route, and is used to determine the fate of entrained fish

Entrainment Rates

The movement strategies of fish during the diversion period are predicted to be similar to baseline conditions (baseline conditions are described in Section 12.3.2.3 above). Species that make extended movements and seasonal migration (e.g., Arctic grayling, bull trout) are expected to continue these movement patterns, and therefore that portion of the population that moves downstream past the Site C Dam are assumed to be entrained. For species with local movement patterns (e.g., small-fish species), only that portion of the population that resides close to the diversion location is expected to be entrained.

Survival Rate of Entrained Fish

The survival of fish entrained through the diversion tunnels is estimated to be high (described in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion). Given the tunnel design and hydraulic conditions, there is a low risk of fish contacting tunnel walls or the outlet structure and low risk of shear-related injury in tunnel exit velocities. Fish that are entrained are expected to have high survival and can reside in the Peace River downstream of the diversion tunnel.

The survival of fish entrained over the spillway and spillway undersluices is estimated to be high. The spillway configuration is similar to that of the Columbia River system dams, with radial gates controlling submerged discharges to similarly sloped spillway ramps equipped with deflectors that produce near surface flow in the stilling basins. Investigations of fish survival rates at Columbia River system dams have been conducted using advanced monitoring techniques that provide reliable measures of fish survival in the range of 98 to 100%. The survival of fish entrained in the Project spillway undersluices is a configuration similar to Removable Spillway Weir systems that have been installed at several dams in the Columbia River system dams. Fish survival measured at Removable Spillway Weir systems is in the range of 98% to 99%. Site C has higher head than the Columbia River facilities where these studies occurred. Therefore, survival is likely lower at Site C than the Columbia River facilities.

The survival of entrained fish during river diversion will vary, given the specific sequence of activities and associated entrainment routes (e.g., diversion tunnels, modified diversion tunnel, spillway, spillway undersluices) during reservoir filling (See Volume 1 Appendix B Reservoir Filling Plan). These entrainment routes and associated fish survival are:

Fish survival through the single, non-modified diversion tunnel is estimated to be high as described above

Fish survival through the modified diversion tunnel is estimated to be low, given the hydraulic impacts of the energy dissipating devices(s) that will be installed in the modified tunnel. The modified diversion tunnel is expected to be operated for one to two weeks, depending on reservoir inflow.

Fish survival through the spillway undersluices and spillway during reservoir filling is estimated to be high, as described above

12.4.3.4 Total Dissolved Gas

This section examines the potential for dissolved gas supersaturation to impair fish health and survival associated with the construction of the Project. A general background narrative on total dissolved gases (TDG) and effects on fish health and survival is provided first. Expected TDG generation during the construction phase of the Project is then reviewed.

<u>Background</u>

Total dissolved gas is “air” dissolved in water. The TDG pressure (all gases plus water vapour) is commonly measured and regulated as a percentage of saturation expressed as a percentage of the amount of air that water will hold when it is in equilibrium (100%) with the atmosphere at ambient water surface conditions. Beneath the water’s surface, the pressure steadily increases with increasing depth due to the hydrostatic pressure (weight of water) above the depth of interest. This increased pressure increases the amount of atmospheric gases that the water will hold when in equilibrium (saturated) at the specific depth. Thus, greater increases in depth result in greater increases in hydrostatic pressure and greater amounts of air in solution at equilibrium. For example, water 2 m deep will hold at equilibrium 120% of the air the same water will hold at surface pressure. Increasing gas solubility with increasing pressure (depth) is the factor that causes TDG supersaturation to occur. When air bubbles are entrained or mixed in water and the air-water mixture is carried to some substantial depth, the gases pass into solution to a substantially greater amount than the water can hold in equilibrium when it returns to the surface pressure. This produces TDG supersaturated water (relative to the surface pressure). As long as the supersaturated water remains under the increased pressure, there is no potential for the amount of dissolved gas to decrease. For this reason, once supersaturated, the level of TDG supersaturation tends to remain in water bodies unless there is considerable turbulence and exposure of the water to surface pressure. For this reason, TDG supersaturation tends to persist and slowly decrease downstream in reservoirs and rivers.

The effects of TDG supersaturation to fish and invertebrates depend on a variety of factors, including the level of supersaturation, the depths occupied by the fish, and duration of exposure to supersaturation (for a review, see Weitkamp 2008). Gas bubble disease (GBD) occurs in fish and invertebrates exposed to substantial levels of TDG supersaturation under near surface pressures. GBD is the formation of bubbles in the blood and other tissues of fish. GBD can range from mild with a few visible bubbles, to severe with numerous bubbles, hemorrhaging, and exophthalmia (bulging eye). Acute GBD occurs to fish restrained in shallow water with a high level of supersaturation (approximately 140% or greater). With acute GBD, numerous small bubbles may form in the blood, resulting in blocked circulation to vital organs and the death of the fish. However, fish that remain under substantial pressures (depths) do not develop GBD even though they are exposed to TDG supersaturation. The same total pressure that causes supersaturation also provides pressure compensation, preventing fish and invertebrates from developing internal bubbles when they are in supersaturated water.

In British Columbia, generalized guidelines have been established based largely on the results from laboratory investigations of the effects of TDG on fish and aquatic life. The guideline limits TDG supersaturation to 110 %, as a conservative means to avoid any occurrence of GBD in natural waters (http://www.env.gov.bc.ca/wat/wq/BCguidelines /tgp/tgp_over.htm). The available literature indicates that the frequency of occurrence and the severity of GBD in natural river conditions are much less than predicted by laboratory investigations, particularly where sufficient habitat depths are available to compensate for pressure (Weitkamp 2008). The literature indicates that TDG supersaturation results in little or no gas bubble disease (GBD) at levels up to 120% of saturation when compensating depths (2 m or more) are available. This occurs for a variety of reasons:

Depths occupied by fish greatly decrease the actual exposure of individual fish because actual TDG saturation is relative to ambient pressure

GBD has been commonly recorded under conditions where fish are restrained or more easily captured in shallow water

GBD is rapidly reduced or eliminated by increasing hydraulic pressure as a fish moves deeper

Signs of GBD do not necessarily indicate decreased survival of individuals or populations

Commonly, fish show only minor signs that likely do not influence behaviour or survival

TDG does not bioaccumulate, as recovery from exposure to supersaturation can be rapid with no apparent chouronic effects, or residual effects compounding subsequent exposure

Effects of TDG are site specific, depending on fish population distribution and habitat use, and physical habitat conditions in the receiving environment, and the period of exposure to TDG (Fidler 2003; Weitkamp 2008).

Peace River supports a diverse community of large- and small-body fish that seasonally utilize different mainstem habitats and tributary habitats (see Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population.

Given known utilization of tributary and confluence habitats, together with the expected depth distributions of the fish present in the main channel habitat, many fish are exposed to little or no TDG supersaturation. For example, fall spawning occurs predominantly in tributary habitats, placing reproductive life stages outside the area potentially affected by TDG supersaturation. However, individuals of each population may tend to occupy shallow water of the mainstem and side channels along Peace River (< 2 m). Where TDG concentrations exceed 120%, this may expose those fish to elevated levels of TDG supersaturation during the reservoir filling period that are sufficient to cause GBD.

<u>TDG Generation during Construction</u>

River Confinement

River confinement activities do not actively control river flow or transfer flow through discharge facilities that could create physical conditions required to cause gas supersaturation. As a result, there is no potential to increase TDG in the river during the confinement phase of dam construction, and no residual effects on fish or fish habitat are expected during that period.

River Diversion

During the diversion stage of construction, two tunnels will be used to control flow and divert river flows around the dam and generating station construction zone. The duration of the diversion phase of the project is approximately 36 months. During this period, the diversion tunnels would not create hydraulic conditions for entrainment of air required to increase total dissolved gas concentration over the ambient condition. As a result, diversion tunnel operation would not cause GBD in fish or other aquatic life.

Reservoir Filling

Following the diversion phase, reservoir filling would be undertaken in three stages over approximately three months. The three stages of reservoir filling and the predicted effect of magnitude and duration of elevated total dissolved gas generation are described below:

Stage 1 – Stage 1 filling is planned to begin in the first or second week of September. At that time, river flows will be reduced to a minimum discharge (> 390 m^3/s) to begin reservoir filling for a period of one to two weeks to allow the reservoir level to rise to elevation 440 m. During this period, all flows will be released from a single modified diversion tunnel and TDG concentrations are predicted to be 120% ± 5% saturation.

Stage 2 – During Stage 2, rising reservoir levels would pass elevation 440 m and allow downstream releases to be accomplished through spillway undersluices. Once flows are confirmed through the undersluices, the diversion tunnel discharge will be terminated. Filling rate is dependent on reservoir inflows and would take between one and two weeks to attain a reservoir level of elevation 452 m. The reservoir would be held at elevation 452 m for about four weeks to allow the commissioning of turbines and generators to begin. This hold period will be between late September and early October. During this period, TDG concentrations released from the undersluice structures are predicted to range between 113% ± 4% and 118% ± 4% saturation.

Stage 3 – The final stage of filling the reservoir would occur between mid-October and late November, depending on inflow conditions. Downstream flows would be controlled by the spillway to ensure minimum flows are sustained and managed to allow reservoir level to safely rise from elevation 452 m to 461.8 m. TDG generated from spillway releases are expected to range between 113 ± 4% and 119% ± 4% saturation for a period of up to four weeks.

There is no quantitative method to estimate the uncertainty of these evaluations. The evaluations are qualitative, based on investigations at numerous constructed dams over many years. There is also a bias in the observations of GBD in fish exposed to TDG supersaturation in rivers and reservoirs, where the fish sampled include only those residing in shallow water, and therefore those most likely to develop GBD signs. The predictions of TDG produced by the Site C spillway are based on the best modelling techniques available and prior monitoring efforts from existing upstream dams on the Peace River. Although the accuracy of predictions cannot be quantitatively evaluated, any bias in modelling estimates would affect equally and in the same manner the estimate of each spillway alternative modelled.

12.4.4 Effects Assessment – Operation – Change in Fish Health and Survival

Fish health and survival would be potentially be changed by operation activities as follows:

Stranding of fish in the reservoir and downstream, due to water level fluctuations

Entrainment of fish over the spillway and through the turbines

Spillway operation may increase total dissolved gas pressure

12.4.4.1 Stranding of Fish

The factors associated with fish stranding risk are poorly understood but are attributed to local site and flow regime characteristics, fish species and size, time of year, and specific time of day when flow changes occur. No detailed studies of the risk of fish stranding or observations of fish stranding are available to quantify the level of fish stranding that occurs under the baseline condition in the Peace River system.

The relative change in the risk of fish stranding resulting from the Project would depend on how the Project would change the daily range of flows/water levels and the rate of stage change under operating conditions. Baseline conditions for flow and water level in the Peace River are described in Section 11.4.2.4 Baseline Flows and Water Levels in Volume 2 Section 11 Environmental Background, and also in BC Hydro (2012). Current operations of Peace Canyon Dam produce daily flow and level variations that have potential to strand fish. Over any given day, water levels may both rise and fall to follow demand for electrical power. In general, observed water levels at Hudson's Hope rise ~45% of the time and fall ~45% of the time, leaving 10% of the time when no change (<0.1 cm change) occurs. Risk of stranding occurs only when water levels decrease. Under the baseline condition, the range and rate of water level reductions is greatest immediately below Peace Canyon Dam and generally diminishes moving downstream as a result of flow attenuation and tributary inflows. For example, for the period 2008 to 2010, below Peace Canyon Dam, the average daily water level range at Water Survey of Canada stations was 0.54 m at Hudson's Hope and 0.26 m at Taylor. Rates of stage change follow this same general pattern, where the rate of water level reduction is largest immediately below Peace Canyon Dam at Hudson's Hope and diminishes moving downstream. Based on the 2008–2010 period, the rate of water level reduction from one hour to the next exceeded 5 cm/hour 12.2 % of the time at Hudson's Hope and 7.0 % of the time at Taylor (BC Hydro 2012).

Changes to fish stranding risk would result from the creation of the reservoir and the alteration of the downstream flow regime. A description of the baseline flow regime and the changes expected during the operation of reservoir and dam and generating station are provided in Section 11.4.5 Surface Water Conditions during Operations in Volume 2 Section 11 Environmental Background. The simulated operation of the Project shows that the Site C reservoir would be operated within the top 0.6 m of the normal operating range, between elevations 461.8 and 461.2 m, at least 83% of the time (see Volume 2 Appendix D Surface Water Regime Technical Data Reports, Part 1 Operations Study). The daily range of Site C reservoir levels was predicted to be 0.6 m or less 60% of the time, and 1.0 m or less 75% of the time. These ranges are similar to the observed conditions at Hudson's Hope from 2008 to 2010. As the changes to the reservoir water level would be more gradual, the risk of stranding would be reduced in the reservoir relative to that existing in the river under the baseline condition.

Downstream of the dam, however, the daily range of water levels and rate of water level change from one hour to the next would increase (see Table 11.4.9). This change would be the greatest in the proximal reach immediately below the Project. For example, the predicted daily range of water levels has been predicted to increase from 0.5 m to 1.0 m at the tailrace of Site C, and from 0.4 m to 0.8 m at Taylor. Changes to the rates of stage change follow this pattern [see Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D)]. The risk of stranding downstream of the Site C Dam would therefore increase as a result of the Project. This increase in fish stranding risk would be most prominent in the section of the Peace River between Site C Dam and the Pine River.

12.4.4.2 Fish Entrainment

Fish may be entrained through the generating station and spillways during the operations phase. Fish entrainment will occur primarily through the generating station since spilling is estimated to be infrequent (Section 11.4 Surface Water Regime in Volume 2 Section 11 Environmental Background).

Entrainment Rates

The entrainment rates for all species in the LAA were calculated using a heuristic model of entrainment risk (described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The model was based on the Entrainment Risk Screening and Evaluation Methodology (BC Hydro 2006); the model expanded on this methodology to provide quantitative estimates of entrainment rates, measured as the proportion of the population entrained per year. The model is based on species-specific information on fish distribution, habitat preference, movement rates, response to velocity fields, and swimming capability, as well as the configuration and operation of the Project, and information on entrainment rates from other hydroelectric facilities.

Annual entrainment rates during the operations phase may differ from baseline conditions, given changes in fish habitat. As described in this section, formation of the Site C reservoir will fundamentally change fish habitats between Site C and the Peace Canyon Dam. These changes in physical conditions and fish habitat may change fish movement patterns and entrainment risks.

Annual entrainment rates estimated by the heuristic model are low ($\leq$ 10% of the population) for all species except for bull trout, kokanee, lake whitefish. and lake trout. Entrainment rates for most species are low due to several factors, which vary by species and include the following:

Only a portion of the population is present in the Site C reservoir, and a portion remains in tributaries to the Site C reservoir

Fish have restricted movement rates and habitat preferences that result in only a portion of fish in the reservoir approaching the dam and generating station

Fish respond to velocity fields and have swimming capabilities to avoid being passively entrained

Bull trout had relatively higher entrainment rates based on their potential future directed movements downstream past Site C by a portion of the population. The population-level consequences to bull trout of these entrainment rates, as well as the subsequent return of entrained bull trout upstream via trap and haul mitigation are examined in more detail in a population model (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives), and summarized in the section on upstream passage below. Kokanee, lake whitefish, and lake trout had higher annual entrainment rates, based primarily on their preference and adaptations for offshore pelagic habitat. The population-level consequences to kokanee that may colonize the reservoir are examined in more detail in a population model (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives).

Entrainment Survival

Fish entrained through the generating station and turbines during operations will have a fish size-dependent survival rate calculated to be greater than 90% for small fish (100 mm fork length) and greater than 60% for the largest fish (750 mm fork length) (described in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-3 Turbine Passage Survival Estimates). Fish survival rate was estimated using a predictive equation developed under the U.S. Department of Energy's Advanced Hydro Turbine System Program (Franke et al. 1997). This equation is based on a comprehensive analysis of fish survival rates from other hydroelectric projects. Fish survival rate is calculated using turbine characteristics, flow, head, mechanical efficiency, and fish length to estimate the probability that a fish of a given size will come near to or in contact with a structural element as it passes through the turbine. The large, slow-rotating Francis turbines proposed for the Project are relatively safe for fish passage, as compared to other typical Francis turbines, especially for smaller fish. The size of the turbine is dictated by the large flow capacity requirements, but is advantageous for fish passage because it creates large volumes for the fish to pass between the buckets of the runner, reducing the likelihood that they will come in contact with them. The rotational speed is relatively low as compared to many turbine-generator installations.

Survival of fish entrained over the spillway during operations is estimated to be high as described above.

12.4.4.3 Total Dissolved Gas Supersaturation

This section examines the potential effects of dissolved gas supersaturation on fish health and survival associated with the operations phase of the Project. A general background narrative on total dissolved gases (TDG) and biological effects of fish and fish habitat is provided as background in Section 12.4.3.4 and in Weitkamp (2012). This section reviews expected TDG generation during the operations phase of the Project, reviews efforts undertaken to mitigate TDG effects, and assesses whether residual effects on the health and survival of fish result from TDG generation.

<u>Total Dissolved Gas Generation During Operations</u>

The operation of the dam spillway and generating station may elevate TDG downstream of the dam through 1) powerhouse operations under low turbine flow conditions, and 2) spillway operation. Normal turbine operations do not raise TDG above 110%. During occasional low flow conditions, a turbine may be operated in a manner that introduces dissolved gas. Low flow turbine operation can raise TDG supersaturation by introducing air under pressure during synchouronous condense operation (no load turbine operation) and during periods of rough load entrainment through atmospheric control (valve/injection). In this situation, turbine discharge volume will be low; however, TDG concentration in the outflow from the single turbine may exceed 120% saturation. Depending on duration of the low flow turbine operation, specific operation of adjacent turbines, and local tailwater mixing processes, this may create spatial zones immediately downstream of the dam with elevated TDG concentration.

Engineering assessments have been conducted to evaluate the TDG generation from the use of the spillway and design options to mitigate it (see Section 12.4.3.4). The concentration of TDG generated by operation of the spillway is a function of total magnitude of discharge release. Spillway operation is expected to produce TDG supersaturation levels in the portion of the discharge passing over the spillway. For spillway discharges of <900 m^3/s, no elevation of TDG levels is expected above typical range of observed ambient conditions (i.e., up to 110%) (Millar and Wilby 1997). For discharges approximately 900 m^3/s and 1350 m^3/s, the predicted TDG levels elevated to

113% ± 4% and 118% ± 4%, respectively (Gulliver 2012). For spillway discharges of approximately 1800 m^3/s, TDG levels may exceed the 120% saturation level required to cause GBD in fish and other aquatic life (122% ± 4%) (Gulliver 2012).

An analysis of expected frequency of spill events for the Project is presented in Section 11.4.4.2 in Volume Section 11 Environmental Background. Two methods were used to predict the frequency, magnitude, and duration of spill events to bracket uncertainty in spill operations. To provide a conservative assessment of effects on health and survival of fish through TDG exposure, this assessment considers the Historical Analysis scenario, which predicts more frequent and larger spills and a consequently higher TDG concentration. Based on the Historical Analysis scenario, on average, a spill is expected once every three years. When spills occur, they can last from several days to as long as several weeks. The average magnitude of spillway discharge is predicted to be 416 m^3/s, which, based on engineering assessments, would not produce elevated TDG, or consequent GBD symptoms in fish or aquatic life. However, the predicted maximum daily average spillway discharge under that scenario is estimated at 1,950 m^3/s; this has potential to produce spillway discharge with TDG concentrations in excess of general thresholds for GBD (120% saturation when fish remain near the water surface or > 2 m compensating depths are not available) (Weitkamp 2008).

Factors that would reduce the potential for effects of TDG generation on the health and survival of fish in the river downstream of the dam are:

Mixing of spillway discharge with turbine discharge

Tributary dilution effects

Physical characteristics of the downstream environment

Observed biological characteristics of resident fish populations living in the Peace River

TDG supersaturation created by spillway discharges will be reduced by mixing with turbine outflows from the generating station. During normal operational spills, up to six available turbines in the powerhouse would be operated at full discharge capacity, allowing approximately 2,500 m^3/s of water from the reservoir to be mixed with TDG-laden spillway discharges. If spills at the Project occur during periods of spill from upstream facilities, the TDG concentration in turbine discharge would likely range between 110% and 120% saturation (Millar and Wilby 1997). If spills at the Project occur when upstream facilities are not spilling, then the TDG concentration in turbine flows would be between 100% and 110% saturation, allowing dilution of TDG concentration. Tributary discharges to the Peace River downstream from the Project will also reduce the TDG supersaturation levels in the river. Since tributary water will be near 100% of saturation, localized areas at tributary confluences and immediately downstream will have reduced TDG concentration (Millar and Wilby 1997). Therefore, average spillway discharges will not create levels known to be harmful for health and survival of aquatic life. However, when maximum spill volume does occur, depending on the duration of peak spillway discharges, there is potential to create GBD in fish and aquatic life.

Two additional factors that reduce the exposure of fish to elevated TDG conditions are the physical environment downstream of the dam and the biological characteristics of fish populations. The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population. Given availability of tributary and confluence habitats, together with the velocity preferences and depth distributions of most of the fish present in the main channel habitat, fish may be exposed to little or no TDG supersaturation during spill events. Spawning occurs predominately in tributary habitats, placing reproductive life stages outside the area potentially affected by TDG supersaturation. Thus, only those individuals of each population tending to occupy shallow water (< 2 m) are exposed to any level of TDG supersaturation during most of the spill events.

Effects of TDG are site specific, depending on fish population distribution and habitat use, and physical habitat conditions in the receiving environment, and the period of exposure to TDG (Fidler 2003; Weitkamp 2008). The basic characteristics of the Peace River (e.g., channel morphology, flow depth, and flow velocity) and the distributions of its fish populations restrict exposure to TDG supersaturation to a portion of each population. Peace River supports a diverse community of large- and small-body fish that seasonally utilize different mainstem habitats and tributary habitats (see Volume 2 Appendix O Fish and Fish Habitat Technical Data Report). Given known utilization of tributary and confluence habitats, together with the expected depth distributions of the fish present in the main channel habitat, many fish are exposed to little or no TDG supersaturation. However, individuals of each population may tend to occupy shallow water of the mainstem and side channels along Peace River (< 2 m). Where TDG concentrations exceed 120%, this may expose those fish to elevated levels of TDG supersaturation during use of the spillway during the operations phase of the Project.

There is no quantitative method to estimate the uncertainty of these evaluations. The evaluations are qualitative, based on investigations at numerous constructed dams over many years. The predictions of TDG produced by the Site C spillway are based on the best modelling techniques available and prior monitoring efforts from existing upstream dams on the Peace River. Although the accuracy of predictions cannot be quantitatively evaluated, any bias in modelling estimates would affect equally and in the same manner the estimate of each alternative mitigation modelled.

12.4.5 Effects Assessment – Construction – Change in Fish Movement

Upstream fish movement may be affected during:

1. Construction Stage 1, river channelization, due to changes in water depths and velocities in the section of the Peace River that is channelized

   Construction Stage 2, river diversion, where the diversion dam and tunnels will create a complete blockage to upstream passage

The overall approach to evaluate upstream fish movement is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. The approach was coordinated with the assessment of entrainment, which is described above.

River channelization confines the Peace River to a single channel, which increases average water velocities (i.e., averaged across the channel) for a given discharge (Section 11. 4 Surface Water Regime in Volume 2 Section 11 Environmental Background). This change has the potential to affect upstream fish movement. Potential effects on upstream movement during river channelization were evaluated using: i) minimum water depth and maximum velocity criteria for upstream fish movement, and

ii) a two-dimensional hydraulic model that predicts water depths and velocities under baseline conditions and during river channelization (Section 11. 4 Surface Water Regime in Volume 2 Section 11 Environmental Background). The analysis was based on minimum fish size of 150 mm fork length. The analysis used a minimum water depth of 25 cm for upstream movement, based on guidelines (Fisheries and Oceans Canada 1993; British Columbia Ministry of Transportation and Highways 2000; Washington Department of Fish and Wildlife 2003) and the criteria used in other fish passage assessments (NHC and Focus Environmental Inc. 2006). The analysis used a maximum water velocity of 0.4 m/s based on the prolonged (30 minute) swim speed for 150 mm fork length fish (described in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-5 Fish Swimming Speeds). The channel area that meets these depth and velocity criteria was estimated under baseline conditions and during river channelization, over a range of river discharges. The channel area that meets these criteria is reduced during channelization because i) the total channel area is reduced, since the Peace River is confined to a single channel, and ii) average water velocities increase. However, during channelization, there is sufficient channel area that meets the depth and velocity criteria for fish to continue to move upstream. Therefore, no effect on upstream passage is anticipated.

The upstream movement patterns during the river diversion period are predicted to be similar to baseline conditions (baseline conditions are described in Section 12.3.2.3 above), since much of the LAA remains as river habitat. Blocked upstream movement would potentially affect those species with an extended (upstream) movement strategy and a core or extended distribution that extends upstream and downstream of the Site C Dam location, as described in Tables 12.7, 12.8 and 12.9. Species that make extended movements and seasonal migration (e.g., Arctic grayling, bull trout) are expected to continue these movement patterns. Thus, a portion of the population is expected to attempt to move upstream of the diversion dam to return to spawning habitats upstream. Species with local movement patterns (e.g., small-fish species) would not be affected by blocked upstream passage because they can complete their life history in habitats downstream of the diversion dam.

12.4.6 Effects Assessment – Operations – Change in Fish Movement

Upstream fish movement will be affected during operations because the dam and generating station will create a complete blockage to upstream fish movement.

The assessment evaluated potential effects on fish movement during construction and operation separately, because habitat conditions and expected movement strategies are predicted to differ between these project phases. As described in this chapter, formation of the Site C Reservoir will fundamentally change fish habitats between the Site C and the Peace Canyon dams. There will also be changes to physical conditions and fish habitat in the Peace River downstream of the Project, in particular that section of the Peace River between the Site C Dam and the Pine River confluence. These habitat changes may change fish movement patterns as fish adapt their life history and movement patterns to these physical conditions. Thus, changes to fish movement consider both the potential habitat effects and blocked upstream movement from the dam.

The approach to evaluate upstream fish movement is described in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment. Given the linkages between entrainment and upstream movement, the approach was coordinated with the assessment of entrainment, which is described above.

The future movement patterns of fish downstream of the Site C Dam during operations are predicted to change from baseline movement patterns (described in Section 12.4.4.2), given changes in physical conditions and fish habitat, described above. Species with local movement patterns would not be affected by blocked upstream passage because they can complete their life history in habitats downstream of the Site C Dam. Species with extended movement strategies may attempt to move upstream past the dam. In the cold/clear water sport fish group, adult Arctic grayling, bull trout, and mountain whitefish that originated from upstream of the Site C Dam may be motivated to move upstream past the Site C Dam in an attempt to return to spawning tributaries (i.e., Moberly River for Arctic grayling and mountain whitefish; Halfway River for bull trout and mountain whitefish). In the cool/turbid water group, walleye, burbot, northern pike, and the three sucker species may be motivated to move upstream of Site C. However, the future distribution of the cool/turbid group in the Peace River is expected to be restricted primarily to downstream of the Pine River confluence (described in Section 12.4.2.2 above), thereby reducing their motivation to move upstream as far as or past the Site C Dam.

More detailed population modelling was completed to predict the potential effects of entrainment and upstream movement on those species predicted to continue to attempt upstream movements past the Site C Dam (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). Single-species population models examined the potential effects fish entrainment and blocked upstream passage for those species predicted to continue to attempt upstream movements past the Site C Dam: bull trout that spawn in the Halfway River and inhabit the Peace River, and Arctic grayling that spawn in the Moberly River downstream of Moberly Lake and inhabit the Peace River. The combined effects of entrainment and blocked upstream movement have a potential effect on the abundance of bull trout, but would not affect population-level conservation objectives. Habitat change from reservoir formation may restrict Arctic grayling movements (see Volume 2 Appendix Q Fish Passage Management Plan, Part 3 Technical Report: Using Single Species Population Models of Bull Trout, Kokanee and Arctic Grayling to Evaluate Site C Passage Alternatives).

12.5 Mitigation Measures

This section provides a description and the expected effectiveness of measures to mitigate potential effects identified in Section 12.4 above. A summary of potential effects and mitigation measures is provided in Table 12.19 below.

12.5.1 Change in Fish Habitat

12.5.1.1 Construction

Loss of Habitat Due to Construction of the Dam and Generating Station, Highway 29, and Hudson's Hope Shoreline Protection

Potential effects on habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection will be addressed through a combination of avoidance and mitigation measures, including:

Implement the Fisheries and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans)

A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing

Material relocation sites resulting from dam site excavation (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat

Material relocation sites resulting from dam site excavation upstream of the dam will incorporate fish habitat into the final capping design. The relocation areas will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase.

Fish habitat features (shears, large riprap point bars, etc.) will be designed in the final design of the north bank haul road bed material that would be placed in the Peace River

Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings. Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint.

The Hudson's Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson's Hope shoreline protection.

Merchantable trees, and vegetation that could interfere with navigation, will be removed using clearing practices to maintain a 15 m machine-free zone

Temporary structures will be removed as soon as they are no longer required

Construction activity footprints are minimized, where possible, to reduce the area of fish habitat. Further efforts will be made during the finalization of design.

Loss of Habitat Due to Construction Headpond and Reservoir Filling

Due to the potential extent of changes to fish habitat caused by the construction headpond and reservoir filling, there are no technically feasible mitigation options for the loss of the riverine habitat due to reservoir creation.

Habitat mitigation measures are proposed where a construction activity presents an opportunity to provide potential fish habitat, including:

Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat.

Material repositioning areas will be capped with gravels and cobbles, and contouring will be undertaken to enhance fish habitat conditions

A 15 m wide riparian area will be planted along the reservoir shoreline adjacent to BC Hydro-owned farmland to provide riparian habitat and bank stabilization

12.5.1.2 Operations

Transformation of Reservoir Habitat during Reservoir Operation

The transformation of the reservoir during reservoir operations has the potential to affect fish and fish habitat. The Site C reservoir operation has been designed to have a minimal reservoir fluctuation during operation of 1.8 m, which reduces the effects to the shoreline (littoral) fish habitat. As a result of the nature and uncertainty of future habitat changes in the reservoir during the operation, it is not technically feasible to propose effective mitigation options. Future mitigation and compensation options will be evaluated after reservoir development and follow-up monitoring. Compensation options that are technically and economically feasible will be implemented.

Downstream Habitat Changes

Operation of the Project will result in limited changes to the pattern of flow released and the changes to fish habitat downstream of the Project. Potential effects will be limited to the section of the river between the dam and the Pine River confluence. To mitigate for these potential effects the proposed measures would include:

The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows

Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat

12.5.2 Fish Health and Survival

12.5.2.1 Construction

Sediment Inputs by Dam and Generating Station Zone

The introduction of sediment to fish habitat as a result of construction activity associated with the dam and generating station has the potential to impair fish health and survival. The following mitigation measures are proposed:

Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials.

Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies.

Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff.

Adjust the timing construction activities to coincide with periods of high background sediment levels, where feasible

Select clean rock materials or wash rock materials for riprap construction to minimize the amount sediments that are introduced into the aquatic environment

Reduce equipment production rates to reduce the amount of sediments generated by equipment where required

Sediment Inputs by Construction Headpond and Reservoir Filling

The introduction of sediment to fish habitat as a result of the presence of the construction headpond and due to the filling of the reservoir has the potential to effect fish health and survival. The following measures are proposed to mitigate adverse effects:

Berm or cap areas with high potential to produce sediments

During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible

Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible

Sediment Inputs by Highway 29 Realignment and Hudson's Hope Shoreline Protection

The introduction of sediment to fish habitat as a result of the realignment of Highway 29 and the Hudson's Hope shoreline protection has the potential to effect fish health and survival. The following measures are proposed to mitigate adverse effects:

Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials.

Dust control plan (Section 35.2.2.7 Dust Control Program in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies.

Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff.

Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment

In-stream construction will be conducted in isolated work areas when feasible

Stranding of Fish

A program of fish salvage and fish relocation is recommended to mitigate for the potential effects of stranding due to water fluctuation on the health and survival of fish during construction. The program will involve:

Surveillance of fish habitat areas where periodic exposure of channel margins occurs as a result of headpond fluctuation

As feasible, salvage and relocation of fish trapped in potholes, side channels, or other habitat area at risk of dewatering as a result of headpond fluctuation

Fish Entrainment

Mitigation options for fish entrainment during construction are summarized in Volume 2 Appendix Q Fish Passage Management Plan, Attachment C-4 Fish Mortality During River Diversion, and require consideration for the river diversion and reservoir filling stages of Project construction.

During river diversion, the design of the large diameter diversion tunnels and associated hydraulics provide a low risk of fish injury or mortality. Additional specific design features to be integrated, where possible, into the construction and operations of the tunnels will reduce the risk of injury or mortality, by:

Incorporating smooth and gradual transitions from the round tunnels to the square exits

Completing tunnel linings with a smooth concrete surface finish

Reducing any obstructions (e.g., boulders) in the tunnel tailrace area

The final approach to implementation of these features will be determined during detailed design and construction. The assessment of residual effects considers that these design features will be implemented since they also increase hydraulic performance of the structures, and will reduce, but not eliminate, low potential risk for fish strike and de-scaling that can cause injury or mortality.

During reservoir filling, the potential effects of injury or mortality of entrained fish during reservoir filling will be mitigated by operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan. The mitigation will be applied to the diversion tunnels (described above under river diversion), since fish will pass through the diversion tunnels at times during reservoir filling.

Approaches to mitigate the potential effects of fish entrainment on health and survival of fish during construction are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Increased Total Dissolved Gas

The Project has the potential to increase TDG, and effect health and survival of fish during construction. BC Hydro has undertaken two general approaches to the mitigation of the potential effects of TDG generation on fish and fish habitat during construction. These measures include:

Modifying spillway design to reduce the magnitude of TDG generated

Developing an operational plan to reduce magnitude, duration, and geographic extent of TDG generation during reservoir filling

To reduce the magnitude of TDG generated during the use of the spillway, BC Hydro undertook an engineering assessment of alternative spillway designs. Four mitigation options were identified: jet deflectors, deflector basin, high ported weir, and low ported weir. The mitigation options would be applicable for mitigating gas generation for any water releases through spill control gates and through undersluices during construction or operational phases of the Project. The assessment used computational modelling to evaluate hydraulics characteristics of the spillway structures and the behaviour of entrained air (bubbles) in spillway flows. The results were applied to estimate flow- dependent TDG generation characteristics for each design option (Gulliver 2012). Preferred options for mitigation of TDG were referred to further evaluations using a physical model to support computational model analyses. Based on the results of modelling and physical model analyses, a jet deflector spillway design was chosen for implementation. Implementation of a jet deflector design was predicted to reduce TDG supersaturation levels from the 139% to 146% range for the original base design to 115%, 118%, and 122% of atmospheric saturation at spillway discharges of approximately 900 m^3/s, 1,350 m^3/s, and 1,800 m^3/s; respectively (Gulliver 2012).

To further minimize the potential for TDG generation during reservoir filling, an iterative process was undertaken to develop and refine an operation procedure to minimize the magnitude and duration of exposure of fish and aquatic life to elevated gases. Seven alternative reservoir filling plans were evaluated to select a preferred operational approach for reduce the frequency and duration of TDG during reservoir filling. In addition to TDG mitigation through spillway design, the plan included consideration for:

Avoidance of local basin freshet to allow controlled filling to minimize spillway discharges during filling

Maintenance of ice control flows during freeze-up at the Town of Peace River (1,450 $m^3/s \pm 1{,}000\ m^3/s$, depending on inflows)

Maintenance of 900 m^3/s at the Project during the ice season (beginning November 15)

Diversion tunnel discharge control structure requirements

The number and duration of reservoir hold periods for engineering stability assessments

Duration of the filling period

12.5.2.2 Operations

Stranding of Fish

The operation of the Project will result in increased daily changes in water level and rates of water level change downstream of the Project. Potential increases to the risk of fish stranding will be limited to the section of the river between the dam and the Pine River confluence. To mitigate for these potential effects, the proposed measures would include:

Surveillance of fish habitat areas where periodic exposure of side channel and mainstem margins occurs as a result water fluctuations

The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat and to reduce stranding potential during low flows

Where practical, contouring mainstem bars to minimize the potential for fish stranding

Fish Entrainment

The operation of Project has the potential to affect the health and survival of fish through entrainment. The proposed approach for mitigating the effects of entrainment include:

The large and slow-rotating Francis turbines, which produce high survival relative to other facilities

Incorporating smooth and gradual transitions at the approach channel, penstock entrances, and tailrace exit structures

Designing the orientation and sizing of all openings and exits to reduce hydraulic turbulence

Completing linings with smooth surface finishing

Reducing obstructions (e.g., boulders) from the turbulent zone in the spillway and tailrace areas

Approaches to mitigate the potential effects of fish entrainment on health and survival of fish during operation are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Total Dissolved Gas

BC Hydro has undertaken two general approaches to avoid and mitigate the effects of TDG generation on health and survival of fish during operations: 1) incorporation of avoidance/mitigation through spillway design, and 2) development of operational procedures to reduce magnitude and duration of TDG events. The overall approach for avoidance and mitigation of TDG effects through design are described in Section 12.5.2.1 (Total Dissolved Gas). These activities resulted in selection of a jet deflector design for the spillway. This mitigation reduced the predicted gas generation from 139% to 146% for the original spillway base design to 115%, 118%, and 122% of atmospheric saturation at discharges of approximately 900 m^3/s, 1,350 m^3/s, and 1,800 m^3/s, respectively (Gulliver 2012). The production of TDG supersaturation at the Site C Dam would be further minimized through operation procedures to minimize gas production. These measures include:

Initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate

Minimize operation of turbines in water discharge ranges that produce ‘rough load’ operation

12.5.3 Fish movement

12.5.3.1 Construction

Obstructed Fish Movement

The Project has the potential to obstruct movement of fish upstream past the dam during the diversion stage of dam construction. The following measures are proposed to mitigate effects resulting from change in fish movement:

Upstream fish passage during construction (river diversion stage) will be provided by a trap and haul facility

A periodic capture and translocation program for small-fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations

Approaches to mitigate the potential effects of obstructed fish movements during the construction stage of the Project are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

12.5.3.2 Operations

Obstructed Fish Movement

The Project has the potential to obstruct movement of fish upstream past the dam during the operation stage of the Project. The following measures are proposed to mitigate effects resulting from change in fish movement:

Upstream fish passage during operations will be provided by a trap and haul facility

A periodic capture and translocation program for small-fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations

Approaches to mitigate the potential effects of obstructed fish movements during the operations of the Project are considered in more detail in the Fish Passage Management Plan. A structured approach was used to assess mitigation options in terms of potential fish passage risks (effects on health and survival, and on impeded movement), technical feasibility, biological benefits, and costs (summarized in Volume 2 Appendix Q Fish Passage Management Plan, Part 2 Fish Passage Alternatives Assessment). The Fish Passage Management Plan summarizes the recommendation from this assessment as a coordinated series of actions and testing to manage upstream and downstream fish passage at Site C, and associated effectiveness monitoring during the construction and operation of Site C.

Environmental Monitoring

An environmental monitoring program during construction will be developed in accordance with Volume 5 Section 35 Summary of Environmental Management Plans. Environmental monitoring during construction would be conducted to: 1) evaluate the effectiveness of standard mitigation measures for reducing sedimentation and fish stranding in the construction headpond and proximal reach of the river downstream of the dam, and 2) to validate predictions about physical changes to habitat in the reservoir area during the development and operation of the construction headpond during the diversion stage of the project. A systematic monitoring program design would be conducted over the approximate eight-year construction period. Physical and biological monitoring would be conducted to an appropriate scale to document spatial and temporal changes occurring in physical environmental conditions resulting from headpond hydrology, and in localized areas in relation to the effects of construction activities and mitigation procedures. The environmental construction monitoring program will also confirm the effectiveness of mitigation measures for management of predicted effects of sediment and fish stranding, and provide information required to adjust the mitigation program to reduce unforeseen adverse effects, as required.

A Site C Habitat Compensation Plan will be developed in accordance with the *Fisheries Act* Section 35(2) Authorization.

Table 12.19 Summary of Potential Project Effects and Mitigation Measures on Fish and Fish Habitat

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Loss of habitat due to construction of the dam and generating station, Highway 29 and Hudson's Hope shoreline protection	Implement Fish and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans) A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing Material relocation sites (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat. Material relocation sites upstream of the dam will incorporate fish habitat into the final capping design. The spoil area will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase. Fish habitat features (shears, large riprap point bars, etc.) will be designed in the final design of the north bank haul road bed material that would be placed in the Peace River. Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings. Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint. The Hudson's Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson's Hope berm. Construction footprints are being finalized to reduce the size of the construction footprint. Temporary structures will be removed as soon as they are no longer required.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Loss of habitat due to construction headpond and reservoir filling	Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat. Material repositioning areas will be capped with gravels and cobbles, and contouring will be undertaken to enhance fish habitat conditions. A 15 m wide riparian area will be planted along the reservoir shoreline adjacent to BC Hydro-owned farmland to provide riparian habitat and bank stabilization.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Operations	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	The Site C reservoir operation has been designed to have a minimal reservoir elevation fluctuation during operation of 1.8 m, which minimizes the effects to the shoreline (littoral) fish habitat. Future mitigation and compensation options will be evaluated after reservoir development and follow-up monitoring. Compensation options that are technically and economically feasible will be implemented.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Operations	Altered fish habitat downstream of Site C Dam	The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows. Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to sediment inputs by dam and generating station construction zone	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Adjust the timing construction activities to coincide with periods of high background sediment levels where feasible. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. Reduce equipment production rates to reduce the amount of sediments generated by equipment where feasible.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro
Construction	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Berm or cap areas with high potential to produce sediments. During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible. Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project.	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to sediment inputs by Highway 29 realignment and construction of Hudson's Hope shoreline protection	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Section 35.2.2.7 Dust Control Program in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. In-stream construction will be conducted in isolated work areas when feasible.	Recommended measures will fully mitigate potential effects	BC Hydro
Construction	Reduced fish health and survival due to stranding	Collection and relocation of stranded fish. Surveillance of fish habitat areas where periodic exposure of channel margins occurs as a result of headpond fluctuation. As feasible, salvage and relocation of fish trapped in potholes, side channels, or other habitat area at risk of dewatering as a result of headpond fluctuation.	Recommended measures will fully mitigate potential effects	BC Hydro
Construction	Reduced fish health and survival due to fish entrainment	Large diameter diversion tunnels and associated hydraulics that provide low risk of fish mortality. Incorporating smooth and gradual transitions from the round tunnels to the square exits. Completing tunnel linings with a smooth concrete surface finish. Reducing any obstructions (e.g., boulders) in the tunnel tailrace area. Operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Reduced fish health and survival due to increased total dissolved gas	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to minimize the number of hold points and the duration of the reservoir filling and turbine commissioning.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operations	Reduced fish health and survival due to stranding	Surveillance of fish habitat areas where periodic exposure of side channel and mainstem margins occurs as a result water fluctuations. The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluences of the Peace and Pine rivers to increase wetted habitat and to reduce stranding potential during low flows. Where practical, contouring mainstem bars to minimize potential for fish stranding.	Recommended measures will fully mitigate potential effects	BC Hydro
Operations	Reduced fish health and survival due to fish entrainment	The large and slow-rotating Francis turbines produce high survival relative to other large facilities. Incorporating smooth and gradual transitions at the approach channel, penstock entrances, and tailrace exit structures. Designing the orientation and sizing of all openings and exits to reduce hydraulic turbulence. Completing linings with smooth surface finishing. Reducing obstructions (e.g., boulders) from the turbulent zone in spillway and tailrace areas.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operation	Reduced fish health and survival due to increased total dissolved gas supersaturation	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate to reduce dissolved gas generation. Develop and implement an operational procedure to minimize operation of turbines in water discharge ranges that produce ‘rough load operation’ to reduce total dissolved gas concentration in tailwater.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

Project Phase	Potential Effects	Key Mitigation Measures	Mitigation Effectiveness	Responsibility
Construction	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. A periodic capture and translocation program for small-fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro
Operation	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. A periodic capture and translocation program for small- fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.	Recommended mitigation measures will reduce but not fully mitigate the potential effects of the Project	BC Hydro

12.6 Residual Effects

Table 12.20 summarizes the residual effects after the implementation of mitigation measures describe above. Activities that have residual effects will be carried through the residual effects characterization in the next sections.

Table 12.20 Summary of Residual Effects on Fish and Fish Habitat

Project Phase	Category of Effect	Potential Effect	Potential Residual Effect
Construction	Habitat	Loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection	Yes – potential loss of 215 ha of fish habitat
Construction	Habitat	Loss of habitat due to construction headpond and reservoir filling	Yes – there would be a change in habitat
Operations	Habitat	Altered fish habitat due to transformation of reservoir habitat during reservoir operation	Yes – there would be a change in habitat
Operations	Habitat	Altered fish habitat downstream of Site C Dam	Yes – there would be a change in habitat
Construction	Health and Survival	Reduced fish health and survival due to sediment inputs by dam and generating station construction	Yes – sediment inputs affecting fish health and survival
Construction	Health and Survival	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Yes – sediment inputs affecting fish health and survival
Construction	Health and Survival	Reduced fish health and survival due to Highway 29 realignment and Hudson's Hope shoreline protection	No – mitigation eliminates potential effects
Construction	Health and Survival	Reduced fish health and survival due to fish stranding	No – mitigation eliminates potential effects
Construction	Health and Survival	Reduced fish health and survival due to fish entrainment	Yes – fish would be harmed due to entrainment
Construction	Health and Survival	Reduced fish health and survival due to increased total dissolved gas	Yes – fish would be exposed to TDG during spills
Operations	Health and Survival	Reduced fish health and survival due to fish stranding	No – mitigation eliminates potential effects
Operations	Health and Survival	Reduced fish health and survival due to fish entrainment	Yes – fish would be harmed due to entrainment
Operations	Health and Survival	Reduced fish health and survival due to increased total dissolved gas	Yes – fish would be exposed to TDG during spills
Construction	Movement	Hindered fish movement due to obstruction to fish passage	Yes – hindered fish movement would occur
Operations	Movement	Hindered fish movement due to obstruction to fish passage	Yes – hindered fish movement would occur

Effect on Habitat

Effects to habitat are predicted during the construction phase and operation of the Project. The infrastructure of dam and generating station, the Highway 29 realignment bridge crossings, and the Hudson's Hope shoreline protection will cause a direct loss of fish habitat. The construction headpond and reservoir filling will reduce quality of habitat and culminate in the loss of riverine habitats upstream of the dam. The construction headpond and reservoir filling phase would transform the river ecosystem and create the Site C reservoir. Upstream of the dam, a new and productive aquatic ecosystem and fish community will develop in the reservoir. Existing fish populations that rely on Peace River mainstem habitats to sustain these populations would be negatively affected. Species that are expected to be adversely affected include: Arctic grayling, bull trout, and mountain whitefish. Distinct groups of fish from those species that are expected to be most negatively affected include: adfluvial components of the Moberly River Arctic grayling and Halfway River bull trout populations, as well as Peace River mainstem spawning mountain whitefish. Fish populations that can adapt to habitats available in the Site C reservoir and that can access important habitats needed to sustain the population may be positively affected, including kokanee, lake whitefish, lake trout, burbot, peamouth, and rainbow trout. Existing fish populations that are able to exploit the rapid change in environmental conditions during the reservoir transition (i.e., water quality, water temperature, nutrients, and food) would be positively affected during the transition period. These species include longnose and largescale suckers, redside shiner, lake chub, and peamouth.

Downstream of the Project, incremental changes in habitat will be observed during construction and operation. Limited changes to fish habitat will occur during construction, due to flow changes during diversion and reservoir filling stages. Operation of the dam and generating station would modify the surface water regime, temperature and ice regime, and sediment regime, as well as other physical characteristics of the Peace River aquatic ecosystem, ecological productivity, and fish communities downstream of the dam. Changes to the habitat would be most evident between the Site C Dam and the confluence of the Pine River, and the magnitude of changes would diminish downstream of the Pine River. The aquatic habitat between the dam and the Pine River would provide conditions that support a productive fish community similar to what presently occurs downstream of the Peace Canyon Dam. These same conditions would be unfavourable to other species, primarily due to changes to the flow, water temperature, and sediment regimes. Small-bodied fish, sucker species, burbot, goldeye, northern pike, and walleye might remain in the downstream areas of the Peace River that provide more favourable cool turbid water conditions. Mitigation activities will be effective in reducing the magnitude of effects; however, they will not eliminate them. Residual effects to habitat are therefore carried forward for characterization.

<u>Effects on Health and Survival</u>

Effects to health and survival are predicted to occur during both the construction and operation phase of the Project. Construction activities associated with the dam and generating station, construction headpond, and reservoir filling will cause sediment inputs that would reduce the quality of fish habitat and impair the health and survival of fish. Elevated concentrations of TDG would be generated during the reservoir filling stage of construction, and infrequent use of the dam spillway during the operations phase would create TDG concentrations that would induce GBD in a portion of the fish and aquatic life downstream of the dam (i.e., using depths of less than 2 m). Effects associated with sediment introduction and the creation of elevated levels of TDG would be reduced through proposed mitigation actions, but not eliminated. These effects on health and survival are therefore carried forward to characterization. Water level fluctuations in the headpond during the diversion stage of the construction phase, and in the reservoir and downstream area during operations phase of the Project have the potential to impair the health and survival of fish through stranding, but mitigation measures would be implemented to eliminate potential for residual effects.

Effects on Movement

Effects to fish movement are predicted during both the construction and operation phases of the Project. The construction of the dam will present a barrier that would physically delay or obstruct movements of some fish on the Peace River. Fish species affected may include bull trout and Arctic grayling. In addition, the creation of the reservoir itself may impede movement of fish from tributaries to other habitats in the reservoir or downstream river that are required to fulfill life history requirements. Mitigation actions (i.e., trap and haul) are proposed to reduce effects of impeded movement on bull trout past the dam, but there is uncertainty whether these measures are technically feasible and whether they will be biologically effective for other species such as Arctic grayling.

12.6.1 Characterization of Residual Effects

Characterization of residual effects is based on criteria provided in Table. 12.21.

Table 12.21 Characterization Criteria for Residual Effects on Fish and Fish Habitat

Criterion	Description	Definition of Criteria
Direction	This refers to the ultimate long-term trend of the fish and fish habitat effect	**Negative:** condition of the VC worsens in comparison to baseline condition
		Positive: condition of the VC improves in comparison to baseline condition
Magnitude	This refers to the amount of change in a key indicator or variable relative to baseline case. Consideration is given to factors such as the uniqueness of the effect, and the comparison to natural or background variation.	**Low:** Low: < 15% change in population or life stage abundance or biomass; hinder movement of small portion of the fish population; < 15% alteration/destruction of important fish habitat.
		Moderate: Moderate: 15% to 30% change in population or life stage abundance or biomass; hindered movement of a portion of the fish population; 15% to 30% alteration or destruction of important fish habitat.
		High: High: > 30% change in population or life stage abundance or biomass; hindered movement of ~~a portion of~~ an entire life stage of a fish population; > 30% alteration or destruction of important fish habitat.
Geographical Extent	This refers to the geographic areas in which a fish and fish habitat ~~heritage~~ effect of a defined magnitude occurs	**Site-specific:** discrete area within the immediate vicinity of a specific Project component or activity
		Local: Portion of LAA that includes sub-local geographic extent.
		LAA: Change occurs within entire LAA
Frequency	The number of times during a project or a specific project phase that a fish and fish habitat ~~heritage~~ effect may occur.	**Once:** occurs once
		Frequently: occurs frequently (on a regular basis and at regular intervals, but with extended rest periods
		Continuous: occurs on a regular basis and at regular intervals

Criterion	Description	Definition of Criteria
Duration	The period of time required until the valued component returns to baseline condition, or the effect can no longer be measured or otherwise perceived	**Short term:** effect is limited to ≤ 1 year
		Medium term: effect occurs > 1 year ≤ 8 years (Construction Phase)
		Long-term: effect lasts from >8 years to the life of the Project (Operations Phase)
Reversibility	This refers to the degree or likelihood to which existing baseline conditions can be regained after the factors causing the effect are removed	Effect is **reversible**
		Effect is not reversible
Context	This refers to the extent to which the area within which an effect may occur has already been adversely affected by human activities; and is ecologically fragile and has little resilience and resistance to imposed stresses	**Disturbed:** Area has been substantially previously disturbed by human development or human development is still present
		Undisturbed: Area relatively pristine or not adversely affected by human activity
Level of Confidence	This is an evaluation of scientific certainty one has in the review of project-specific data, relevant literature, and professional opinion	**Low:** Low ability to predict the effect, relative to predicted changes and mitigation effectiveness
		Moderate: Moderate ability to predict the effect, relative to predicted changes and mitigation effectiveness
		High: High ability to predict the effect, relative to predicted changes and mitigation effectiveness
Probability	The likelihood that an adverse effect will occur	**Low:** An effect is unlikely to occur
		High: An effect is likely to occur

Residual effects of the Project on the fish and fish habitat VC are characterized in Table 12.22.

Table 12.22 Characterization of Residual Fish and Fish Habitat Effects

Activity	Potential Effect	Residual Environmental Effect Criteria								
		Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context	Probability	Level of Confidence
Construction										
Dam and generating station construction Highway 29 realignment Reservoir clearing Hudson's Hope shoreline protection	Loss of fish habitat (assumes a permanent effect)	N	L	L	~~H~~L	~~L~~O	I	D	H	H
Construction headpond and reservoir filling	Altered fish habitat	N	H	M	M	~~H~~O	I	D	H	H
Operations										
Reservoir operation	Altered fish habitat in reservoir	N	H	M	L~~H~~	~~H~~O	I	D	H	H
	Altered downstream fish habitat	N	L	M	L~~H~~	~~H~~O	I	D	H	H
Construction										
Dam and generating station construction	Reduced fish health and survival due to sediment inputs	N	M	M	M	~~M~~F	R	D	H	H
Construction headpond and reservoir filling	Reduced fish health and survival due to sediment inputs	N	M	M	M	~~H~~O	I	D	H	H
Reservoir filling	Reduced fish health and survival due to fish entrainment	N	L	M	M	~~M~~F	I	D	H	M
	Reduced fish health and survival due to increased total dissolved gas	N	L	M	~~L~~S	~~L~~O	R	D	H	H
Operations										
Reservoir operations	Reduced fish health and survival due to downstream fish entrainment	N	L	M	~~H~~L	~~M~~F	I	D	H	M
	Reduced fish health and survival due to increased total dissolved gas	N	L	M	~~L~~S	~~L~~F	R	D	H	H

Activity	Potential Effect	Residual Environmental Effect Criteria								
		Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context	Probability	Level of Confidence
Construction										
Dam and generating station	Hindered fish movement due to obstruction to fish passage	N	H	M	M	F~~M~~	I	D	H	M
Operation										
Dam and generating station	Hindered fish movement due to obstruction to fish passage	N	H	M	L~~H~~	F~~M~~	I	D	H	M

12.6.2 Standards or Thresholds for Determining Significance

The significance of each residual effect is evaluated taking into consideration the criteria provided in Table 12.22, existing knowledge about the fish and fish habitat, and the likely effectiveness of mitigation. A significant residual affect is assigned if the Project component or activity is predicted to result in either:

a) the loss of an indigenous fish species, sub-species, populations, or distinct groups or,

b) a reduction in the long-term average standing stock biomass of the fish community relative to the existing baseline condition

Threshold criteria for establishing significance of residual effects were selected to be consistent with priorities of the B.C. Freshwater Fisheries Program Plan (BCMOE 2007) and Conservation Framework (BCMOE 2009), and to align with the goals of federal regulatory direction on conservation of fish species and protection of the productivity of fish, fish habitat and fisheries through the *Species at Risk Act*, and the *Fisheries Act*.

The key goals of the British Columbia Freshwater Fisheries Management Program (BCMOE 2007) are to conserve wild fish and their habitats, and to optimize recreational opportunities based on the freshwater fisheries resources. Significance criterion “a” is consistent with the conservation goal. Significance criterion “b” is consistent with the goal of supporting long-term recreational opportunities. The provincial Conservation Framework provides an approach for resource managers to prioritize the conservation of species and ecosystems in British Columbia (BCMOE 2009). The goals of the conservation framework are: 1) to contribute to global efforts for species and ecosystems conservation, 2) to prevent species and ecosystems from becoming at risk, and 3) to maintain the full diversity of native species and ecosystems. Significance criterion “b” is consistent with these goals.

Federal goals for conservation and protection of the productivity of fish and fish habitat are found in the *Species at Risk Act* and the *Fisheries Act*, respectively. The *Species at Risk Act* provides useful regulatory context and objectives for supporting the conservation of wild fish populations (i.e., criterion “a” above). The intent of the *Species at Risk Act* is to prevent loss of indigenous species of wildlife in Canada and to prevent species of special concern from becoming extirpated, endangered, or thoureatened. Currently there are no fish species in the Peace River listed under the provisions of the *Species at Risk Act*; therefore, the criterion “a” is intended to provide an objective threshold for assessing the degree to which conservation goals of preventing species from becoming at risk.

The provisions of the *Fisheries Act* provide mechanisms to allow development of projects to occur while providing for the protection of fish and fish habitat. Criterion “b” acknowledges the public interest in fish and fish habitat, in particular, the interest in maintaining long-term productive capacity of fish habitats and, accordingly, the societal benefits of recreational, commercial, and Aboriginal fisheries. The productive capacity of freshwater fisheries habitats can be maintained or improved through: maintenance of the current productive capacity of habitats, restoration of damaged fish habitats, and development of new habitats. The Project will result in a transformation of fish habitat conditions and potentially alter the productive capacity of fish habitats in the Peace

River. Criterion "b" above is therefore intended to provide an objective threshold for assessing the degree to which the goal of maintaining long-term productive capacity of fish and fish habitat is achieved.

12.6.3 Determination of Significance of Residual Effects

A summary of the potential effects, mitigation, and significance of residuals effects are presented in Table 12.23.

Table 12.23 Summary of Assessment of Potential Significant Residual Adverse Effects on Fish and Fish Habitat

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Loss of fish habitat due to construction of dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection	Implement Fish and Aquatic Habitat Management Plan (Volume 5 Section 35 Summary of Environmental Management Plans) A 15 m riparian buffer will remain adjacent to watercourses during reservoir clearing Material relocation sites (R5a, R5b, and R6) will be relocated 15 m back from the high water level to avoid affecting Peace River fish habitat. Material relocation sites upstream of the dam will incorporate fish habitat into the final capping design. The spoil area will be contoured and capped with gravels and cobble substrate between elevations 455 m and 461 m to provide productive fish habitat that will be available to fish during the operation phase. Fish habitat features (shears, large riprap point bars, etc.) will be designed in the final design of the north bank haul road bed material that would be placed in the Peace River. Fish habitats affected by Highway 29 watercourse crossings will be compensated in the vicinity of the habitat loss. Fish habitat features will be incorporated into the final designs of the watercourse crossings.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
		Disturbed riparian areas will be replanted with local vegetation. The Highway 29 roadway that would border the reservoir, east of Lynx Creek, will also have fish habitat features incorporated into the final design of the footprint. The Hudson's Hope shoreline protection will be constructed of large material that will provide replacement fish habitat. Additional fish habitat features (e.g., shear zones and point bars) will be incorporated into the final design of the Hudson's Hope berm. Construction footprints are being finalized to reduce the size of the construction footprint. Temporary structures will be removed as soon as they are no longer required.			
Construction	Loss of habitat due to construction headpond and reservoir filling	Highway 29 borrow sites will be located between the Peace River and the future reservoir shoreline. Borrow sites that are located in the littoral zone of the reservoir will be contoured prior to decommissioning to provide gravel/cobble littoral fish habitat. Material repositioning areas will be capped with gravels and cobbles and contouring will be undertaken to enhance fish habitat conditions. A 15 m wide riparian area will be planted along the reservoir shoreline adjacent to BC Hydro-owned farmland to provide riparian habitat and bank stabilization.	Yes	No	Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Operations	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	The Site C reservoir operation has been designed to have a minimal reservoir elevation fluctuation during operation of 1.8 m, which minimizes the effects to the shoreline (littoral) fish habitat. Compensation options that are technically and economically feasible will be implemented.	No	No	Not Significant
Operations	Altered fish habitat downstream of Site C Dam	The enhancement of side channel complexes (e.g., Old Fort) in the reach between the dam site and the confluence of the Peace and Pine rivers to increase wetted habitat during low flows. Creation of wetted channels and back channel restoration on the south bank island downstream of the dam to create off channel and back channel habitat.	No	No	Not Significant
Construction	Reduced fish health and survival due to sediment inputs by construction of dam and generating station, Highway 29 realignment, and Hudson's Hope shoreline protection	Erosion prevention and sediment control plan (in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of standard preventive measures such as silt fences or other erosion prevention materials Dust control plan (Air Quality Management Plan Volume 5 Section 35 Summary of Environmental Management Plans). Measures include use of dust suppression techniques to prevent airborne deposition into water bodies. Surface water quality management plan (Section 35.2.21 Surface Water Quality Management Plan in Volume 5 Section 35 Summary of Environmental Management Plans). Measures include control, management, and treatment of surface runoff. Adjust the timing construction activities to coincide with	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
		periods of high background sediment levels where feasible. Select clean rock materials or wash rock materials for riprap construction to minimize the amount of sediments that are introduced into the aquatic environment. Reduce equipment production rates to reduce the amount of sediments generated by equipment where required.			
Construction	Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling	Berm or cap areas with high potential to produce sediments. During reservoir clearing, stumps in the headpond area will be left in place to reduce soil disturbance and potential sedimentation issues where feasible. Soil disturbance during reservoir clearing will be minimized by clearing in winter where feasible.	Yes	No	Significant
Construction	Reduced fish health and survival due to fish entrainment	Large diameter diversion tunnels and associated hydraulics that provide low risk of fish mortality. Incorporating smooth and gradual transitions from the round tunnels to the square exits. Completing tunnel linings with a smooth concrete surface finish. Reducing any obstructions (e.g., boulders) in the tunnel tailrace area. Operating the modified diversion tunnel for a short duration, as described in Volume 1 Appendix B Reservoir Filling Plan.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Reduced fish health and survival due to increased total dissolved gas	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to minimize the number of hold points, and the duration of the reservoir filling and turbine commissioning.	No	No	Not Significant
Operations	Reduced fish health and survival due to fish entrainment	The large and slow-rotating Francis turbines produce high survival relative to other large facilities. Incorporating smooth and gradual transitions at the approach channel and penstock entrances and tailrace exit structures. Designing the orientation and sizing of all openings and exits to reduce hydraulic turbulence. Completing linings with smooth surface finishing. Reducing obstructions (e.g., boulders) from the turbulent zone in spillway and tailrace areas.	No	No	Not Significant
Operation	Reduced fish health and survival due to increased total dissolved gas supersaturation	Modify spillway design to reduce total dissolved gas generation. Develop and implement an operational procedure to initiate spillway discharge operations through multiple gates to reduce the rate of discharge at each gate to reduce dissolved gas generation. Develop and implement an operational procedure to minimize operation of turbines in water discharge ranges that produce ‘rough load operation’ to reduce total dissolved gas concentration in tailwater.	No	No	Not Significant

Project Phase	Potential Effect	Key Mitigation Measures	Result in Loss of Distinct Fish Group (criterion a)	Reduction in Long-Term Net Biomass (criterion b)	Significance Analysis of Residual Effects
Construction	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. A periodic capture and translocation program for small-fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.	Yes	No	Significant
Operations	Hindered fish movement due to obstruction to fish passage	Upstream fish passage during operations will be provided by a trap and haul facility. A periodic capture and translocation program for small-fish species will be implemented, contingent on the results of investigative studies into the genetic exchange requirements of upstream and downstream populations.	Yes	No	Significant

12.6.3.1 Discussion of the Significance of Residual Adverse Effects

This assessment was structured to determine the potential of the Project to have an adverse effect on the fish and fish habitat VC. To accomplish this, the assessment was structured to evaluate how categories of effects on the VC (habitat, health and survival, and movement) would be affected by the activities within each phase (Construction and Operation) of the Project. Table 12.24 provides a summary of significant and non-significant residual effects evaluated for each category of effect across the construction and operation phases of the Project. Residual effects have been predicted for each of the three categories of effects on fish and fish habitat. These effects are briefly discussed below.

Table 12.24 Summary of Residual Effects During Construction and Operation Phases of the Project (Significant Residual Effects in Boldface Type)

Category of Effect	Construction Phase	Operations Phase
Habitat	Loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection Loss of habitat due to construction headpond and reservoir filling	Altered fish habitat due to transformation from river to reservoir habitat Altered fish habitat downstream of Site C Dam
Health and Survival	Reduced fish health and survival due to sediment inputs by dam and generating station construction Reduced fish health and survival due to sediment inputs from construction headpond and reservoir filling Reduced fish health and survival due to fish entrainment Reduced fish health and survival due to increased total dissolved gas	Reduced fish health and survival due to fish entrainment Reduced fish health and survival due to increased total dissolved gas
Movement	Hindered fish movement due to obstruction to fish passage	Hindered fish movement due to obstruction to fish passage

<u>Effect on Habitat</u>

The Project has the potential to affect fish habitat in locations upstream and downstream of the Site C Dam site. Changes to habitat upstream of the dam site would begin during construction phase (loss of habitat due to construction of the dam and generating station, Highway 29, and Hudson's Hope shoreline protection; loss of habitat due to construction headpond and reservoir filling) and a complete alteration of habitat would occur once the reservoir is filled. The residual effects resulting from habitat loss due to the construction headpond and reservoir filling would be adverse and significant, because they would be sufficient to reduce the abundance of fish populations in the river over the spatial extent of the headpond during the diversion period, and would result in an irreversible loss of key riverine habitats required for some distinct groups of fish when the reservoir is filled. Following the construction phase of the Project, a new reservoir ecosystem will develop over time and support a new diverse and productive fish community. The new ecosystem is predicted to support equal or greater levels of long-term standing stock biomass of fish populations, and is expected to change the relative species composition. The change in species composition cannot be reliably predicted with existing information, but it would favour species or distinct groups that persist by exploiting reservoir habitat conditions. The residual change in habitat resulting from operations would not be significantly adverse because the future operation of the reservoir would not result in additional habitat alteration that would either reduce productivity or result in loss of additional distinct groups of fish.

Operation of the Project will result in modest changes to fish habitat downstream of the dam. These changes to habitat have been assessed to be of low magnitude and limited in the proximal reach of the Peace River between the Project and the Pine River confluence. Downstream of the Pine River, changes diminish as a result of flow attenuation and tributary inflows. The changes to habitat would include increases in the range of flow fluctuations, and limited changes to temperature and water quality. These changes are not large enough to cause a loss in distinct groups of fish or to result in a reduction in the long-term standing stock biomass of downstream fish populations. The cool turbid water fish species that inhabit the Peace River would be able to complete their entire life histories downstream of the Project and would not be significantly affected by the Project.

Effects on Health and Survival

The Project has the potential to affect the health and survival of fish in the Peace River due to: 1) suspended sediment inputs resulting from dam and generating station construction, 2) suspended sediment inputs resulting from construction headpond and reservoir filling, 3) entrainment, and 4) exposure to increased dissolved gas concentrations. Suspended sediment inputs resulting from construction of the dam and generating station will cause adverse residual effects, but will not be significant because they are not of sufficient magnitude to either result in the loss of distinct groups of fish or to reduce long-term standing stock biomass of fish. However, suspended sediment inputs resulting from the construction headpond and reservoir filling would be of sufficient magnitude and duration to cause significant adverse effects. These effects would contribute to the loss of distinct groups of fish that exclusively inhabit existing clear water habitats, use the Peace River in the region that would be transformed into reservoir and immediately downstream of the dam. Effects on health and survival resulting from entrainment and total dissolved gas exposure in shallow water will occur during the construction and operation phase, but will not be significant because they are not of sufficient magnitude to either result in the loss of distinct groups of fish or to reduce long-term standing stock biomass of fish.

Effects on Movement

The Project has the potential to affect fish movement in the Peace River and movements to tributaries upstream of the Site C Dam site during the construction and operation phases. The habitat changes from the construction headpond and reservoir creation may alter the movement patterns of fish that are not adapted to reservoir habitats such are Arctic grayling. As well, upstream fish movement will be hindered at the dam site. This effect on fish movement is significant because it contributes to the loss of distinct groups of fish.

12.6.3.2 Conclusion

Based on criteria “a”, the project is predicted to have a significant adverse effect on the fish and fish habitat VC as a result of the potential for the loss of indigenous fish populations or distinct groups of fish. The three distinct groups of fish that may be lost are the adfluvial component of the Moberly River Arctic grayling, migratory (adfluvial) bull trout that spawn in the Halfway River, and mountain whitefish that rear in the Peace River and spawn in tributaries of the Peace River or the Peace River mainstem upstream of the Site C Dam site. The loss of these distinct groups occurs because of loss of river habitat, reduced fish health and survival during construction and reservoir filling, and hindered fish movement. Although these distinct groups will be affected, the species as a whole of Arctic grayling, bull trout and mountain whitefish will continue to be present in Peace River tributaries and downstream of the reservoir and may persist in the reservoir. These distinct groups include:

Moberly Arctic Grayling: The most prominent of these three groups is the Arctic grayling that spawn in the Moberly River and rear in the Peace River in proximity to the construction headpond and reservoir, and immediately downstream of the project. Peace River Arctic grayling populations have been demonstrated to be sensitive to changes in habitat conditions, particularly those related to the transformation of riverine habitats to reservoirs. The loss of distinct groups of Arctic grayling in the upper Peace River watershed was observed following the construction of the Williston Reservoir. As a result, the maintenance of distinct groups of Arctic grayling in the Peace watershed is a species conservation concern. Arctic grayling are abundant in other Peace River tributaries, which may provide recruitment to the Peace River.

<u>Halfway River Bull Trout</u>: Bull trout that spawn in the Halfway River watershed and rear in the Peace River maybe affected by reservoir creation, and have their movements impeded by the dam. Bull trout that spawn in the Halfway River watershed have two life histories (which form two distinct groups): 1) a migratory life history that rear in the Peace River (i.e., an adfluvial or large river rearing life history), and a resident life history that rear entirely in the Halfway watershed. The migratory life history may rear in the reservoir or continue downstream to rear in the Peace River, downstream of the dam site. There is uncertainty regarding how Halfway River migratory bull trout will inhabit the reservoir; however, evidence from modelling and from other reservoirs in B.C. and elsewhere suggest that bull trout are resilient to this type of habitat change. There is uncertainty in the extent to which bull trout will continue to migrate downstream past the dam site, and whether upstream passage mitigation at the Site C Dam site will be required for bull trout. Given the habitat available in the reservoir, the potential available habitat downstream of the dam site, and the potential for fish passage, the probability of loss of the migratory component of the Halfway bull trout population is low.

<u>Mountain Whitefish</u>: Mountain whitefish are abundant in the Peace River and its tributaries. Mountain whitefish are not adapted to reservoir habitats, which creates a risk for the loss of distinct groups of mountain whitefish that rear in the Peace River and spawn in the Peace River mainstem or tributaries upstream of the Site C Dam.

Based on criteria “b”, the Project is not predicted to have a significant adverse effect on the fish and fish habitat VC as a result of a reduction in the long-term average standing stock biomass of the fish community relative to the existing baseline condition. Short-term reductions in standing stock biomass are predicted to occur during the construction phase. Over the long term, standing stock biomass in the reservoir and Peace River downstream of the Project in the LAA is predicted to be equal to or greater than baseline conditions.

12.7 Cumulative Effects Assessment

The list of projects and activities in the cumulative effects assessment (Table 10.7 in Section 10.7 in Volume 2 Section 10 Effects Assessment Methodology) were reviewed to determine which projects are within the Projects RAA, to assess whether their residual effects extend into the Project’s LAA, and if there would be an overlap in residual effects. The review identified two projects and activities that lie in the Regional Assessment Area for fish and fish habitat where there might be overlap in residual effects (Table 12.24). These project include the Dunvegan Hydroelectric Facility on the Peace River 187 km downstream of the Project, and the Montney Gas Play, which encompasses the northern part of the Peace River watershed from the east slopes of the mountains east into Alberta.

Table 12.25 Other Projects/Activities that Lie with the Regional Assessment Area

Project/Activity	Location	Description
Dunvegan Hydroelectric Project	187 km downstream of the Project near the Highway 2 Bridge crossing	100 MW run-of-river hydro project on Peace River near Dunvegan, Alberta. Project components include a spillway and powerhouse across the Peace River to increase the water level in the river at the headworks by an average of 6.6 m. Headpond would extend up to 26 km upstream of powerhouse and spillway. Permitted, but not constructed.
Montney Gas Play	Northeast B.C. – Fort St. John area and western Alberta	Shale rock deposit containing large quantities of natural gas. Includes multiple projects and activities. Exploration, extraction, processing, and transport (pipeline and truck) currently underway. Expansion of development activities to continue into the foreseeable future.

The Dunvegan Project assessment concluded that a significant residual effect would be restricted to the local project area and limited to three fish species. Dunvegan's local area residual effect is limited to the headpond area, 161 km downstream of the Site C Dam site. Site C has no overlapping residual effects with the Dunvegan Project.

The Montney Gas Play could have point source effects on fish and fish habitat in tributaries to the Site C LAA. However, based on the limited interactions that natural gas exploration has with watercourses, it is anticipated that gas exploration would not interact with Site C residual effects. Therefore, there would be no cumulative effects.

12.8 Follow-Up Programs

In accordance with Section 23.5 of the EIS Guidelines, follow-up programs would be required to verify the accuracy of the effects assessment and to determine the effectiveness of the measures implemented to mitigate the adverse effects of the project on fish and fish habitat. A summary of the follow-up programs is provided in Table 12.26~~5~~ below.

A fish and fish habitat follow-up plan would be implemented to address key uncertainties about the accuracy of effects assessment and the effectiveness of mitigation. The follow-up program will be implemented as a phased approach to match three discrete time periods associated with the Project. These include:

Construction period (eight years)

The reservoir transformation period following reservoir filling (15 years)

The reservoir post-transformation period (15 years)

The scope of the program would be to address:

Uncertainty in effects assessment in each stage

Uncertainty in mitigation effectiveness

Uncertainty in both effect and mitigation effectiveness

The plan would be to include provisions to address five key uncertainties:

Effectiveness of environmental protection measures undertaken during construction to mitigate effects on fish and fish habitat

Effects of total dissolved gas supersaturation on the health and survival of fish

Effects of the dam on the movement of fish

The effects of river to reservoir transformation on fish and fish habitat

The effect of altered flow regime on fish and fish habitat in the river downstream of the dam

Following reservoir filling and commencement of operation, follow-up monitoring will be required to test the hypothesis used to predict the temporal development of the new reservoir, and changes in the downstream river physical environment and productivity. Follow-up monitoring would be organized in four discrete programs:

1. Fish and fish habitat productivity monitoring program for reservoir and reservoir tributaries

Fish and fish habitat productivity monitoring program for downstream Peace River

Fish passage management program

Total dissolved gas monitoring program

The information collected during the follow-up monitoring programs will be used to verify assessment predictions. Depending on the verification, additional adaptive programs may be required including:

Confirm specific adaptive management plans based on follow-up monitoring results

Implement directed studies to address specific uncertainties (e.g., what is the kokanee population in the reservoir?)

As part of the habitat compensation program, funding will be available to verify uncertainty in the effects and will be used on technically feasible, cost-effective, and environmentally sound projects to compensate for unforeseen adverse effects

Table 12.26 Follow-up Monitoring Programs for Fish and Fish Habitat

Project Phase	Category of Effect	Potential Effect	Follow-Up Program
Construction	Habitat (Residual)	Loss of habitat due to construction of the dam and generating station, Highway 29 and Hudson's Hope shoreline protection	Construction Environmental Monitoring Program Habitat Compensation Program
Construction	Habitat (Residual)	Altered fish habitat due to construction headpond and reservoir filling	Habitat Compensation Program
Operations	Habitat (Residual)	Altered fish habitat due to transformation of reservoir habitat during reservoir operations	Fish and Fish Habitat Productivity Monitoring Program (Reservoir) Habitat Compensation Program
Operations	Habitat (Residual)	Altered fish habitat downstream of Site C Dam	Fish and Fish Habitat Productivity Monitoring Program (River) Habitat Compensation Program
Construction	Health and Survival (Not Residual)	Reduced fish health and survival due to stranding in construction headpond	Construction Headpond Fish Salvage and Monitoring Program
Construction	Health and Survival (Residual)	Reduced fish health and survival due to fish entrainment	Fish Passage Management Program
Construction	Health and Survival (Residual)	Reduced fish health and survival due to increased total dissolved gas	Total Dissolved Gas Monitoring Program
Operations	Health and Survival (Residual)	Reduced fish health and survival due to fish entrainment	Fish Passage Management Program
Operations	Health and Survival (Residual)	Reduced fish health and survival due to increased total dissolved gas	Total Dissolved Gas Monitoring Program
Construction	Movement (Residual)	Hindered fish movement due to obstruction to fish passage	Fish Passage Management Program
Operations	Movement (Residual)	Hindered fish movement due to obstruction to fish passage	Fish Passage Management Program

Site C fish and fish habitat baseline study designs were developed with follow-up monitoring in mind. Follow-up fish and fish habitat productivity monitoring programs would use established sampling methodology and sampling site locations in the Peace River and tributaries for consistency. Specific sampling designs would be developed for individual reservoir studies.

The environmental monitoring and follow-up program details and reporting requirements will be part of the *Fisheries Act* 35 (2) Authorization.

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