6 ALTERNATIVE MEANS OF CARRYING OUT THE PROJECT

6.1 Introduction

The need for and purpose of the Project are discussed in Volume 1 Section 5 Need for, Purpose of, and Alternatives to the Project, and the benefits of the Project are described in Volume 1 Section 7 Project Benefits. As discussed in Volume 1 Section 5 Need for, Purpose of, and Alternatives to the Project, the specific purpose of the Project is to cost-effectively maximize the development of the hydroelectric potential of the Site C Flood Reserve.

This section describes the:

- Flood reserves that were put in place by the government of British Columbia to reserve Crown land in the Peace River watershed for hydroelectric development
- History of the selection of the dam site
- Study that was undertaken to evaluate alternate means of developing the hydroelectric potential of the Peace River within the Site C Flood Reserve
- Alternatives for the transmission line connecting the Site C substation to the transmission system at the existing substation at Peace Canyon Dam
- Alternatives for Highway 29 realignments
- Alternatives for worker accommodation
- Alternatives for quarried and excavated materials
- Alternatives for road and rail access

The Peace Site C Project Application for an Energy Project Certificate submitted to the British Columbia Utilities Commission in 1980 described the dam located downstream of the Moberly River, with a maximum normal reservoir level of elevation 461.8 m.

Whenever BC Hydro considered the Site C project since 1980, it was for the location and reservoir level described in the 1980 British Columbia Utilities Commission application. Furthermore, BC Hydro considers that when the government of British Columbia instructed BC Hydro to consider the Site C project under the *BC Energy Plan*, it was implicitly the location and reservoir level described in the 1980 application.

6.2 Flood Reserve

The first steps to develop the hydroelectric potential of the Peace River in British Columbia were undertaken in the 1950s. The government of British Columbia reserved Crown land in the Peace River watershed for the purposes of hydroelectric development through Orders-in-Council issued by the Executive Council as described below.

Order-in-Council 2452 dated October 11, 1957 reserved an area of Crown land from alienation, pursuant to Section 94 of the *Land Act*, R.S.B.C., 1948, c. 175. The Order-in-Council included the following portions of the watershed and tributaries of the Peace River:

- All the portion downstream from the 121°55’ meridian of West longitude to the British Columbia-Alberta border and situated below the 1,700 ft. (518.2 m) contour of elevation
- All the portion upstream from the 121°55’ meridian of West longitude and situated below the 2,450 ft. (746.8 m) contour of elevation

Order-in-Council 369 dated February 15, 1963 amended Order-in-Council 2452 by changing the contour elevations to 1,525 ft. (464.8 m) in the downstream portion and 2,250 ft. (685.8 m) in the upstream portion.

Order-in-Council 1995 dated August 5, 1963 amended Order-in-Council 369 by changing the contour elevation to 2,225 ft. (678.2 m) in the upstream portion.

Order-in-Council 1079 dated May 30, 1985 amended Order-in-Council 369 by cancelling the portion from the easterly border of Township 83, Range 19, West of the 6th Meridian, Peace River District, downstream to the British Columbia-Alberta boundary, and situated below the 1,525 ft. (464.8 m) contour of elevation (G.S.C. datum).

The current reserve is shown on Figure 4.7 in Volume 1 Section 4 Project Description. The portion of the reserve between Peace Canyon Dam and the easterly border of Township 83, Range 19, West of the 6th Meridian, Peace River District is referred to herein as the Site C Flood Reserve.

6.3 Historic Selection of the Location of the Site C Dam

The selection of the proposed dam site, summarized below, is based on the Review of Alternate Sites on the Peace River (Klohn Crippen Berger, SNC-Lavalin, Hatch 2011), which is contained in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

Studies to develop the hydroelectric potential of the Peace River between Peace Canyon and the British Columbia-Alberta border commenced in 1958. Five sites (designated A through E) were identified based on consideration of preliminary engineering, environmental, and social issues.

A feasibility study of power development on the Peace River between the site of the Peace Canyon Dam and the Alberta border by International Power and Engineering Consultants Limited in 1972 concluded that the best options to develop the 79.2 m of head on the Peace River were either:

- A single dam located at Site E near the Alberta border, or
- Two low dams, one at Site E and the other at Site C

Although the single high Site E option was more economic than the two-dam option, neither of the two options studied appeared to have any major advantage over the other, and it was recommended that the possibility of selecting better axes at Site E and at Site C should be investigated further.

The first location considered for Site C was upstream of the confluence of the Peace and Moberly rivers (referred to as Axis C1); however, based on the results of subsurface investigations completed in 1976, a second location further downstream but still upstream of the Moberly River (referred to as Axis C2) was investigated.

Studies culminated in 1978 with the selection of a third location downstream of the Moberly River (referred to as Axis C3) as preferred because at this location:

- The overburden on the abutments was substantially less than on Axis C1 and Axis C2, and less material to be excavated means less cost and less time for construction
- The abutments appeared to be more stable

- Both abutments are protected by terraces from potential slides originating above the crest of the proposed dam

The Site C project described in the 1980 British Columbia Utilities Commission application (BC Hydro 1980) consisted of a dam located downstream of the Moberly River at Axis C3 with a maximum normal reservoir level of elevation 461.8 m. References to Site C since the British Columbia Utilities Commission hearings have been to a project at this location and with this reservoir level.

In 2006, an assessment was undertaken of the cost and schedule effects of relocating the Site C Project back to Axis C1 or Axis C2 (Klohn Crippen Berger & SNC-Lavalin 2006). The assessment considered the history of selecting the Site C axis, the stability of the valley slopes, and the general topography of the sites. Simplified geological sections were developed for Axis C1 and Axis C2 in order to estimate the order of magnitude of changes to the major quantities that would result by moving the dam location to one of the upstream axes.

As shown in Figures 10-8 and 10-10 in Volume 1 Appendix E Review of Alternate Sites on the Peace River, at Axis C1 and Axis C2, the valley walls rise steeply to the plateau at about elevation 640 m on the north bank and 625 m on the south bank, and there are considerable depths of landslide debris on the slopes.

In comparison, at Axis C3:

- The slopes above the dam are lower than at Axis C1 and Axis C2: the north bank slope rises steeply to about elevation 570 m and then relatively gently to elevation 610 m, while on south bank the slope rises steeply to elevation 450 m, where a broad terrace is located that rises gently to elevation 480 m followed by a relatively flat slope to elevation 630 m
- Bedrock is exposed in the north bank to above dam crest level, and on the south bank bedrock is close to the surface

The key findings were that moving the Site C axis to Axis C1 or Axis C2 would:

- Require 95 million m^3 to 100 million m^3 more excavation for the dam to remove the landslide debris because of the higher slopes
- Require 8 million m^3 to 10 million m^3 more earthfill for construction of the earthfill dam
- Reduce average annual energy generation by approximately 5% to 8%
- Double the direct cost of the project
- Increase the schedule by approximately 5 years

As a result, it was concluded that Axis C3 was topographically and geologically superior to the two upstream axes and, due to the adverse topography and geology, it would not be possible to develop a project layout and design at either of the upstream axes that would have a similar cost to the proposed Site C project.

6.4 Location and Number of Dams

During the period 2001 to 2006 when BC Hydro was reconsidering development of a hydroelectric project at Site C, four reviews of alternative means of developing the hydroelectric potential in the Site C Flood Reserve were undertaken. These reviews

ranged in level from a three-day workshop to prefeasibility studies. Three reviews were based on using a cascade of lower dams and included a cascade of low dams similar to that being considered at the Dunvegan site on the Peace River in Alberta. One of the reviews was based on a single dam constructed upstream of the Moberly River.

Between 2009 and 2011, Klohn Crippen Berger Ltd., SNC-Lavalin Inc., and Hatch Ltd. undertook a comprehensive study (the Alternates Study) to evaluate alternate means of developing the hydroelectric potential of the Site C Flood Reserve (Volume 1 Appendix E Review of Alternate Sites on the Peace River). The intent was to undertake a comprehensive review of all previously identified alternates and any new alternates and compare them to the Project using a consistent evaluation process.

6.4.1 Alternates Considered

The following alternates were considered that would reduce the total reservoir area and, accordingly, the potential reservoir effects:

- A single dam located upstream of the Moberly River to avoid effects on that river, but that would not develop all of the available head between Peace Canyon Dam and Axis C3. Single-dam alternates considered were:
    1. A dam located at Axis C1, 5.5 km upstream of Axis C3
    2. A dam located at Axis C2, 3 km upstream of Axis C3
    3. A dam located just downstream of Wilder Creek, 11.5 km upstream of Axis C3
- Cascades of two or more dams lower in height than the proposed Site C dam that would reduce the area of flooded land while maximizing development of all of the head between Peace Canyon Dam and Axis C3. Cascades of multiple dams considered were:
    1. A two-dam cascade with a dam at Axis C3 and an additional dam located approximately 66 km upstream
    2. A three-dam cascade with a dam at Axis C3 and two other low dams located approximately 22 km and 59 km upstream
    3. A four-dam cascade with a low dam at Axis C3 and three other low dams located approximately 18 km, 39 km, and 61 km upstream
    4. A seven-dam cascade with a dam at Axis C3 and six other dams located approximately 10 km, 23 km, 37 km, 53 km, 65 km, and 79 km upstream

The eastern boundary of the Site C Flood Reserve is approximately 3.7 km downstream of Axis C3. Moving the dam further downstream was not considered since downstream of Axis C3 the geological conditions are less favourable, as the elevation of the bedrock outcrop on the north bank of the river drops and the slopes above bedrock comprise debris from slides and slumping of the overburden.

6.4.2 Technical Assessment

6.4.2.1 Layouts

Layouts were developed for the Project and the alternates as described below to prepare relative cost estimates and the facility characteristics (see Section 6.4.2.2).

The layout for the Project was adjusted with the allowances for the increased maximum design earthquake and rebound mitigation identified in Stage 2 (Klohn Crippen Berger & SNC-Lavalin 2009). Rebound refers to long-term swelling of the shale bedrock, which occurs when the weight of a structure is less than the weight of the soil and rock excavated to reach the foundation of the structure.

A dam at Wilder Creek and the two-dam cascade were new alternates that had not been previously studied. Layouts for these alternates were therefore developed and the dimensions of the various components determined in sufficient detail to allow the major quantities to be estimated so that the facility characteristics could be determined.

Dams at Axis C1 and Axis C2 had been previously studied and the facility characteristics were based on the previous work. Since the previous study, the maximum design earthquake had been increased, and allowances for the measures required to mitigate rebound of the rock due to unloading had been made for the Project. These design changes would also affect the design at Axis C1 and C2, which would increase the scope, cost, and schedule of dams at these locations. The intent was to update the previous study to include allowances for the increased maximum design earthquake and the measures required to mitigate rebound at Axis C1 and Axis C2, only if the initial screening (Section 6.4.5.3) indicated that development of a dam at one of those axes could be competitive with the Project.

A cursory evaluation had previously been done of three- and four-dam cascade alternates, which had developed layouts based on the topography at Axis C3 and assumed that suitable topographically similar sites could be found upstream. In the Alternates Study, it was assumed that the dam locations and layouts would be as identified in the previous evaluation; however, the dimensions of the various components were updated so that the facility characteristics could be determined on a consistent basis with the other alternates. The intent was to undertake detailed topographic studies, detailed layouts, and cost estimates for the dams located upstream of Site C only if the initial screening (Section 6.4.5.3) indicated that the three-dam or the four-dam cascade could be competitive with the Project.

The seven-dam cascade had been previously studied and was updated so that the facility characteristics would be determined on a consistent basis with the other alternates. In particular, allowances were made for increasing the spillway capacity so that the dams could pass the probable maximum flood, and increasing the number of anchors to withstand the new maximum design earthquake. The intent was to undertake a more detailed analysis (increasing the maximum normal reservoir level at the upstream dam and replacing the post-tensioned anchors with mass concrete), only if the initial screening (Section 6.4.5.3) indicated that the seven-dam cascade could be competitive with the Project.

Figures and more detailed descriptions of the layout for the Project and each alternate are provided in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.2.2 Facility Characteristics

The facility characteristics required to assess the technical feasibility, economic feasibility, environmental effects, and functionality of each alternate relative to the Project are related to the location and number of dams, site topography and geology, site layout, number of construction sites, sequence of construction, construction schedule, Highway 29 realignments, and transmission lines and substation(s).

The layouts enabled definition of the following key facility characteristics of the Project and each alternate:

- Location of dam(s)
- Geological characteristics:
  - Physical and topography
  - Surficial geology
  - Bedrock geology
  - Slope stability
  - Seismicity
  - Geological investigations
- Hydrological and reservoir characteristics:
  - Mean annual flow
  - Inflow design flood
  - Maximum normal reservoir level
  - Tailwater elevation at mean annual flow
  - Gross head at mean annual flow
  - Total net head at maximum capacity
  - Reservoir area
  - Reservoir shoreline length
  - Reservoir volume
  - Reservoir filling time
  - Reservoir flushing time
  - Length and area of the Peace River and tributaries inundated (the Moberly River, Tea Creek, Wilder Creek, Cache Creek, the Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek)
  - Length of shoreline created along the Peace River and tributaries inundated (the Moberly River, Tea Creek, Wilder Creek, Cache Creek, the Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek)
- Infrastructure characteristics:
  - Lengths of Highway 29 realignments and bridges at Cache Creek, the Halfway River, Farrell Creek, and Lynx Creek
  - Lengths of new permanent access roads required
  - Number of new bridges required
- River diversion characteristics, including location, type, and length of diversion works, and duration of diversion
- Excavation and relocation of surplus excavated materials including:

  - Total volume of excavation
  - Volume of dam materials required
  - Location of materials sources
  - Location of relocated surplus excavated materials
- Dam characteristics, including number of dams, dam types, dam height, and crest elevation
- Approach channel location and configuration
- Intake/water conduits/powerhouse characteristics, including type and size of conduits, service bay, and powerhouse size
- Spillway characteristics, including location, layout, and capacity
- Tailrace location and layout
- Mechanical and electrical characteristics, including:
  - Number and type of turbines
  - Installed capacity
  - Number and size of intake gates
  - Number and size of spillway gates
- Switchyard characteristics, including location and area
- Transmission line characteristics, including:
  - Number of transmission corridors
  - Characteristics of transmission lines and corridors
  - Length and cleared area
- Navigation facilities
- Fish passage facilities
- Availability of construction material, including:
  - Dam fill (or roller compacted concrete aggregate)
  - Dam core material
  - Concrete aggregate
  - Slope erosion protection
- Locations of areas for temporary works, camps, and laydown
- Accessibility, including road and rail access
- Schedule estimates, including site investigations, applications, design, and construction
- Energy estimates:
  - Total gross head at weighted average flow

  - Total net head at weighted average flow
  - Total average annual energy production
  - Relative average energy production
  - Total firm annual energy production
  - Relative firm annual energy production
- Energy cost ratio

For details, refer to the Facility Characteristics Matrix in Appendix A1 in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

For each alternate, the physical footprint areas in the Facilities Characteristics Matrix were overlaid on terrestrial ecosystem mapping data and physical environment themed data. These data were used to determine the effect of each footprint area on the physical, biological, and socio-economic environments.

The themed data consisted of the following areas affected by each alternate subdivided by reservoir, transmission line(s), dam, and each segment of highway realignment:

- Proposed protected areas
- Visual landscape inventory
- Petroleum titles
- Oil and gas fields
- Property: BC Hydro leased
- Property: BC Hydro owned
- Property: Crown
- Property: Private
- *Land Act* tenures
- Hunting zones
- Trapline areas
- Cut blocks
- Old Growth Management areas
- Timber Harvesting Land Base Class "C"
- Timber Harvesting Land Base Class "N"
- Timber Harvesting Land Base Class "P"
- Timber Harvesting Land Base Class "X"
- Recreational reserves and sites
- Grazing leases

The terrestrial ecosystem mapping data consisted of the following parameters affected by each alternate subdivided by reservoir, transmission line(s), dam, and each section of highway realignment:

- TEM – AM:ap – Creamy peavine (seral association) (01) both majority and minority
- TEM – CB – Cutbank (00) both majority and minority
- TEM – CF – Cultivated field (00) both majority and minority
- TEM – FM02 – Cottonwood-spruce-red-osier dogwood (09) both majority and minority
- TEM – GB – Gravel bar (00) both majority and minority
- TEM – SE – Sedge wetland (09) both majority and minority
- TEM – SH:ac – Cow parsnip (seral association) (07) both majority and minority
- TEM – WS – Willow sedge (00) both majority and minority
- TEM – SH:sw – Currant-horsetail (07) both majority and minority

For details of the terrestrial ecosystem mapping data categories and environmental themes, as well as the areas of the data affected by each footprint category, refer to the Environmental Areas Matrix in Appendix A2 in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.2.3 Functionality Assessment

An assessment was made of the functional differences between the Project and each alternate. The engineering parameters considered in this assessment were:

- Dam safety factors:
  - Capability to draw down the reservoir
  - Time to draw down the reservoir(s)
  - Hydrological – the relative reliability to pass high inflows
  - Landslide risks – the relative vulnerability to landslides
  - Seismic – the relative vulnerability of each alternate to large earthquakes
  - Geological conditions:
    - Effects of rebound, which is exacerbated by excavation depth
    - Effects of creep, which is likely less with lower dams
    - Piping potential, which is less with lower dams
  - Consequence of failure
  - Resilience and robustness
- Life cycle factors:
  - Operation and maintenance
  - Operating flexibility

- Personnel safety during operation
- Potential for environmental incidents
- Generation reliability

The assessment is presented in Section A of the Engineering Comparative Matrix contained in Appendix E in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.2.4 Comparative Assessment of Engineering Parameters

A comparative assessment of the engineering parameters of the Project and the alternates was undertaken. The parameters assessed included:

- Geological risks, including:
  - Certainty
  - Slope stability
  - Shoreline impacts (i.e., potential effects of reservoir shoreline slides on the dams)
  - Foundation conditions
  - Rebound conditions
- Design risks including:
  - Level of design development
  - Dam
  - Discharge facilities
  - Generating facilities
  - Other aspects, such as diversion logistics
- Construction factors, including:
  - Construction materials
  - Excavation and relocation of surplus excavated materials
  - Accessibility (road and rail)
  - Areas for temporary works, camps, and laydown
  - Project sequencing
- Schedule and cost certainty, including pre-construction and construction

The assessment is presented in Section B through D of the Engineering Comparative Matrix contained in Appendix E in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

Technical issues affecting the feasibility of a dam at Axis C1 or Axis C2 are:

- The stability of the very high slopes
- Substantially greater rebound than at the Project, due to deeper excavations

- Volume of surplus excavated material requiring relocation several times that of the Project

6.4.3 Economic Feasibility

The criterion developed to assess the economic feasibility was the energy cost ratio, which takes into account the energy cost of an alternate relative to the Project and how efficiently the alternative developed the hydroelectric potential in the Site C Flood Reserve. An energy cost ratio greater than 1.00 indicates that compared to the Project, an alternate produces higher cost energy, or produces less energy, or produces less energy at a higher cost. Examples are given below.

The energy cost ratios for the six alternates relative to the Project are shown in Table 6.1.

Table 6.1 Energy Cost Ratios

Single Dam		Cascading Dams			
C1 or C2	**Wilder Creek**	**Two Dams**	**Three Dams**	**Four Dams**	**Seven Dams**
2.14	1.38	1.55	1.88	2.27	1.76

The energy cost ratios show that all six alternates would have a greater energy cost ratio than the Project.

A single dam at Wilder Creek would have an energy cost ratio of 1.38 because the unit energy cost would be 20% higher and it would produce 87% of the energy produced by the Project (energy cost ratio = 1.20 ÷ 0.87 = 1.38).

The two-dam cascade would have an energy cost ratio of 1.55 because the unit energy cost would be 49% higher and it would produce 96% of the energy of the Project (energy cost ratio = 1.49 ÷ 0.96 = 1.55).

As described in Section 6.3, the site geology and topography at Axis C1 and Axis C2 are adverse, resulting in a construction cost that is double the cost of construction of the Project.

The Project is better economically, compared to the two single-dam alternates, as those alternates would produce less energy at higher unit energy costs.

Compared to single dams, alternates consisting of two or more dams have two important disadvantages: multiple dams are less energy-efficient and they cost more to build.

6.4.4 Environmental Effects

6.4.4.1 Physical Environment

The information contained in the Facilities Characteristics Matrix was used to assess the relative differences between the potential effects on the physical environment of each alternate and the Project as follows:

- Construction effects on the geological environment, including:
  - Reservoir filling, resulting in loss or alteration of Peace River physiographic features

  - Dam facility and associated infrastructure construction footprint, resulting in alteration of the local topography (i.e., landforms) at dam site
  - Reservoir filling and facility construction (e.g., roads, dam, etc.), resulting in loss of existing soils that support productive uses (e.g., agriculture)
  - Reservoir clearing and filling, resulting in terrain instability and shoreline erosion
  - Reservoir filling and dam construction, resulting in decreased ability to either extract resources or depletion of existing resources or both
  - Reservoir filling, resulting in decreased ability to extract oil and gas resources
- Construction effects on the hydrological environment including:
  - Flow diversions (e.g., cofferdams and tunnels), resulting in changes to Peace River flows and water levels
  - Reservoir filling, resulting in decreased flows in the Peace River
- Construction effects on water quality due to suspended sediment and turbidity resulting from:
  - Vegetation removal and potential soil erosion
  - Cofferdam installation and removal, and in-stream construction
- Construction effects on the atmospheric environment and air quality due to:
  - Vehicle and equipment exhaust
  - Fugitive dust (equipment, road traffic, blasting, wind-generated dust from either exposed or disturbed soils)
  - Vegetation burning
- Operation effects on the geologic environment, including shoreline instability and erosion
- Operational effects on the hydrologic environment, including:
  - Timing and magnitude of reservoir level fluctuations and downstream river flows
  - Slowing of river velocities resulting in increased residence time
  - Ice conditions in the reservoir and in the downstream Peace River
  - Changes to sediment transport and deposition within the reservoir, tributaries, and Peace River downstream
  - Effects on local groundwater conditions
- Operational effects on water quality, including:
  - Changes to water chemistry (e.g., suspended sediment, total metals, nutrients)
  - Changes to water temperature
  - Increases in methyl mercury levels due to decaying vegetation
  - Supersaturation of dissolved gases in spillway discharges harmful to fish
- Operational effects on the atmospheric environment, including:

  - Climatic conditions (fog, wind, temperature) in the vicinity of the reservoir
  - Greenhouse gas emission from decaying vegetation flooded by reservoir and construction emissions
- Effects of climate change

For details, refer to the Physical Environment Matrix in Appendix B Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.4.2 Biological Environment

The information contained in the Facilities Characteristics Matrix was used to assess the relative differences between the potential effects on the biological environment of each alternate and the Project as follows:

- Construction effects on the aquatic environment, including:
  - Fish communities in the Peace River, the Moberly River, Wilder Creek, Cache Creek (including Red Creek), the Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek
  - Upstream and downstream fish movements and migrations
  - Lower trophic level communities (plankton, benthos, and macrophytes)
  - Rare and listed species
- Construction effects on aquatic habitat, including:
  - Spawning and rearing habitat in the Peace River, the Moberly River, Wilder Creek, Cache Creek (including Red Creek), the Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek
  - Foraging and or refuge habitat in the Peace River, the Moberly River, Wilder Creek, Cache Creek, the Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek
  - In-stream flows
- Construction effects on riparian habitat and species, including:
  - Wetlands
  - Shoreline vegetation community
  - Islands or in-stream structures
  - Rare and listed riparian species or communities
- Construction effects on terrestrial habitat and wildlife, including songbirds, raptors, owls, bats, butterflies, waterfowl, shorebirds, beavers, amphibians, ungulates, and rare and listed wildlife species or communities
- Operation effects on aquatic habitat and fauna, including:
  - Reservoir habitat characteristics (shoreline erosion, sedimentation, nutrients, and temperature regime)
  - Reservoir fish community (composition, abundance, growth, and health)

  - Entrainment and turbine mortality
  - Upstream fish movement and migrations
  - Downstream habitat (erosion and sediment transport, side channels/dewatering, drift organisms, contaminants)
  - Lower trophic level communities (plankton, benthos, and macrophytes)
  - Fish mercury concentrations (results transferred to Wildlife and Socio-Economic accounts for inclusion into health assessments)
  - Rare and listed species
- Operation effects on riparian habitat and species, including shoreline vegetation community and islands, or in-stream structures
- Operation effects on the terrestrial environment, including vegetation species and communities, and wildlife

For details, refer to the Biological Environment Matrix in Appendix C in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.4.3 Socio-Economic Environment

The information contained in the Facilities Characteristics Matrix was used to assess the relative differences between the potential effects on the socio-economic environment of each alternate and the Project as follows:

- Construction effects on land use and land tenure
- Construction effects on resource use, including:
  - Agricultural lands
  - Forestry lands
  - Oil and gas
  - Mining and aggregates
  - Irrigation
- Construction effects on roads and traffic
- Construction effects on transmission line interconnections
- Construction effects on public health and safety, including:
  - Fugitive dust emissions
  - Noise
  - Worker and public safety, including recreation users
- Construction effects on culture and heritage, including:
  - Archaeological sites
  - Cultural resources
- Construction effects on recreation and tourism, including:

  - Fishing
  - Hunting
  - Trapping and guiding
  - Recreational boating and navigation
  - Recreational sites
  - Proposed protected areas
  - Viewscapes and area aesthetics
  - Tourism
- Construction effects on employment and economic opportunities, including:
  - Labour requirements and effects
  - Construction services and infrastructure
- Construction effects on:
  - Community services and infrastructure
  - Economic development and finances
- Construction effects on First Nations, including:
  - Traditional lands and uses
  - Economic opportunities
  - Public interest and quality of life
- Operations effects on land use
- Operations effects on groundwater and water wells
- Operations effects on recreation and tourism, including
  - Recreational fishing
  - Hunting, trapping, and guiding
  - Recreational boating and navigation
  - Scenic viewscapes and tourism potential
- Operations effects on employment and economic opportunities, including:
  - Employment
  - Local and regional economic development
  - Public interest and quality of life

For details, refer to the Socio-Economic Environmental Matrix in Appendix D in Volume 1 Appendix E Review of Alternate Sites on the Peace River.

6.4.5 Multi-Attribute Decision-Making Process

The multi-attribute decision-making process used to confirm whether the Project is the preferred means of developing the hydroelectric potential in the Site C Flood Reserve is described in the Alternates Study and summarized below.

6.4.5.1 Overview

As described in the Alternates Study and summarized below, a multi-attribute decision making process was used to assess the six alternates relative to the Project.

The evaluation process consisted of:

- Identifying environment effects and engineering functionality of each alternate relative to the Project and one another
- Ranking and weighting the environmental effects and functionality of each alternate, and comparing these relative to the Project and each other
- Comparing the relative footprint ratio and energy cost ratio of each alternate to the Project

The relative footprint ratio was determined for each alternate relative to the Project by weighting and combining the ratings for each of the four attributes, namely:

- Functionality (Section 6.4.2.3)
- Effects on the physical environment (Section 6.4.4.1)
- Effects on the biological environment (Section 6.4.4.2)
- Effects on the socio-economic environment (Section 6.4.4.3)

A preliminary analysis screened out four alternates as a result of a higher energy cost ratio due to higher project cost and lower energy production without providing a decrease in the relative footprint ratio. A series of sensitivity analyses were performed on the three remaining alternatives to determine whether changing the various weightings would materially change their ranking.

6.4.5.2 Evaluation Process

The attributes of the Project and each alternate that was evaluated were contained in the following four “accounts” as described in Volume 1 Appendix E Review of Alternate Sites on the Peace River:

- Physical Environment Matrix (Appendix B of the Alternates Study)
- Biological Environment Matrix (Appendix C of the Alternates Study)
- Socio-Economic Environmental Matrix (Appendix D of the Alternates Study)
- Functionality Matrix (Section A of the Engineering Comparative Matrix in Appendix E of the Alternates Study)

Using a bottom-up approach, ratings were assigned representing the potential change (positive, neutral, or negative) resulting from a particular action or activity for each account relative to that same attribute for the Project. Once all the individual attributes had been rated, weightings were assigned to provide an overall weighted rating for each

of the four accounts for each alternate relative to the Project. For the most part, the ratings were based on a quantitative comparison of such things as inundation areas, number of terrestrial ecosystem units, and length of road or transmission line between alternates. However, where quantitative data were not available, ratings and weightings were assigned by the discipline experts and then reviewed, confirmed, and challenged in two separate decision-making Delphi workshops. These qualitative ratings were based on changes that could potentially result from various construction and operations activities associated with a hydro development project of the scope and scale of the Project. The principles applied were those generally accepted in conducting multiple-criteria analyses.

The first Delphi workshop focused on the three environmental accounts, with participants representing the three discipline areas (physical environment, biological environment, and socio-economic environment). BC Hydro also participated in this process. Its role was to ensure that recent and historical data from BC Hydro's records were made available for the analysis, to provide input on operating regimes for existing BC Hydro facilities located on the Peace River, and to respond to questions of clarification regarding BC Hydro practices. The outcome of this first workshop was a refinement of the ratings and weightings within and between the three environmental accounts.

The second workshop focused on all of the discipline areas (engineering and environment) and was attended by BC Hydro engineering and environmental discipline leads teams. The outcome of this second workshop was:

- Further refinement of the environmental ratings and weightings
- Refinement of the engineering rankings and weightings
- Weighting between the four accounts

BC Hydro enlisted the services of Mr. Mike Saxton from Manitoba Hydro International to act as an external peer reviewer at critical steps throughout the evaluation of alternates. Mr. Saxton attended the second Delphi workshop. Mr. Saxton is Department Manager, Project Sustainability Review & Coordination, Manitoba Hydro International.

To assist in sorting data, ranking, and weighting the outcomes of given actions or activities on the various attributes, and to provide a visual representation of the comparison of the alternates relative to the Project, Hatch's proprietary Four Quadrants of Analysis (4QA) decision support tool was used.

The relative differences in physical risks, construction factors, schedule, and cost certainty between each alternate and the Project (Sections B through D of the Engineering Comparative Matrix, contained in Appendix E in Volume 1 Appendix E Review of Alternate Sites on the Peace River) were included in the range of energy cost ratios used in the assessments.

Sensitivity analyses were conducted at various levels, first by adjusting the relative ranking and weighting of sub-accounts within individual accounts, and then by adjusting the relative weighting between each of the four accounts.

6.4.5.3 Initial Screening

The following Base Case weightings were used to undertake an initial screening of the alternates to the Project:

- Physical environment 10%
- Biological environment 20%
- Socio-economic environment 20%
- Functionality (dam safety and life cycle factors) 50%

The ratings for each account (rating category) for the six alternates relative to the Project are shown in Figure 6.1. The total rating for each alternate shown on Figure 6.1 is the relative footprint ratio.

In summary, for the potential effects on the physical environment:

- Dams at Axis C1, Axis C2, the three-dam and seven-dam alternates were all rated better than the Project, largely due to less:
    - Effect on physiography
    - Inundated soils and lands
    - Effect on oil and gas resources
    - Effect on shoreline stability or erosion, and associated effect on water quality
    - Effect on local climate
- The four-dam alternate was rated worse than the Project overall due to the following factors, which offset the advantages listed in the preceding bullet points:
    - Larger disturbance (four large dams at four sites, with associated access roads and infrastructure)
    - Larger predicted effects on water and air quality during construction
    - Higher greenhouse gas production, due to greater volumes of excavation and construction materials, including concrete

In summary, for the potential effects on the biological environment:

- The three-, four- and seven-dam alternates were all rated worse than the Project, largely due to:
    - Greater effects on the Peace River fish communities, including their spawning, rearing, foraging, and refuge habitat
    - Greater effects on fish movements during both construction and operations, due to multiple dams and multiple work sites
    - The smaller reservoirs provide less opportunity for development of reservoir fish communities and would have higher operational effects, due to entrainment and turbine mortality at multiple work sites
- The aquatic effects were partially offset by less effect on terrestrial habitats and species, as the smaller reservoirs would inundate less terrestrial and riparian habitats

In summary, for the potential effects on the socio-economic environment:

- The two-, three-, four- and seven-dam alternates were all rated better than the single dam alternates, due to:

  - Less effect on land and resource use
  - Fewer archaeological sites and cultural resources affected
  - Less effect on trapping and hunting
  - Greater employment and economic opportunities for local communities, associated with the longer construction period needed for the multiple dam alternates
  - Greater employment during operation
  - Greater economic benefit to local companies and industries associated with the maintenance of the facilities
- The foregoing advantages were partially offset by greater effects on:
  - Transportation
  - Infrastructure
  - Health
  - Safety
  - Recreational boating during both construction and operation

In summary, for functionality, the three-, four- and seven-dam alternates were rated worse due to:

- Dam safety factors:
  - Increased potential for spillway gate malfunctions, due to the large number of gates
  - Landslide risk, due to dams located in close proximity to previous slides
  - Resilience and robustness – multiple gates and turbines increase the potential for malfunction
- Life cycle factors which rated lower (i.e., worse), due to the large number of smaller units at multiple sites adversely affecting:
  - Operation and maintenance
  - System integration
  - Personnel safety

The overall results are shown on the 4QA plot for the Base Case in Figure 6.2 where the relative footprint ratios versus the energy cost ratio is plotted for each alternate and the Project. This plot demonstrates that four of the alternates, namely a dam at Axis C1 or Axis C2, and the three-, four- and seven-dam alternates were dominated by the Project and the other two alternates. This means that changing to a dominated alternate would increase the energy cost ratio and not decrease the relative footprint ratio, whereas changing to a non-dominated alternate would increase the energy cost ratio and decrease the relative footprint ratio.

For example, a change from the Project to the Wilder Creek alternate increases the energy cost ratio and decreases the relative footprint ratio, and changing from the Wilder Creek alternate to the two-dam alternate increases the energy cost ratio and decreases

the relative footprint ratio; however, changing from the two-dam alternate to the seven-dam alternate increases the energy cost ratio and increases the relative footprint ratio.

It would not be logical to get less energy at a higher cost with greater environmental effects; therefore, Axis C1 or Axis C2 and the three-, four-, and seven-dam alternatives were screened out from further analysis.

6.4.5.4 Comparison of Non-Dominated Alternates

Figure 6.3 shows the comparison between the physical environment ratings by subcategory of the Project, and the Wilder Creek and two-dam alternates with the Base Case weightings.

For the physical environment:

- Wilder Creek rated highly for all subcategories during construction, as it would affect a shorter length of the Peace River than the Project and the two-dam alternate, and would avoid any effects to the Moberly River valley
- During operation, Wilder Creek and the two-dam alternate were rated similarly for most subcategories, with the exception of the geological environment, where the shorter shoreline around the Wilder Creek reservoir would result in less potential for shoreline erosion and stability issues
- Summing all physical environment subcategories for both construction and operation, the difference between Wilder Creek and the two-dam alternate was minimal

Figure 6.4 shows the comparison between the biological environment ratings by subcategory of the Project, and the Wilder Creek and two-dam alternates with the Base Case weightings.

For the biological environment:

- Wilder Creek rated highly within most subcategories during construction, as it would affect a shorter length of the Peace River than the Project and the two-dam alternate, and would avoid any effects to the Moberly River valley. The one exception was in the riparian habitat subcategory, where construction of the two-dam alternate would have less effect on wetlands
- The two-dam alternate was rated worse than the Project and Wilder Creek for aquatic fauna and habitat, due to the presence of two work sites within the river valley and associated effects on fish community and habitat, including:
    - More disturbance to movement patterns including migrations
    - Larger footprint area associated with the two dam sites
    - Greater potential for sediment releases, resulting in water quality impairment from work at two sites, compared to one
- During operation, Wilder Creek and the two-dam alternate were rated similarly for most subcategories, with the exception of riparian habitat, where Wilder Creek would have the shorter length of shoreline

- Overall, the aquatic effects/benefits of one alternate would be generally offset by the riparian/terrestrial effects/benefits of the other alternate, such that only very small differences were present between alternates

Figure 6.5 shows the comparison between the socio-economic environment ratings by sub-category of the Project, and the Wilder Creek and two-dam alternates with the Base Case weightings.

For the socio-economic environment, as with the physical environment and biological environment, each alternate has its own positive and negative aspects:

- During construction, the two-dam alternate was rated higher than the Project and the Wilder Creek alternate in the land and resource use; culture, heritage and first nations; and employment and economic opportunities subcategories because the two sites would:
    - Result in less inundation of valley lands and terraces
    - Provide a longer construction period with more employment and economic opportunities
- During construction, the positive aspects of two-dam alternate in the foregoing would be partially offset by greater effects on the transportation, infrastructure, and health and safety subcategories because for the two sites, there would be:
    - Longer travel distances, with construction traffic affecting a larger area
    - Greater need for services and infrastructure
- During construction, the recreation and tourism subcategory effects would be less for the Wilder Creek alternate, due to less effect on:
    - Recreational boating and navigation, as the Moberly River would not be affected
    - Proposed protected area, including the Peace River Boudreau Lake
- During operation:
    - Wilder Creek and the two-dam alternate were both rated higher than the Project in the land and resource use, and public interest subcategories, due to the smaller inundation area and less effect on future land use
    - Wilder Creek was rated higher in the recreation and tourism subcategory due to the retention of the Moberly River valley and positive effects on downstream recreational fisheries
    - The two-dam alternate was rated higher, as the two facilities would provide additional employment opportunities and greater economic benefits to the local communities
- Overall, the Wilder Creek and the two-dam alternates were rated better than the Project, with the two-dam alternate rated better than the Wilder Creek alternate

Figure 6.6 shows the comparison between the functionality ratings by subcategory of the Project, and the Wilder Creek and two-dam alternates with the Base Case weightings.

For functionality:

- The two-dam alternate:

  - Rated higher than the other two alternates on all dam safety factors because the smaller dams and reservoirs present less risk
  - Rated lower than the other two alternates for most life cycle factors because the larger number facilities and components:
    - Require more operation and maintenance
    - Are harder to integrate into the electrical system
    - Have greater potential for worker accidents and environmental incidents
  - Would have higher generation reliability because with the greater number of units in the two facilities, a single unit outage for maintenance or repairs would have less effect on the system
- Overall, the potential dam safety advantages of a two-dam alternate were offset by the lower rating of the life cycle factors, resulting in all three alternates having similar ratings

6.4.5.5 Sensitivity Analysis

Sensitivity analyses were performed to determine whether changing the weightings would materially change the relative footprint ratio of the Wilder Creek and the two-dam cascade alternates so that the higher energy cost ratios of either of these alternates could be justified.

For the Wilder Creek alternate, the main difference is that this alternate would not flood the lower part of the Moberly River, although there would be some terrestrial effects in the Moberly catchment, mainly due to transmission. Therefore, the question would be how much more one would have to value the Moberly River to make a difference in the outcome.

For the two-dam alternate, the main difference is that this alternate would flood less land, particularly agricultural land and Watson Slough. Therefore, the question would be how much more one would have to value the land and the socio-economic factors to make a difference in the outcome.

These two questions were addressed by the following sensitivity analyses:

1. Changing the overall environment weighting to 60% and functionality to 40%, which was considered to be the lowest weighting reasonable for functionality, given the nature of the project, the size of the investment, and the consequences of a dam failure or operational problems. The ranking of the alternates did not change and the differences between the alternates remained the same.
2. Increasing the weighting of the Moberly River to 50% relative to the other fish bearing watercourses (i.e., the Moberly River was valued the same as the Peace River and all other tributary rivers and creeks combined). The ranking of the alternates did not change, but the Wilder Creek alternate was rated better.
3. Increasing the weighting of the Moberly River to 100% relative to the other fish bearing watercourses (i.e., all other tributary rivers and creeks combined were assumed to have no value), and increasing the weighting of the aquatics environment to 100% relative to terrestrial (i.e., terrestrial effects were assumed to

have no value). The ranking of the alternates did not change, but the Wilder Creek alternate was rated better than in sensitivity analysis #2, above.

4. Increasing the weighting of Watson Slough and valley bottom agriculture. Riparian habitat, islands, and shoreline vegetation community value were given higher weightings for the biological environment, and agricultural land was weighted 50% of overall land value for the socio-economic environment. The ranking of the alternates did not change and the differences between the alternates remained the same.

The results of the sensitivity analyses are shown in Figure 6.7.

Sensitivity #2 assigned an equivalent weight to the Moberly River aquatic resources as the Peace River and all other tributaries and Sensitivity #3 gave no weight to aquatic resources other than the Moberly River (including the total exclusion of terrestrial values in Sensitivity #3). These two sensitivities are unreasonable, given the size and importance of the Peace River and other tributaries, including the Halfway River, which provides habitat for the blue-listed bull trout, as well as other species. While other tributary streams (i.e., Wilder Creek, Cache Creek, Farrell Creek, Lynx Creek, and Maurice Creek) are less important, it is unreasonable to give them no value. However, the results of these three sensitivities demonstrated that the relative footprint ratios are not sensitive to the weighting applied to the aquatic resources of the Moberly River.

Sensitivity #4 demonstrated that the relative footprint ratios are not sensitive to the weighting applied to the terrestrial and agricultural resources.

6.4.5.6 Preferred Alternate

As discussed in Volume 1 Section 5 Need for, Purpose of, and Alternatives to the Project, the specific purpose of the Project is to cost-effectively maximize the development of the hydroelectric potential of the Site C Flood Reserve.

Volume 1 Section 7 Project Benefits describes the ratepayer, taxpayer, economic, and sustainability benefits of the Project.

The potential environmental effects of the Project and the alternates were not monetized, i.e., dollar values were not assigned to the various environmental and functional attributes that were combined to give the relative footprint ratio. In contrast, the energy cost ratio is a measure of the cost-effectiveness of each alternate for developing the hydroelectric potential of the Site C Flood Reserve relative to the Project. Figure 6.2 shows the energy cost ratio and the footprint ratio for each alternate relative to the Project. The scales of the two axes are different:

- Suboptimal energy cost ratios, i.e., greater than 1.0, indicate less energy production at a higher unit energy cost. As shown in Table 6.1, the energy cost ratios for the Wilder Creek alternate and the two-dam alternate are 1.38 and 1.55, respectively. A 38% to 55% increase of energy cost ratio indicates a commensurate loss in economic efficiency.
- Optimal relative footprint ratios indicate less environmental effects; however, as shown in Figure 6.7, the differences between the Wilder Creek alternate and the two dam alternate are modest

The Alternates Study concluded that:

- There are no environmental factors that would eliminate an alternate

- The relative differences in environmental effects and functionality between alternates are small
- The small relative differences in benefits between the alternates do not justify the greater costs

The Alternates Study demonstrates that the Project is the preferred means of cost-effectively maximizing the development of the hydroelectric potential of the Site C Flood Reserve.

6.5 Substation and Transmission Line to Peace Canyon

Section 4.3.3.2 describes the following alternatives that were considered for connecting the Site C substation to the Peace Canyon substation:

- Locating the transmission corridor on the north side of the Peace River
- Connecting via submarine transmission cables in the reservoir

As described in Section 4.3.3.2, location of the transmission lines on the north side of the Peace River is not proposed because:

- Of the increased cost of the transmission line
- This alternative would require the acquisition of rights on 135 parcels of land totaling 1,263 ha while BC Hydro already has a right-of-way on the south bank
- Widening of the existing right-of-way would have lesser environmental effects

As described in Section 4.3.3.2, connecting the Site C substation to the Peace Canyon substation through submarine cables would be uneconomic, with higher risks and lower reliability.

The transmission line alternatives are also addressed in Section 34.4.2 Summary of Mitigation Measures Suggested by Aboriginal Groups.

6.6 Highway 29 Realignments

6.6.1 Lower Bench Alternative Alignments

Section 4.3.4.1 provides a general description of the six segments of Highway 29 that would be realigned as part of the Project. These six segments are located on lower benches near the valley bottom and would be flooded or otherwise directly affected by the reservoir.

For three of these segments - Lynx Creek, Halfway River and Cache Creek - multiple alignments are technically feasible. Therefore, BC Hydro conducted a multiple account evaluation to consider the potential effects of the alignment alternatives and to select the preferred alignment for each of these three segments. Section 4.3.4.2 provides an overview of the evaluation and the following subsections describe:

- The multiple accounts assessment process that was used to select the preferred alignments
- The criteria used for the evaluation
- The alternative realignments

- The preferred alignment selected for each segment

6.6.1.1 Process

In Stage 2, Highway 29 was a public consultation topic and participants identified the following areas to be considered when evaluating the relocation of the highway:

- Safety
- Environment
- Heritage sites
- Private property impacts
- Scenic views
- Costs

The assessment of alternative alignments took into account the input received during Stage 2 consultation from property owners and other members of the public, updated geotechnical information and input from Transport Canada on navigation criteria for proposed bridges.

The BC Ministry of Transportation and Infrastructure (MOTI), who will own, operate and maintain the re-aligned highway, was an active participant in the re-alignment design process and the selection of preferred alignments.

In the multiple account evaluation process, the relative safety, environmental impacts (including those on fish, wildlife and habitat), social impacts (including those on property, heritage and agriculture) and costs of each option were considered to arrive at a consensus for a preferred alignment. The indicators used to evaluate the options are shown in Table 6.2. Participants included representatives of BC Hydro, the Site C Integrated Engineering Team, MOTI, and engineering design consultants (R. F. Binnie & Associates, AMEC, MMM Group and Northwest Hydraulics.

Table 6.2 Indicators Used in Highway 29 Multiple Account Evaluation

Engineering	Environment	Archaeology	Property	Agriculture
Capital cost	Area of aquatic and riparian habitat affected	Number of known sites within 50 metres of alignment	Number of private holdings affected	Area of land within ALR occupied by right-of-way
Life cycle cost	Area of in-stream works	Number of known sites directly affected	Number of private holdings severed	Net length of actively farmed land severed
Geotechnical risk	Area of forest removed	Area of alignment with high or moderate potential	Area of private land affected	
Landslide induced wave impact	Area of field removed		Area of Crown land affected	
Operational safety	Area of other habitat removed			
Public and worker safety	Area between alignment and reservoir			

6.6.1.2 Lynx Creek

As summarized in Section 4.3.4.2, the alignment shown in Section 4 Figure 4.28 for the Lynx Creek segment was selected as the preferred alternative, even though it would have higher cost than the next highest ranked alternative, due to lower environmental and socio-economic effects.

At Lynx Creek, approximately 8 km of highway would require re-alignment. Four alignments were considered during Stage 2. During public consultation in 2008, property owners expressed a preference for using the existing Millar Road, so two additional alignments using Millar Road were considered. The alignments were located in three corridors based on their relative locations at the mouth of Lynx Creek (see Figure 6.8):

- Alignments 1, 2 and 3 inland at the toe of the bench above the flood plain
- Alignment 4 along the proposed reservoir shoreline
- Alignments 5 and 6 located between the other two corridors and using Millar Road

Each alignment alternative has short bridge/ causeway combination and long bridge only options.

A preliminary multiple account evaluation was undertaken to select the preferred alignment from each corridor for further study.

Alignment 3 was selected from the inland alignment alternatives for further engineering because it would have the lowest potential environmental and social effects and there would be no material differences in safety and costs between the alternatives in this corridor. A short bridge was selected over a long bridge because:

- It would have a shorter length within the Landslide Generated Wave Impact Line (see Section 11.2.3 for a description of the Reservoir Impact Lines)
- The costs would be substantially lower
- The environmental and social impacts would not be materially different

Alignment 4 would have the lowest overall potential environmental and social effects out of all six alignment alternatives; however it would be within the Landslide Generated Wave Impact Line and the Stability Impact Line.

Alignment 5 was selected from the central corridor for further engineering because it would have lower overall potential environmental and social effects than Alignment 6, it would be less costly and there would be no material differences in safety between the alternatives.

A short bridge was selected over a long bridge because it would be safer due to a shorter distance within the Landslide Generated Wave Impact Line, the costs would be lower and the environmental and social impacts would not be materially different.

Further engineering was done on the three selected alternatives and a final multiple account evaluation was then conducted. The alignments considered in the final multiple account evaluation are shown in Figure 6.9.

Alignment 4 was eliminated because of its location immediately adjacent to the proposed reservoir shoreline and within the Landslide Generated Wave Impact Line, resulting in an unacceptably high safety risk.

Alignment 5 would have a higher cost than Alignment 3; however Alignment 5 was selected as the preferred alternative because it:

- Utilizes a portion of the existing Millar Road alignment and therefore has lower private property effects
- Has lower field footprint and a relatively small forested land footprint, resulting in lower potential wildlife effects
- Requires no in-stream works and therefore is associated with minimal aquatic or riparian habitat effects
- Has lower potential for wildlife crossing
- Has lower potential agricultural effects

A short bridge is preferred over a long bridge due to lower capital and maintenance costs.

6.6.1.3 Halfway River

As summarized in Section 4.3.4.2, the alignment shown in Section 4 Figure 4.32 for the Halfway River segment was selected because it was the lowest overall cost and was considered to have a reasonable balance between the environmental and social factors.

At Halfway River approximately 4 km of highway would require re-alignment. The three alignments shown in Figure 6.10 were evaluated. An overriding concern at Halfway River is the potential effect of a landslide generated wave on a bridge and its support structures. For each of the alternatives, the costs of mitigating the effects from the impact of a landslide generated wave were included in the capital cost estimate.

A preliminary multiple account evaluation was conducted for the Halfway River alignments. Only the long bridge option for Alignment 2 was eliminated because its cost was substantially greater than for any other option. Further engineering was done on the remaining options and a final multiple account evaluation was then conducted.

Alignment 3 was selected as the preferred alignment because it has a good balance between environment and social indicators and the lowest overall cost. Alignment 3 has:

- The lowest area of in-stream works
- No private property impacts
- No agricultural land severance
- Relatively lower loss of Agricultural Land Reserve (ALR) land.

A short bridge was preferred over a long bridge due to lower capital and maintenance costs.

6.6.1.4 Cache Creek

As summarized in Section 4.3.4.2, the alignment shown in Section 4 Figure 4.33 for the Cache Creek segment was selected because it would have the lower overall cost and lower socio-economic effects.

At Cache Creek approximately 9 km of highway would require re-alignment. The two alignments shown in Figure 6.11 were evaluated. Alignment 1 follows the future

reservoir shoreline and Alignment 2 traverses the valley escarpment. The escarpment at the edge of the valley is known to be unstable and is prone to sliding and sloughing (see Section 11.2.2.3 and Volume 2 Appendix B, Part 1 Terrain Stability Mapping for the discussion on terrain stability).

Alignment 2 has greater technical challenges than Alignment 1 as it would be located along the toe of the escarpment, which results in higher costs and construction risks. Alignment 1 also has:

- Lower area of private land impacted
- Less length of actively farmed land severed
- Less area of Agricultural Land Reserve (ALR) land needed for the right-of-way.

Therefore, Alignment 1 with a short bridge was selected as the preferred alignment. Several routing refinements are possible at the east end of Alignment 1, which is considered as a preferred corridor.

6.6.2 Upland Alternative Alignments

During Stage 2 consultation and subsequent discussions with landowners and the public, BC Hydro was requested to examine alternate highway alignments on the upper benches or on the plateau rather than on the lower benches where Highway 29 is currently located. The results of a conceptual review of these alternatives are summarized below.

6.6.2.1 Cache Creek – Alternative Alignment Along Existing Transmission Line

This route would generally follow the existing 138 kV transmission line along the bench above Bear Flat, but would divert around larger gullies where possible (Figure 6.12). The upper alignment would be 11.5 km long compared to 9 km for the lower alignment and would require the construction of 5 km of additional secondary roads to maintain access to landowners.

In addition to being longer than the proposed option, the alternative route faces the additional challenge of crossing the Cache Creek valley at a much higher elevation, which would either require a very large bridge on the order of 1 km long and 120 m high, or a smaller (but still very large) structure might be possible by routing the highway down into the Cache Creek valley. Routing the highway down into the valley may not be possible with geometry maintaining the 90 km/h design speed, and would entail very large earthworks on slopes which have been characterized as unstable glaciolacustrine silts and clays (see Section 11.2.2.3 and Volume 2 Appendix B, Part 1 Terrain Stability Mapping for the discussion on terrain stability). The cost of the alternative alignment on the upper bench was estimated to be $180 million greater than the alignment on the lower bench.

Because of the additional 2.5 km of highway and 5 km of secondary roads required and the large bridge, fills and cuts required to cross Cache Creek, the environmental effects of the upper alignment would be greater.

6.6.2.2 Halfway River

Figure 6.13 shows two alternatives for upper bench routes at the Halfway River (in red). Also shown are the alternative alignments on the lower bench (in blue).

Alternative 1 on the upper bench would require an even larger structure than required for the upper bench alternative at Bear Flat as well as a new sidehill cut up to the upper bench through difficult topography and poor geotechnical conditions. The brdge across the Halfway River would be 180 m high and 1.3 km long with abutments on steep slopes of glaciolacustrine silts and clays. The cost of the bridge alone would be over $260 million and it was considered that this option would be technically and economically unfeasible.

Alternative 2 would include approximately 2 kilometres of new highway on a sidehill cut through glaciolacustrine silts and clays in difficult topography. The lower bench alignments utilize the existing section of highway that crosses the escarpment from the upper bench tpo the lower bench. The difficulties associated with constructing a new 2 km section of highway in a sidehill cut on steep unstable ground would outweigh any benefits of this alternative.

6.6.2.3 Connections from Highway 97 North of Highway 29

Figure 6.14 shows alternative routes from Mile 68 and Mile 95 on the Alaska Highway (97). Table 6.3 tabulates the salient data for each route which consists of the lettered segments shown on Figure 6.14, e.g. Route 1 which consiss of segments M-N-P is the existing route of Highway 29.

Table 6.3 Alternate Routes via the Alaska Highway

Route	1	2	3	4
Highway Route	M-N-P	A-B-C-D	A-B-C-E-H-J-P	A-G-F-H-J-P
Upgraded Secondary Road Segments Required to Maintain Access to Landowners		G, F, L,H,J,K	K, G, L	L, K
Distance from Hwy97/29 Junction to Hudson's Hope (km)	72	198	212	118
Length of New Highway (km)	28	133	143	91
Number of Major Bridges	1	0	1	1
Number of Large Bridges	3	2	0	0
Number of Small Bridges	1	2	4	4

Route	1	2	3	4
Length of Upgraded Secondary Road to Maintain Access to Landowners (km)	0	122	73	40
Incremental Cost ($ Million)[1]	0	170	188	76

Notes:

1. Construction cost only, excludes property aqusition costs.

Alternatives Routes 2, 3 and 4 were considered to be unfeasible due to:

- Substantially higher cost than Route 1
- Greater environmental effects due to larger footprint
- Indirect routes with substantially greater travel times.

6.6.3 Bridge Removal

As described in Section 4.4.6, the existing Lynx Creek and Cache Creek bridges would be dismantled and the existing bridges at Farrell Creek and Halfway River may remain in place to avoid the cost of demolition and removal. This section describes the potential impacts of leaving bridges in place on navigation clearances, currents and sediment buildup. Figures 4.30 and 4.32 show the segments of the existing highway that would be flooded at Farrell Creek and the Halfway River, respectively.

Section 4.3.2 describes the characteristics of the reservoir, and Section 4.5.2.1 and Section 11.4.4 describe reservoir levels during operations.

As described in Section 4.5.2.1, the reservoir could be drawn down below the minimum normal reservoir level for unusual system requirements or system emergencies. The current expectation is the lowest reservoir level at which the generating station could operate during a system emergency would be elevation 455 m. Unusual system requirements or a system emergency that would require a drawdown below the minimum normal reservoir level would be a condition on the integrated system, such as outage(s) of major transmission line(s) or generating station(s) at a time when sufficient capacity support was not available through interties with neighbouring utilities, so that maximum output from the Project generating station would be required to prevent cascading blackouts of all or a major part of the BC Hydro system. BC Hydro has never experienced a system emergency that led to blackouts of all or a major part of the system. Therefore, drawdown below the minimum normal reservoir level is considered unlikely.

As described in Section 4.5.1.3, the spillway gates and undersluices would be capable of drawing the reservoir down to elevation 442 m so that inspections, maintenance and repairs could be made if required. A need to draw down the reservoir below the minimum normal reservoir level is unlikely. Nevertheless, it is feasible and prudent to incorporate the ability to do so into the design. The following information is provided to clarify why a draw down below the minimum normal reservoir level is considered to be a rare occurrence.

As described in Section 4.3.1.2, the Project's approach channel has an impervious lining to reduce seepage into the underlying bedrock. The approach channel lining would be designed and constructed to have a life of over 100 years; therefore, a drawdown for inspection, maintenance and repairs would not be a planned event, and is considered unlikely for the following reasons:

- The permeability of the intact bedrock is lower than that of the impervious fill used for the lining. The purpose of the lining is to limit inflow into the discontinuities (e.g. joints and fissures) in the bedrock. The design of the impervious lining is redundant with four seepage barriers:
  - A geomembrane
  - A layer of compacted impervious fill
  - Discontinuities exposed in excavated rock surfaces would be sealed before placing the impervious fill
  - A grout curtain from the RCC buttress to seal discontinuities within the bedrock
- As described in Section 4.3.1.3, the RCC buttress would have a system to drain any seepage from the rock. As described in Section 37.1.8.1.4, the approach channel lining and the drainage system would be designed to be functional after the deformations (movements) expected to occur under all loading conditions, including the earthquake design ground motion. Nevertheless, the buttress has been designed to withstand a severe loading condition, which represents a complete failure of the lining and drainage system.

6.6.3.1 Navigation Clearances

As described in Section 26, research on a variety of vessel types likely to use the Site C reservoir confirmed that a navigation envelope that accommodates 1.5 m of draft, 25 m horizontal clearance, and 8 m vertical clearance would support future navigation use.

The existing Farrell Creek bridge has two end spans of approximately 9 m and two centre spans of approximately 15 m. The bridge deck elevation is 449.3 m and the top of the railing is at elevation 450.1 m.

With the reservoir at the minimum normal reservoir level the depths of water would be 10.7 m above the bridge deck and 9.9 m above the bridge rails. At the minimum operating level of elevation 455.0 m the clearance would be 5.7 m above the bridge deck and 4.9 m above the bridge rails.

The existing Halfway River bridge has two spans of approximately 61 m. The bridge deck elevation is 442.3 m and the top of the railing is at approximately elevation 443.1 m.

With the reservoir at the minimum normal reservoir level the depths of water would be 17.7 m above the bridge deck and 16.9 m above the bridge rails. At the minimum operating level of elevation 455.0 m the clearance would be 12.7 m above the bridge deck and 11.9 m above the bridge rails.

The clearances with the reservoir in the normal operating range and drawn down to the minimum operating level are greater than the navigation envelope; therefore leaving the two bridges in place would have no effect on navigation under these conditions.

The two bridges would be exposed if the reservoir was drawn down to elevation 442 m. If such a drawdown was required, the planning associated with the drawdown would include navigation provisions at both locations.

6.6.3.2 Currents

As described in Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report:

- The mean annual flows of Farrell Creek and the Halfway River are estimated to be 1.4 m^3/s and 68.4 m^3/s, respectively (Table 3.3)
- The largest peak flow at WSC Gauge 07FA004 that was generated primarily by tributary inflows below the Peace Canyon Dam as opposed to flow releases from the reservoirs is 3,230 m^3/s in 2001, of which the Halfway River contributed 2,790 m^3/s (Section 2.3.2.4), and which is approximately 41 times the mean annual flow.

With the reservoir at the minimum normal reservoir level, the average current velocities would be:

- 0.00039 m/s (0.00076 knots) at the mean annual flow and 0.016 m/s (0.0031 knots) during a flood assuming a flood peak 41 times greater than the mean annual flow at the submerged Farrell Creek bridge
- 0.0019 m/s (0.0037 knots) at the mean annual flow and 0.078 m/s (0.15 knots) during a flood equal to the 2001 flood at the submerged Halfway River bridge
- If the bridges were removed the average current velocities would decrease by 2% and 1% at Farrell Creek and the Halfway River, respectively.

With the reservoir at the minimum operating level, the average current velocities would be:

- 0.00092 m/s (0.0018 knots) at the mean annual flow and 0.0038 m/s (0.0074 knots) during a flood assuming a flood peak 41 times greater than the mean annual flow at the submerged Farrell Creek bridge
- 0.0029 m/s (0.0056 knots) at the mean annual flow and 0.12 m/s (0.23 knots) during a flood equal to the 2001 flood at the submerged Halfway River bridge
- If the bridges were removed the average current velocities would decrease by 4.8% and 1.9% at Farrell Creek and the Halfway River, respectively.

The estimated average current velocities in the Peace River pre construction of the Project are:

- At Farrell Creek:
  - 1.6 m/s to 1.7 m/s (3.1 knots to 3.3 knots) at the mean annual flow
  - 1.7 m/s to 2.0 m/s (3.3 knots to 3.9 knots) with the Peace Canyon powerhouse at full discharge
- At the Halfway River:
  - 1.2 m/s to 1.5 m/s (2.3 knots to 2.9 knots) at the mean annual flow and 2.2 m/s (4.3 knots) during a flood equal to the 2001 flood

Thus, currents at the locations of the submerged bridges at Farrell Creek and the Halfway River would be less than existing currents in the Peace River.

6.6.3.3 Sediment Build-up

Sediment transport in the reservoir is described in Section 11.8.5 and Volume 2 Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report.

Appendix I Figures 4.13 and 4.14 show the 50-year deposition results from the accelerated model with average tributary sediment inputs for the entire reservoir and for the Halfway River embayment, respectively. The model results indicate that the upstream part of the reservoir (upstream of Halfway River) would be characterized by 0.25 m to 0.5 m of deposition. Higher deposition would occur in the middle section of the reservoir near the Halfway River confluence (1 to 2 m).

The submerged bridges are not expected to change the behaviour of sediment within the reservoir. There room under the bridges for highly sediment-laden water to flow down the old river channels (5 m at Farrell Creek and 12.8 m at halfway River). Clay that is suspended higher up in the water column would flow around the submerged bridges. Since both submerged bridges are located near the downstream end of the embayments the majority of the coarser sediment would settle out near the upstream end and only the finer materials would reach the bridges. Thus it is conservative to assume that the majority of the sediment accumulates on top of the bridges.

As shown in Appendix I Figure 4.13 deposition in the vicinity of the submerged bridge at Farrell Creek would be less than 1 m, which would not adversely affect the required navigation clearance even if all of the sediment deposited on the top of the bridge deck.

As shown on Appendix I Figure 4.14 deposition in the vicinity of the submerged bridge at the Halfway River would be less than 2 m, which would not adversely affect the required navigation clearance even if all of the sediment deposited on the top of the bridge deck.

6.6.3.4 Conclusion

Based on the information provided above, leaving the Farrell Creek and Halfway River bridges in place would have no adverse effects on navigation.

6.7 Quarried and Excavated Construction Materials

As described in Section 4.3.5, a variety of quarried and excavated materials would be required for construction of the dam, generating station and spillways, Highway 29 realignments, access roads and the Hudson's Hope shoreline protection.

Generally, the use of on-site material (as defined in Section 4.3.5) is preferred as this results in lower cost and less environmental effects, particularly less ground disturbance, less traffic and lower emissions. When there are no suitable on-site materials and off-site materials have to be used, investigations have focused on finding the closest source of material that meets the technical requirements because closer sources result in less traffic and less emissions.

The alternative sources of off-site materials that were considered are discussed in the following subsections.

6.7.1 Impervious Core Material

The impervious core is a key element of an earthfill dam.

The glacio-lacustrine silts and clays that would be excavated from the north bank stabilization (a large excavation to remove unstable materials from the bank above the earthfill dam and flatten the slope for long-term stability, see Section 4.3.1) was found to be suitable for use as impervious core because of:

- High variability of gradation and plasticity
- In-situ moisture content considerably wet of optimum
- Beds of granular (pervious) material comprising approximately 39% of the height of the cut
- Layers of materials with shear strengths as low as 11 degrees.

Section 4.3.5.4.1 describes the investigations carried out in 2009 and 2010 to identify potential sources of impervious core material and the reasons why 85th Avenue Industrial Lands was selected as the source of the impervious fill.

6.7.2 Riprap

Rock riprap for erosion protection must be hard and durable.

Section 11.2.2.1 describes the regional geology. The Cretaceous shale does not meet the technical requirements for riprap but suitable rock can be found in sandstone and limestone outcrops.

6.7.2.1 Dam, Generating Station and Spillways

Section 4.3.5.4.2 describes why the potential Tea Creek source of temporary riprap (sandstone) was eliminated to minimize the environmental effects. As described in Section 4.3.5.2.2, temporary riprap would be sourced from the existing Wuthrich Quarry (sandstone).

Section 4.3.5.2.3 describes the West Pine Quarry that has been selected as the source of permanent riprap (limestone) and the transportation alternatives. Section 4.3.5.4.3 describes the reasons why the Portage Mountain Quarry was eliminated as a potential source of permanent riprap (sandstone).

6.7.2.2 Highway 29 and Hudson's Hope Shoreline Protection

Section 4.3.5.4.4 describes the reasons why the Castle and Pringle formations (sandstones) were eliminated from consideration of sources of riprap.

6.7.3 Gravel

6.7.3.1 Del Rio Pit

As described in Section 4.3.5.2.5, the existing Del Rio Pit would be used as a source of gravel for the construction of the Project access road. This pit is located adjacent to the western end of the road. Other potential sources of suitable materials are further away and use of these sources would require development of new pits and greater haul distances with greater traffic and emissions.

6.7.3.2 Inundated Areas

As described in Section 4.3.5.2.6, the closest sources within the area that would be flooded by the proposed reservoir to the Highway 29 segments requiring realignment and the Hudson's Hope shoreline protection have been identified as off-site sources for the required construction materials.

Use of alternative sources would increase the footprint of the Project by extracting material from outside of the reservoir area, potentially developing new gravel pits and in some cases increase the haul distances.

6.7.3.3 Commercial Pits

As described in Section 4.3.5.2.7, some materials would be sourced from commercial pits.

Use of alternative sources would increase the footprint of the Project by potentially developing new gravel pits.

6.7.3.4 Area E

As described in Section 4.3.5.2.8, Area E has been identified as a contingency pit for gravel to be used for road construction on the south bank or for construction of the earthfill dam. This source will only be used if it is found during construction that there is insufficient volume of suitable material in the dam site area.

Area E is the closest off-site gravel source that has been identified. Alternative sources would require longer hauls with greater effects.

6.8 Worker Accommodation

Section 4.3.6 describes:

- The objectives and considerations used in planning worker accommodation
- The planning for in-community accommodation
- Temporary accommodation at the dam site
- Temporary accommodation at regional locations
- RV parks

6.8.1 Dam Site Worker Accommodation Alternatives

As described in Volume 1 Section 4.3.6.2, there would be two camps at the dam site:

- A camp on the north bank with a capacity of 500 persons
- A camp on the south bank camp with a base capacity of 500 persons with capacity to be expanded up to a potential peak capacity of 1200 persons.

Volume 4 Appendix A Part 3 Population Effects Model Table 2 provides housing and demographic assumptions for in-camp Project labour. As described in Volume 4 Section 29.4.2 BC Hydro has planned to provide on-site and in-community accommodation to support the Project's workforce requirements. BC Hydro is developing a flexible approach to the implementation of worker housing, given that

labour expectations, market conditions, and community preferences could change during the Project's planning and assessment period, and during Project construction.

A key mitigation measure to retain balanced housing conditions and minimize potentially adverse effects on housing supply and demand would be to scale camp capacity up or down as required to accommodate direct workers. BC Hydro would construct the camps so that the base infrastructure and utilities such as water, sewer and power are provided at each camp location so that the camp capacity could be ramped up to provide the peak accommodation plus contingency. Construction contractors will be required to include information on their camp accommodation requirements with their bids to provide BC Hydro with the information required for planning the accommodation requirements for the Project as a whole with the objective of retaining balanced housing conditions.

An assessment of on-site worker accommodation alternatives was undertaken by Klohn Crippen Berger (KCB, 2013). The objective of this study was to provide a high level analysis of various worker accommodation options for housing construction workers at the dam site. The base case for this study was the camps described in Volume 1 Section 4.3.6.2. Key considerations for planning construction workforce accommodation used in the study were:

- Reducing worker and public safety hazards
- Planning for flexibility in accommodation capacity (i.e., being able to expand and contract the number of units to match the actual number of workers on-site) to mitigate against accommodation related impacts to construction productivity and cost
- Identifying means to accurately forecast worker numbers to enable camp operators to provide the accommodation required and, thereby, avoid schedule delays
- Identifying means through which services such as first aid, emergency services, medical support, water, sewer, power, fire protection and security services can be provided on-site
- Enhancing benefits to the local community while reducing potential adverse effects
- Attracting and retaining workers by providing a high quality of life and wellbeing through the delivery of health, recreation and leisure facilities.
- Incorporating input gathered to date from interested parties.

The nine alternatives for the two camps shown in Table 6.4 were evaluated. As described in KCB (2013) option H was selected as the preferred option because of its ability to respond to worker schedules, accommodate worker preferences, reduce productivity loss, reduce safety hazards, and to allow workers to access the community. A sensitivity analysis was undertaken on this option varying:

- The percentages of workers who live off-site (i.e., 15% [the base case], 20%, 25%, 30% and 40% of the workforce being housed off-site)
- The operational periods of the north and south bank camp (during construction years 1 through 8)

Overall, the results of the sensitivity analysis showed that cost-wise, there is very little difference between varying percentages of workers on / off site, and operational periods of each camp, based on the information available.

Table 6.4 List of Options Used for Initial Analysis

Type	Option		Key Features	Reason for Inclusion
Base Case	A	Two Camp Base Design	• North Camp: 500 beds * • South Camp: 1200 beds	Study Base Case and the basis against which the other Options are compared.
Single Camp	B	One South Bank Camp	• South Camp: 1700 beds	To assess a one-camp Option with the camp being located on the south side of the river.
	C	One North Bank Camp	• North Camp: 1700 beds	To assess a one-camp Option with the camp being located on the north side of the river. This Option was considered at the request of the City of Fort St. John.
Varying Operational Periods Based on Construction Schedule	D	Two Camp Design with Early North Bank Camp Closure	• North Camp: 500 beds, operates until 2020 • South Camp: 1200 beds	To determine the effect of shutting down the north camp earlier and bussing north bank workers from the south side to the north side.
	E	Two Camp Design Optimized for Schedule	• North Camp: 750 beds, operates from 2015 to 2020 • South Camp: 1200 beds, operates 2018 to 2022	To mirror the worker locations based on the schedule (peaks and troughs) and to house workers in the closest possible camp to their worksite.
	F	Two Equivalent-Sized Camps, with South Bank Camp During Three Peak Years	• North Camp: 850 beds, operates 2015 to 2022 • South Camp: 850 beds, operates during 3 peak years (2019 to 2021)	To determine if it would be feasible to increase the size of the north camp (as per the request of Fort St. John) so that, for the majority of the Project life, workers are situated as close as possible to Fort St. John. During peak years (2017 to 2019) the south camp would be operated to reduce logistical issues, productivity losses, and safety concerns associated with bussing a large number of workers across an active construction site.
	G	Two Camp Design with South Bank Camp During Four Peak Years	• North Camp: 750 beds, operates 2015 to 2022 • South Camp: 1200 beds, operates during 4 peak years (2018 to 2021)	To determine what would happen if more workers are housed closer to Fort St. John. During peak years all workers would be housed on their respective side. This is similar to Option F except, far fewer workers would be required to be bussed across the active construction site.

Type	Option		Key Features	Reason for Inclusion
Investigation of Off-site Accommodation **	H	Two Camp Design with 15% of Workers Living Off-Site	• South Camp: 1200 beds • North Camp: 250 beds • 15% of workers live off-site	To determine if it would be feasible to have a portion of workers living off site (e.g. Fort St. John, RV parks etc.) to enhance local economic effects, encourage relocation to Fort St. John, and to provide opportunities for workers to bring their families to the region. Because the assumption for all Options was that all workers would vacate their rooms during the off-shift, a larger number of rooms would have to be rented off site to house the workers (Section 4.1.1). Workers housed off-site would not be able to vacate their rooms on the off-shift.
	I	Two Camp Design with 15% of Workers Living Off-Site with Reduced Infrastructure	• South Camp: 1037 beds • North Camp: 418 beds • 15% of workers live off-site	To determine the magnitude of the economic benefits associated with reducing the infrastructure in Option H based on the actual projected capacity.

Notes:

* The term "beds" refers to the number of accommodation units required at the anticipated maximum capacity. It is important to note that in actuality dormitories will be added and removed according to worker schedules.

** Based on a review the number of supervisory versus craft positions and local industry experience, BC Hydro estimated that 15% of total workers would prefer to live off-site.

KCB 2013 recommended that the final worker accommodation plan should contain the following elements:

- A camp on each side of the river to enable workers to be housed closest to their worksite
- Minimizing bussing and travel between sides to minimize conflicts between industrial and legal traffic and any associated productivity and safety issues
- Optimizing operational periods for the camp based on actual contractor requirements
- Providing base infrastructure to support the maximum number of anticipated workers to avoid productivity effects if housing is not available in the region
- Installing and removing dormitories to match real time requirements including ensuring that proper planning is in place to determine both contractor needs in terms of beds at site and actual available accommodation in the region.

The preferred alternative includes all the elements of the analysis, combining safety, production, worker preferences, locating workers closest to their worksite, and minimizing costs to the extent possible given certain safety and socio-economic considerations.

Based on the information provided in Volume 4 Appendix A Part 3 Tables 1 & 5, approximately 40% of the total project workforce could reside in the community as local residents, which would include both existing and new local residents. The base case camp described in KCB 2013 was based on the assumption that 15% of the workers would find accommodation in the community. These proportions of in-community accommodation represent reasonable lower and upper bounds and were used to bound the range of percentages of in-community workers in the sensitivity analysis in KCB 2013.

The actual requirements for on-site accommodation would be determined in the future as the Project advances and would depend on a number of factors including contractor requirements, scheduling, availability of in-community housing and socio-economic conditions.

As part of Project planning BC Hydro would:

- Plan the base infrastructure and utilities at each camp location so that the camp capacity could be ramped up to provide the peak accommodation plus contingency to:
  - Situate workers as close as possible to their work site to:
    - Enhance worker safety and productivity
    - Minimize the costs and logistical issues of transporting workers through an active construction site.
  - Be able to house all workers requiring accommodation at the core facility site to avoid potential impacts to productivity should off-site housing not be available.
- Continue to work with local communities to retain balanced housing conditions and minimize potentially adverse Project effects on housing supply and demand.

6.8.2 Camp Water Supply and Wastewater System Alternatives

As described in Section 4.3.6.2 the camps would be designed, constructed, operated, decommissioned, and permitted to be compliant with all applicable regulations. The camp facilities would be generally self-sufficient and include facilities for water supply, treatment, and distribution, and waste water management.

A study (Urban Systems 2012) was undertaken to evaluate the feasibility of the following alternatives for servicing the proposed north and south bank camps:

- North bank camp potable water servicing options:
  - Construction of a standalone potable water system with groundwater source(s)
  - Construction of a standalone potable water system with surface water source(s)
  - Connection to the City of Fort St. John's potable water system.
- South bank camp potable water servicing options:
  - Construction of a standalone potable water system with groundwater source(s)
  - Construction of a standalone potable water system with surface water source(s)
- North bank camp sanitary sewer integrated servicing options:
  - Connect to the Peace River Regional District's Charlie Lake Lagoons, and
  - Connect to the City of Fort St. John's sanitary sewer system.

BC Hydro undertook and shared the results of the study with the City of Fort St John and the Peace River Regional District to determine whether it would be mutually beneficial to connect the north bank camp to existing municipal water and sewer services. The study results suggested that a self-sufficient approach to meeting the Project needs may be most appropriate due to the timeline from Project approval to service requirements, volume differences during construction and post-construction, and uncertainty related to long-term municipal development and planning in the area. Based on these findings, BC Hydro has proposed a self-sufficient servicing approach for the North and South Bank project sites, and communicated this intent to the City of Fort St. John and the Peace River Regional District.

Both surface water and groundwater appear to be suitable sources for a standalone water supply system for both camps; however, additional analysis is required to confirm a suitable location for each source. Also, as part of the design phase, the supply and treatment systems should be designed to accommodate the range of design flow for the range of camp capacities that could be required. This may be achieved a number of different ways such as having multiple pumping/treatment trains in parallel or potentially retrofitting the processes to accommodate large reductions in water demand post construction at the north bank camp.

6.9 Road and Rail Access

6.9.1 North Bank Access

Section 4.3.7.1 describes the access to the dam site area from the north bank via existing municipal and provincial public roads and the upgrades that would be done to those roads as part of the Project.

Volume 4 Appendix B Project Traffic Analysis describes the peak Project traffic on the north bank roads during construction. Comparison with the background traffic showed that there would generally be few changes in the level of service resulting from the addition of Project traffic during the peak year of construction. Active traffic management during construction would minimize construction related increases in traffic and may involve the use of shuttle busses and car-pooling, and/or restricting Project related vehicle access to sections of specific roads.

As noted in Volume 1 Section 4.2, Table 4.1 transportation of till from 85th Avenue Industrial Lands to the dam site area by conveyor was selected to reduce heavy truck traffic on public roads reducing the risk to human safety, noise and dust.

Alternatives to upgrading and using the existing road network would require the construction of a network of new roads which would clearly have greater effects than upgrading and using the existing road network.

6.9.2 South Bank Access

Section 4.3.7.2.2 describes the alternate access routes from the south bank to the dam site area that were evaluated.

References

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