4.4 Fish and Fish Habitat Assessment Highlights:

- The proposed bridge will have a clear span over the Fraser River South Arm and Deas Slough, avoiding or minimizing Project-related effects on fish and fish habitat.
- The small area of fish habitat affected by the Project will be offset or improved by proposed habitat enhancements, including restoring Green Slough to its historic alignment, resulting in a net environmental benefit for fish and fish habitat.
- Mitigation, including timing windows for undertaking in-stream works and other measures outlined in Project-related Environmental Management Plans, will ensure that potential effects on fish and fish habitat are effectively addressed.
- Given the disturbed nature of much of the Project alignment, revegetation and restoration of areas within the Project alignment, including under the new bridge and adjacent to relocated ditches, represents an opportunity to provide a net improvement to ecological conditions. The productive capacity of local ecosystems will be enhanced by:
  - Improvements to local water quality through Project-related improvements in stormwater management
  - Removal of non-native species
  - Replanting with species that provide habitat value for fish and wildlife.
- No significant Project-related residual or cumulative effects on fish and fish habitat are expected.

4.4 Fish and Fish Habitat Assessment

This section presents the results of the assessment of potential Project effects on fish and fish habitat and includes the rationale for selecting fish and fish habitat as a valued component (VC), identification of Project-related effects, proposed approaches to mitigation, and evaluation of residual Project-related and cumulative effects. Monitoring to be conducted with respect to fish and fish habitat is also described.

Project-related changes in other environmental components along the pathway of effects of the Project–specifically, river hydraulics and morphology, sediment and water quality, and underwater noise–have the potential to affect fish and fish habitat. These intermediate components (ICs) and potential effects of the Project on them are discussed in the following sections: **Section 4.1 River Hydraulics and River Morphology**, **Section 4.2 Sediment and Water Quality**, and **Section 4.3 Underwater Noise**.

4.4.1 Context and Boundaries

This section describes the context for assessment of Project-related effects on fish and fish habitat in terms of Project setting, and defines the assessment boundaries. Rationale for selecting the assessment boundaries as defined is also provided.

4.4.1.1 Assessment Context

The lower Fraser River and estuary provide habitat for fish species of high ecological, social, cultural, and commercial value. Fish species important to the viability of commercial, recreational, and Aboriginal (CRA) fisheries[1] include salmonids (family Salmonidae), eulachon (*Thaleichthys pacificus*), and sturgeon (*Acipenser* spp.). Salmonids use the lower Fraser River during adult spawning migration, and juvenile outmigration to marine environments. Juvenile salmonids and sturgeon rear and overwinter in brackish habitats. Eulachon migrate upstream to spawning habitats in the lower Fraser River and the mouths of large tributaries. Additional information supporting the selection of fish and fish habitat as a VC is provided in **Section 3.1 Issues Scoping and Selection of Valued Components**.

4.4.1.2 Methodology

The assessment of fish and fish habitat follows the general methodology described in **Section 3.0 Assessment Methodology** and applied to all VCs. Building on this approach, the assessment of fish and fish habitat was designed to focus on specific species considered most appropriate in the context of existing conditions in the Project alignment. In this context, the assessment of fish and fish habitat focuses on five sub-components as presented in **Table 4.4-1**. Life history requirements and status of sub-components are summarized in **Section 4.4.2.3** and described in detail in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

[1] As defined under the *Fisheries Act* R.S.C. 1985, c. F-14 (as amended on February 26, 2015), “commercial” in relation to a fishery, means that fish is harvested under the authority of a licence for the purpose of sale, trade or barter;, “recreational”, in terms of a fishery, means that fish is harvested under the authority of a licence for personal use of the fish or for sport; and “Aboriginal”, in relation to a fishery, means that fish is harvested by an Aboriginal organization or any of its members for the purpose of using the fish as food, for social or ceremonial purposes or for purposes set out in a land claims agreement entered into with the Aboriginal organization;

Table 4.4-1 Sub-components for Fish and Fish Habitat

Sub-component	Rationale for Selection
Salmon Chinook salmon Chum salmon Coho salmon Pink salmon Sockeye salmon	Pacific salmon are important to Aboriginal Groups and are also harvested commercially and recreationally. Pacific salmon and their habitat are managed by DFO under the *Fisheries Act* and are listed within the B.C. Conservation Framework with a goal of preventing the species from becoming at risk.
Sturgeon Green sturgeon White sturgeon	Sturgeon are protected under the *Fisheries Act* and are of traditional importance to Aboriginal Groups. White sturgeon support a Fraser River catch-and-release recreational fishery. They are also important for conservation. White and green sturgeon are listed as Endangered and of Special Concern, respectively, under *SARA* Schedule 1, and both are provincially Red-listed.
Eulachon	Eulachon are protected under the *Fisheries Act* and are of traditional importance to Aboriginal Groups. Eulachon are also important for conservation as they are provincially Blue-listed and designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).
Trout Coastal cutthroat trout Rainbow/steelhead trout	Trout are protected under the *Fisheries Act,* are of importance to Aboriginal Groups, and support recreational fisheries in the Fraser River. Coastal cutthroat trout are also important for conservation as they are provincially Blue-listed.
Char Dolly Varden Bull trout	Char are protected under the *Fisheries Act* and are of traditional importance to Aboriginal Groups. Char support recreational fisheries in the Fraser River. Bull trout are also important for conservation as they are provincially Blue-listed and designated as Special Concern by COSEWIC.

Likelihood of injury or mortality, and change in habitat conditions were used as indicators to assess fish and fish habitat trends within the assessment area and evaluate potential Project-related effects. The indicators chosen for the assessment of Project-related effects on fish and fish habitat and the rationale for their selection are presented in **Table 4.4-2**.

Table 4.4-2 Indicators for Fish and Fish Habitat

Indicator	Rationale for Selection
Likelihood of injury or mortality of fish	This indicator will be used to assess Project-related physical injury or direct mortality to fish. Causing death of fish is prohibited under the *Fisheries Act* based on the definition of serious harm to fish. Killing or harming of listed fish species is prohibited under *SARA.*
Total suspended solid (TSS) levels (mg/L) and Turbidity (nephelometric turbidity units (NTU))	This indicator will be used to assess the potential for physical injury or direct mortality to fish resulting from from elevated TSS levels, and changes in fish habitat quality from induced turbidity. Increase in TSS and turbidity levels will be evaluated against Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2002) and B.C. *Approved Water Quality Guidelines* 2006 Edition (B.C. MOE 2006*a*).
Underwater sound levels (SPL_{peak} and SEL_{cum})	This indicator will be used to assess Project-related physical injury (including direct mortality) to fish, and changes in fish habitat quality associated with elevated underwater sound levels. Increase in underwater sound levels will be evaluated against the Fisheries Hydroacoustic Working Group (2008) thresholds and the B.C. Marine and Pile Driving Contractors Association (2003) thresholds, as recommended by DFO.
Loss of habitat area (ha)	This indicator will be used to assess Project-related changes in habitat availability. Permanent alteration or destruction of fish habitat is defined and governed under the *Fisheries Act*, based on the definition of serious harm to fish.

4.4.1.3 Assessment Boundaries

Spatial and temporal boundaries identified for the assessment of Project-related effects on fish and fish habitat and the rationale for selecting them are discussed below. No political, economic, or social constraints that could impose limitations on the assessment of potential Project-related effects on fish and fish habitat, or accessibility constraints or gaps in data that could limit the ability to predict the effects of the Project were identified; therefore administrative and technical boundaries have not been defined for this VC and are not discussed further.

Spatial Boundaries

The local assessment area (LAA) and regional assessment area (RAA) for fish and fish habitat are defined in **Table 4.4-3** and shown in **Figure 4.4-1**.

Table 4.4-3 Spatial Boundary Definitions for Fish and Fish Habitat

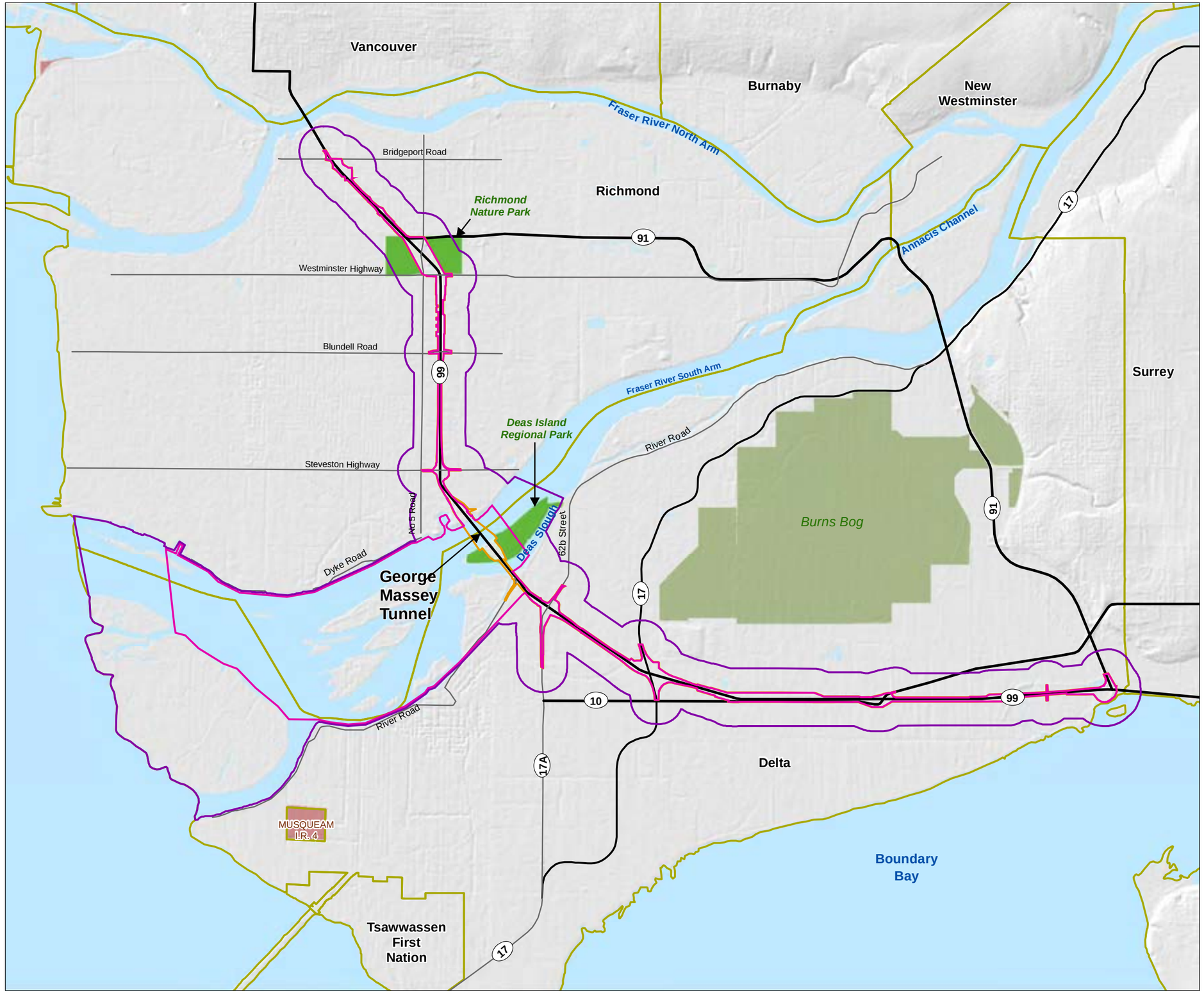
Spatial Boundary	Description of Assessment Area
Local Assessment Area (LAA)	Fraser River South Arm extending from approximately the middle of Shady Island to 500 m upstream of the Project alignment, and Project alignment plus 30 m on either side of the Project alignment in upland areas.
Regional Assessment Area (RAA)	Section of the Fraser River South Arm (including Canoe Pass) extending from the river mouth to 1,000 m upstream of the Project alignment, and Project alignment plus 500 m on either side of the Project alignment in upland area.

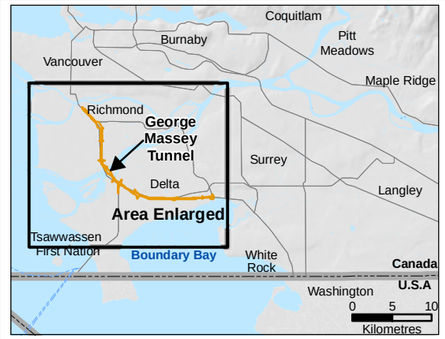
The LAA was established to encompass the area within which the Project is expected to most likely interact with, and potentially have an effect on, fish and fish habitat. In determining the LAA boundaries, consideration was given to the nature and characteristics of fish and fish habitat, potential exposure of fish and fish habitat to various influences (e.g., elevated total suspended solids (TSS), underwater noise), and the maximum extent of potential Project-related effects on fish and fish habitat.

The RAA was established to provide a regional context for the assessment of Project-related effects. The RAA was also established to encompass the area within which the residual effects of the Project on fish and fish habitat may combine with the effects of other projects and activities to result in potential cumulative effects.

Temporal Boundaries

The temporal boundaries for the assessment of fish and fish habitat include the existing conditions of the LAA and RAA, the Project construction phase (including decommissioning of the Tunnel), and the Project operations phase (i.e., the new bridge and upgraded highway in operation). Temporal characteristics of the Project's construction phase, including decommissioning of temporary construction-related facilities, and the operations phase are defined in **Section 1.1 Description of Proposed Project**.





Legend

- Fish and Fish Habitat Local Assessment Area
- Fish and Fish Habitat Regional Assessment Area
- Project Alignment
- First Nation Reserve
- Municipal Boundaries
- Burns Bog Ecological Conservancy Area
- Waterbody
- Canada - U.S. Border
- Highway
- Arterial/Collector Road

SOURCES

Parks and Protected Lands, First Nations Reserves from GeoBC, United States basemap data courtesy of USGS. Burns Bog courtesy of The Corporation of Delta and based on the Metro Vancouver Burns Bog Ecological Conservancy Area Management Plan - May 2007, all other data courtesy of Canvec - GeoGratis.

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GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

FISH AND FISH HABITAT
LOCAL AND REGIONAL ASSESSMENT AREAS

Figure 4.4-1	14/07/2016

George Massey Tunnel Replacement Project | BC JOBS PLAN | B.C. on the Move

Path: O:\21\7-299285\07\03\mxd\FishEA\Fig4-4-1_285_077_03_EA_Fish_AA_160714_FINAL.mxd

Project-related construction activities are likely to occur during sensitive life periods of sub-components. For juvenile fish (e.g., Pacific salmon and white sturgeon), these life periods include rearing, foraging, and overwintering. For adult fish, sensitive periods include adult spawning migration (e.g., Pacific salmon and eulachon).

4.4.2 Existing Conditions

This section provides an overview of the methodology for collecting baseline data, and describes the existing conditions of fish and fish habitat within the assessment areas. An overview of the regulatory context for management of fish and fish habitat as relevant to the Project is also provided.

4.4.2.1 Baseline Data Collection

In 2014, the Ministry initiated studies on fish and fish habitat to support Project planning and assessment. Building on available information, these studies were designed to address known data gaps. Desktop and field studies conducted with respect to fish and fish habitat are summarized in **Table 4.4-4**.

Table 4.4-4 Desktop and Field Studies Related to Fish and Fish Habitat

Study Name	Purpose of Study
Desktop literature review	• Determine fish habitat values and fish species use of watercourses within the study area • Identify key data gaps and areas of uncertainty within the study area
Freshwater fish sampling	• Verify and update available information on fish species use of watercourses within the study area, focusing on data gaps
Fish habitat assessment	• Assess the quality of fish habitat in watercourses within the study area, focusing on data gaps

In addition, the results of modelling conducted to evaluate potential Project-related changes to river hydraulics and morphology (see **Section 4.1 River Hydraulics and River Morphology**) and underwater noise using a Marine Operations Noise Model (see **Section 4.3 Underwater Noise**) were used to assess potential effects of the Project on fish and fish habitat.

Information provided by Aboriginal Groups during pre-Application consultation has been provided, where applicable, in the discussion of existing conditions.

Given that existing conditions and trends of fish and fish habitat in the lower Fraser River are well -known, field sampling efforts focused on channelized watercourses along existing highway infrastructure (referred to hereafter as upland ditches, for sake of consistency) where fish presence and fish habitat values are less well studied and less documented. Fish and fish habitat sampling was conducted in watercourses that parallel or intersect the Highway 99 right-of-way (ROW) within the LAA. Descriptions of fish and water quality sampling, aquatic habitat assessment methods, data management and analysis are provided in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

Based on the results of the desktop and field studies, watercourses within the LAA were classified for the purposes of this assessment based on CRA fisheries values as follows:

- Red: year-round habitat for CRA or listed fish species
- Dashed-red: seasonal (e.g., overwintering) habitat for CRA or listed fish species
- Orange: significant upstream source of food or nutrients to Red or Dashed-red habitat
- Yellow: non-CRA fish bearing and with no value to CRA or listed fish species
- Green: no value for fish (CRA, listed, or other fish species)

4.4.2.2 Regulatory Context

Regulation and management of fish and fish habitat in B.C. occurs primarily through the following federal and provincial legislation:

- Federal *Fisheries Act*, R.S.C. 1985, c. F-14 (as amended on February 26, 2015)
- Federal *Species at Risk Act* (*SARA*), S.C. 2002, c. 29
- B.C. *Water Sustainability Act*, SBC 2014, c. 15
- B.C. *Wildlife Act*, RSBC 1996, c. 488

The *Fisheries Act*, administered by Fisheries and Oceans Canada (DFO), protects the ongoing productivity and sustainability of CRA fisheries. Any work, undertaking, or activity that results in serious harm to fish[2] that are part of, or support, CRA fisheries is prohibited. The *Fisheries Act* also prohibits the deposition of deleterious substances in water frequented by fish, unless authorized by regulations under the *Fisheries Act* or other federal legislation.

[2] The *Fisheries Act* defines “serious harm to fish” as “the death of fish or any permanent alteration to, or destruction of, fish habitat”. “Fish”, in turn, is defined as (a) parts of fish, (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.

DFO is responsible for the protection of fish and fish habitat, including fish species listed under *SARA*. At-risk fish species that occur in the vicinity of the Project include white sturgeon (*Acipenser transmontanus*; *SARA* Schedule 1: Endangered) and green sturgeon (*A. medirostris*; (*SARA* Schedule 1: Special Concern) (Government of Canada 2006). At present, Endangered and Special Concern status is being considered for Fraser River and central Pacific coast populations of eulachon (DFO 2014a), and south coast populations of bull trout (*Salvelinus confluentus*) (DFO 2014b), respectively.

Changes in and about a stream require notification or approval under Section 11 of the B.C. *Water Sustainability Act*, administered by the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNR). Under this Act, the term "stream" applies to natural and manmade watercourses, including channelized streams and constructed ditches.

Enacted under Section 12 of the B.C. *Fish Protection Act*, the Riparian Area Regulations (RAR), outlines requirements for establishment of development setbacks from streams, lakes, and wetlands and applies to lands under the jurisdiction of municipalities. The Ministry's ROW is exempt from the RAR, and the regulation does not apply directly to the Project.

The B.C. *Wildlife Act* provides for the conservation and management of wildlife populations (including fish) and habitat. The Act also provides for assignment of species and ecological communities at risk in B.C. to one of three lists (Red, Blue, Yellow) by the B.C. Conservation Data Centre (CDC) based on provincial Conservation Status Rank[3]. Further explanation regarding the assignment of Conservation Status Rank by the CDC to species and ecosystems at risk is provided in **Section 4.7 Vegetation**.

Provincially-listed fish species occurring in the vicinity of the Project include the Red-listed white sturgeon and green sturgeon, and the Blue-listed coastal cutthroat trout (*Oncorhynchus clarkii clarkii*).

[3] Red-listed species and ecological communities are Extirpated, Endangered, or Threatened in B.C., Blue-listed species and ecological communities are of Special Concern, and Yellow-listed species are considered to be secure. The legal designation as Endangered or Threatened under the Act increases the penalties for harming a species and enables the protection of habitat in a Critical Wildlife Management Area.

4.4.2.3 Existing Conditions

Fish Habitat

Fraser River South Arm

The Project is located approximately 18 km upstream of the Fraser River mouth, within a section of the Fraser River South Arm that is influenced by a tidally-driven salt water wedge that penetrates near the river bottom (Kostaschuk 2002). Annual maintenance dredging occurs at several locations within the South Arm (FREMP 2006, PMV 2014). Downstream of New Westminster, the river has deepened in response to dredging, training, and confinement by bridges and dikes. Further information on the lower Fraser River hydraulics and morphology is provided in **Section 4.1 River Hydraulics and River Morphology**.

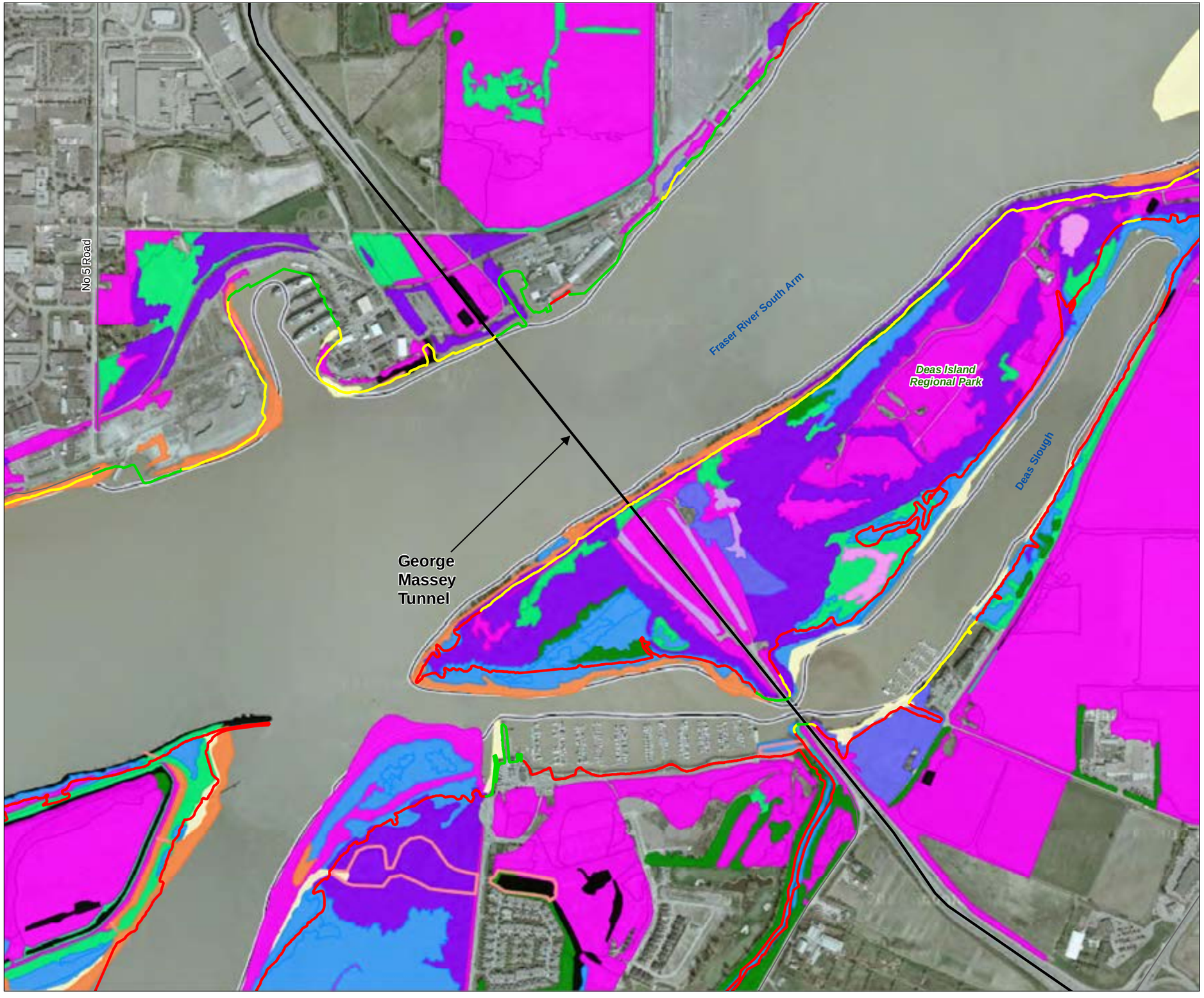
Shoreline of the Fraser River South Arm is characterized by extensive industrial activity. A high proportion of habitat, including that in the Project alignment, is classified as of low (green-coded) or moderate (yellow-coded) productivity (**Figure 4.4-2**; BIEAP - FREMP 2014). Productive (red-coded) shoreline habitat is generally confined to a narrow band of intertidal marshes, mud- and sand-flats around Tilbury and Annacis islands (**Figure 4.4-2**; BIEAP - FREMP 2014). With respect to shoreline conditions in the Fraser River South Arm, during pre-Application consultation, Aboriginal Groups expressed concern regarding lack of shade from trees or areas for juvenile salmon to hide. For a detailed description of the lower Fraser River shoreline habitats in the LAA, and their respective FREMP designations, refer to the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

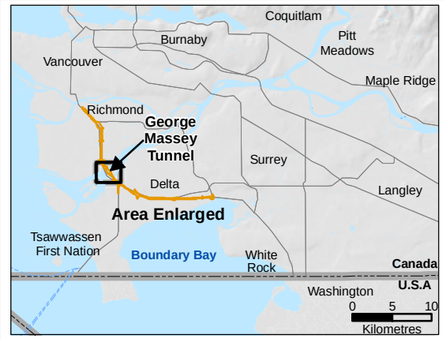
The lower Fraser River supports 42 species of fish (Richardson et al. 2000). Anadromous CRA species that rely on aquatic habitats in the Fraser River estuary include salmonids, sturgeon, and eulachon. Common non-CRA fish species that inhabit the lower Fraser River mainstem, sloughs, backwaters, and tributaries include: prickly sculpin (*Cottus asper*), peamouth (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), northern pikeminnow (*Ptychocheilus oregonensis*), starry flounder (*Platichthys stellatus*), lamprey (*Lampetra* sp.), and threespine stickleback (*Gasterosteus aculeatus*) (Richardson et al. 2000).

Deas Slough

Deas Slough, a backwater feature of the Fraser River South Arm, is approximately 2,700 m long and 250 m wide, with an average depth of 5 m. Deeper sections exist in the vicinity of the two marinas on the slough's south bank, which are dredged to maintain boat access (FREMP 2006). In contrast to sandy sediments in the South Arm, substrate in the slough consists predominantly of silt and clay (Birtwell et al. 1987*a*). Deas Slough is tidally-influenced; however, a sill on the slough's bed at the mouth prevents salt water penetration in depths greater than 4 m (Birtwell et al. 1987*a*).

The slough's shoreline is designated primarily as highly productive (red-coded) habitat. In contrast, riprap-armoured shoreline in the vicinity of the Deas Slough Bridge is characterized as low (green-coded) to moderate (yellow-coded) productivity habitat (BIEAP - FREMP 2014). A detailed description of tidal foreshore habitats, riparian vegetation, and upland land uses surrounding Deas Slough is included in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.





Legend

- Waterbody
- Canada - U.S. Border
- Highway
- Arterial/Collector Road
- High Productivity Habitat
- Moderate Productivity Habitat
- Low Productvity Habitat

- deciduous tree woodland
- coniferous tree woodland
- mixed tree woodland
- low shrub woodland
- tall shrub woodland
- meadow, vascular
- meadow, non-vascular
- marsh
- eel-grass
- macroalgae
- mud
- sand
- rock
- other
- habitat compensation site

SOURCES

Parks and Protected Lands, First Nations Reserves from GeoBC, United States basemap data courtesy of USGS. Burns Bog courtesy of The Corporation of Delta and based on the Metro Vancouver Burns Bog Ecological Conservancy Area Management Plan - May 2007, all other data courtesy of Canvec - GeoGratis. All other data obtained from the Fraser River Estuary Management Program & Burrard Inlet Environmental Action Program Habitat Atlas available online through the Community Mapping Network (http://www.cmnbc.ca/atlas_gallery/fremp-bieap-habitat-atlas). Data was accessed in November 2014. Productivity data was digitized at a scale of 1:5000 and is an approximate representation only.

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GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

FRASER RIVER ESTUARY MANAGEMENT PROGRAM HABITAT INVENTORY

Figure 4.4-2 | 13/05/2016

George Massey Tunnel Replacement Project | BC JOBS PLAN | B.C. on the Move

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Deas Slough is used by a number of rearing and overwintering fish species. Rearing habitat has been documented for underyearling sockeye salmon (*Oncorhynchus nerka*), which are present in the slough from April to October, with numbers peaking in late June to late July (Birtwell et al. 1987*b*). Underyearling starry flounder also rear in the slough in spring and summer, and adult starry flounder are present in the slough in autumn and winter (Birtwell et al. 1993). Other fish species recorded in Deas Slough include, but are not limited to, chinook (*O. tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), and pink salmon (*O. gorbuscha*), prickly sculpin, and threespine stickleback (FISS 2014).

Green Slough

Green Slough flows northeast along River Road West and then parallels Highway 99 before flowing into Deas Slough. Green Slough is 15 to 20 m wide along most of its length, but the channel narrows to about 9 to 10 m wide near the pump station at Crescent Slough. The channel is a low gradient glide, with silty substrates and uniform depths that range from about 0.9 to 1.5 m at low water.

Green Slough is tidally-influenced and drains into the lower reaches of Deas Slough and ultimately into the Fraser River South Arm, with unimpeded flows. Through the Green Slough Pump Station (5596 River Road), it drains agricultural and residential runoff from Crescent Slough in autumn and winter for flood protection, and irrigates agricultural lands in spring and summer (LGL et al. 2009). The pumps are not screened to prevent fish entrainment, and no fish deflection devices are employed at the station (LGL et al. 2009).

Green Slough is classified as an environmentally sensitive area under Delta's Official Community Plan (Delta 2014). The slough's shoreline is classified as habitat of high productivity (red-coded) (BIEAP - FREMP 2014). Marsh and riparian habitats of Green Slough are described in detail in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

Green Slough provides perennially wetted rearing and overwintering habitat for salmonids (LGL et al. 2009). It is also used by non-salmonid species, such as threespine stickleback, prickly sculpin, and redside shiner. Non-native fish species, such as carp (*Cyprinus carpio*) and black crappie (*Pomoxis nigromaculatus*), have also been reported in Green Slough (FISS 2014).

Upland Ditches

Of the 43.5 km of assessed ditches that parallel or intersect Highway 99 within the LAA, 5.2 km (12%) are coded as dashed-red, and 10.0 km (23%) as orange. The remaining ditches are of low or no value to CRA fish; 26.9 km are coded as yellow (62 %), and 1.5 km (3 %) are coded as green. A description of watercourse classification codes specific to this assessment is provided in **Section 4.4.2.3**.

Ditches within the LAA are low-gradient straight runs, with fine sediments, but without pools or riffles. In general, these ditches are poorly connected to the tidal waters of the lower Fraser River (e.g., located upland of flood control infrastructure, included floodgates and pump stations), which limits access for CRA fish. Instream vegetative cover is generally limited and riparian vegetation consists mainly of grassed roadside shoulders, shrubs lining ditch banks, backed by agricultural fields. A detailed assessment of upland ditch habitat within the LAA is included in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

Previous sampling in upland ditches has resulted in the capture of non-CRA fish, including native (e.g., brassy minnow (*Hybognathus hankinsoni*), peamouth, redside shiner, and threespine stickleback), and introduced fish species (FISS 2014). Only one CRA fish species (i.e., cutthroat trout) has been historically documented in Crescent Slough; however, these observations date back to 1983 (FISS 2014). No salmonids have been detected in the slough since then. Crescent Slough is generally considered to have low values for rearing salmon, especially within reaches close to the Highway 99 ROW (Hemmera 2006). Species captured in upland ditches during field sampling, conducted for the Project, include brassy minnow and threespine stickleback, as well as brown bullhead (*Ameiurus nebulosus*), goldfish (*Carrasius auratus*), and pumpkinseed (*Lepomis gibbosus*).

Fish

Fish species of CRA importance that rely on aquatic habitats throughout the lower Fraser River during different life history stages include Pacific salmon, sturgeon, eulachon, trout, and char. As discussed in **Section 4.4.1**, these species were selected as sub-components to facilitate assessment of potential effects of the Project on fish and fish habitat. Life history requirements, status, and limiting factors for each sub-component are summarized in this section, and described in greater detail in the technical volume, ***Fish and Fish Habitat Study*** included under **Section 16.4**.

Pacific Salmon

Chinook Salmon: Chinook salmon is the largest of the Pacific salmon species that return to the Fraser River and tributaries to spawn. The Fraser River estuary provides important rearing habitats for juvenile chinook. Stream-type chinook,(i.e. fish from the interior Fraser River) generally rear in estuarine habitats with greater marine influence, whereas ocean-type chinook (i.e. ocean-type fish from the Harrison River) occupy tidal channels and brackish marshes of the lower Fraser River, such as the Woodward Island complex and Ladner Marsh just downstream of the Project (Levy and Northcote 1982, Northcote et al. 2007). Adult chinook use the lower Fraser River as a migratory corridor during their return to spawn (DFO 2011). Generally,

stream-type chinook migrate upriver from March to September, while ocean-type chinook migrate upriver from September to November (Fraser et al. 1982). Aboriginal Groups noted that during return migration a natural funnel is created so that fish are held in the lower reaches before they run up river.

Fraser River chinook salmon stocks are not federally or provincially listed.

Chum Salmon: Chum salmon spawn in streams and the lower Fraser River mainstem between Chilliwack and Hope (Ryall et al. 1999). In the Fraser River, chum salmon consist of autumn run stocks that migrate upstream to spawn from September to December, with peak spawning migration occurring in October (Grant and Pestal 2009). The majority of chum salmon spawning habitat is located in Fraser River tributaries downstream of Hell's Gate (near Hope) such as the Harrison, Chehalis, Chilliwack, and Stave rivers (Ryall et al. 1999, Holtby and Ciruna 2008).

Upon emergence, chum fry promptly migrate downstream to the estuary, including the brackish marshes and tidal channels of the lower Fraser River, where they linger as they transition to higher salinity waters (Salo 1991). Chum fry outmigration occurs from February to June, with a peak between mid-March and the end of April (Beacham and Starr 1982, Salo 1991).

Chum salmon stocks of the Fraser River are not federally or provincially listed.

Coho Salmon: Adult coho salmon typically return to spawn in autumn and early winter, and discrete seasonal runs do not generally exist (Holtby and Ciruna 2008). Fry emerge from mid-March to late June and remain in the spawning stream for a year or more (Fraser et al. 1982, Sandercock 1991). Coho smolt outmigration in the Fraser River generally occurs from mid-April to mid-June, with a peak observed in mid-May (Fraser et al. 1982). Coho smolts remain for a few weeks in rearing habitats of Sturgeon and Roberts Banks while adapting to higher salinity conditions. They are scarce in brackish marshes and tidal channels of the lower Fraser River (Fraser et al. 1982).

Coho salmon is not federally or provincially listed; however, the Interior Fraser populations were designated in 2002 as Endangered (COSEWIC 2002). The status of the Interior Fraser coho salmon is anticipated to be re-assessed by COSEWIC and an updated status report is expected to be produced in 2015 (Decker and Irvine 2013). Declines in coho salmon catches in south coastal B.C. have been attributed largely to overharvesting, as well as implementation of conservation measures (e.g., limited exploitation, fisheries closures, non-retention; DFO 2012).

Pink Salmon: Pink salmon have the shortest life cycle of all Pacific salmon, since they always mature as two-year-old fish. In the Fraser River, pink salmon return in odd years. Aboriginal Groups noted that pink salmon populations cycle in two- year periods of relative abundance (i.e., high run years). Spawning is concentrated in tributaries downstream of Hope, but significant spawning also occurs in the Thompson River (Labelle 2009). Spawning migration through the lower Fraser River peaks in late August to early September (Heard 1991).

Outmigration of pink fry occurs from late February through to mid-May (Heard 1991). On average, the time pink fry spend rearing in sloughs and backwater features of the lower Fraser River appears to be negligible (Dunford 1975, Godin 1981, Levy and Northcote 1982).

Pink salmon is numerically the most abundant salmon species in B.C. and is not federally or provincially listed (B.C. CDC 2015).

Sockeye Salmon: Sockeye salmon typically return as four-year-old adults, and populations have characteristic return timings, classified into four groups or runs. Return migrations extend from mid-June through to September (Gable and Cox-Rogers 1993). During consultation on the Project, Aboriginal Groups noted that sockeye salmon populations cycle in four-year periods of relative abundance (i.e., high run years), and that during return migration a natural funnel is created so that fish are held in the lower reaches before they run up river.

Smolt outmigration generally occurs from early April to the end of May (Beamish et al. 2010). One notable exception is the Harrison sockeye stock. Harrison sockeye fry migrate to the estuary shortly after emergence, and rear in Fraser River estuarine habitats, including Deas Slough and Ladner Reach, before entering the Strait of Georgia (Dunford 1975, Levy and Northcote 1981, 1982, Birtwell et al. 1987*b*). In Deas Slough, sockeye underyearlings have been caught from April to October, with peak abundance from late June to early July (Birtwell et al. 1987*b*).

Sockeye salmon is not a federally or provincially listed species, however, the Cultus Lake population was designated in 2003 as Endangered (COSEWIC 2003*a*). On average, sockeye is the most important of the Pacific salmon species in terms of commercial landed value, followed by chinook and chum (DFO 2012). Sockeye salmon is also caught in sport fisheries and in Aboriginal active food drift gillnet fisheries on the lower Fraser River.

Sturgeon

White Sturgeon: White sturgeon, a demersal species resident in the lower Fraser River downstream of Hell's Gate (km 211), are genetically distinct from the rest of the Fraser River system (Nelson et al. 1999, Smith 2002). Spawning occurs during peak freshet (typically from May to July), from the confluence of the Sumas River upstream to the Coquihalla River, with no evidence of spawning in the tidally-influenced river mainstem (Levings and Nelson 2003, Perrin et al. 2003).

Important spring and summer feeding areas for adult sturgeon include the Matsqui Channel and Hatzic Eddy upstream of Mission, as well as the mouth of the Pitt River, and the waters at the Port Mann Bridge, Barnston, Douglas, and Annacis Islands (Glova et al. 2010). During consultation on the Project, Aboriginal Groups noted that adult sturgeon are present seasonally, and identified two main sturgeon staging areas in the lower Fraser River–one in the direct vicinity of the Tunnel and the other in Ladner Reach (Deas Slough, downstream of Canoe Pass). Aboriginal Groups also indicated that sturgeon feed on dead eulachons and herring in April and May, especially within Ladner Reach through to Sea Reach.

During winter, white sturgeon migrate to overwintering areas, where they become sedentary and congregate in densely spaced groups in slow-moving pools as water temperatures drop below 7°C (Neufeld et al. 2010, Ghilarducci and Reeve 2012). Overwintering habitat is widely scattered from Deas Island to the Sumas River confluence, but mainly concentrated in the waters near Annacis Island, the Port Mann Bridge, the mouth of the Pitt and Stave rivers, and Matsqui. Overwintering typically occurs in slow moving water and depths greater than 10 m (Neufeld et al. 2010, Ghilarducci and Reeve 2012).

Juvenile white sturgeon disperse downstream to feed and overwinter, and rear in the lower reaches of tributaries, large backwaters, side-channels, and sloughs throughout the lower Fraser River (Fraser River White Sturgeon Working Group 2005). Rearing of juveniles occurs in tidally-influenced, slow-moving, turbid water, at least five metres deep, over substrates consisting mainly of sand, silt and clay, mixed with gravel (Lane and Rosenau 1995).

In the vicinity of the Project, individual juvenile white sturgeon have been reported from the BC Ferries Fraser Shipyards, immediately downstream of the Project alignment, and in the main channel off Deas Island, immediately upstream of the Project alignment. However, aggregations of up to five overwintering juveniles have also been reported upstream of the Annacis Channel (Glova et al. 2008, 2009). In general, the influence of the salt wedge in estuarine and brackish environments precludes use by smaller juveniles, as the ability of white sturgeon to tolerate brackish and saline waters increases with size (Parsley and Beckman 1994).

Aboriginal Groups have relayed historic declines in numbers of sturgeon in the lower Fraser River. At the federal level, the COSEWIC status of the lower Fraser River white sturgeon population was downgraded in 2012 to Threatened, from the 2003 designation of Endangered (COSEWIC 2003*b*). Provincially, white sturgeon is Red-listed (B.C. CDC 2015).

Green Sturgeon: Green sturgeon are found in BC along the entire coast (Scott and Crossman 1973). They are rarely observed in freshwater and the extent of freshwater habitat use is unknown. Since 1985, there have been about 15 to 20 reports of green sturgeon in the lower Fraser River, from the river mouth to 90 km upstream. Spawning is known to occur in only three rivers in North America from Oregon to California; there is no evidence that spawning has ever occurred in Canadian rivers (COSEWIC 2004).

Although rare, sub-adult and adult green sturgeon may occur in the Fraser River estuary and lower reaches throughout the year. Habitat requirements in brackish environments are thought to resemble those of white sturgeon (COSEWIC 2004).

At the federal level, COSEWIC re-assessed the status of green sturgeon in 2013 and maintained its designation as species of Special Concern (COSEWIC 2014). Green sturgeon is listed as Special Concern under *SARA* Schedule 1 (Government of Canada 2006), and is provincially Red-listed (B.C. CDC 2015).

Eulachon

Eulachon return every year to the lower Fraser River to spawn when they are three to four years of age (Cambria Gordon Ltd. 2006). Spawning migration begins in mid-March and continues to mid-May (Hay and McCarter 2000, LGL and Terra Remote Sensing 2009). Within the lower Fraser River, spawning occurs from Deas Island upstream to Mission, however, spawning locations vary considerably among years (Hay and McCarter 2000, Hay et al. 2002).

Historically, most spawning has occurred upstream of New Westminster, and on occasion, in the mouths of large tributaries such as the Pitt River (Hay and McCarter 2000), where the influence of lower salinity water is greater. Due to inter-annual variation in spawning locations, the entire lower Fraser River is considered to contain areas with suitable eulachon spawning habitat (B. Ennevor, Fisheries Resource Manager, DFO, personal communication, January 6, 2014).

Preferred spawning habitat is in areas of relatively slow current (<0.7 m/s), on plateaus or edges composed of stable fine-medium and coarse sand, pebbles, and gravel, in depths of less than seven metres (LGL and Terra Remote Sensing 2009). The river mainstem in the vicinity of the Project is predominantly 12 m deep with no shallow shoals, characterized by unstable sandy substrates subject to annual maintenance dredging. Also considering the low tolerance of eulachon eggs to higher salinity water, the likelihood of suitable eulachon spawning habitat in the Project alignment is greatly reduced. To reach spawning habitat, eulachon transit through areas of relatively slow current (<0.7 m/s) that are 5 to 12 m deep, and have stable sandy

substrates (LGL and Terra Remote Sensing 2009). In the vicinity of the Project alignment, these transit areas likely occur close to the shoreline rather than mid-channel. Immediately after hatching, larvae are flushed seaward (Hay and McCarter 2000).

Eulachon (central Pacific coast and Fraser River populations) was designated as Endangered by COSEWIC in 2011 (COSEWIC 2011), and is provincially Blue-listed (B.C. CDC 2015). The Fraser River and central Pacific coast populations are currently being considered for listing as Endangered under *SARA* (DFO 2014*a*). Although historically very abundant, numbers of eulachon returning to the lower Fraser River began declining steadily in the mid-1940s, then exhibited a steeper decline in the 2000s (Moody 2008, Schweigert et al. 2012). During consultation with the Ministry in the context of the Project, Aboriginal Groups cited loss of habitat along with other factors as the cause of these declines, but noted they have also reported that eulachon have been recovering in recent years.

Trout

Coastal Cutthroat Trout: Coastal cutthroat trout inhabit low elevation lakes and rivers along much of the B.C. coast, including streams in the Fraser River basin. They range as far upstream as Hope (160 km inland), and use sloughs and backwaters of the lower Fraser River mainstem, as well as several of its major tributaries (i.e., Pitt, Stave, Harrison, and Chilliwack Rivers and associated lakes) (McPhail 2007, Costello 2008). Sloughs and backwaters provide rearing, overwintering, and migratory habitat for coastal cutthroat trout.

Coastal cutthroat trout are able to spawn multiple times in successive years, usually from late winter to spring, though sea-run populations have also been known to spawn during autumn (McPhail 2007). Depending on the life history form, adults either remain in natal streams, or migrate to lakes or larger river systems to forage before returning to spawn. Sea-run cutthroat migrate to the ocean between March and June (Slaney and Roberts 2005).

Coastal cutthroat trout is provincially Blue-listed (B.C. CDC 2015).

Rainbow/Steelhead Trout: Steelhead trout (*Oncorhynchus mykiss*) is the sea-run form of rainbow trout. Steelhead are found along the entire coast of B.C. in larger streams and rivers, including the Fraser River, that empty directly into the ocean (Hartman and Gill 1968). In the Fraser River, winter-run steelhead enter fresh water in various stages of maturation between November and April (Withler 1966), and spawn by May (McPhail 2007). Summer-run steelhead enter fresh water between May and September as immature fish (Withler 1966), and do not mature and spawn until the following spring, between late March and early May (McPhail 2007). Typically, winter runs are associated with coastal populations and summer runs with inland

populations (Pauley et al. 1986). Steelhead may spawn over multiple years. Some spent spawners migrate to the ocean to feed and may return to their spawning grounds within the same year, or skip a year before spawning again (Levy and Parkinson 2014).

Upon emergence, fry rear in fresh water for one to three years, then migrate to salt water between late April and mid-June, where they feed and grow rapidly before moving out into the open ocean (Quinn 2005). Steelhead use the Fraser River South Arm as a migratory corridor during smolt outmigration and adult spawning migration to natal streams. Resident forms of rainbow trout may also use rearing and overwintering habitats in the Fraser River South Arm.

Rainbow/steelhead trout are not federally or provincially listed.

Char

Dolly Varden: Dolly Varden (*Salvelinus malma*) are associated with cold water streams in most B.C. coastal drainages. Dolly Varden occur as anadromous, migrating between freshwater streams and the ocean; stream-resident, remaining in rivers and streams for most of their life; and lake-run, remaining in a single freshwater body and spawning in adjacent streams. Anadromous Dolly Varden enter the ocean regularly (McPhail 2007).

Spawning occurs in autumn within headwaters of small streams. Upon emergence, juveniles remain in the stream for two to four years (Armstrong 1970). The lower Fraser River is likely used as a migratory corridor by Dolly Varden, due to its proximity to nearshore estuarine and coastal feeding and overwintering grounds. Dolly Varden smolts migrate to the ocean in spring and may remain for only two to four months before returning to fresh water (Armstrong and Morrow 1980). Alternatively, Dolly Varden may remain in marine waters well into the autumn, returning only for spawning or overwintering in freshwater habitats (Bond and Quinn 2013).

Dolly Varden are not federally or provincially listed.

Bull Trout: Bull trout are associated with cold water streams (Dunham et al. 2003). They exhibit variable life histories, including stream resident, lake-run, large river, and sea-run. Anadromous bull trout populations are suspected in the lower Fraser River (McPhail and Baxter 1996, McPhail 2007). Because anadromous char populations occur where bull trout and Dolly Varden overlap, evidence that these char are bull trout rather than Dolly Varden is often circumstantial.

Bull trout spawn in autumn in shallow stream habitats (McPhail and Baxter 1996). Upon emergence in spring, juvenile bull trout rear in spawning streams for at least two years before migrating to larger rivers, or the ocean, depending on the form (Pratt 1992, McPhail and Baxter 1996). The lower Fraser River is likely used as a migratory corridor by bull trout, due to its proximity to nearshore estuarine and coastal feeding and overwintering grounds.

Bull trout is provincially Blue-listed (B.C. CDC 2015), and was designated in 2012 as a species of Special Concern (COSEWIC 2012). Bull trout populations of the B.C. south coast are currently being considered for listing as species of Special Concern under *SARA* (DFO 2014*b*).

4.4.3 Potential Effects

This section discusses anticipated interactions of Project components and activities with fish and fish habitat, and the potential effects of such interactions. Information on the mitigation of potential effects, including Project design measures to avoid adverse effects, is provided in **Section 4.4.4**. Potential residual effects (i.e., effects remaining following the implementation of mitigation measures) are described in **Section 4.4.5.** A discussion of potential cumulative effects on fish and fish habitat is presented in **Section 4.4.6**.

4.4.3.1 Project Interactions

An overview of potential interactions between Project activities and fish and fish habitat during the construction and operation of Project components is provided in **Appendix A**. A preliminary evaluation of the potential effects of Project interactions on fish and fish habitat, intended to focus the assessment on those interactions of greatest importance, is presented below. Interactions rated as having no effect are not considered further in the assessment.

Construction: Potential interactions of Project-related construction activities with fish and fish habitat include the following:

- Exposure of fish to construction equipment, underwater noise generated by activities such as pile driving and Tunnel decommissioning, and increased suspended sediment and turbidity levels resulting from activities associated with Tunnel decommissioning and other instream or near-shore construction activities.
- Potential disturbance of fish habitat during construction adjacent to water.
- Potential overlap of Project components with small portions of fish habitat along the edges of Deas Slough and Green Slough.
- Potential release of construction area run-off into adjacent waterbodies during highway upgrades.

Operation: Once operational, interactions of the Project with fish and fish habitat are expected to be limited to the following:

- Potential release of stormwater runoff from the new bridge and upgraded highway into the river and sloughs.
- Sedimentation during routine maintenance activities such as vegetation and debris removal, and temporary disruption of natural flows during ditch maintenance.

4.4.3.2 Potential Effects

Potential Effect #1: Physical Injury or Mortality to Fish through Crushing or Entrainment

Crushing or entrainment of fish during Project-related activities can be lethal or sub-lethal, as a result of physical abrasion of the body surface, removal of protective mucous, or physiological stress associated with respiratory obstruction and anoxic conditions. Juvenile and smaller size-class fish are more susceptible to crushing or entrainment than larger fish, due to their limited swimming capability, which may prevent them from avoiding the area of disturbance (Larson and Moehl 1990, McGraw and Armstrong 1990, Reine and Clarke 1998). Because they are associated with bottom substrates, demersal species, such as sturgeon, are more likely to experience adverse effects during dredging (sediment removal) than are pelagic species (Hatin et al. 2007). The potential for crushing or entrainment of fish in the Fraser River South Arm and in upland ditches during Project construction and operation is discussed below.

Fraser River South Arm, Deas Slough and Green Slough

Crushing or entrainment of fish could occur during activities associated with Tunnel decommissioning, including removal of sediment and the protective rock apron and concrete mattress on top of the Tunnel sections.

Crushing or entrainment of salmonid and sturgeon eggs will not occur as these species spawn beyond the RAA boundaries. Eulachon eggs are also unlikely to be crushed or entrained since sediment removal will be conducted in areas where conditions are unsuitable for eulachon spawning (i.e., at a depth of approximately 12 m over a dynamic section of the river with unstable substrates that lack plateaus or stable edges shallower than seven metres, and where the influence of higher salinity water is greater).

Juvenile fish sub-components may be susceptible to crushing or entrainment if present in the Project alignment during sediment removal. Crushing and entrainment during sediment removal does not typically result in the mortality of adult fish because they are highly mobile and able to avoid the area of disturbance.

To the extent that is technically feasible (see **Section 4.4.4**), sediment removal for Tunnel removal is proposed to occur between July 16 and February 28, the least-risk timing window for the protection of juvenile salmon and eulachon (FREMP 2006). Adherence to this timing window will avoid or minimize the potential for crushing and entrainment of these species.

Sturgeon forage and overwinter in the lower Fraser River. Small size classes of juvenile sturgeon may experience physical injury or mortality due to crushing or entrainment if present within the RAA and near the sediment removal site during the least-risk timing windows. The risk of entrainment increases when sediment removal occurs in areas of overwintering aggregations of juvenile sturgeon that are smaller than 19 cm fork length (Boysen and Hoover 2009). Since it is not possible to fully mitigate this effect, it is identified as a potential residual effect and assessed further in **Section 4.4.5**.

Upland Ditches

Construction activities associated with highway improvements that may require works in and around upland ditches will be undertaken in accordance with provincial standards and best practices, including the Ministry's *Standard Specifications for Highway Construction* (B.C. MOTI 2012). Project construction activities that involve instream works will be conducted within prescribed regional least-risk fisheries timing windows[4] (i.e., July 15 to September 30; Delta 2003, B.C. MOE 2006*b*) or will use alternative, standard mitigation approaches that protect fish and fish habitat (e.g., work in-the-dry, combined with fish salvages), and will adhere to the provisions of the B.C. *Water Sustainability Act* (where applicable).

The majority of upland ditches within the Project alignment are of relatively low values from a CRA fish habitat perspective (**Section 4.4.2.3**). Further information regarding standard mitigation pertaining to instream works is provided **Section 4.4.4**. After implementation of these mitigation measures, no effects to fish from crushing or entrainment in upland ditches are anticipated, and are not considered further in this assessment.

Potential Effect #2: Physical Injury or Mortality to Fish through Exposure to Underwater Noise during Construction

Exposure to loud, pulsed underwater sound, such as that generated during impact pile driving, can result in:

- Non-auditory effects, such as traumatic injury (i.e., severe tissue or organ damage)
- Auditory effects, such as temporary reduction of hearing sensitivity, thereby compromising the ability of fish to communicate, detect predators or prey, or assess their surroundings

[4] Prescribed regional least-risk fisheries timing windows encompass Delta's timing window for the protection of salmonids (i.e., August 1 to September 30; Delta 2003), as well as B.C. MFLNRO's timing window for the protection of Pacific salmon (i.e., July 15 to September 15; B.C. MOE 2006*b*).

Mortality to fish can occur from exposure to peak sound pressure levels (SPL_{peak}) that exceed 30 kilopascal (kPa) (~210 dB re 1 µPa) (Vagle 2003, Popper and Hastings 2009). Adult fish are typically more tolerant of underwater noise than juvenile fish of the same species (Halvorsen et al. 2011, 2012, Casper et al. 2012).

Continuous sound, generated from activities such as vessel movement, vibratory piling, and sediment removal, is less intense, and generally insufficient to cause injury or mortality to fish (Michel et al. 2007, Popper and Hastings 2009). Continuous sound, however, has the potential to result in behavioural effects (e.g., habitat avoidance).

For projects that involve loud underwater activities, DFO requires underwater sound monitoring, and deployment of mitigation (e.g., bubble curtain) within one metre from the sound source if underwater sound levels exceed 30 kPa (B.C. MPDCA 2003), or if evidence of impacts to fish is observed.

The U.S. Fisheries Hydroacoustic Working Group (FHWG 2008) has set the following threshold criteria for avoiding injury to fish: 206 dB re 1 µPa SPL_{peak} per single strike, or 187 dB re 1 μPa^2s cumulative sound exposure levels (SEL_{cum}) for fish heavier than or equal to two grams; for fish weighing less than two grams, the SEL_{cum} threshold is 183 dB re 1 μPa^2s (FHWG 2008). Mitigation is required if a strike is likely to exceed SPL_{peak} or if multiple strikes reach SEL_{cum} (FHWG 2008). Further details regarding threshold criteria for injury to fish are described in **Section 4.3 Underwater Noise**.

Fraser River South Arm, Deas Slough and Green Slough

Potential effects to fish resulting from Project-related underwater noise were assessed by comparing the results from JASCO Applied Science's Marine Operations Noise Model against the FHWG (2008) criteria for fish weighing less than two grams, as well as the BC Marine and Pile Driving Association Contractors (2003) criteria adopted by DFO. Modelled scenarios of Project construction activities are described in **Section 4.3 Underwater Noise**.

Impact pile driving is the only Project-related construction activity that has the potential to generate pulsed underwater noise at levels that, if not mitigated, could injure fish. Underwater noise modelling suggests that, without mitigation, impact pile driving could generate noise at levels that exceed FHWG and DFO SPL_{peak} thresholds within a radius of 53 m and 42 m, respectively (see **Section 4.3 Underwater Noise**).

For 100 minutes of continuous impact piling, the FHWG SEL_{cum} threshold extends to a radius of 602 m for fish with body weight greater than or equal to two grams, and 698 m for fish with body weight less than two grams (see **Section 4.3 Underwater Noise**).

Project siting and design are expected to help prevent or minimize underwater noise-related effects to fish. For example, current Project construction plans call for the piles to be driven either on land or along the edge of Deas Slough to avoid or minimizes the need for driving piles through deep water. Underwater noise is expected to be more strongly attenuated in shallow water, restricted by the surrounding slough and river banks, and absorbed by silt and clay sediments. As sediment-borne sound is approximately 20 dB lower than water-borne sound (Zampolli et al. 2013), sound propagating through soil is expected to be sufficiently attenuated before it reaches the water.

Mitigation measures to further minimize adverse effects to fish from underwater noise during Project construction are described in **Section 4.4.4**.

Upland Ditches

Project-related construction activities in upland ditches are not expected to generate underwater noise. Therefore, effects to fish in upland ditches as a result of underwater noise exposure during construction are not considered further in this assessment.

Potential Effect #3: Behavioural Changes due to Increase in Underwater Noise Levels during Construction

In general, fish can be sensitive to changes to the acoustic environment, with species-specific effects depending on fish anatomy and the physical characteristics of the underwater noise. Continuous underwater noise has the potential to result in fish behavioural effects, including alarm response, habitat avoidance, interference with sensory orientation and navigation, and communication masking effects (Knudsen et al. 1997, Fay and Popper 2000). Aboriginal Groups have noted that salmon are sensitive to noise and show changes in behaviour in response to noise.

In the lower Fraser River, fish are continually exposed to ambient noise of low- to moderate-frequency generated predominantly by shipping traffic and intermittently by construction activities. Ambient measurements in the lower Fraser River in the vicinity of the Project exceed 120 dB re 1 µPa about 20% of the time, primarily due to larger vessels, such as tugs and container ships, transiting the river. Ambient noise levels in Deas Slough are lower than in the lower Fraser River mainstem, because slough traffic consists primarily of smaller, slow-moving pleasure craft using the marinas. Details on ambient underwater noise levels (i.e., existing conditions) in the vicinity of the Project are provided in **Section 4.3 Underwater Noise**.

Fraser River South Arm

Project construction activities anticipated to generate continuous underwater noise include vibratory pile driving and vibrodensification of native loose soils for the installation of foundations on the edge of Deas Slough and sediment and rip rap removal in preparation for and during Tunnel decommissioning. Underwater noise will also be generated by tugs, which may be operating at the Tunnel crossing during Tunnel removal.

There are no specific behavioural threshold criteria in place for fish exposed to continuous underwater noise; however criteria for marine mammals (see **Section 4.3 Underwater Noise**) is appropriate for reference as a potential disturbance level. As with marine mammals, underwater noise does not have the potential to cause behavioural effects in fish when it falls below background ambient noise levels.

Anthropogenic noise is commonly categorized as pulsed or non-pulsed sounds. Pulsed sounds are brief (less than a few seconds) and intermittent, with rapid changes of sound pressure (e.g., impact-hammer strike, from impact pile-driving). In contrast, non-pulsed sounds are characterized by gradual changes in sound pressure over time (e.g., marine vessels transiting or a vibratory pile driver in operation). Without mitigation, impact-pile driving is expected to result in the highest level of pulsed sound while vibratory pile driving and vibrodensification of native soils are expected to be the most notable sources of non-pulsed sound. Sediment removal and vessel operations are expected to result in minimal change in underwater noise conditions as the noise predicted to be generated by these activities are similar to ambient acoustic levels measured in the lower Fraser River where behavioural disturbance threshold is exceeded 20% of the time (see **Section 4.3 Underwater Noise**). The most notable potential source of changes to ambient noise levels, construction-based noise from impact pile-driving, vibratory pile driving and vibrodensification of native soils are proposed to occur either on land or in shallow water. Given this planned approach, the sound generated by these activites is expected to be sufficiently attenuated before it reaches the receptors so that any potential behavioural effects will be avoided (see **Section 4.4.4** below for a description of proposed mitigation measures and monitoring related to pile driving).

Project operation is not anticipated to involve any activity that could generate underwater noise. Therefore, noise-related behavioural effects on fish during Project operation are not considered further in this assessment

Upland Ditches

No Project-related construction or operation activities are anticipated to generate underwater noise in upland ditches. Therefore, behavioural effects to fish as a result of underwater noise in upland ditches are not considered further in this assessment.

Potential Effect #4: Physical Injury or Mortality due to Exposure to Elevated Levels of Total Suspended Solids

Exposure to elevated TSS levels in the water column can affect fish through:

- Mechanical abrasion and hyper-secretion of mucous, clogging of the gill tissue and consequent respiratory distress caused by lack of the passage of water, and mortality
- Physiological stress leading to reduced growth, reduced feeding rates, and increased susceptibility to invasion by disease-causing parasites

Fish eggs, larvae, and later stages of juvenile fish are typically more sensitive to elevated TSS levels than adults of the same species.

The potential for Project activities to affect fish through elevated TSS levels was determined by comparing TSS concentrations expected to be encountered in plumes generated during Project-related sediment removal activities against B.C. water quality guidelines (WQG) (B.C. MOE 2006*a*), and the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2014) (see **Table 4.4-2**).

Fraser River South Arm, Deas Slough, and Green Slough

Project-related construction activities that may result in elevated TSS levels in the lower Fraser River, Deas Slough, and Green Slough include instream and near-shore construction activities associated with decommissioning the Tunnel and Deas Slough Bridge, realignment of Green Slough to its historic location, and installation of support structures for the new bridge and approaches. Of the proposed instream construction activities, removal of Tunnel segments and overlying sediment and protective cover are anticipated to generate the greatest amounts of re-suspended sediment.

Most fish present in the vicinity of the Project at the start of Tunnel removal activities are likely to disperse out of the immediate area due to elevated noise and physical disturbance associated with the operation. However, fish, especially larval and juvenile stages that remain in or near the sediment plume, could be exposed to elevated TSS levels due to their limited ability to disperse away from a plume.

To prevent or minimize potential Project-related effects to fish from exposure to elevated TSS levels within the Fraser River, mitigation measures will be implemented to maintain TSS levels within the B.C. WQG (B.C. MOE 2006*a*) and CCME *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2014) (see **Table 4.4-2**). These include undertaking instream activities between July 16 and February 28 (FREMP 2006) to the extent that is technically feasible and viable, and use of a hydraulic (hopper or cutter) suction dredge where possible to reduce the amount of re-suspended sediment. Sediment suspension during activities associated with Tunnel removal will be of a short temporal nature, and the incremental change in sediment volume is predicted to range from one to nine per cent, which is considered low in comparison with background TSS loads in the lower Fraser River (**Section 4.1 River Hydraulics and River Morphology**). Some CRA fish, in particular sturgeon, are known to use the lower Fraser River outside the least risk timing window. However, turbid conditions often exceeding 50 NTU appear to be favoured by sturgeon, because these conditions provide cover and minimize the risk of predation (Hatfield et al. 2004, Gadomski and Parsley 2005). Also, adult salmon that migrate upriver to natal spawning streams during the least risk timing window have evolved in this highly turbid environment.

Mitigation measures to prevent or minimize potential effects to fish from exposure to elevated TSS levels within Green and Deas sloughs will include undertaking instream works in a manner that provides for maintenance of TSS levels within the B.C. WQG (B.C. MOE 2006*a*) and CCME *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2014). As noted previously with respect to Tunnel decommissioning, a key mitigation measure for instream activities will be application of least-risk timing window (July 16 and February 28), to the extent that is technically feasible and viable. Further to the application of seasonal timing to reduce risk to CRA fish, these tidal sloughs extensively dewater during low tides which will facilitate application of additional mitigation measures (e.g., working during low tide when the work site is extensively dewatered, temporary isolation of flow, fish salvage, installation of fill containment berms). Silt curtains can also be deployed within Green and/or Deas sloughs, adjacent to the infill area, if warranted.

Further mitigation measures to minimize physical injury or mortality to fish from exposure to elevated TSS levels during instream Project activities are described in **Section 4.4.4**.

Sediment suspension during activities associated with Tunnel removal will be of a short temporal nature, and the incremental change in sediment volume is predicted to range from one to nine per cent, which is considered low in comparison with background TSS loads in the lower Fraser River (**Section 4.1 River Hydraulics and River Morphology**). Sediment suspension during activities within Green Slough provides for more extensive mitigation, given the tidal

characteristics and separation from the South Arm. As a result, any sediment suspension in Green or Deas sloughs is anticipated to occur within an even shorter timeframe and will result in a more reduced change in background TSS levels than will apply within the South Arm during Tunnel removal.

Some CRA fish, in particular sturgeon, are known to use the lower Fraser River outside the least risk timing window. However, turbid conditions often exceeding 50 NTU appear to be favoured by sturgeon, because these conditions provide cover and minimize the risk of predation (Hatfield et al. 2004, Gadomski and Parsley 2005). Also, adult salmon that migrate upriver to natal spawning streams during the least risk timing window have evolved in this highly turbid environment.

Regardless of the extent of change in TSS levels, it is not possible to fully mitigate sediment suspension effects during either Tunnel removal or partial infilling of Green Slough resulting in identification of a potential residual effect which is assessed further in **Section 4.4.5**.

Upland Ditches

Clearing and grubbing of vegetation along ditches in the LAA for Highway 99 widening and interchange upgrades have the potential to result in localized streamside disturbance, erosion, and sedimentation. In addition, relocation of or modifications to ditches have the potential to result in a temporary increase of TSS levels.

Works proposed in and around upland ditches will be conducted will comply with provincial standards and best practices, adhering to the provisions of the B.C. *Water Sustainability Act* (where applicable) (see **Section 4.4.4**). The majority of upland ditches within the Project alignment are of low value from a CRA fish habitat perspective (**Section 4.4.2.3**). After implementation of these mitigation measures, effects to fish from exposure to elevated TSS levels in upland ditches are not anticipated, and are therefore not considered further in this assessment.

Once operational, highway maintenance activities such as ditch cleaning, clearing, brushing, road maintenance, and repaving of road surfaces have the potential to result in elevated TSS levels within upland ditches.

Maintenance activities will comply with provincial standards and best management practices, adhere to the provisions of the B.C. *Water Sustainability Act* (where applicable), and be undertaken in accordance with the Ministry's *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010). As such, potential adverse effects to fish from exposure to elevated TSS levels in upland ditches during Project operation are not likely to occur and not considered further in this assessment.

Potential Effect #5: Effects of changes in Ambient Water Quality

Changes in habitat quality have the potential to alter the ability of fish to carry out essential life processes such as spawning, rearing, or foraging, increase physiological stress, and result in behavioural changes.

Ambient water quality may be affected during Project-related construction and operation activities that have the potential to induce increased levels of turbidity, re-mobilization of sediment contaminants, and siltation from re-deposition of suspended sediments. Potential effects to fish and fish habitat from changes in ambient water quality are assessed below with reference to baseline conditions as described in **Section 4.2 Surface Water and Sediment Quality**.

Turbid conditions may affect vertical migration of visually-dependent species such as salmon, and induce an alarm reaction, resulting in habitat avoidance. Turbid conditions may also limit light penetration through the water column, restrict prey capture, and reduce the ability of fish to avoid predation.

Conversely, turbid conditions, which may reduce the risk of predation, appear to be favoured by juvenile sturgeon that rear or overwinter in habitats of the river mainstem (Hatfield et al. 2004, Gadomski and Parsley 2005). It has also been suggested that increased turbidity may temporarily increase organic matter in the water column, and cause sturgeon to react positively to the perception of greater food availability (Parsley et al. 2011).

The lower Fraser River is naturally turbid and also subject to annual dredging for maintenance of the navigation channel. Since 1987, ambient water quality has been screened against CCME *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2014) for parameters including TSS, pH, dissolved oxygen (DO), and metals (e.g., Phippen 2008). On average, objectives have been met 98% of the time and ambient water quality in the South Arm is assessed as good (Phippen 2008).

Concentrations of total aluminum, chromium, and copper exceeding CCME WQG were observed during field sampling conducted for the Project in September 2014 at a mid-channel location upstream of the Tunnel crossing. Total aluminum and chromium concentrations exceeding CCME WQG were also observed at the Deas Slough mouth; although, total chromium concentrations in Deas Slough were lower than those in the South Arm. Petroleum hydrocarbons, oil, and grease were not detected in any water samples.

Arsenic, chromium, and copper in sediment samples collected in September 2014 from the Fraser River mainstem in the vicinity of the Tunnel crossing and Deas Slough consistently exceed *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 1999). Exceedances of Canadian sediment quality guidelines have not been recorded for PCBs.

Fraser River South Arm, Deas Slough, and Green Slough

Project-related construction activities that may result in changes to ambient water quality in the LAA, include sediment removal, removal of the Tunnel and its protective rock apron and concrete mattress. Other activities that involve local disturbance of surficial sediments (e.g., installation of temporary barging facilities, vibrodensification of native soils, pile driving) may also have some potential to affect ambient water quality.

To prevent or minimize potential Project-related changes in ambient water quality, mitigation measures will be implemented to maintain turbidity levels within the B.C. WQG (B.C. MOE 2006*a*) and CCME *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2014) (see **Table 4.4-2**). These include undertaking instream activities between July 16 and February 28 (FREMP 2006) to the extent that is technically feasible and viable, and use of a hydraulic suction dredge where possible to reduce the amount of re-suspended sediment.

Some CRA fish, in particular sturgeon, are known to be present within the lower Fraser River throughout the year including the period outside the aformentioned least-risk fisheries timing window of July 16 to February 28. However, turbid conditions appear to be favoured by sturgeonand migrating adult salmon are adapted to inhabit and transit through this highly turbid environment. Therefore, potential effects to habitat quality resulting from changes in ambient water quality are not considered further in this assessment.

Localized disturbance of sediments will occur in Deas and Green sloughs as a result of pile driving and vibrodensification of native soils. As noted above, concentrations of metals greater than those found in the sandy sediments of the Fraser River South Arm in the vicinity of the Project alignment have been documented in the sediments of Deas Slough historically and during field sampling conducted in September 2014. Proposed mitigation measures to limit the dispersion of these sediments during instream works are described in **Section 4.4.4**.

Accidental spills of toxic or hazardous materials (e.g., hydrocarbon fuels, lubricants, concrete), or potential failure of sediment containment measures could result in changes to ambient water quality during Project-related construction activities. Potential changes to ambient water quality resulting from accidents or malfunctions during Project construction are assessed in **Section 8.0 Accidents and Malfunctions**.

Post construction, the increase in impervious surface area associated with the new bridge over the Fraser River South Arm and Deas Slough may result in the discharge of larger volumes of stormwater runoff into these watercourses. Contaminants in stormwater runoff can degrade ambient water quality and may result in toxicity to aquatic life. Mitigation measures to prevent or reduce adverse effects associated with stormwater runoff are described in **Section 4.4.4**. With respect to stormwater runoff, Aboriginal Groups expressed concern for potential project related effects on fish and associated fisheries as a result of highway runoff.

Upland Ditches

Clearing and grubbing along ditches within the LAA in support of Highway 99 widening and interchange upgrades have the potential to result in streamside disturbance, erosion, and sedimentation of the receiving aquatic environment. In addition, relocation or modifications to upland ditch also have the potential to result in changes to ambient water quality.

Construction activities that require works in and around red and dashed-red upland ditches will be conducted, where appropriate, within prescribed regional least-risk fisheries timing windows (i.e., July 15 to September 30; Delta 2003, B.C. MOE 2006*b*), in isolation of water flows, and with fish salvages as required. In general, instream works that may be required in upland ditches will be undertaken in accordance with provincial standards and best practices, including the Ministry's *Standard Specifications for Highway Construction* (B.C. MOTI 2012), and will comply with the B.C. *Water Sustainability Act*. For more information on standard mitigation pertaining to instream works, refer to **Section 4.4.4**.

After implementation of mitigation, no changes to ambient water quality are expected in upland ditches during instream works. The majority of upland ditches within the Project alignment are of low values from a CRA fish habitat perspective (**Section 4.4.2.3**). Therefore, associated potential adverse effects to fish habitat quality are not considered further in this assessment.

Maintenance activities will comply with provincial standards and best practices, adhere to the provisions of the B.C. *Water Sustainability Act* (where applicable), and be undertaken in accordance with the Ministry's *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010).

Widening of Highway 99 and interchange upgrades are expected to result in an increase of impervious surface area and consequently increased volumes of stormwater runoff that may enter upland ditches. Mitigation measures to prevent or reduce adverse effects associated with stormwater runoff are described in **Section 4.4.4**.

Potential Effect #6: Fish Habitat Alteration

Project-related activities that have the potential to alter fish habitat include: upgrades to existing riprap and new rip rap in the vicinity of the new bridge, removal of the Tunnel, and disturbance or realignment of ditches associated with interchange upgrades, highway widening, and construction of bridge approaches.

Fraser River South Arm, Deas Slough and Green Slough

The new bridge will have a clear span over the Fraser River South Arm. Instream construction activities will be limited to upgrading the existing riprap protection around the base of the bridge support towers. Tunnel removal will be undertaken such that the river banks will be left intact. No excavation and river training works will be required (see **Section 4.1 River Hydraulics and River Morphology**). The extent of fish habitat alteration associated with changes in river hydraulics and morphology as a result of slope armouring upgrades is considered negligible and consequently is not carried forward in the assessment.

Tunnel removal, and associated sediment removal and floating of the Tunnel segments will result in localized scour and sedimentation, as river flow is reduced over the trench left behind after the tunnel segments have been removed. The hydraulic/morphodynamic model (see **Section 4.1 River Hydraulics and River Morphology**) assumes that Tunnel removal will begin in mid-summer during the least-risk timing window, after freshet has receded and turbidity is relatively low, and that any effects will be instantaneous. Since Tunnel removal will actually occur over several months, model results are conservative (i.e., actual effects will likely be of lower magnitude than they would be if the Tunnel removal occurred all at one time).

The incremental change in sediment volume during Tunnel removal is predicted to range from one to nine per cent above ambient, which is considered low compared to existing TSS loads in the lower Fraser River. Elevated TSS may result in a short-term, localized increase in turbidity which will persist during the period in which the disturbance is occurring. Effects from re-deposition of suspended sediment are expected to be minimal.

Therefore, potential fish habitat alteration from sediment suspension and re-deposition in the LAA during Tunnel removal are considered negligible, and potential associated changes in habitat quality in the Fraser River South Arm are not considered further in this assessment.

Operation of the proposed clear-span bridge is not expected to affect river hydraulics and morphology on the Fraser River South Arm. On Deas Slough, where some instream foundations are expected to be located along the water edge, effects related to changes in flow conditions are not anticipated due to the backwater nature of this habitat. Potential associated changes in habitat quality from the new bridge are therefore not considered further in the assessment.

In the Fraser River South Arm, Tunnel removal is not anticipated to result in short-term bank erosion or create barriers to fish migration (**Section 4.1 River Hydraulics and River Morphology**). Predicted changes to river hydraulics and morphology are modest and will occur in a dynamic section of the river that has been previously affected by annual and historic dredging (**Section 4.1 River Hydraulics and River Morphology**), and other manmade disturbances to the river bed such as the downstream Metro Vancouver watermain.

Potential effects on habitat quality associated with decommissioning of the existing Tunnel are considered negligible. Sensitive life stages of salmonids migrating through or foraging in this section of the river tend to occupy the upper water column. As previously noted, eulachon spawning habitat is absent near the Tunnel crossing, while sturgeon overwintering habitat will continue to be present after the trench has naturally infilled. As a result, potential Project-related effects associated with fish habitat alteration are not considered further in the assessment (see **Section 4.4.5**).

Upland Ditches

Proposed highway improvements involving construction activities in and around upland ditches have the potential to alter fish habitat. As described in **Section 4.4.3**, instream works are proposed in or around 15 km (35 %) of total ditch length of dashed-red-, and orange-coded ditches within the LAA.

Most of these instream works will involve relocation of manmade, channelized watercourses (upland ditches), poorly connected to the tidal waters of the lower Fraser River (e.g., located upland of flood control infrastructure, included floodgates and pump stations) and with relatively low values from a CRA fish habitat perspective. Without mitigation, works in and around dashed-red- and orange-coded ditches with the potential to alter fish habitat include, but are not limited to, the following:

- Removal of vegetation cover, potentially resulting in increased water temperatures and decreased food/nutrient inputs
- Temporary flow diversion and ditch realignment, potentially resulting in impairment of ditch connectivity for fish
- Temporary impairment of fish habitat functions within upland ditches, until replacement and/or relocated channels become more mature

Potential encroachment on watercourses and fish habitats, as well as potential environmental effects resulting from ground disturbance and instream works, will be minimized as Project construction is proposed to occur primarily within the existing Highway 99 ROW. Project-related construction in and around ditches will be conducted in accordance with provincial standards and best practices, including the Ministry's *Standard Specifications for Highway Construction* (B.C. MOTI 2012). For more information on standard mitigation pertaining to instream works, refer to **Section 4.4.4**.

Potential effects associated with fish habitat alteration in upland ditches during Project construction are expected to be negligible.

Project activities during operation with the potential to result in fish habitat alteration in upland ditches include highway maintenance activities, such as ditch cleaning, removal of in-channel vegetation, brushing, and clearing.

Instream works will be conducted in accordance with provincial standards and best practices, including the Ministry's *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010) (see **Section 4.4.4**).

Given the low existing values, no potential fish habitat alteration in upland ditches during Project operation is anticipated and resultant changes in habitat quality of these manmade watercourses are not considered further in this assessment.

Potential Effect #7: Changes in Fish Habitat Quantity

Changes in habitat quantity involve the direct loss of fish habitat associated with overlap of Project components with fish habitat. Loss of habitat that supports CRA fish can be expected to meet the definition of serious harm under the *Fisheries Act*. Potentially affected aquatic habitats include highly productive (red-coded) tidal brackish marsh, and intertidal and shallow subtidal channel areas of Deas and Green sloughs. Fish habitat loss has the potential to affect fisheries productivity, because it may result in a measureable reduction in the slough's productive capacity as year-round rearing habitat for CRA fish, including juvenile Pacific salmon.

The new bridge is proposed as a clear span structure over the Fraser River South Arm and without any instream supports; however, there will be a small overlap between bridge/approach support piers and the edges of Deas Slough and Green Slough. The nature and extent of this overlap was determined by overlaying the proposed alignment on the terrestrial ecosystem maps for the assessment area. As shown in **Table 4.4-5**, this exercise indicated that Project alignment overlap with fish habitat is expected to be limited to portions of Deas Slough and Green Slough.

Mitigation measures to minimize the potential loss of fish habitat during Project construction are discussed in **Section 4.4.4**.

Table 4.4-5 Estimated Fish Habitat Losses Associated with Construction of the New Bridge and Approaches

Structure	Estimated Habitat Loss (m^2)	
	Instream Area	Riparian Area
Deas Slough Piers Total	2,027	2,080
Green Slough Piers Total	5,707	1,654
Total Habitat Loss	7,734	3,734

Activities during the Project's operation phase are not anticipated to result in the permanent loss of fish habitat. As a result, changes in fish habitat quantity during Project operation are not considered further in this assessment.

4.4.4 Mitigation Measures

A hierarchical approach based on the four types of mitigation as outlined below was used in identifying strategies to avoid or minimize potential Project-related effects:

- Avoidance: Measures to avoid potential effects on the VC have been/will be incorporated into project considerations such as site and route selection, project scheduling, project design, and construction and operation procedures and practices.
- Minimization: Where potential effects on the VC cannot be avoided through project considerations, standard mitigation measures, best management practices (BMPs), and construction and operation environmental management plans (EMPs) will be implemented to minimize potential Project-related effects or reduce them to acceptable levels.
- Restoration or Habitat Enhancement: Where potential Project-related effects cannot be avoided or minimized through standard mitigation measures, best practices, or implementation of EMPs, affected components will be restored on-site to pre-Project conditions.
- Compensation/offset: Where on-site restoration is not feasible, appropriate means to counteract, or make up for potential Project-related effects on the VC will be identified.

4.4.4.1 Avoidance

The design for the new bridge includes a clear span across the Fraser River South Arm, thereby avoiding instream footprint effects in the river mainstem.

4.4.4.2 Minimization

Selection of measures to minimize unavoidable effects of the Project has been informed by a review of standard industry and BMPs; consideration of mitigation measures and follow-up programs undertaken for past developments by the Ministry; input from regulators, public and Aboriginal Groups; and evaluation of the technical and economic feasibility of proposed measures. Design considerations, standard industry practices and BMPs proposed to avoid or minimize effects on fish and fish habitat described in the following key documents have also informed the development of Project-specific mitigation measures as discussed in this section:

- *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2013*a*).
- *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013*b*).
- *Environmental Management Strategy for Dredging in the Fraser River Estuary* (FREMP 2006).
- *Dredge Management Guidelines* (FREMP 2005).
- *2012 Standard Specifications for Highway Construction* (B.C. MOTI 2012).
- *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010).
- *Standards and Best Practices for Instream Works* (B.C. MWLAP 2004).
- *Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia* (B.C. MOE 2014).
- *Best Management Practices for Pile Driving and Related Operations* (B.C. MPDCA 2003).
- *Land Development Guidelines for the Protection of Aquatic Habitat* (Chilibeck et al. 1993).
- *Riparian Restoration Guidelines* (B.C. MOE 2008).
- *Tree Replacement Criteria* (B.C. MELP 1996).

Project Design

Highway 99 improvements are proposed to occur primarily within the existing Highway 99 ROW. Potential encroachment on fish habitat, as well as potential effects resulting from instream works, ground disturbance, clearing, and grubbing of riparian vegetation will be minimized and restricted within the ROW.

Design and construction of the new bridge crossing will conform to standards outlined in the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA S6-06, and the Ministry's Supplement to CHBDC S6-06 *Bridge Standards and Procedures Manual* (B.C. MOTI 2007).

The new bridge design will incorporate stormwater management considerations to mitigate potential effects to fish and fish habitat due to storm runoff-related changes in ambient water quality in the Fraser River South Arm during. This will involve the management and treatment of stormwater runoff from the bridge deck, with stormwater flows diverted away from the river and into stormwater detention ponds.

To prevent or minimize potential effects associated with stormwater runoff during highway operation, roadside ditches will be designed to maintain ambient water quality and pre-development flow regimes. Mitigation measures will include the incorporation of vegetated shoulders and drainage swales, stormwater storage facilities to control runoff rates, headwall structures in culverts, wide bottom ditches, and stormwater management ponds for flood protection.

Best Management Practices and Environmental Management

Environmental protection measures that will be implemented during Project construction and operation to prevent or minimize potential effects on fish and fish habitat will be outlined in a Construction Environmental Management Plan (CEMP) and subsequently in an Operational Environmental Management Plan (OEMP), as described in **Section 12.0 Management Plans**. The CEMP and OEMP will include Fish and Fish Habitat Management Plans that describe mitigation measures to avoid or minimize potential Project-related adverse effects to fish and fish habitat, including physical injury or direct mortality, exposure to underwater noise or elevated TSS levels, and potential changes in fish habitat quality. The plan will comply with best practices, including:

- *Standard Specifications for Highway Construction* (B.C. MOTI 2012).
- *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010).

As described below, the plan will identify regional least-risk timing windows during which Project construction and operation activities with the potential to cause adverse effects to fish and fish habitat can be undertaken. Alternatively, instream work can proceed after implementation of mitigation approaches that protect fish and fish habitat. The plan will also describe the approach and measures to mitigate potential effects from elevated underwater sound and TSS levels.

Timing Windows

To the extent that is technically feasible and viable, sediment removal for Tunnel removal and realignment of Green Slough for bridge support structure construction will be undertaken between July 16 to February 28, the least-risk timing window for the protection of juvenile salmon and eulachon (FREMP 2006). Other CRA fish species can be expected to receive some level of protection from adherence to this instream construction window.

Project construction activities (e.g., site preparation and installation of equipment lay-down areas, highway widening, and interchange upgrades) and Project operation activities (e.g., routine highway and ditch maintenance) involving instream work on upland ditches with CRA fish habitat values will be undertaken during prescribed regional least-risk fisheries timing windows (i.e., July 15 to September 30; Delta 2003, B.C. MOE 2006*b*), or alternative mitigation approaches will be implemented to protect fish. For example, alternative mitigation may include isolation of flow and pump-arounds, to facilitate work in-the-dry supported by fish (and aquatic life) salvages.

Least-risk timing windows, by their nature, have been developed as standard mitigation measures by regulators (e.g., B.C. FLNR and DFO) to limit activities that involve changes in and around water to periods of least risk. Adherence to the prescribed least-risk timing windows is therefore anticipated to be very effective at minimizing potential effects to fish and fish habitat. Should instream work outside a least-risk timing window be required, the application of alternative mitigation measures as described above is also expected to be effective in protecting fish as well as other aquatic life. The success of adhering to timing windows and/or the application of alternative mitigation measures will be continuously verified through environmental monitoring efforts (see below).

Mitigation of Underwater Noise Effects

Construction activities that have the potential to generate underwater noise will adhere to BMPs and other standard industry practices which set appropriate sound thresholds for the protection of fish. Specifically, *BMPs for Pile Driving and Related Operations* will be adhered to so that underwater noise does not exceed sound levels (i.e., SPL_{peak} 210 dB re 1 µPa) that may cause harm to fish (B.C. MPDCA 2003).

Impact pile driving, vibratory pile driving and vibrodensification of native soils during Project construction are anticipated to be the most notable sources of underwater noise (**Section 4.4.3.2**). The potential effects of underwater noise on fish will be avoided or minimized by limiting the occurrence of these activities to land or shallow water along the edge of Deas Slough. For activities that have the potential to generate underwater sound levels in exceedance of thresholds causing physical injury to fish, underwater noise monitoring will be conducted. If considered necessary, additional mitigation measures will be deployed.

As described above, the most effective mitigation measure for avoiding potential effects from underwater noise will be limiting activities with the most notable sources of ambient noise levels to land or shallow water environments. The effectiveness of this mitigation will be confirmed through construction monitoring. If, during a noise-generating activity, a threshold is either exceeded or negative effects to fish in the immediate vicinity of the activity are noted, the activity will cease until additional mitigation measures are implemented.

Mitigation of Effects from Turbidity or Elevated Levels of Total Suspended Solids

Construction activities with the potential to adversely affect fish and fish habitat through increased turbidity and elevated TSS levels will adhere to BMPs and standard industry practices that specify water quality criteria to be met for the protection of fish and fish habitat. To prevent or minimize elevated turbidity and TSS levels associated with Project-related construction activities, mitigation measures will be implemented to maintain levels within the CCME (2002) and B.C. (B.C. MOE 2006*a*) WQG (see **Table 4.4-2**). Measures that will be implemented to mitigate effects from turbidity or elevated TSS levels in the Fraser River South Arm, and Deas and Green sloughs, as well as provisions for water quality monitoring are described in **Section 4.2 Sediment and Water Quality**. In and around upland ditches, standard industry practices and BMPs that will be adhered to during Project construction activities will include, but will not be limited to:

- Demarcation of vegetation clearing limits on drawings and in the field.
- Delineation (flagging or fencing) in the field of environmentally sensitive no work areas.
- Temporary water diversion, ditch isolation, and fish salvage/relocation to suitable aquatic habitats outside the Project's immediate zone of influence.
- Ditch realignment in accordance with applicable standards and guidelines (e.g., B.C. MWLAP 2004, B.C. MOTI 2012).
- Restoration and revegetation or hydroseeding of cleared areas promptly after use.
- Implementation of a riparian planting design to enhance pre-Project condition, according to applicable riparian restoration guidelines (e.g., B.C. MELP 1996, B.C. MOE 2008).

Erosion and Sediment Control plans within the CEMP and OEMP will describe measures to be followed to avoid or minimize potential physical injury or direct mortality of fish from elevated TSS levels, or changes in fish habitat quality resulting from degradation of ambient water quality due to induced turbidity, and re-mobilization of sediment contaminants. The plans will comply with the *Fisheries Act*, the B.C. *Water Sustainability Act* and associated Water Regulation, provincial standards and best practices, including:

- *Standard Specifications for Highway Construction* (B.C. MOTI 2012).
- *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010).

Erosion and sediment control measures to be implemented during Project construction and operation (bridge and highway maintenance) activities, including works in and around upland ditches will include, but will not be limited to:

- Minimizing the extent and duration of ground disturbance.
- Installing functional erosion and sediment control measures at potentially affected watercourses prior to the onset of Project construction and operation activities.
- Maintaining (repairing or replacing) functional erosion and sediment control measures throughout Project construction and operation (highway maintenance phases).
- Operating construction equipment in-the-dry from the top top-of-bank of watercourses
- Restoration, revegetation or hydroseeding of cleared areas promptly after disturbance, according to applicable riparian restoration guidelines (e.g., B.C. MELP 1996, B.C. MOE 2008).

Erosion prevention and sediment control measures to be implemented in Deas and Green sloughs to control the dispersion of re-suspended sediments generated during ground improvements, pier construction activities, and removal of existing infrastructure may include:

- Developing temporary drainage systems to receive, filter, and direct stormwater and runoff during construction
- Installation of sediment control measures (e.g., turbidity curtains)
- Developing sediment settlement ponds, if required
- Re-stabilization of vegetated areas that are cleared or disturbed during construction
- Careful storage of waste material and soil to prevent possible entry into the aquatic environment

Specific mitigation to be implemented during Tunnel decommissioning to maintain TSS levels within the CCME and B.C. WQG may include such measures as using a hydraulic (hopper or cutter) suction dredge where possible during fill removal to reduce the amount of re-suspended sediment. Removed material is expected to be transported off-site using spoil barge(s) equipped with a sediment containment system (e.g., filter cloth, concrete lock blocks, straw bales).

Environmental Monitoring

The environmental monitoring approach and procedures to be followed during Project construction to evaluate the effectiveness of mitigation measures intended to avoid or minimize potential Project-related adverse effects to fish and fish habitat will be described in the CEMP. The plan will comply with the Ministry's *Standard Specifications for Highway Construction* (B.C. MOTI 2012).

A description of water quality monitoring during Project construction in the Fraser River South Arm and the sloughs, is provided in **Section 4.2 Sediment and Water Quality**.

A description of underwater noise monitoring during Project construction in the Fraser River South Arm and the sloughs, is included in **Section 4.3 Underwater Noise**.

4.4.4.3 Habitat Enhancement

Proposed Project design provides the following opportunities to enhance fish habitat within and adjacent to the Project alignment:

- Restoration of historic Green Slough under the new south approach span into a small embayment on Deas Slough, and creation of 1,700 m^2 of instream (intertidal and shallow subtidal) habitat and 1,275 m^2 of riparian habitat.
- Restoration of 125 m^2 of shallow subtidal fish habitat in Deas Slough, following removal of the existing Deas Slough Bridge instream support piers.

Additional habitat to offset the difference between habitat lost and habitat enhanced will be described in a Fish Habitat Offsetting Plan, as described below.

Habitat enhancement features are generally anticipated to become productive within the first year and become fully productive and viable within 3 to 5 years following restoration. Effectiveness of Project-related habitat enhancement features will be closely monitored and managed through a follow-up monitoring program.

4.4.4.4 Habitat Offsetting

Unavoidable footprint effects of the Project on Deas Slough and Green Slough will be offset through the development of comparable habitat. A Fish Habitat Offsetting Plan will be developed in consultation with regulatory authorities. The offsetting plan will identify on- or near-site offsetting opportunities and outline offsetting implementation methods. Offsetting options described in this plan will be designed to maintain or improve the productivity of CRA fisheries. Offsetting options currently under consideration include:

- Other on- or near-site offsetting opportunities expected to offset any outstanding fish habitat losses, including tidal habitats and adjacent riparian areas of comparable or higher value than the impacted habitat (e.g., construction of intertidal fish habitats on Deas Island within the Highway 99 ROW to provide long-term substantive benefits to CRA fish).

As with habitat enhancement sites, habitat offsetting features are expected to provide some immediate benefits (e.g., construction of new tidal habitat features), and become fully productive and viable within 3 to 5 years. To address the potential risk associated with offsetting habitat(s) not becoming fully functional, effectiveness of these features will be confirmed through a follow-up monitoring program.

Through implementation of a Fish Habitat Offsetting Plan, changes in fish habitat quantity resulting from permanent fish habitat loss will be avoided and are therefore not considered further in this assessment.

4.4.5 Residual Effects and their Significance

After implementation of measures described above, the following potential adverse effects to fish and fish habitat during construction are not expected to be fully mitigated, and are considered further in this assessment:

- Physical injury or mortality to fish from crushing or entrainment
- Physical injury or mortality due to exposure to elevated levels of total suspended solids

Potential residual effects to fish and fish habitat are characterized with respect to the direction, magnitude, extent, duration, frequency, reversibility, and likelihood of each anticipated residual effect. Definitions for ratings applied to residual effects criteria, developed with specific reference to fish and fish habitat are presented in **Table 4.4-6**. Summaries of criteria ratings for the potential residual effects are provided in **Table 4.4-7** (Physical injury or direct mortality to fish from crushing or entrainment) and **Table 4.4-9** (Injury or Mortality due to exposure to elevated levels of total suspended solids). Context, i.e., sensitivity and resilience of fish and fish habitat, based on existing conditions, to changes was also taken into account in characterizing potential Project-related residual effects.

Table 4.4-6 Criteria Used to Characterize Residual Effects on Fish and Fish Habitat

Criteria	Description	Definition of Rating	
Direction	Overall nature of the residual effect	Adverse	Negative effect as a result of the Project.
		Positive	Beneficial effect as a result of the Project.
		Neutral	Neutral effect as a result of the Project.
Magnitude	Intensity of the effect relative to natural or baseline conditions	Negligible	No measurable change in fish populations, fish habitat quality or quantity, or contaminant levels.
		Low	A measurable change within the range of natural variability, but not affecting fish population viability.
		Moderate	A measurable change outside the range of natural variability, but not posing a risk to fish population viability.
		High	A measurable change outside the range of natural variability and may affect long-term fish population viability.
Extent	Geographic extent / distribution of the residual effect	Site	Effect is restricted to the immediate Project alignment.
		Local	Effect is restricted to the LAA.
		Regional	Effect is restricted to the RAA.
Duration	Length of time over which the residual effect is expected to persist	Transient term	Effect occurs once during Project construction or operation.
		Short term	Effect occurs throughout Project construction or operation.
		Moderate term	Effect persists until the first freshet following Project construction or operation before returning to existing conditions.
		Long term	Effect persists beyond the first freshet following Project construction or operation before returning to existing conditions and is unlikely to return to existing conditions.

Criteria	Description	Definition of Rating	
Frequency	Nature of the occurrence of the residual effect (e.g., how often the stressor affects the VC)	Rare	Effect occurs once during Project construction or operation.
		Uncommon	Effect occurs intermittently during Project construction or operation.
		Frequent	Effect occurs frequently during Project construction or operation.
		Continuous	Effect occurs continuously during Project construction or operation.
Reversibility	Potential for the effect to be reversed or naturally return to baseline level after the disturbance has ceased (or after a period of time after the disturbance has ceased)	Reversible	Baseline conditions will be naturally restored after disturbance has ceased.
		Irreversible	Baseline conditions will not be naturally restored after disturbance has ceased.
		Change	Effect may fluctuate between positive and adverse for the duration of the disturbance.
Likelihood	Likelihood that the residual effect may occur	Low	Likelihood of residual effect is less than 25%.
		Moderate	Likelihood of residual effect is between 25% and 75%.
		High	Likelihood of residual effect is greater than 75%.

Residual Effect #1: Physical Injury or Mortality to Fish from Crushing or Entrainment

Activities associated with Tunnel removal have the potential to result in physical injury or direct mortality of fish, particularly demersal fish species, such as sturgeon. While low, there remains a risk of crushing or entrainment of smaller size classes of juvenile sturgeon in the event that Project-related sediment removal occurs within deep holding areas where sturgeon aggregate. Low numbers (up to five individuals) of juvenile sturgeon are known to aggregate in deep (>10 m) mainstem pools within the Fraser River South Arm. Such features have been identified in Annacis Channel (approximately nine kilometres upstream of the Tunnel) and upstream of the New Westminster trifurcation. Although the river deepens appreciably (>20 m) immediately downstream of the Tunnel along the south bank, holding areas for juvenile sturgeon have not been identified at that location.

The risk may be higher if Project-related sediment removal occurs during the winter months when water temperature drops below 7°C, and juvenile sturgeon become more sedentary within overwintering habitats (Neufeld et al. 2010, Ghilarducci and Reeve 2012). However, residual effects to fish from physical injury are expected to be of low magnitude, to occur only during sediment removal, and to be limited to the immediate vicinity of the sediment removal operations. An overview of the criteria ratings for this residual effect is presented in **Table 4.4-7**.

Context for Characterization Ratings for Residual Effect #1: Project-related sediment removal is proposed to occur in a dynamic section of the river, where maintenance dredging of sections of the navigation channel is conducted on an annual basis. Near-bed water flows are also high at this location, uncharacteristic of low to moderate flow velocities that appear to be more typical of holding and overwintering areas preferred by sturgeon.

Although most fish tend to disperse away from the noise and physical disturbance associated with sediment removal, it is possible that juvenile sturgeon may be entrained if they are unable to swim away from the disturbance. Increased turbidity may also temporarily increase organic matter in the water column and cause sturgeon to perceive greater food availability and swim towards the disturbance. In the lower Fraser River, juvenile white sturgeon as small as 19 cm have been caught upstream of the Annacis Channel and the presence of smaller size classes of sturgeon cannot be precluded from the Fraser River South Arm including the Project alignment (Glova et al. 2008, 2009). As a result, entrainment and loss of a few individual fish may occur during Project-related sediment removal; however, this is not expected to adversely affect overall population integrity.

Fish that do disperse are likely to return to the affected area soon after the disturbance has ceased. Substantial areas of alternative feeding and holding habitat to accommodate any dispersed fish also exist outside of the proposed Project alignment.

Table 4.4-7 Criteria Ratings for Residual Effect #1: Physical Injury or Mortality to Fish Resulting From Crushing or Entrainment

Criteria	Criteria Rating	Rationale for Criteria Rating
Direction	Adverse	Individual demersal fish that may be present where in-river Project construction activities are occurring may experience physical injury or direct mortality through crushing or entrainment.
Magnitude	Low	Change will be within the range of natural variability and is not expected to adversely affect fish population viability. A measureable change is not expected to apply, as only low numbers of individual demersal fish may be directly affected by these construction activities.
Extent	Site	Spatial extent will be restricted to the area of disturbance.
Duration	Transient term	Effect will occur only during Tunnel removal.
Frequency	Rare	Effect will occur only in association with Tunnel removal.
Reversibility	Reversible	Affected fish populations are expected to return to baseline conditions.
Likelihood	Low	Similar habitat for sturgeon and other demersal species is abundant outside the RAA. Only smaller fish size classes are expected to be at any risk and small numbers are expected to be present during in-river Project construction activities.

Residual Effect #2: Physical Injury or Mortality to Fish Due to Exposure to Elevated Levels of Total Suspended Solids

Activities associated with Tunnel removal in the Fraser River South Arm and Green Slough realignment have the potential to result in physical injury or direct mortality of fish due to exposure to elevated levels of total suspended solids. Although mitigation measures will be applied to minimize the exposure of fish to elevated TSS levels during these activities, such measures will not completely remove the potential for residual effects on some fish species and life history stages. As the primary mitigation measure, adherence to the least-risk work window of July 16 through February 28 will provide for the substantial avoidance of sensitive life history stages, most notably upstream-migrating adult eulachon and downstream-migrating juvenile Pacific salmon, and eulachon larvae. There are, however, fish present within the river on a year-round basis, and the aforementioned timing window does not provide for avoidance of upstream-migrating adult Pacific salmon or trout and char that are present within a broader timeframe. Although fish populations are well-adapted to the turbid waters of the Fraser River and are often exposed to other sources of elevated TSS levels (both natural and human-sourced), it is recognized that both physical injury and direct mortality can apply in some cases.

Demersal fish species, including sturgeon, are less likely to be adversely affected by elevated TSS levels, given their ecology and physiology. The impact of sediment generation on non-demersal fish during these activities will depend on the ambient suspended sediment concentrations at the time of the works. It is assumed that Tunnel removal will commence in mid-summer and will likely occur after freshet flows have receded, and extend into the winter low-flow period. Suspended sediment volume is predicted to temporarily increase between one per cent and nine per cent over ambient levels during the course of the disturbance. This increase is considered low, given the natural variability of suspended sediment seasonally and annually in the river main channel. Any elevated TSS levels generated during realignment of Green Slough is less likely to be transported and fewer fine sediments would remain in suspension. An overview of the criteria ratings for effects associated with construction-related increase in TSS levels is presented in **Table 4.4-8**.

Context for Characterization Ratings for Residual Effect #2: It is noted that most fish tend to disperse away from impaired water quality, especially when there are opportunities to do so. By avoiding sensitive life history stages (juvenile Pacific salmon and larval eulachon), potential effects of elevated TSS levels will generally be limited to fish that are more active and strong swimmers that can swim away from zones of temporarily impaired water quality. Although it is still possible that physical injury or direct mortality may apply to small numbers of fish, this is not expected to adversely affect overall population integrity. Fish that do disperse are likely to return to the affected area soon after the disturbance has ceased. In addition, substantial areas of alternative migratory, holding, and feeding habitat is present within the wide channel of the Fraser River South Arm to temporarily accommodate any dispersed fish. Similarly, within Green and Deas sloughs there are extensive alternate habitat areas for any dispersed fish that may be present.

Table 4.4-8 Criteria Ratings for Residual Effect #2: Physical Injury or Mortality to Fish Due to Exposure to Elevated Levels of Total Suspended Solids

Criteria	Criteria Rating	Rationale for Criteria Rating
Direction	Adverse	Individual fish that may be present at, or in close proximity to, in-river or in-slough Project construction activities may experience physical injury or direct mortality due to exposure to elevated levels of total suspended solids.
Magnitude	Low	Change will be within the range of natural variability and is not expected to adversely affect fish population viability. A measureable change is not expected to apply, as only low numbers of individual fish may be directly affected by these construction activities.
Extent	Site	Spatial extent will be restricted to, or in close proximity to, the area of disturbance.
Duration	Transient term	Effect will occur only during Tunnel removal (Fraser River South Arm) and partial infilling activities (Green Slough).
Frequency	Rare	Effect will occur only in association with Tunnel removal (Fraser River South Arm) and partial infilling activities (Green Slough).
Reversibility	Reversible	Affected fish populations are expected to return to baseline conditions.
Likelihood	Low	Similar habitat for potentially affected species is abundant outside the RAA. Only a small subset of CRA fish species and age/size classes are expected to be at risk and only small numbers are expected to be present during in-river and in-slough Project construction activities.

4.4.5.1 Determination of Significance of Residual Adverse Effects

Significance Definition

A significant adverse residual effect to fish and fish habitat is one that may cause a decline in fish abundance or change in fish distribution to a level at which long-term population integrity is compromised. For a residual adverse effect to be considered significant, re-establishment of the population through natural recruitment (e.g., reproduction or immigration from unaffected areas) would not be expected to occur within a fish species' generation time, after the disturbance has ceased. Fish sub-components that are most susceptible to population effects as a result of the Project are those with longer generation times, such as sturgeon. Fish sub-components with shorter generation times are more likely to re-establish population levels following an adverse effect.

Significance Determination

The significance determination of residual effects to fish and fish habitat is presented in **Table 4.4-9**.

Likelihood characterization was based on professional judgement, with effects defined as those having low, moderate, or high probability of resulting in an adverse residual effect on fish and fish habitat. Low, moderate, or high confidence reflects the level of uncertainty associated with determinations of significance and likelihood.

The residual effect of physical injury or direct mortality of individual fish during Project construction (i.e., from crushing/entrainment or exposure to elevated levels of total suspended solids) is not expected to affect the population integrity of any fish sub-components. Adherence to prescribed least-risk timing windows and implementation of standard industry practices and mitigation measures will limit the extent and magnitude of Project-related effects, and reduce the likelihood of individual fish injury or mortality. As such, the potential residual effects of physical injury or direct mortality are both assessed as not significant. Confidence in the assessment is high due to the localized nature of the effects and the corresponding absence of an anticipated effect on population integrity.

Table 4.4-9 Summary of Determination of Significance of Residual Effects for Fish and Fish Habitat

Residual Effect	Significance (significant/ not significant)	Likelihood (low/moderate/high)	Level of Confidence (low/moderate/high)
Residual Effect: Physical injury or mortality due to crushing or entrainment	Not significant	Low	High
Residual Effect: Physical injury or mortality due to exposure to elevated levels of total suspended solids	Not significant	Low	High

4.4.6 Cumulative Effects Assessment

This section describes the assessment of potential cumulative effects associated with residual effects to fish and fish habitat. The combination of the residual Project effects in concert with the effects of other certain and reasonably foreseeable projects and activities comprise the future cumulative effects.

Spatial Boundaries

The spatial boundary of the cumulative effects assessment for fish and fish habitat is defined as the section of the Fraser River South Arm extending from the river mouth to 1,000 m upstream of the Project alignment, and Project alignment plus 500 m on either side of the Project alignment in upland area. The extent of the cumulative effects assessment area coincides with that of the RAA (**Table 4.4-3**).

Other Certain and Reasonably Foreseeable Projects and Activities

Annual maintenance dredging along sections of the navigation channel within the Fraser River South Arm is the only certain and reasonably foreseeable activity that could interact temporally and spatially with the Project. Maintenance dredging is undertaken annually to maintain adequate depth to accommodate vessel draft (FREMP 2006). Vancouver Fraser Port Authority performs annual maintenance dredging operations in the Fraser River South Arm, which are managed in a way that minimizes adverse effects to fish and fish habitat. Dredging operations adhere to BMPs, including use of suction dredging, avoidance of productive fish habitat areas, and adherence to least-risk timing windows (i.e., July 16 to February 28) for the protection of juvenile salmon and eulachon (FREMP 2006).

Cumulative Interactions and Potential Cumulative Effects

It is assumed that future maintenance dredging operations within the navigation channel of the Fraser River South Arm will continue to be undertaken by Vancouver Fraser Port Authority in a manner that minimizes adverse effects to fish and fish habitat. The potential for an interaction with the effects of the Project resulting in residual effects would depend on the timing and location of the maintenance dredging relative to the Project alignment. It is considered very unlikely that maintenance dredging within the RAA would be scheduled to coincide, spatially or temporally, with the Project's in-river construction activities, including Tunnel removal or partial infilling of Green Slough. Therefore, no cumulative effects to fish and fish habitat are anticipated as a result of an interaction between the Project and future annual maintenance dredging.

4.4.7 Follow-up Strategy

Monitoring will be conducted during and after construction to ensure the mitigation measures identified in **Section 4.4.4** are implemented and expected outcomes in terms of avoiding or minimizing effects on fish and fish habitat are achieved. Broadly, monitoring will include the following:

- Fish habitat monitoring in the vicinity of the Project alignment during construction (including Tunnel removal and decommissioning of any temporary construction-related facilities and post-construction to record any physical habitat changes as a consequence of the Project. During the post-construction period, monitoring will be conducted until the trench has infilled and the riverbed has returned to a stable state. This monitoring will involve ongoing assessment and evaluation of fish habitats located in close proximity to the Project, including fish habitat reference sites within the Fraser River South Arm, Deas Slough and Green Slough.
- Water quality monitoring during Project construction to ensure turbidity levels are maintained below thresholds for the protection of aquatic life.
- Hydrophone monitoring (when applicable) during Project construction activities that have the potential to generate underwater noise to ensure sound levels are maintained below relevant thresholds.

Further follow-up may be undertaken, subject to the results of these monitoring measures and discussion with regulatory agencies.

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APPENDIX A

Overview of Potential Project Interactions with Fish and Fish Habitat

Table 1 Overview of Potential Project Interactions with Fish and Fish Habitat

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Fish and Fish Habitat			
Pre-Construction / Site Preparation			
Pre-Construction / Site Preparation	No interaction	• Surveying • Acquiring property for the Project • Relocating utilities	**Nature of interaction:** No interaction anticipated **Rationale:** All activities to be land-based
	No effect	• Conducting additional site investigations (i.e. geotechnical drilling program)	**Nature of interaction:** Riverbed disturbance associated with additional site investigations (e.g., in the vicinity of the Tunnel) **Rationale:** Riverbed disturbance expected to be localized with low-volume of re-suspended sediment
	Potential Effect	• Clearing and grubbing vegetation within the existing Highway 99 ROW • Installing temporary roads, laydown areas, and site offices • Installing temporary bridges and barging facilities • Installing temporary drainage structures and diversions • Preloading for embankment and highway construction • Restoration of Green Slough to its historic alignment	**Potential Project-related effects include:** • Potential decrease in ambient water quality in upland watercourses due to sedimentation during clearing and grubbing, and in the Fraser River and sloughs due to sedimentation during installation of temporary barging facilities • Acoustic effects to fish from noise during ground improvements for new bridge piers (i.e., vibrodensification of native soils) • Accidental spills of deleterious substances (e.g., concrete fines, concrete wash water) (see **Section 8.0 Accidents and Malfunctions**)

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Construction			
New bridge including approaches and ramp connections	No interaction	• Installing upland piers, including pile installation • Installing retaining walls • Installing drainage structures/settling ponds • Constructing approach spans (concrete deck slab on steel or concrete girder) • Constructing bridge towers and installing support cables using land-based equipment	**Nature of interaction:** No interaction anticipated **Rationale:** Proposed activities to include use of precast concrete structures and to be land-based
	No effect	• N/A	N/A
	Potential effect	• Realignment of Green Slough • Ground improvements associated with new bridge piers • Installing piers adjacent to Deas Slough and Green Slough, including pile installation • Hoisting pre-assembled deck segments from barges in the river or land-based transport system	**Potential Project-related effects include:** • Physical injury or direct mortality to fish from elevated TSS levels • Physical injury or direct mortality to fish due to auditory injuries from pulsed noise (i.e., impact pile driving) • Changes in fish habitat quality due to acoustic effects to fish from continuous noise (vibratory pile driving, in-river operation of construction vessels, machinery, and equipment), and changes to ambient water quality from sedimentation in the Fraser River and sloughs • Changes to fish habitat quantity due to permanent placement of in-stream piers in Deas and Green sloughs, and partial infilling of Green Slough

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Highway 99 improvements, including interchange upgrades	No interaction	• N/A	N/A
	No effect	• N/A	N/A
	Potential effect	• Replacement of interchanges at Westminster Highway, Steveston Highway and Highway 17A • Replacement of over/underpasses at Cambie Road, Shell Road, Highway 91 Westbound Ramp, Blundell Road, Ladner Trunk Road and 112th Street • Highway widening from Bridgeport in Richmond to Highway 91 in Delta including construction of embankments, placing and compacting fill for road base, establishing improved drainage and paving	**Potential Project-related effects include:** • Potential changes to ambient water quality due to sedimentation in upland watercourses • Accidental spills of deleterious substances (e.g., concrete debris, asphalt, hydraulic fluids) into upland watercourses (see **Section 8.0 Accidents and Malfunctions**)

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Tunnel decommissioning	No interaction	• N/A	• N/A
	No effect	• N/A	N/A
	Potential effect	• Removing electrical/mechanical/utilities equipment from the Tunnel • Removing of four Tunnel segments and associated scour protection • Backfilling of onshore portions of Tunnel approaches • Transporting Tunnel elements for offsite recycling and operating support vessels for that activity	**Potential Project-related effects include:** • Physical injury or direct mortality from crushing or entrainment, and elevated TSS levels • Changes in fish habitat quality due to acoustic effects to fish from noise (jetting, mechanical demolition, tug and equipment operation), changes in ambient water quality as a result of induced turbidity, and alteration of fish habitat as a result of riverbed lowering, local scouring
Decommissioning of Deas Slough Bridge	No interaction	• N/A	N/A
	No effect	• N/A	N/A
	Potential effect	• Removal of Deas Slough Bridge including substructures	**Potential Project-related effects include:** • Potential changes to ambient water quality from localized sedimentation during removal of instream concrete piers • Accidental spills of deleterious substances (e.g., concrete debris, asphalt debris, hydraulic fluids) into the river and slough (see **Section 8.0 Accidents and Malfunctions**)

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Operation and Maintenance			
Highway 99 and interchanges	No interaction	• N/A	N/A
	No effect	• N/A	N/A
	Potential effect	• Operating reconfigured Highway 99 and interchanges. • Highway 99 and interchange maintenance (drainage maintenance, winter maintenance, emergency maintenance, road cleaning, etc.).	**Potential Project-related effects include:** • Changes in ambient water quality resulting from increased stormwater runoff into upland watercoursees due to increase in impervious surface • Alteration of fish habitat due to watercourse maintenance activities, vegetation and debris removal, temporary disruption of natural channel flows • Accidental spills of deleterious substances (e.g., asphalt, hydraulic fluids) into upland watercoursees (see **Section 8.0 Accidents and Malfunctions**)
New bridge	No interaction	• N/A	N/A
	No effect	• N/A	N/A
	Potential effect	• Operating the new bridge. • Bridge maintenance (winter maintenance, emergency maintenance, structure maintenance, etc.).	**Potential Project-related effects include:** • Potential changes in ambient water quality resulting from increased stormwater runoff into the river due to increase in impervious surface • Accidental spills of deleterious substances (e.g., asphalt, hydraulic fluids) into manmade watercourses (see **Section 8.0 Accidents and Malfunctions**)

"N/A" indicates that no Project works and/or activities are applicable to the category