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Volume 1

[Final Draft]

Prepared for BC Hydro Site C Project by

R.F. Binnie & Associates Ltd.

April 2012

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SITE C HYDRO PROJECT

HIGHWAY 29 DEFINITION DESIGN REPORT

Doc 05-0044

Volume 1

[Final Draft]

Prepared for BC Hydro Site C Project

By

R.F. Binnie & Associates

April 2012

Lead Author: [redacted]

Contributors: [redacted]
(by section)

Task Lead Review by:

Accepted by:

EXECUTIVE SUMMARY

R.F. Binnie & Associates and its team of sub-consultants have been retained by BC Hydro to provide engineering design services for several segments of Highway 29 between Hudson's Hope and Fort St. John that would require relocation if the proposed Site C Clean Energy Project were approved and constructed.

The Site C Clean Energy Project includes construction of a proposed new dam on the Peace River in northeast BC. The Proposed Dam will be the third dam on the Peace River system and will be located downstream of the W.A.C. Bennett and the Peace Canyon Dams. The Proposed Dam will result in the formation of a new reservoir that spans from the existing Peace Canyon Dam to the proposed new Site C Dam site near Fort St. John.

The total length of Highway 29 between Hudson's Hope and the Highway 97 junction is approximately 75 kilometres of which 30 kilometres or 40 percent would require relocation due to the proposed reservoir. The 30 kilometres of relocation is in six distinct segments as listed below and shown in **Figure ES1**.

- Lynx Creek
- Dry Creek
- Farrell Creek
- Km 21 to Km 26.5
- Halfway River
- Bear Flat / Cache Creek

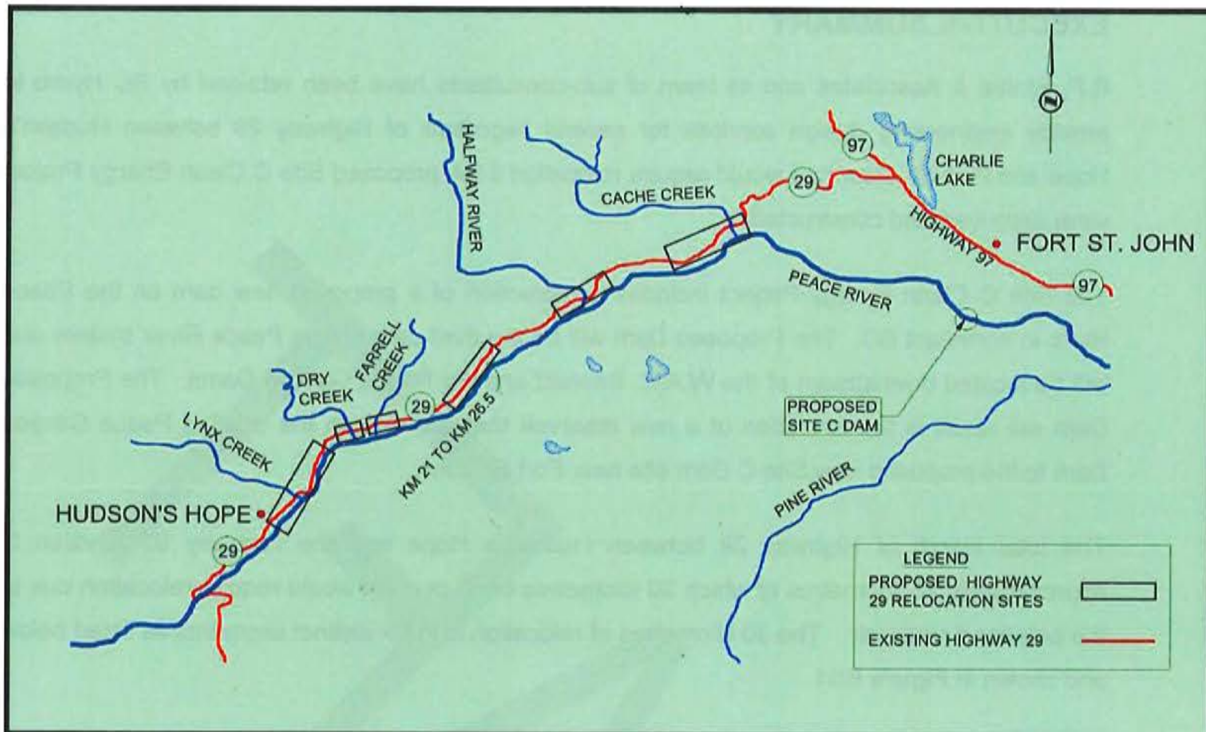

Figure ES1: Map of Highway 29 Project Corridor

Previous studies dating back to the 1980s were prepared that evaluated several corridor or alignment options for Highway 29. The Design Team reviewed these previous reports and alignment options and have been working on updating them based on current design standards. The Design Team also explored new alignment options based on feedback received from local residents during the public consultation process that took place in 2008. The findings contained in this report are based on limited geotechnical investigations and mapping obtained from remote sensing. More detailed geotechnical investigations and ground surveys would be required to confirm actual ground conditions and material sources.

A project wide design criteria document has been developed for Highway 29 and associated side roads. The design criteria document was developed in collaboration with the BC Hydro Site C Integrated Engineering Team, the BC Ministry of Transportation and Infrastructure, and the Binnie Design Team.

The primary objective of the studies undertaken by the Binnie Design Team was to determine safe, cost effective re-alignment options that meet all the required Ministry of Transportation and Infrastructure design standards and criteria while minimizing environmental, agricultural and private property impacts. Mitigating the impacts due to landslide generated waves and addressing global stability concerns as a result of the proposed new reservoir are also key design considerations. Additional objectives of the Highway 29 Definition Design stage included:

- Reviewing previous alignment options from earlier studies;
- Providing initial geotechnical assessment of each segment;
- Determining potential material sources;
- Providing support for the Multiple Account Evaluation process;
- Preparing roadway and structural Definition Design drawings;
- Preparing right of way Definition Design drawings to assess property requirements;
- Providing estimated construction cost estimates to help facilitate the selection of a preferred alignment option for each segment;

A Multiple Accounts Evaluation process was used to help in the selection of the preferred alignment options for the Lynx Creek, Halfway River and Bear Flat / Cache Creek segments. Several indicators were quantified or assumed and used in the Multiple Accounts Evaluation process. Indicators used included Cost and Constructability, Safety, Environment and Social accounts.

The other three segments, Dry Creek, Farrell Creek and Km 21 to Km 26.5, were subject to a design review and refinement process instead of a Multiple Accounts Evaluation process because only a single viable corridor existed for each of these segments.

Six alignments were considered for the Lynx Creek segment each with short and long bridge variants for a total of 12 options. The preferred option takes into consideration the recommendation of local residents that the realignment utilized as much of Millar Road as possible. That recommendation resulted in a preferred alignment that has the least amount of property impacts and agricultural severances. The total length of the preferred alignment option is 8.22 kilometres and includes a 160 metre bridge and a 290 metre causeway. The estimated total project cost of the Lynx Creek preferred alignment option all in is [redacted]

The capacity of the existing culvert at Dry Creek is less than that required to handle the 200 Year Instantaneous Flow. In addition it would be fully submerged once the Proposed Dam is constructed. The existing highway alignment and profile within the Dry Creek segment also do not meet the design criteria used for this project. The preferred option at Dry Creek replaces the existing culvert with an 8.2 metre by 4.1 metre precast concrete arch culvert and improves the horizontal and vertical alignment of the highway to a 90 kilometre per hour design speed. The preferred alignment option at Dry Creek has a total length of 1.40 kilometre and an estimated total project cost o[redacted]

As previously noted only a single alignment was considered at Farrell Creek including short and long bridge variants. The total length of the preferred alignment option is 2.12 kilometres and includes a 170 metre bridge and a 150 metre causeway. The estimated total project cost of this alignment option is [redacted]

The Km 21 to Km 26.5 segment is in an area where the preliminary erosion and stability impact lines crossed over the existing highway. A highway realignment option was selected as the best way to deal with this issue. The preferred alignment option at Km 21 to Km 26.5 has an estimated total project cost of [redacted]

Three alignment options were considered at Halfway River each with short and long bridge variants. The total length of the preferred alignment option is 3.7 kilometres and includes a 305 metre bridge and a 640 metre causeway. The estimated total project cost of the preferred alignment option at Halfway River is [redacted]

Two corridor options were considered at Bear Flat / Cache Creek each with short and long bridge variants. The total length of the preferred alignment option is 8.36 kilometres and includes a 200 metre bridge and a 240 metre causeway. The estimated total project cost of the preferred alignment option at Bear Flat / Cache Creek is [redacted]

The estimated total project costs referenced above includes both construction and non-construction costs. A 20 percent contingency has been added to the sub-total construction costs to account for the uncertainty in the estimate due to unknown conditions. Other non-construction project costs such as project management, engineering, construction supervision, environmental mitigation and property acquisition have been included as part of the total project costs.

Limited field programs such as topographical field survey and geotechnical drilling were initiated during the Definition Design stage, and a more comprehensive field survey and geotechnical drilling program will be required to advance the Definition Design to a preliminary design stage.

The Design Criteria Document for Highway 29 Relocation and Associated Roads includes structural Design Criteria for all bridges and structures to withstand all loadings identified and quantified during Definition Design including landslide generated wave loads. As part of the Definition Design process potential gravel and riprap sources were identified. Additional effort will be required to confirm the source of construction materials as well as the subsurface soil conditions.

LIST OF ACRONYMS

IET	Site C Integrated Engineering Team
BCMOT	BC Ministry of Transportation and Infrastructure
MAE	Multiple Accounts Evaluation
LKI	Landmark Kilometre Inventory
AADT	Annual Average Daily Traffic
SADT	Summer Average Daily Traffic
GIS	Geographic Information System
ALR	Agricultural Land Reserve
TAC	Transportation Association of Canada
EIL	Erosion Impact Line
SIL	Stability Impact Line
EHRL	Extreme High Reservoir Level
BGC	BGC Engineering
FIL	Flood Impact Line
WIL	Landslide Generated Wave Impact Line
NSL	Natural Stability Line
FSL	Full Supply Level
SGSB	Select Granular Sub-Base
WGB	Well Grade Base Course
TLCA	Temporary Licence for Construction Access

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- Approved Project Design Criteria Document
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- Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2
- Collision Prediction / Safety Modelling
- Risk Review Sheets
- Recreational Access Mitigation Concepts Review memo
- Meeting Minutes – Opening discussions between engineering and environmental groups on wetland opportunities at the proposed reservoir"
- Bear Flat / Cache Creek Option G Alignment Option

1.0 INTRODUCTION

R.F. Binnie & Associates (Binnie) and its team of sub-consultants (Design Team) have been retained by BC Hydro to provide the engineering design services for several segments of Highway 29 that would require relocation due to the proposed Site C Clean Energy Project.

The Site C Clean Energy Project includes construction of a proposed new dam on the Peace River in northeast British Columbia. The Proposed Dam will be the third dam on the Peace River system and will be located downstream of the W.A.C. Bennett and the Peace Canyon Dams. The Proposed Dam will result in the formation of a new reservoir that spans from the existing Peace Canyon Dam to the proposed new Site C Dam site near Fort St. John.

Previous studies dating back to the 1980s have been prepared that evaluated several re-alignment options for Highway 29. The Design Team reviewed these previous reports and alignment options and have been working on updating them based on current design standards. Alternate alignment options were also explored by the Design Team with consideration given to local resident' concerns during previous public consultation process, reducing construction costs and minimizing impacts to environmental and agricultural land.

Highway 29 is a two-lane Provincial Highway that begins in Tumbler Ridge and runs northwest through the communities of Chetwynd and Hudson's Hope. The highway then heads in a north easterly direction along the north bank of the Peace River terminating at the junction with Highway 97 at Charlie Lake. It is this latter section of Highway 29 that will be impacted by the proposed reservoir created from the Proposed Dam.

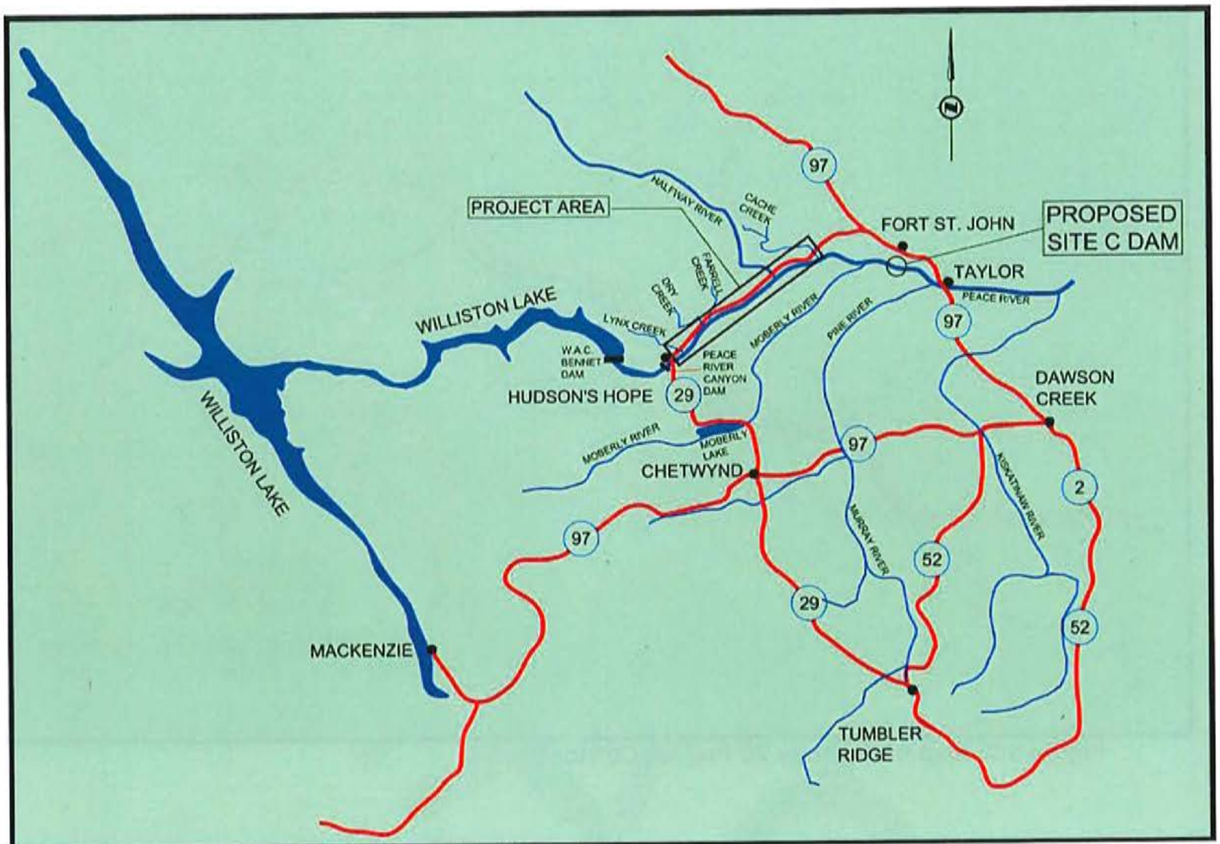


Figure 1.1: Highway 29 Overview Map

The total length of Highway 29 between Hudson's Hope and the Highway 97 junction is approximately 75 kilometres of which 30 kilometres or 40 percent will require relocation due to the construction of the Proposed Dam. The 30 kilometres of relocation is in six distinct segments as listed below:

- Lynx Creek
- Dry Creek
- Farrell Creek
- Km 21 to Km 26.5
- Halfway River
- Bear Flat / Cache Creek

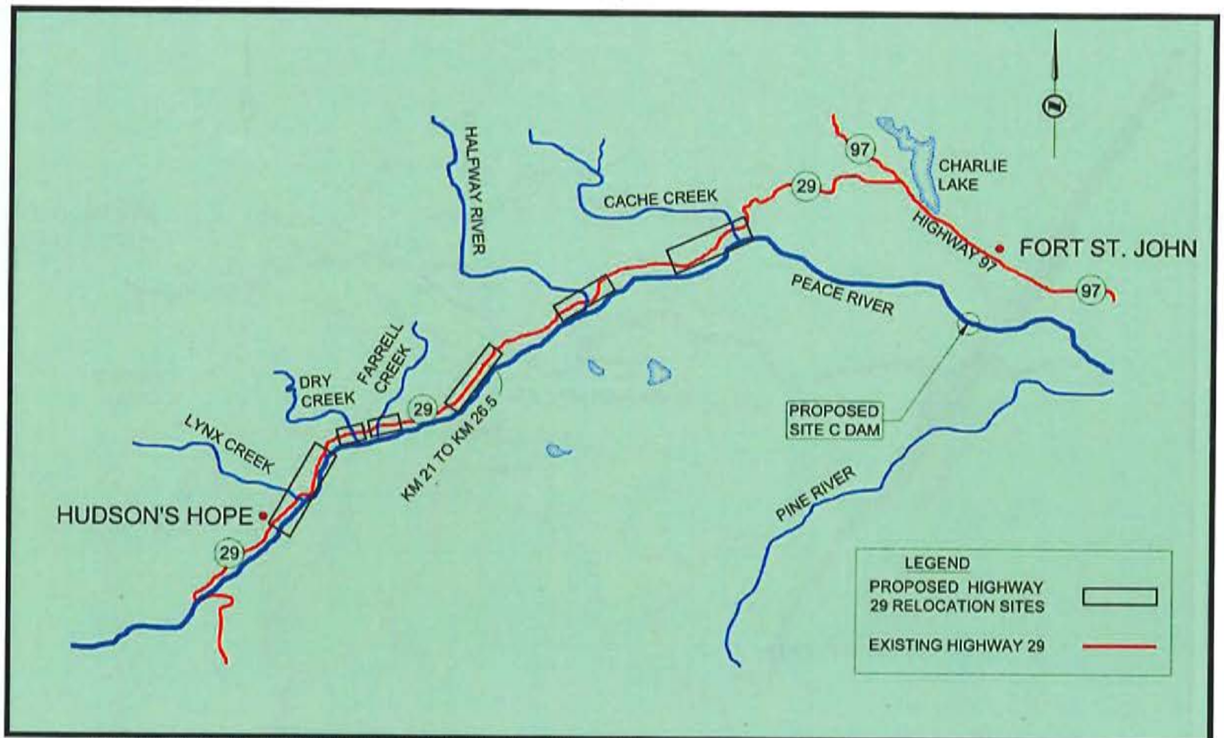


Figure 1.2: Map of Highway 29 Project Corridor

The Design Team has been working closely with the Site C Integrated Engineering Team (IET) as well as with the BC Ministry of Transportation and Infrastructure (BCMOT) to determine a preferred alignment option for each of the six segments listed above. A Multiple Accounts Evaluation (MAE) process was used at the Lynx Creek, Halfway River and Bear Flat / Cache Creek segments to select the preferred alignment. The MAE process evaluated each alignment option based on several key indicators including Financial, Engineering, Environmental and Socio-Economic accounts. The MAE process is further described in **Section 4** of this report.

The Dry Creek, Farrell Creek, and Km 21 to Km 26.5 segments were not subjected to the MAE process since only a single viable corridor was available for each alignment within these segments. Instead these segments underwent design reviews to optimize the alignments and minimize construction costs, property impacts and environmental impacts.

2.0 EXISTING CONDITIONS

Highway 29 within the project area is a two-lane rural arterial undivided highway under the jurisdiction of the BCMOT. For the purpose of this report, Highway 29 will be considered an east west highway which connects the community of Hudson's Hope in the west with Charlie Lake and Fort St. John to the east. The posted speed on Highway 29 is 90 kilometres per hour however there are several locations along the corridor that require a lower advisory speed due to tight horizontal curves and are identified with advisory curve warning signs. The cross section generally consists of two 3.5 metre paved lanes with 0.5 to 1.5 metre paved shoulders. Embankment side slopes vary between 2H:1V and 4H:1V with 3H:1V appearing to be the most common slope. Excavation cut slopes vary between 2H:1V and 3H:1V depending on the native ground conditions. Concrete roadside barrier is provided at bridge approaches, on the outside of sharp curves and in high fill locations.

2.1 LYNX CREEK

The Lynx Creek segment is the westernmost segment of Highway 29 that will require relocation and is located just east of the District of Hudson's Hope. The start of the Lynx Creek segment is located approximately 1.5 kilometres west of the existing Lynx Creek Bridge and continues east for approximately 8.2 kilometres ending approximately 600 metres west of the existing Farrell Creek Road as depicted in **Figure 2.1.1**. Based on the BCMOT Landmark Kilometre Inventory (LKI) referencing system, the realigned Lynx Creek Segment is located between kilometre 4.5 and 12.9 on LKI Segment 1181.

2.1.1 Geometry and Cross-sections

The existing horizontal alignment through the Lynx Creek segment contains several curves with horizontal radii that are below the requirements for a 90 kilometres per hour design speed. At the western end of the segment, the alignment is generally tangential until the approach to the Lynx Creek Bridge where reverse curves of radius 150 metres left and radius 175 metres right lead to the bridge. Just north of the bridge, a sharp right hand curve of 70 metres is followed by a left hand curve of 190 metres. The remainder of the existing alignment is generally curvilinear containing several gentle curves with radii ranging from 300 metres to 2,000 metres with the exception of two curves of 200 metre and 130 metre radii.

The highway passes through rolling terrain with grades between 1 percent and 3 percent throughout the segment. The exception to this is at the west approach to the Lynx Creek Bridge and the eastern project limits where vertical grades reach approximately 5 percent and 6 percent respectively.

The existing cross section through the Lynx Creek Segment consists of two 3.5 metre lanes with paved shoulders varying in width between 0.5 to 1.0 metres. Concrete roadside barrier is located on the high fills at the eastern project limits. The existing highway that would be inundated by the reservoir will have to be deactivated prior to being flooded.

Figure 2.2.1: Lynx Creek Existing Conditions

2.1.2 Traffic

The Annual Average Daily Traffic (AADT) and Summer Average Daily Traffic (SADT) along the Lynx Creek segment are estimated to be 699 vehicles per day and 1,001 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 999 vehicles per day and 1,431 vehicles per day respectively. The two way design hourly volume is estimated to be 70 vehicles per hour for the 2010 year and 100 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2**" dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.1.3 Intersections and Accesses

There are several intersections and accesses located within the current limits of Lynx Creek. Most are minor gravel driveways or field access providing access to adjacent properties but some are public roads. The public road intersections close to or within the Lynx Creek segment include Reschke Road, Backman Road, Millar Road and Farrell Creek Road.

Reschke Road is a rural local paved road located approximately 200 metres west of the western project limits. This intersection is located west of the current project limits.

Backman Road is a rural local gravel road located within the sharp horizontal curve on the east approach of the Lynx Creek Bridge. This intersection provides access to several properties north of the existing highway.

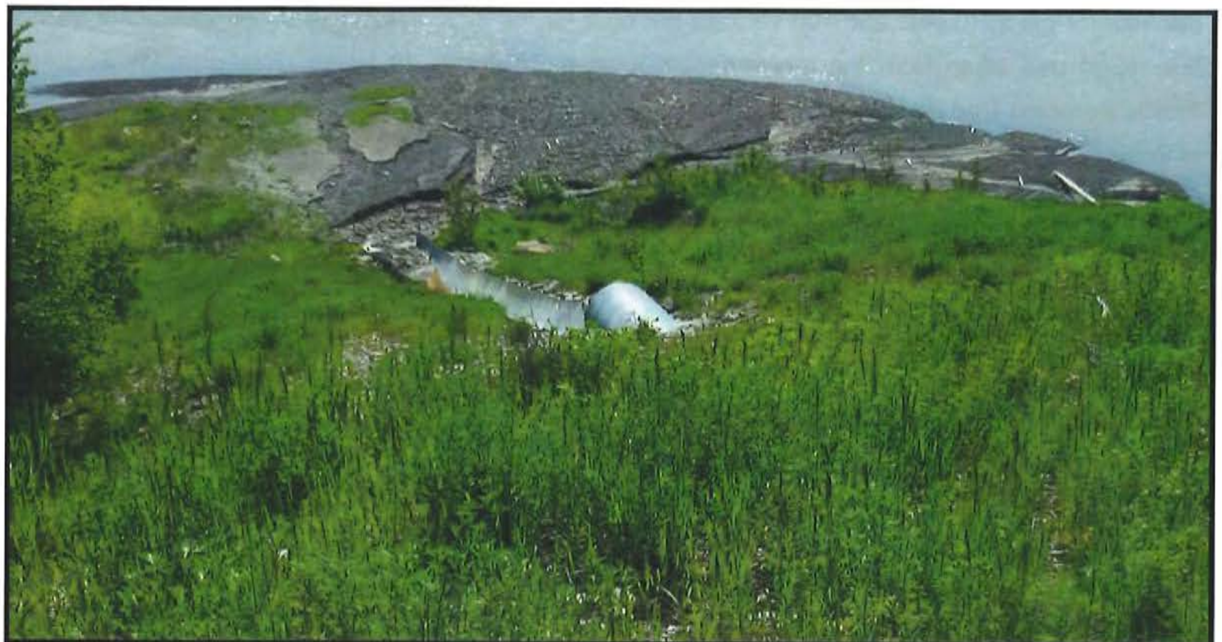
Millar Road crosses Highway 29 providing access to properties on both the south and north sides of the Highway. Millar road is paved on the north side of the highway and gravel on the south side.

Farrell Creek Road is a gravel road located just east of the Lynx Creek project limit.

2.1.4 Drainage

Lynx Creek is a tributary of the Peace River, draining an area of 320 square kilometres upstream of the existing Highway 29 Lynx Creek Bridge. The channel has an average gradient of about 1.1 percent, is about 20 metres wide bank-to-bank and meanders within an entrenched valley that varies from 200 metres to 600 metres in width. The present Highway 29 Lynx Creek Bridge and approaches are protected from erosion with a moderate amount of approximately 250 Kg Class riprap.

Shallow drainage ditches are provided in cut sections to collect water from the adjacent slopes and from highway surface runoff. Cross culverts convey surface water from the north side of the highway to the south side. Steep slopes and embankments are protected from erosion using half culverts anchored to the face of the slopes as shown in the **Photograph 2.1.1** below.



Photograph 2.1.1: Example of pipe outfall in Lynx Creek (Credit: Binnie)

A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent design stages. A site visit by the project team however did identify that several culverts are in poor condition and draining directly on to the existing slope causing slope instability and erosion. This is illustrated in **Photograph 2.1.2**.

Photograph 2.1.2: Example of broken pipe and slope failure (Credit: Binnie)

2.1.5 Geotechnical

From a geotechnical perspective, the proposed Lynx Creek highway relocation segment can be generally divided into two distinct sections.

From the western extent of the proposed relocation extending approximately 6.5 kilometres towards the east (from Station 999+540 to 1006+000), the current Highway 29 alignment (and proposed realignment) traverses a series of fluvial terraces adjacent to the north bank of the Peace River. These terraces represent post-glacial fluvial deposits, formed as part of the down-cutting of the Peace River. Construction along the fluvial terraces is expected to encounter primarily granular soils, with variable but generally minimal thicknesses of surficial silt and organic soils requiring sub-excavation or stripping. Conventional cuts and fills, and a pavement structure based on primarily non-frost susceptible subgrade soils can be applied in the design.

East of the fluvial terraces to the eastern limit of the segment (Station 1006+000 to 1007+774), there are fine-grained soils of different origins (Willis Cunliffe Tait Delcan, 1982) and/or bedrock on the toe of the north slope of the Peace River Valley. There are fluvial fans at the base of drainage gullies emerging from adjacent north slope of the Peace River Valley, and colluvial deposits overlying bedrock or late-glacial glaciolacustrine deposits. The overburden and bedrock (shale) contact varies in elevation. Above the current Highway 29 alignment, the valley slope is comprised primarily of steep, unstable, bedrock-controlled valley bluffs that are covered in colluvium in many places and overlain by thick deposits of fine grained soils at the valley crest. The bedrock exposed in the highway cuts is weathered sedimentary rock (typically shale). Below the highway, the fine-grained colluvium and side-cast fill generally continues to the river level. Along this section all the proposed highway alignment options are required to traverse a tightly constricted slope area, where the Peace River impinges directly on the lower portion of the north Peace River valley sidewall slope. This is a geologically active area, where a number of pre-existing slope failures are located both above and below the current alignment of Highway 29 and construction will be more challenging. Given the tightly constricted location, and the directly adjacent valley sidewall stability conditions, it is unlikely that an alternate cost effective highway alignment at the east end of the design segment can be found that can completely avoid existing slides and the effects of the reservoir.

A Preliminary Geotechnical Assessment report for the Proposed Lynx Creek segment report is included in **Volume 3** of the report and provides additional details.

2.1.6 Structures

The existing bridge at Lynx Creek is approximately 48 metres in length and consists of two spans approximately 15 metres long , and two end spans 9 metres long. The bridge, built in 1967, is of a composite deck construction with the reinforced concrete deck and steel plate girders. Reinforced concrete piers are supported on 5-steel H-piles and the abutment foundations use 4-steel H-piles. The existing bridge will be flooded by the construction of the Proposed Dam and may have to be demolished after the new replacement bridge is constructed.

A Bridge Definition Design Report is included in **Volume 3** of the report and provides additional details.

2.1.7 Utilities and Infrastructure

There are existing utility poles within the Lynx Creek Segment as well as an underground telephone line that appears to cross the highway near the eastern project limit. The exact location of the poles and underground lines shown on the design drawings are approximate and based on Geographic Information System (GIS) data provided by BC Hydro. The location and owners of the utilities will need to be confirmed in subsequent design stages in order to properly assess the impacts and potential relocation costs. There is also an area identified as being approved for gas and oil exploration near the Lynx Creek segment.

2.1.8 Environment

2.1.8.1 Fisheries

Lynx Creek is a small stream located approximately 73 kilometres upstream from the Proposed Dam. Mountain Whitefish, Rainbow Trout and Arctic Grayling have been captured in Lynx Creek. Adults and juveniles of these three species have been observed in the creek suggesting that it provides spawning and rearing habitat for them. Upstream movement of fish is limited in Lynx Creek due to a steep canyon approximately 3.2 kilometres upstream from the confluence. Rainbow Trout have been found above the canyon but likely represent an isolated population. Lynx Creek contains Longnose Sucker and Northern Pike minnow as the most abundant non-sport fish.

Fish historically recorded in the Lynx Creek system include Arctic Grayling, Bull Trout, Mountain Whitefish, Burbot, Largescale Sucker, Longnose Sucker, White Sucker, Flathead Chub, Lake Chub, Longnose Dace, Northern Pikeminnow, Peamouth, Redside Shiner, Trout Perch, Prickly Sculpin, Slimy Sculpin, and Spoonhead Sculpin.

An Environmental Assessment report is included in **Volume 3** of the report.

2.1.8.2 Wildlife

Many carnivores have been identified to use the riparian community of Lynx Creek. Wolves commonly use this drainage for hunting. Large congregations of waterfowl are also a common sight along the outflow of Lynx Creek to the Peace River. Numerous other species were detected during the winter track counts as noted in the Site C Project inventory (Keystone Wildlife Research 2009. Peace River Wildlife Surveys – Baseline Inventory Surveys – 2006) including species of Ruffed Grouse, Marten, Fisher, Long-tailed Weasel and Mink.

An Environmental Assessment report is included in **Volume 3** of the report.

2.1.8.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report.

2.1.8.4 Development and industry

The BCMOT Rieske Pit is located to the west of Lynx Creek and local farming and agricultural operations are located adjacent to and accessible from the Highway.

2.1.9 Property

The property ownership within the Lynx Creek Segment is a mix of private properties, Crown Land, BC Hydro Owned Land and BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased). Most of the properties within the limits of the proposed reservoir are either BC Hydro Owned or BC Hydro Leased. The land use within the Lynx Creek segment is primarily residential or agricultural with the majority of the segment within the Agricultural Land Reserve with the exception of the last 3 kilometres at the east end of the segment and the immediate adjacent areas west and east of Lynx Creek.

There are buildings present on some properties and the foundations of other old buildings may be present on others. It is likely that wells and septic systems have been constructed on these properties as well. There is an abandoned gas station property located at the east end of the Lynx Creek Bridge.

2.2 DRY CREEK

The Dry Creek segment begins just east of the Farrell Creek Road intersection and is shown in **Figure 2.2.1**. Based on the BCMOT LKI referencing system, the realigned Dry Creek Segment is located between kilometre 13.5 and 14.9 on LKI Segment 1181.

2.2.1 Geometry and Cross-sections

The existing horizontal alignment through the Dry Creek section consists of back to back curves with curve radii of 190 metres and 450 metres. The 190 metre radius curve meets a 70 kilometres per hour design speed but is well below the 340 metre minimum radius required for a 90 kilometres per hour design speed.

The vertical alignment consists of a sag vertical curve with a K-Value of approximately 16 which is within the design domain for a 60 kilometres per hour design speed assuming headlight control. There is a steep grade of 8.5 percent which is located within the tight 190 metre radius curve. The combination of the tight horizontal curve and the steep grades results in this segment of Highway 29 having one of the lowest standards on the entire corridor.

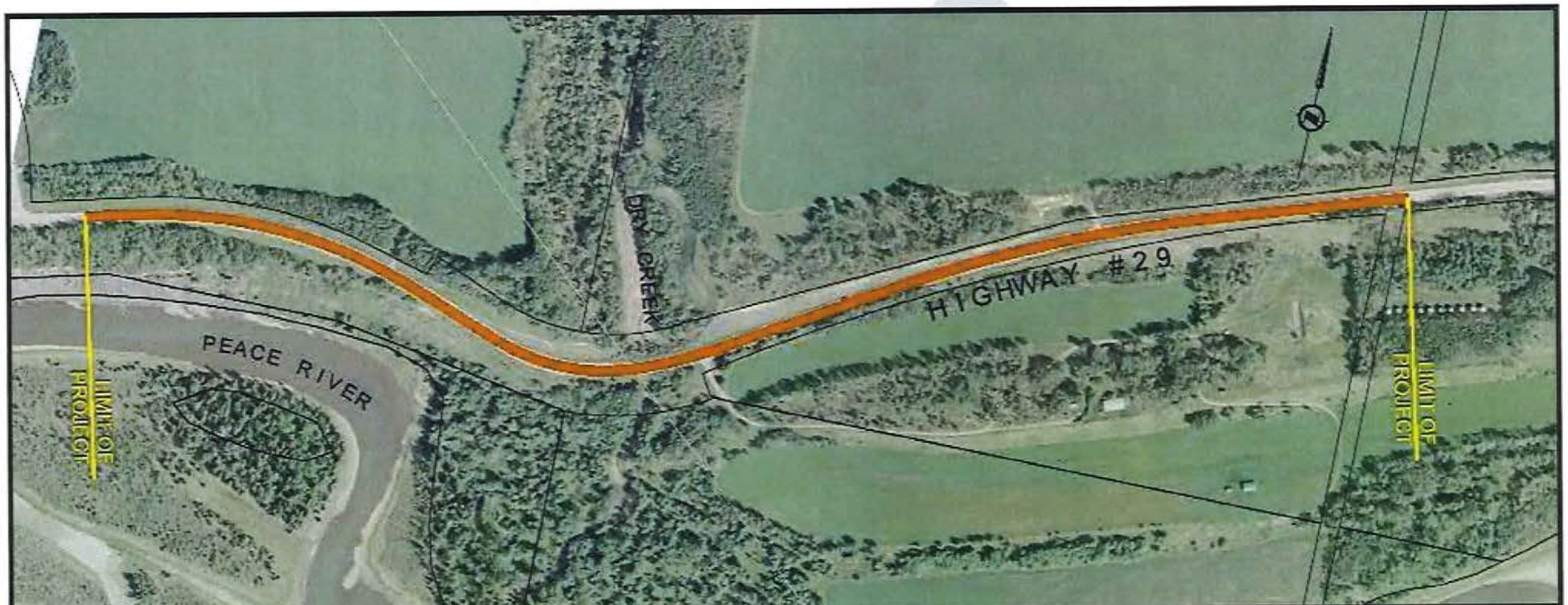


Figure 2.2.1: Dry Creek Existing Conditions

The existing cross section through the Dry Creek section consists of two 3.5 metre lanes with paved shoulders varying between 0.5 to 1.0 metres. Concrete roadside barrier is located on the outside of the small tight radius curves.

2.2.2 Traffic

The AADT and SADT along the Dry Creek segment are estimated to be 699 vehicles per day and 1,001 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 999 vehicles per day and 1,431 vehicles per day respectively. The two way design hourly volume is estimated to be 70 vehicles per hour for the 2010 year and 100 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2**" dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.2.3 Intersections and Accesses

There are three existing accesses located within the current limits of the Dry Creek Segment. These are gravel driveways or farm access providing access to properties on either side of the highway. There are no major intersections or local roads within the Dry Creek Segment.

2.2.4 Drainage

Dry Creek is a small tributary of the Peace River, draining an area of approximately 58 square kilometres. The existing culvert appears to be a barrier to bed load. Outside of the highway right of way (RoW), the upstream channel is steep and highly eroded. The channel flattens out within the RoW slowing flows and resulting in a 40 meter wide un-vegetated deposition area. Under natural conditions, the active channel would likely be in the order of 10 metres in width. Just upstream of the highway, the channel is confined in a 30 metre deep ravine.

The existing culvert at Dry Creek is a 2.4 metre diameter steel multi-plate culvert that does not have enough capacity to handle the 200 year (Q200) Instantaneous Flow, which is estimated to be 44.3 cubic metres per second. The normal operating level of the reservoir is estimated to vary between 460 metres to 461.8 metres and the existing culvert invert elevation under the existing highway is at an elevation of approximately 456.8 metres. The culvert will be fully submerged when the reservoir is at full supply level. It is generally not desirable to have a culvert fully submerged in water if it can be avoided because they are difficult to maintain, they may produce undercurrents which could be of concern and they are difficult to replace in the event the culvert fails.

A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent stages.

2.2.5 Geotechnical

Dry Creek is an ephemeral stream that has incised a deep, steep-sided, tributary valley into the upland terrain and thick soil deposits north of the main Peace River Valley. Just upstream from the existing crossing of Highway 29, the Dry Creek channel is situated in a steep-sided, flat-bottomed gulley that has been incised into a relatively flat lying river terrace in the bottom of the Peace River Valley. Below the existing Highway 29 culvert and fill crossing, Dry Creek discharges onto a fluvial fan, lower terrace level and flood plain of the Peace River. The existing Highway 29 alignment is located on a bench of cut/fill transition across an intermediate slope between the upper and lower terrace levels. Based on exposures observed in the adjacent highway cuts, it is anticipated that the terrain and gulley slopes immediately adjacent to and north of the existing Highway 29 alignment are underlain by a thin deposit of sand and gravel overlying shale bedrock at a relatively shallow depth. The existing highway fill appears to consist of locally borrowed granular material constructed at or slightly above its natural angle of repose (36 to 40 degrees). Foundation conditions under the highway fill and existing culvert are unknown. The Dry Creek channel bottom upstream from the crossing has significant bed load deposits consisting of variable fine grained sediments, woody debris, coarse gravel and boulders on surface. Given the nature of the deeply eroded upstream valley, it is likely that the foundation for the existing highway fill and the Dry Creek channel bottom are underlain by quite variable debris flow deposits that can be unreliable or unsuitable for structure foundations. Subsurface investigation is required to determine the extent and nature of these deposits.

2.2.6 Structures

The existing culvert at Dry Creek was installed in 1964. It is a 58 metres long steel multi-plate culvert with a 2.4 metre diameter. An inspection in 2010 found signs of the early stages of culvert failure with roof distortion and small, but growing, steel cracks. Options to deal with the submerged culvert include filling it with grout and leaving it in place or removal.

A Bridge Definition Design Report is included in **Volume 3** of the report and provides additional details.

2.2.7 Utilities and Infrastructure

There are existing utility poles within the Dry Creek Segment. The location of the poles shown on the design drawings are approximate and based on GIS data provided by BC Hydro. There also appears to be an underground telephone line crossing just east of Dry Creek. The location and owners of the utilities will need to be confirmed in subsequent design stages in order to properly assess the impacts and potential relocation costs.

2.2.8 Environment

2.2.8.1 Fisheries

Dry Creek only flows intermittently and historical reports indicate no fish are in the lower sections.

An Environmental Assessment report is included in **Volume 3** of the report.

2.2.8.2 Wildlife

The section of Dry Creek impacted by the proposed works is limited in its ability to provide diverse wildlife habitat but it has good nesting sites for common species of songbirds.

An Environmental Assessment report is included in **Volume 3** of the report.

2.2.8.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report.

2.2.8.4 Development and Industry

Shale-gas facilities accessed off Farrell Creek Road and local farming and agricultural operations are located adjacent to and accessible from the Highway.

2.2.9 Property

The properties within the Dry Creek Section include private properties which are located on both the north and south sides of Highway 29 and a small parcel of crown land located on the east side of the highway. The land use within the Dry Creek segment is primarily agricultural and is all within the Agricultural Land Reserve with the exception of the areas immediately adjacent to Dry Creek.

2.3 FARRELL CREEK

The Farrell Creek segment is located just to the east of the Dry Creek segment and is shown in **Figure 2.3.1**. Based on the BCMOT LKI referencing system, the realigned Farrell Creek Segment is located between kilometre 15.3 and 18.0 on LKI segment 1181.

2.3.1 Geometry and cross-sections

The existing horizontal alignment approaching the Farrell Creek Bridge consists of a 180 metre radius curve that appears to be compounded with curves of 120 metres, 200 metres and 250 metre radii. Based on these radii, these curves meet the requirements of a 50 kilometres per hour design speed and are below the requirements for a 90 kilometres per hour design speed. Advisory curve warning signs are provided at these curves.

The vertical alignment consists of a sag vertical curve with a K-Value of approximately 21 which is within the design domain for a 70 kilometres per hour design speed but well below the requirements for a 90 kilometres per hour design speed. There are steep downhill grades of 5.2 percent and 9.3 percent on the approaches to the existing Farrell Creek Bridge.

The existing cross section through the Farrell Creek segment consists of two 3.5 metre lanes with paved shoulders varying between 0.5 to 1.0 metres. A short section of concrete roadside barrier is located on the outside of the curve where the highway alignment comes close to the river.

2.3.2 Traffic

The AADT and SADT along the Farrell Creek segment are estimated to be 699 vehicles per day and 1,001 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 999 vehicles per day and 1431 vehicles per day respectively. The two way design hourly volume is estimated to be 70 vehicles per hour for 2010 and 100 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2**" dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.3.3 Intersections and Accesses

There are seven existing driveways located within or near the current limits of the Farrell Creek Section. Most are minor gravel driveways providing access to adjacent properties. There are no major intersections or local roads within the Farrell Creek Segment.

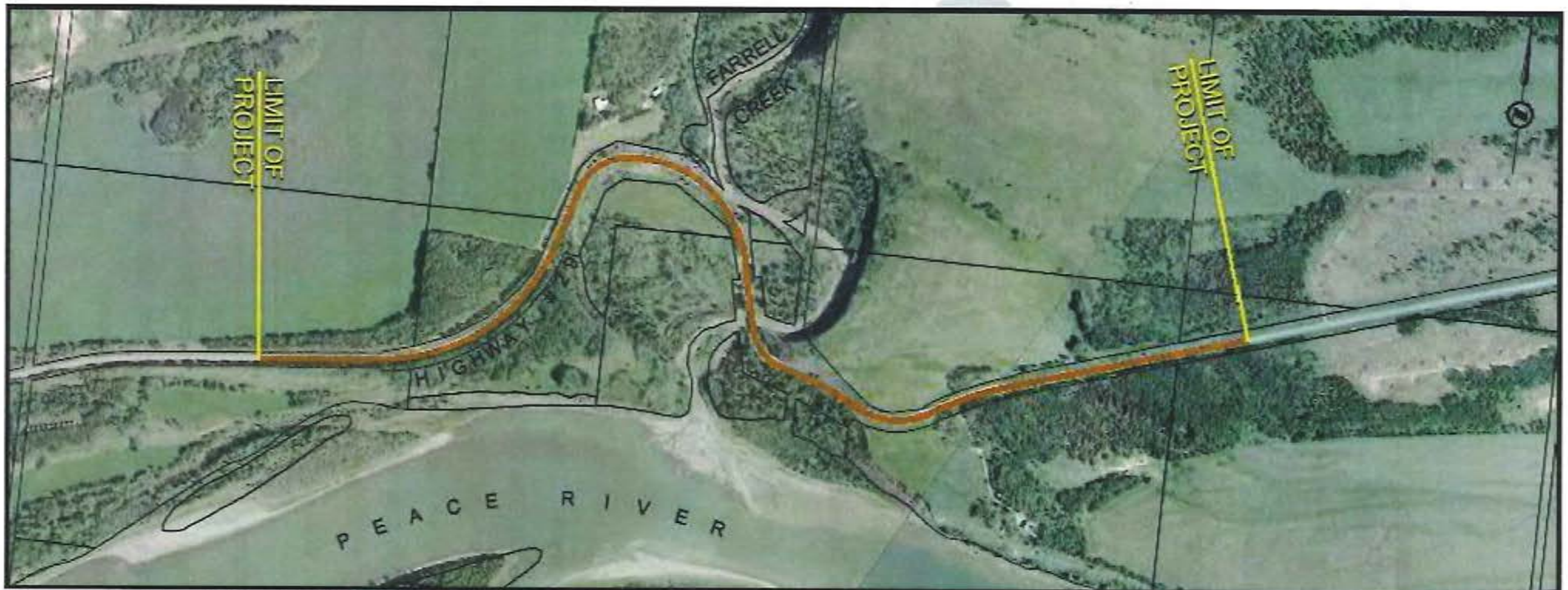


Figure 2.3.1: Farrell Creek Existing Conditions

2.3.4 Drainage

Farrell Creek is a tributary of the Peace River, draining an area of 642 square kilometres upstream of the existing Highway 29 Bridge. The channel has an average gradient of 0.07 percent and is approximately 30 metres wide bank-to-bank. It has a meander pattern that is entrenched in a steep sided valley that is 50 metres deep and 200 metres to 400 metres wide. At the current highway crossing the channel is confined by a near vertical shale bank to the east and the highway approach to the west. The present Highway 29 Farrell Creek Bridge has a small amount of 100 Kg and 250 Kg Class riprap used to protect the local stream banks and highway endfill from erosion.

Shallow drainage ditches are provided in cut sections to collect water from the adjacent slopes and from highway surface runoff. Cross culverts then convey surface water from the north side of the highway to the south side. A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent stages.

2.3.5 Geotechnical

The topography along Highway 29 in the immediate proximity of the Farrell Creek project segment consists of relatively flat lying raised fluvial terraces adjacent to the north bank of the Peace River. These fluvial terraces consist primarily of sand and gravel soils which are underlain by sedimentary bedrock (siltstone and shale) at depths shallower than approximately 5 metres. Farrell Creek, a tributary of the Peace River, flows in an underfit meandering channel in the base of a north-south oriented valley that dissects the terraced terrain. The Farrell Creek valley is about 200 to 500 metres wide through the area and has steep, bedrock controlled 25 metres to 30 metres high side walls and a relatively flat bottom. The existing Highway 29 alignment at Farrell Creek includes a curved descent into and out of the Farrell Creek valley to access a bridge crossing in the base of the valley.

A Preliminary Geotechnical Assessment report for the Proposed Farrell Creek segment report is included in **Volume 3** of the report and provides additional details.

2.3.6 Structures

The existing bridge at Farrell Creek is a four-span structure with two main spans of approximately 15 metres and a 9 metres long side span on either end. The bridge, built in 1967, is of a composite deck construction with the reinforced concrete deck cast onto steel plate girders supported on reinforced concrete piers. The piers are found on 5-steel H piles and the abutments are found on 4-steel H piles. The existing bridge will be flooded by the construction of the new dam and may have to be demolished after the new replacement bridge is constructed.

A Bridge Definition Design Report is included in **Volume 3** of the report and provides additional details.

2.3.7 Utilities and Infrastructure

There are existing utility poles within the Farrell Creek Segment including an overhead crossing east of the bridge. The exact location of the poles shown on the design drawings are approximate only and based on GIS data provided by BC Hydro. The location and owners of the utilities will need to be confirmed in subsequent design stages in order to properly assess the impacts and potential relocation costs.

2.3.8 Environment

2.3.8.1 Fisheries

Farrell Creek is a small stream located approximately 63 kilometres upstream from the Proposed Dam. Juvenile Mountain Whitefish were the most abundant species in Farrell Creek in the first set of surveys completed for the Project in the late 1970's. Non-sport fish including Redside Shiners, Longnose Sucker, Slimy Sculpin, Longnose Dace and Lake Chub are present in the creek. A pair of spawned out Walleye were observed in the creek in 1989 that mark the furthest upstream observation of this species. A resident population of Rainbow Trout has been reported in the upper reaches of Farrell Creek and juvenile Rainbow Trout were observed in small numbers in the lower sections of this watercourse.

Fish historically recorded in the Farrell Creek system include Arctic grayling, Mountain Whitefish, Rainbow Trout, Burbot, Largescale Sucker, Longnose Sucker, White Sucker, Flathead Chub, Lake Chub, Longnose Dace, Northern Pikeminnow, Redside Shiner, Trout Perch, Prickly Sculpin, and Slimy Sculpin.

An Environmental Assessment report is included in **Volume 3** of the report.

2.3.8.2 Wildlife

Farrell Creek is used extensively by wolf and other carnivores for hunting abundant furbearer prey in the lower Peace area. They use the Farrell drainage, especially along the riparian community. Farrell Creek also has a diversity of bird species and has had a recorded sighting of a rare Canada Warbler along its stretch. Large congregations of waterfowl are common along the outflow of Farrell Creek to the Peace River. It has a known bat roosting location along its section where the Northern Myotis bat has been recorded. Beavers appear to be common downstream of Farrell Creek Bridge but uncommon upstream of the crossing location. The rare Fisher was captured along the riparian community of Farrell Creek during Site C Project surveys.

An Environmental Assessment report is included in **Volume 3** of the report.

2.3.8.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report.

2.3.8.4 Development and industry

Local farming and agricultural operations are located adjacent to and accessible from the Highway.

2.3.9 Properties

The properties within the Farrell Creek Section consist of both Private Properties and BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased). The land use within the Farrell Creek section is a mix of residential and agricultural and is all within the Agricultural Land Reserve with the exception of the area immediately adjacent to Farrell Creek.

2.4 Km 21 to Km 26.5

The Km 21 to Km 26.5 segment begins approximately 21 kilometres east of Hudson's Hope and extends for approximately 5.85 kilometres as shown in **Figure 2.4.1**. Based on the BCMOT LKI referencing system, the Segment is located between kilometre 20.8 and 26.7 on LKI Segment 1181.

2.4.1 Geometry and cross-sections

The existing horizontal alignment between Km 20.8 and Km 26.7 is good, consisting of large radius curves between 460 metres and 2,500 metre radii with the majority of the curves having radii greater than 800 metres which is well above the requirements for a 90 kilometres per hour design speed.

The vertical alignment through the Km 21 to Km 26.5 segment is generally flat with gentle vertical curves throughout. The grades are under 2.5 percent throughout the segment with the exception near the eastern limit where the grades increase to approximately 4 percent.

The existing cross section through the Km 21 to Km 26.5 segment consists of two 3.5 metre lanes with 1.0 metre paved shoulders. South of the highway, natural hillsides varying between 30 metres to 65 metres in height extend down to the river. These hillsides are steep and are susceptible to erosion and slope failure.

Figure 2.4.1: Km 21 to Km 26.5 Existing Conditions

2.4.2 Traffic

The AADT and SADT along the Km 21 to Km 26.5 segment are estimated to be 735 vehicles per day and 1,053 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 1,051 vehicles per day and 1,505 vehicles per day respectively. The two way design hourly volume is estimated to be 74 vehicles per hour for the 2010 year and 105 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2"** dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.4.3 Intersections and Accesses

There are several existing driveways and field access located within the current limits of the Km 21 to Km 26.5 segment. Most are minor gravel driveways providing access to adjacent properties including a gravel pit near the eastern project limit. There are no major intersections or local roads within the Km 21 to Km 26.5 segment.

2.4.4 Drainage

Shallow drainage ditches are provided in cut sections to collect water from the adjacent slopes and from highway surface runoff. Cross culverts then convey surface water from the north side of the highway to the south side and down the slope. There is a large erosion gulley located approximately 500 metres east of the western project limits. A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent stages.

2.4.5 Geotechnical

In the vicinity of the Km 21 to Km 26.5 highway segment, the existing alignment of Highway 29 is located on some relatively broad, flat lying, fluvial terraces within the bottom of the Peace River Valley. From the western end of the segment (Sta. 6000+000 to approximately Sta. 6005+000), Highway 29 follows the southern edge of a main terrace level (approx. elevation 485 to 490 metres). Between Sta. 6005+000 and 6005+600 the highway climbs up onto a second higher main terrace level (approx. elevation 505 to 510 metres). From Sta. 6005+600 towards the east end of the project segment (approx. Sta. 6006+400), the current Highway 29 alignment gradually moves away from the south edge of the terrace. Existing sand and gravel borrow pits are located adjacent to and north of Highway 29 in the vicinity of Sta. 6005+400 and on both sides of the highway near Sta. 6006+200. Soils immediately underlying the existing highway and the main terrace levels adjacent to and immediately north of the highway are anticipated to consist primarily of well drained sand and gravel, although a surface layer of fine grained (silty) topsoil can be expected.

Between approximately Sta. 6000+900 to 6003+700, the southern side of Highway 29 is located along the crest of an approximately 50 to 55 metres high, partially vegetated, terrace slope face that descends directly down into the main channel of the Peace River. Beneath some upper sand and gravel layers, this slope is likely underlain by finer grained soils and shale bedrock. The slope has an average natural angle of repose ranging between about 1.5:1 and 2:1, although there are many steeper segments, particularly at the locations of local river bank erosion, slope erosion, slope failures and incised gullies. Some perched groundwater tables and areas of seepage day-lighting along the slope face are also likely present.

Between Sta. 6003+700 and 6005+600, the main channel of the Peace River is located further south, away from the terrace slope face below the highway, and the toe of the terrace slope is generally located on lower, minor terraces and partially abandoned side channels on the flood plain of the Peace River. Along this section, the slope ranges from 30 to 40 metres in height, has a natural angle of repose ranging from about 1.5H:1V and 2.5H:1V, and is generally well vegetated and appears naturally more stable than the previously described upstream (westerly) section. The geology underlying the slope area is currently unknown, but is suspected to be similar to that of the upstream section.

Easterly, beyond Sta. 6005+600 to the end of the segment at Sta. 6006+400, the terrace face below the highway transitions into a more uniform, partially vegetated slope in the order of 55 to 65 metres in height. The upper one half to two thirds of the slope appears to be underlain primarily by sand and gravel. However, shale bedrock and intervening fine grained soils likely occur at lower elevations on the slope. With the exception of some locally steeper areas of shallow raveling failure apparently induced by surface erosion, the slope appears to be relatively stable and is at or near its natural angle of repose which is in the order of 1.5H:1V. More frequent evidence of erosion and surface raveling failure of the slope is apparent east (downstream) of Sta. 6006+300.

2.4.6 Utilities and Infrastructure

There are no known utilities within the Km 21 to Km 26.5 segment but this will need to be confirmed in subsequent design stages.

2.4.7 Environment

2.4.7.1 Fisheries

No fish bearing watercourses are known with this section.

An Environmental Assessment report is included in **Volume 3** of the report.

2.4.7.2 Wildlife

This section is located primarily through agricultural fields that provide limited wildlife habitat but are favoured by ungulate species. The treed locations down slope of the highway and on the east end of the segment are more significant as they provide thermal and security habitat for ungulates.

An Environmental Assessment report is included in **Volume 3** of the report.

2.4.7.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report

2.4.7.4 Development and industry

Local farming and agricultural operations are located adjacent to and accessible from the Highway. A private gravel pit is located at the eastern project limit.

2.4.8 Property

The property ownership within the Km 21 to Km 26.5 segment north of the existing highway consists primarily of private land and one parcel of crown land. On the south side of the existing highway the property ownership is primarily BC Hydro Owned or BC Hydro owned land that is leased (BC Hydro Leased) with the exception of three parcels of private land and one parcel of crown land. The land use is primarily agricultural and is all within the Agricultural Land Reserve with the exception of approximately 0.5 kilometres at the east end. There is an existing private gravel pit located near the east end of the project limit.

2.5 HALFWAY RIVER

The Halfway River segment is located near the eastern end of the project corridor approximately 8 kilometres west of the Bear Flat / Cache Creek segment as shown in **Figure 2.5.1**. Based on the BCMOT referencing system, the realigned Halfway River Segment is located between kilometre 36.9 and 41.0 on LKI Segment 1181.

Figure 2.5.1: Halfway River Existing Conditions

2.5.1 Geometry and Cross-sections

The existing horizontal alignment within the Halfway River segment consists of two smaller radius curves of 320 metres and 330 metres located just east of the existing Halfway River Bridge. These curves are below the minimum radius of 340 metres required for a 90 kilometres per hour design speed.

The vertical profile consists of steep grades on both the west and east approaches as you descend into the river valley on the approach to the Halfway River Bridge. The grade west of the existing bridge is approximately 5 percent and the grade just east of the existing bridge is between 4 percent and 6 percent. At the east end of the Halfway River segment, the vertical grade increases to over 9 percent.

The existing cross section through the Halfway River segment consists of two 3.5 metre lanes with 1.0 metre paved shoulders.

2.5.2 Traffic

The AADT and SADT along the Halfway River segment are estimated to be 735 vehicles per day and 1,053 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 1,051 vehicles per day and 1,505 vehicles per day respectively. The two way design hourly volume is estimated to be 74 vehicles per hour for the 2010 year and 105 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2**" dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.5.3 Intersections and Accesses

There are several existing driveways located within the current limits of the Halfway River segment. Most are gravel driveways and field access providing access to adjacent properties. There are no major intersections or local roads within the Halfway River Segment.

2.5.4 Drainage

Halfway River is one of the main tributaries to the Peace River in the area, with a drainage basin of 9,350 square kilometres above the Highway 29 Bridge. Near the present highway crossing, the channel is 100 metres to 150 metres in width bank-to-bank and has numerous gravel bars and vegetated islands. It has a meander pattern that is entrenched in a steep sided valley that is 40 metres deep and more than 700 metres in width. The present highway crossing is located near the confluence of the Peace River where the river valley widens. The Highway 29 Halfway River Bridge has a moderate amount of approximately 250 Kg Class riprap protecting the highway endfill from erosion.

Shallow drainage ditches are provided in cut sections to collect water from the adjacent slopes and from highway surface runoff. Cross culverts then convey surface water from the north side of the highway to the south side. A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent stages.

2.5.5 Geotechnical

This proposed Halfway River highway realignment segment is located within the Peace River Valley adjacent to the confluence of the Halfway River with the Peace River. At this location, the Peace River Valley bottom is 2 to 3 kilometres wide and is dominated by various relatively flat-lying raised fluvial terraces on the north side of the river that are related to historic river valley development. Throughout these terraces, sands and gravels or silty sands are most likely to be encountered near surface, although a silt cap is likely present in areas east of the Halfway River. The Halfway River, a major tributary of the Peace River, has cut into these terraces and created its own local floodplain area within which the channel has developed several meanders upstream from the confluence with the Peace River. Bedrock outcrops are exposed on actively eroding slopes along the Halfway River as well as at the present Highway 29 road cut to the east of the existing river crossing. The exposed bedrock consists of friable shale with a few thin (5 to 10 centimetres thick) interbedded sandstone layers. From the exposures along the Halfway River valley slopes it was noted that the sand and gravel overlying the shale bedrock was in the order of 5 to 8 metres thick.

A large scale slope instability, the Attachie Landslide, is located southwest of the confluence of Halfway River and the Peace River on the southern slope of the Peace River Valley. This area failed rapidly in May 1973 mobilizing an estimated 12.4 million cubic metres of material. There is an estimated 6.0 million cubic meters of potentially unstable material remaining on the slope. Debris from the 1973 slide crossed the river and remains in place adjacent to the existing Highway 29 alignment upstream from the confluence of the Peace and Halfway Rivers.

A Preliminary Geotechnical Assessment report for the Proposed Halfway River segment report is included in **Volume 3** of the report and provides additional details.

2.5.6 Structures

The existing bridge at Halfway River is a three-span structure with two main spans of approximately 61 metres, and a westerly side span of approximately 13 metres. The bridge, built in 1975, is of a composite deck construction with the reinforced concrete deck cast onto steel plate girders supported on reinforced concrete piers found on spread footings. The existing bridge will be flooded by the construction of the new dam and may have to be demolished after the new replacement bridge is constructed.

A Bridge Definition Design Report is included in **Volume 3** of the report and provides additional details.

2.5.7 Utilities and Infrastructure

There are existing utilities poles within the Halfway River Segment including an overhead crossing of the highway near the east project limits. There is also an underground telephone line with an underground crossing of the highway near the west project limit. The exact location of the poles and underground lines shown on the design drawings are approximate only and based on GIS data provided by BC Hydro. The location and owners of the utilities will need to be confirmed in subsequent design stages in order to properly assess the impacts and potential relocation costs.

2.5.8 Environment

2.5.8.1 Fisheries

The Halfway River is the largest tributary upstream of the Proposed Dam. Major tributaries of the Halfway River include the Chowade, Graham, and Cameron rivers and Cypress, Colt, Kobes, and Ground Birch creeks. It is known to be used by 16 fish species including 7 sport fish and 9 non-sport fish species. Mountain whitefish are the most abundant species in the Halfway system and adults, juveniles and young of year have been captured or observed. The presence of young of year fish suggests that mountain whitefish use the Halfway River for spawning and rearing. Juvenile and adult rainbow trout and Arctic Grayling have also been observed in the Halfway River and its tributaries. Adult and juvenile Bull Trout are commonly found in the Halfway River and its tributaries. This system also provides habitat for numerous sucker, cyprinid and sculpin species. Fish historically recorded in the Halfway River system include Mountain Whitefish, Bull Trout Arctic Grayling, Bull Trout, Kokanee, Rainbow Trout, Burbot, Northern Pike, Largescale Sucker, Longnose Sucker, White Sucker, Flathead Chub, Lake Chub, Longnose Dace, Northern Pikeminnow, and Slimy Sculpin.

An Environmental Assessment report is included in **Volume 3** of the report.

2.5.8.2 Wildlife

The Halfway River system is broad and wide. It is used by many species of wildlife. Wolves use this drainage for hunting commonly along the riparian communities as they follow the deer and elk along the fields and its riparian community. The wetlands provide nesting and roosting for many species of birds. A wide diversity of bird species such as the rare provincially Red-listed Connecticut Warbler and Bluelisted Canada Warbler have been recorded along the lower section of the Halfway River system. Furbearers like the rare Fisher and Marten were confirmed along this corridor during wildlife surveys for the Site C Project. The wetland communities also provide suitable bat roosting locations, especially upstream of the existing highway on Halfway River. The lower section contains extensive beaver use, especially along the Peace River where slow moving water is present. Large numbers of ungulate (deer and elk) use the lower sections of the Halfway River system, especially in the winter due to the low snow pack. Moose are scattered through the area but 41 percent of all ungulates that were recorded in historical Site C Project studies show that the Halfway River area is favored habitat.

An Environmental Assessment report is included in **Volume 3** of the report.

2.5.8.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report.

2.5.8.4 Development and industry

Local farming and agricultural operations are located adjacent to and accessible from the Highway.

2.5.9 Property

The properties within the Halfway River Section are a mix of BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased) and Crown Land. No private properties are located within the Halfway River Segment. The land use is primarily agricultural and is all within the Agricultural Land Reserve with the exception of approximately 0.5 kilometres at the western project limit and the area immediately adjacent to Halfway River.

2.6 BEAR FLAT / CACHE CREEK

The Bear Flat / Cache Creek segment is the most easterly segment within the corridor that would require relocation and is shown in **Figure 2.6.1**. Based on the BCMOT LKI referencing system, the realigned Bear Flat / Cache Creek Segment is located between kilometre 48.59 and 56.95 on LKI Segment 1181.

Figure 2.6.1: Bear Flat / Cache Creek Existing Conditions

2.6.1 Geometry and Cross-sections

The section of existing highway within the project boundaries is approximately nine kilometres in length, the majority following the Peace River Valley floor on a bench which is roughly 15 metres above the river level.

Along the valley floor the horizontal alignment is good, consisting of gentle horizontal curves. A sharp substandard horizontal curve is located at the eastern project limit.

The vertical alignment, along the valley floor, is generally flat with some slightly undulating vertical curves which follow the contours of the existing ground. At the project limits the highway exits the valley floor and the vertical grades increase. To the west at Watson Hill, the highway climbs up a steep grade of 10 percent which is cut into a side slope with stability concerns. To the east the highway climbs up a steep grade that continues for approximately two kilometres.

The existing cross section through the Bear Flat / Cache Creek segment consists of two 3.5 metre lanes with 1.0 metre paved shoulders.

2.6.2 Traffic

The AADT and SADT along the Bear Flat / Cache Creek segment are estimated to be 735 vehicles per day and 1,053 vehicles per day respectively for the 2010 year. For the 2035 horizon year, the AADT and SADT are estimated to be 1,051 vehicles per and 1,505 vehicles per day respectively. The two way design hourly volume is estimated to be 74 vehicles per hour for the 2010 year and 105 vehicles per hour for the 2035 horizon year. All traffic data used in this report was taken from the memorandum entitled "**Highway 29 North (Realignment Sections) Traffic Forecast Update Version 2**" dated January 27, 2012. A copy of the memorandum can be found in **Volume 3** of this report.

2.6.3 Intersection and Accesses

There are several existing driveways and intersections located within the current limits of the Bear Flat / Cache Creek segment. Most are gravel driveways and farm accesses providing access to adjacent properties. There is a access to a BCMOT gravel pit, a private gravel pit and to a campground as well as one main intersection at Watson Road within the Bear Flat / Cache Creek segment.

2.6.4 Drainage

There are two significant tributary streams of the Peace River within this segment. An unnamed stream is located at the west end of the segment and flows in a small draw and Cache Creek which is located near the east end of the segment. Cache Creek has a drainage basin of 932 square kilometres upstream of the Highway 29 Cache Creek Bridge. Near the present highway crossing, the channel is 30 metres to 35 metres wide bank-to-bank. Upstream, the channel and floodplains are entrenched in a steep sided valley that is 40 metres deep and 400 metres to 700 metres in width, but downstream of the existing bridge the channel is unconfined as it approaches Peace River. The Highway 29 Cache Creek Bridge has a moderate amount of 500 Kg Class riprap used to train the channel and protect the highway endfill from erosion.

Storm water reaches the existing highway alignment, flowing from the high escarpment to the north, across the low lying farm fields via a series of valleys and swales and crosses the highway through a series of culverts. Watson Slough intercepts and retains some surface runoff, prior to it crossing the highway.

Down pipes are common in the area as illustrated in **Photograph 2.6.1**. however they are prone to damage due to ground movement.

Photograph 2.6.1: Example of broken pipe (Credit: AMEC)

A detailed survey of the existing drainage features was not included as part of the Definition Design but will be completed during subsequent stages.

2.6.5 Geotechnical

The Peace River Valley is 2 to 3 kilometres wide through the Bear Flat / Cache Creek segment, and about 200 metres deep. The valley bottom adjacent to the river is characterised by fluvial features such as floodplain areas and older abandoned river channels. The river morphology is primarily sinuous. Bear Flat gets its name from two broad flat terraces located within the Peace River Valley, but above and north of the current river flood plain.

The lower elevation terrace feature within the Bear Flat / Cache Creek section (hereafter called the lower terrace) is situated just below the proposed reservoir Full Supply Level (FSL), around 460 metres above sea level (ASL) elevation at the upstream end of the section and 440 metres ASL elevation at the downstream end. Throughout much of its length, the surface of the lower terrace has a slightly higher elevation closer to the current river channel than it does to the north, and the north margin of the terrace is occupied by a long, narrow, wetland area, known locally as Watson Slough. The wetland likely represents the surface of an infilled and, abandoned ancient channel of the Peace River. The margin of the lower terrace adjacent to the floodplain has been exploited for aggregate resources in the past (e.g. Peaceview Pit).

An upper elevation terrace, approximately 10 to 15 metres higher than the lower terrace (hereafter called the upper terrace) occupies the northern third to half of the Peace River Valley. It is generally flat-lying, with a few rolling features. Like the lower terrace, its surface has a higher elevation along the southern margin, and it also contains topographic features that suggest an ancient channel of the Peace River may be present underlying its north edge, below the main Peace River Valley north sidewall slopes. Portions of the upper terrace have been mined for aggregate resources in both the BCMOTs Thomas Pit and in private gravel pits (e.g. Bentley Pit).

The adjacent north sidewall slopes of the Peace River Valley are moderately to steeply sloping and highly erodible. There are many well defined gullies and creeks along the valley slopes that have formed from runoff of rainfall and snow melt. While the Peace River Valley is considered mature, the valley slopes are still unstable (Thurber, 1978).

There are two significant tributary streams within the Bear Flat segment: an unnamed stream located at the west end of the segment; and Cache Creek, located near the east end of the segment. The unnamed stream flows in a small draw which is crossed by the existing highway on a steep-sided embankment fill.

Cache Creek, a major tributary stream of the Peace River, flows in a meandering, braided channel within the base of its own mature valley. Where the Cache Creek valley meets the Peace Valley, it extends through the upper Bear Flat terrace at nearly the same elevation as the Peace River. The valley is between 40 and 55 metres below the adjacent terrace surface. The lower terrace ends just upstream of Cache Creek. Due to its width, depth, and proximity to the existing highway corridor which rises up out of the Peace River Valley at the east end of the Bear Flats section, the Cache Creek valley represents a major topographic obstacle which must be accommodated by the proposed realignment.

Three significant areas of large scale slope instability have been identified within or adjacent to the Bear Flat project area: The slope crossed by the existing highway between the west end of the project and Szoo Road (Watson Hill), where the fill slope of the highway shows signs of instability; the slopes crossed by the existing highway as it climbs Cache Creek Hill, where side cast clay fill over clay slopes have resulted in a long history of instability; and Cache Creek slide, adjacent to and east of the project segment. Cache Creek slide is an ancient deep seated bedrock landslide estimated to have a volume of at least 70 million cubic metres, and is thought to have blocked the Peace River on at least one occasion (Thurber, 1978). A portion of the slide debris is thought to have remobilized early in the 20th century (Bidwell, 1999).

A Preliminary Geotechnical Assessment report for the Proposed Bear Flat segment report is included in **Volume 3** of the report and provides additional details.

2.6.6 Structures

The existing bridge at Cache Creek is a single span structure of 46 metres in length and is shown in **Photograph 2.6.2** below. It was reconstructed in 2008 with precast concrete deck panel on steel plate girders. The superstructure is supported on four 610 millimetre diameter x 19.1 millimetre thick steel pipe piles at each abutment. The existing bridge is expected to be flooded by the construction of the proposed new dam and may have to be demolished after the new replacement bridge is constructed. However, the existing steel plate girders may have value for re-use.

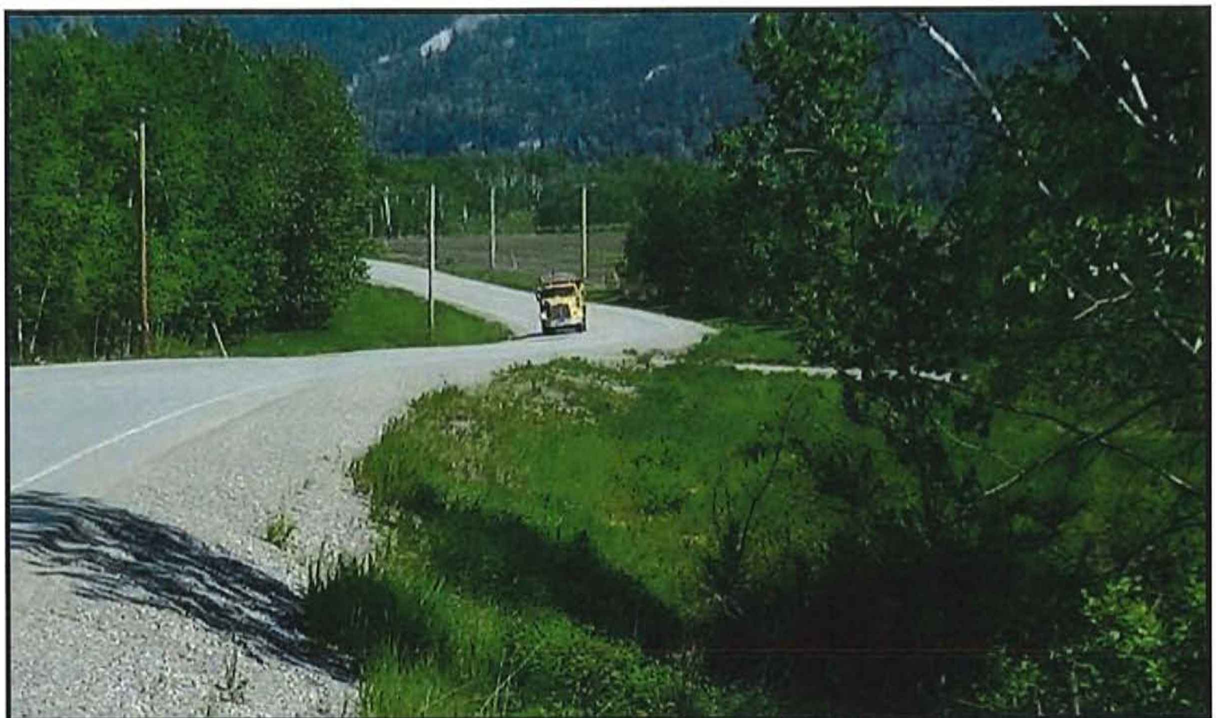
A multi-plate structure is located in a steep valley at the east end of the project. The condition of the multi-plate was not assessed during the Definition Design.

A Bridge Definition Design Report is included in **Volume 3** of the report and provides additional details.

Photograph 2.6.2: Existing Cache Creek Bridge (Credit: AMEC)

2.6.7 Utilities and infrastructure

A BC Hydro overhead line runs most of the length of this section switching from side to side of the existing highway as can be seen in **Photograph 2.6.3** below. It diverges from the highway corridor at the east end of the segment. Also present is an underground telephone line. The location and owners of the utilities will need to be confirmed in subsequent design stages in order to properly assess the impacts and potential relocation costs.



Photograph 2.6.3: Overhead lines (Credit: AMEC)

2.6.8 Environmental

2.6.8.1 Fisheries

Cache Creek is located approximately 25 kilometres upstream from the proposed Site C dam. Most common fish species recorded in recent surveys include Northern Pikeminnow and Lake Chub. They are common in all reaches of Cache Creek. Species like the Longnose Dace and Longnose Sucker were also found in Cache Creek. Fish historically recorded in Cache Creek consisted of Rainbow Trout, Arctic Grayling, Bull Trout, Longnose Sucker, White Sucker, Flathead Chub, Lake Chub, Longnose Dace, Northern Pikeminnow and Redside Shiner.

An Environmental Assessment report is included in **Volume 3** of the report.

2.6.8.2 Wildlife

The Bear Flat / Cache Creek area provides habitat for a diversity of species. As part of the inventory surveys completed for the Site C Project, Eastern Red Bats have been identified in the area. Mallards and Canada Geese are the dominant waterfowl in Cache Creek especially at its confluence with the Peace River. The Bear Flat / Cache area provides good habitat for furbearers like the provincially Bluelisted Fisher which has been recorded along the system. Wolf and other carnivores commonly use the riparian community for hunting. Large mammals like Stone Sheep have historically been identified along the higher elevation areas. Bat roost sites along the banks of Cache Creek and the existing bridge have been identified for species like Little Brown Bats, Northern Myotis, Long-legged Myotis and Big Brown Bats. A rare Red Bat was recorded historically in the area.

An Environmental Assessment report is included in **Volume 3** of the report.

2.6.8.3 Other

As part of the Site C Project's Stage 3 work, BC Hydro has engaged consultants to study and document other elements of the physical and social environment. These other elements include vegetation, agriculture, archaeological and heritage, contaminated sites, climate, socio-community, socio-economic, and recreation, and are reported-on outside of this report.

2.6.8.4 Development and industry

A BCMOT gravel pit, a private gravel pit, a private campground, and a wetland area with visiting facilities are located within the Bear Flat / Cache Creek segment. Local farming and agricultural operations are located adjacent to and accessible from the Highway.

2.6.9 Property

There are 10 separate access points to adjacent properties in the Bear Flat / Cache Creek segment. On the western section there are several residences at the top of an escarpment and east of Cache Creek there are two residences. Active farm land is present throughout the length of this project immediately to the north of these residences. One kilometre west of the existing Cache Creek Bridge there is an access that serves a private gravel pit and campground. The Watson Slough immediately adjacent to the highway has a parking area. Opposite Watson's Slough is an access to a BCMOT gravel pit.

The property ownership throughout this segment varies between BC Hydro Owned, BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased) and privately owned property. The land use is primarily agricultural and is all within the Agricultural Land Reserve with the exception of approximately 1.7 kilometres east of the western project limit and 0.3 kilometres west of the eastern project limits.

3.0 PROJECT OBJECTIVES

The primary objective of this project was to determine safe, cost effective re-alignment options that meet all the required BCMOT design standards and criteria while minimizing environmental, agricultural and private property impacts. Mitigating impacts due to erosion caused by wind induced waves on the reservoir and from impacts due to landslide generated waves are key design elements that were considered during the Definition Design stage. Additional objectives of the Highway 29 Definition Design stage included:

- Reviewing previous alignment options from earlier studies;
- Providing initial geotechnical assessment of each segment;
- Determining potential material sources;
- Providing support for the Multiple Account Evaluation process;
- Preparing roadway and structural Definition Design drawings;
- Preparing right of way Definition Design drawings to assess property requirements;
- Providing construction cost estimates to help facilitate the selection of a preferred alignment option for each segment;

3.1 DESIGN CRITERIA

A project wide design criteria document has been developed for Highway 29 and associated side roads in collaboration with the BC Hydro Site C IET, the BCMOT, and the Binnie Design Team. The purpose of the design criteria document is to ensure that acceptable current standards are met in a consistent manner. The key design criteria elements used in the Definition Design of the highway include the following:

- Functional Classification = Rural Arterial Undivided
- Design Speed = 90 kilometres per hour
- Lane Width = 3.6 metres
- Paved Shoulder Width = 1.5 metres
- Minimum Horizontal Radius = 340 metres
- Minimum Grade = 0.5 percent (1.0 percent on Bridges)
- Maximum Grade = 6 percent
- Minimum Highway/Causeway Elevation = 468 metres (2 metres above Flood Impact Line)

- Minimum Bridge Elevation established so the 10,000 year return period landslide generated wave passes underneath structure

All proposed new major intersections along the Highway 29 corridor will be designed in accordance with Figure 710.E, Figure 710.G.1 or Figure 710.H from the BCMOT Supplement to TAC Geometric Design Guide. The exact intersection configuration, including the need for quadrant islands, auxiliary lanes and storage lengths will be assessed on a site specific basis and based on a traffic analysis during subsequent design stages.

All private accesses and driveways along the Highway 29 corridor will be designed in accordance with a Type 1A, Type 1B, Type 2A or Type 2B access as shown in the BCMOT Supplement to TAC Geometric Design Guide. The exact access type will be assessed on a site specific basis and in consultation with property owners during subsequent design stages.

The design criteria document also contains guidelines for the structural, hydrotechnical and geotechnical components of the design. The approved design criteria document can be found in **Volume 3** of this report.

3.2 Problem Definition

The construction of the proposed new dam will result in the formation of a new reservoir in the Peace River valley. Four segments of Highway 29 (Lynx Creek, Farrell Creek, Halfway River, and Bear Flat / Cache Creek) would be inundated by the new reservoir and will require relocation. Two additional segments (Dry Creek and Km 21 to Km 26.5) would not be inundated but are still impacted by the reservoir and also require relocation. The reservoir will also cause erosion and increased instability to the existing highway embankment slopes at these two sites. This will require either some form of slope protection to mitigate the erosion and instability or the relocation of the highway to outside the zone of erosion and instability. This zone of erosion and instability is depicted on the Definition Design drawings by the Erosion Impact Line (EIL) and Stability Impact Line (SIL) respectively.

The preferred alignment options have been developed to comply with the criteria set out in the design criteria document. In addition, several other key constraints were taken into considered in developing and selecting preferred alignment options. These key constraints include the following:

- Geotechnical Ground Conditions: It is preferable to select an alignment option on "good" geotechnical ground conditions to minimize initial construction costs and future maintenance costs.

- Environmental Effects: The selection of the preferred alignment considered the effects to aquatic and riparian habitat, wildlife habitat and vegetation loss with the aim to minimize these effects.
- Archaeological Sites: The selection of the preferred alignment considered the effects on known and potential archaeological sites with the aim of minimizing effects on these sites.
- Agricultural Land Effects: The selection of the preferred alignment considered effects on agricultural lands with the objective of minimizing the total loss of agricultural land as well as minimizing the creation of agricultural severances.
- Effects on Private Properties: The selection of the preferred alignment considered minimizing effects on private properties.
- Navigable Waters Protection Act: A Navigable Clearance Envelope achieving the requirements of the Navigable Waters Protection Act will likely be required at the proposed new structures at Lynx Creek, Farrell Creek, Halfway River and Cache Creek. Although no final decisions have been made by Transport Canada regarding the dimensions of the Clearance Envelopes, a draft memo prepared by the IET dated August 5, 2011 provided estimated clearance envelope dimensions that were used in the preparation of the Definition Design preferred options. This memo was provided to Transport Canada and while they were generally accepting of the proposed Clearance Envelopes no formal acceptance was made by them. The clearance envelopes are measured from the Extreme High Reservoir Level (EHRL). The clearance envelopes and the EHRL elevations used during the Definition Design are summarized in **Table 3.2.1** below.

Table: 3.2.1: Estimated Navigation Clearance Envelopes

Location	Extreme High Reservoir Level Elevation	Estimated Required Navigation Clearance Envelope (Height by Width)
Lynx Creek	462.1 m	8 m by 25 m
Dry Creek	461.9 m	No Navigation Clearances
Farrell Creek	461.9 m	8 m by 25 m
Halfway River	461.8 m	8 m by 25 m
Cache Creek	461.8 m	8 m by 25 m

A key consideration in the selection and design of the highway, causeway and bridge structures is the effects of a potential landslide generated wave. The landslide generated wave is a wave that would be produced by a landslide event impacting the proposed reservoir. The amplitude of the wave, which is the height of wave measured from reservoir water surface level, and the forces produced by this wave on the bridge abutments and piers and to a lesser extent the superstructure approach spans, assuming the superstructure is positioned to clear the wave at the main channel are critical elements that were considered when selecting a preferred alignment option and will need to be considered during subsequent design stages. BGC Engineering (BGC) has provided some preliminary estimates on the expected Wave Amplitudes at the various bridge crossing sites based on an estimated 10,000 year return period landslide. The values used in the Definition Design are shown in **Table 3.2.2** below.

Table: 3.2.2: Peak 10,000 year wave amplitudes at bridge sites

Proposed Bridge Location	Modeled Peak Wave Amplitude based on a 10,000 Year Return Period Landslide
Lynx Creek	3 m
Dry Creek	<1 m
Farrell Creek	3 m
Halfway River	14 m
Cache Creek	3 m

3.3 Impact Lines

BGC has developed preliminary impact lines around the proposed Site C reservoir that were considered when developing the preferred highway alignment options. The impact lines are preliminary and the lines shown on the drawings are the January 27, 2012 version. The following section provides a brief description of each of the impact lines and these are further described in the approved project design criteria document found in **Volume 3**.

The impact lines that have been produced by BGC include the following:

- Erosion Impact Line (EIL) is "defined as the boundary beyond which land adjacent to the proposed reservoir is not expected to regress due to progressive erosion caused by normal reservoir action". The EIL was based on an estimated 100 year horizontal beach erosion distance and recession of the bank to an anticipated angle of repose. Conservative input parameters have been used to determine the EIL, and it is expected that in the majority of cases actual erosion will be less than predicted by the EIL.
- Stability Impact Line (SIL) is "defined as the boundary beyond which land adjacent to the proposed reservoir is not expected to be subjected to sudden landsliding due to reservoir action, to an annual probability of exceedance of 1/10,000".
- Flood Impact Line (FIL) is "defined as the boundary beyond which land adjacent to the proposed reservoir is not expected to be inundated as a result of normal reservoir or flood event". The preliminary FIL has been set at a single elevation of 466 metres which is approximately 4 metres above full supply level.

- Landslide Generated Wave Impact Line (WIL) is "defined as the boundary beyond which waves produced by a landslide into the proposed reservoir are not expected to cause erosion or other damage to an annual probability of exceedance of 1/10,000".
- A Natural Stability Line (NSL) has also been produced to provide an indication of areas potentially subject to sudden landslides under current (natural) conditions. The NSL is "described as the boundary beyond which land adjacent to the current river is not expected to be subjected to sudden landsliding under current conditions, to an annual probability of exceedance of 1:10,000 (or approximately 1% in 100 yrs)."

4.0 OPTIONS ANALYSIS

The Options Analysis process used to select a preferred alignment differed slightly between the six segments. The Lynx Creek and Halfway River segments were subjected to a pre-screening MAE process as well as a final MAE session. The pre-screening MAE was used at Lynx Creek and Halfway River to eliminate less feasible alignment options from further consideration. The final MAE sessions at Lynx Creek and Halfway River were used to select a preferred alignment option to proceed with through Definition Design. The preferred alignment options were then subjected to further design refinements and optimization.

A corridor at the Bear Flat / Cache Creek segment, and not an alignment, was selected using an MAE process. The reason that only a corridor was selected was due to the pending updates to the impact lines and the project's approach to residences within the impact lines being undetermined. The outcome of these two unknowns would have an influence on the alignment east of Cache Creek and therefore a preferred alignment could not be selected. The selected corridor was subjected to further design review, refinement and optimization and will continue to be refined as new information becomes available during subsequent design stages.

The remaining three segments, Dry Creek, Farrell Creek and Km 21 to Km 26.5, were subject to a design review, refinement and optimization process only and not to a pre-screening or final MAE process. The reason for this is that all the alignment options within these segments were contained within a single viable corridor.

A MAE process is commonly used by the BCMOT to evaluate highway alignment options based on key criteria or accounts. While the MAE process used to select the preferred alignments at Lynx Creek, Halfway River and Bear Flat / Cache Creek slightly differed from the BCMOT process in that Net Present Value costs were not calculated for each account; the process was still effective in comparing and selecting a preferred alignment option and was accepted by the BCMOT. The MAE team was made up of subject matter experts from BCMOT, BC Hydro, Binnie and the IET.

The MAE Accounts used in both the Pre-screening and Final MAE processes included the following key accounts and indicators:

- **Cost and Constructability Account**
    - ***Capital Cost*** – Total Project Costing including Bridge and Roadway, Property, and Engineering Design costs. Environmental mitigation and compensation costs were also included as a percentage of the cost. The capital costs used in the Pre-screening and Final MAE processes were based on early stages of designs and on historical unit rates. The capital costs were intended for comparison purposes only and should not be considered absolute or final. The capital costs are subject to change as the design process advances to a more detailed stage.
    - ***Life Cycle Costs*** – [redacted]
- **Safety Account**
    - ***Geotechnical Risk*** - Area of unfavorable ground conditions
    - ***Landslide Induced Wave Impact*** - Length of highway and bridge within the preliminary Landslide Generated Wave Line
    - ***Operational Safety*** – Collision prediction / safety modelling to determine expected collisions over 25 years. The results from the collision prediction / safety modelling can be found in **Volume 3.**
- **Environment Account**
    - ***Effects on Aquatic and Riparian Habitat*** **-** Area of riparian habitat loss
    - ***Wildlife Habitat for Listed Species*** **-** Area of habitat loss by listed species
    - ***Vegetation*** **-** Area of vegetation loss

- **Social Account**
  - ***Property Effects -*** Number of private properties impacted
  - ***Change in Land Ownership-*** Area of private land impacted by roadway alignment
  - ***Effects on Archaeological Sites -*** Number of known sites within 50 metres of the alignment and directly impacted by the alignment
  - ***Potential for unknown Archaeological Sites -*** Area of high and moderate archaeological potential
  - ***Loss of ALR -*** Areas of land within Agricultural Lane Reserve converted to road right of way
  - ***Agricultural Severance*** – Length of actively farmed land severed by an alignment

4.1 LYNX CREEK

The Lynx Creek segment underwent a pre-screening MAE and a final MAE in order to select a preferred alignment.

4.1.1 Pre-screening MAE – Lynx Creek

The pre-screening MAE took place over two days on July 22, 2011 (Meeting No. 1) and on July 28, 2011 (Meeting No. 2). The purpose of Meeting No. 1 was to allow the Design Team an opportunity to present the different alignment options to the IET and BCMOT for their review and consideration. The purpose of Meeting No. 2 was to review the indicator data compiled for each alignment option and eliminate the alignment options that were not considered feasible from further consideration.

Six alignment options were evaluated during the pre-screening MAE process. Four of these six alignment options were enhancements of previous alignment options developed by Willis Cunliffe Taite Delcan in 1982 and subsequently updated by Urban Systems in 2008. These previous alignment options can be found in the following reports:

- Highway 29 Relocation Hudson Hope to Charlie Lake Section 2, prepared by Willis Cunliffe Tait Delcan, dated February, 1982
- Peace River Site C Hydro Project Highway 29 Relocation Hudson Hope to Charlie Lake, prepared by Urban Systems, dated November 2008

The other two alignment options utilize the existing Millar Road alignment and were identified as potential options based on feedback received during the 2008 public consultation process. For each of the six alignment options, a short bridge with a causeway and a long bridge with no causeway were considered.

These proposed six alignment options generally followed three main corridors. An inland-corridor located away from the reservoir, a shoreline-corridor located adjacent to and in close proximity to the proposed reservoir and the Millar Road options which can be considered mid-corridor options. A brief description of the six options is provided below and drawings can be found in **Volume 3**.

Option 1 – This is similar to the previous alignment Option 2A from the 2008 Urban Systems report. The total length of this option is 7.2 kilometres and can be considered one of the three inland-corridor options. The short bridge option consisted of a 130 metre long bridge and a 320 metre causeway. The long bridge option consisted of a 450 metre long bridge and no causeway. The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

Option 2 - This is similar to the previous alignment Option A from the 2008 Urban Systems report. The total length of this option is 7.1 kilometres and can be considered one of the three inland-corridor options. The short bridge option consisted of a 160 metre bridge and 290 metre causeway. The long bridge option consisted of a 450 metre bridge with no causeway. The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

Option 3 - This is similar to the previous alignment Option 1A from the 2008 Urban Systems report. The total length of this option is 8.0 kilometres and can be considered one of the three inland-corridor options. The short bridge option consisted of a 210 metre long bridge and a 320 metre causeway. The long bridge option consists of a 530 metre long bridge and no causeway. The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

Option 4 - This is similar to the previous alignment Option B from the 2008 Urban Systems report. The total length of this option is 7.2 kilometres and is the only shoreline-corridor option. The short bridge option consisted of a 160 metre long bridge and a 530 metre long causeway. The long bridge option consisted of a 690 metre long bridge with no causeway. The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

Option 5 – This is one of two Millar Road options. The total length of this option is 7.1 kilometres and can be considered a "mid-corridor" option. The short bridge option consisted of a 160 metre long bridge and a 290 metre causeway. The long bridge option consisted of a 450 metre long bridge with no causeway.

The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

Option 6 – This is one of two Millar Road options. The total length of this option is 7.3 kilometres and can be considered a "mid-corridor" option. The short bridge option consisted of a 160 metre long bridge and a 530 metre causeway. The long bridge option consisted of a 690 metre bridge with no causeway. The total project cost of the short bridge option was estimated at [redacted] and the total project cost of the long bridge option was estimated at [redacted]

One alignment option from each of the "inland-corridor", "shoreline-corridor" and a Millar Road Option was selected to proceed to the next stage. The options selected were Option 3 Short Bridge, Option 4 Short and Long Bridge and Option 5 Short Bridge. The options eliminated during the MAE process were Option 1, Option 2 and Option 6. The pre-screening MAE report containing all the indicator data and the meeting minutes can be found in **Volume 3**.

4.1.2 Final MAE Process – Lynx Creek

The final MAE process for Lynx Creek took place on October 28th, 2011 (Meeting No. 4). At the meeting the Binnie Design Team provided an overview of the four remaining options which were Option 3 Short Bridge, Option 4 Short and Long Bridge and Option 5 Short Bridge. An updated list of indicators was provided at the meeting for review and discussion. The strategy used to select the preferred alignment was to look at the lowest cost option first and determine if there were any significant concerns with any of the accounts. If no significant concerns were identified by the Project Team, or the impacts were comparable, then the low cost option was considered the preferred option.

4.1.3 Final MAE Results – Lynx Creek

The capital costs for the four options evaluated during the Final MAE session were as follows:

- Option 3 Short - [redacted]
- Option 4 Short – [redacted]
- Option 4 Long – [redacted]
- Option 5 Short – [redacted]

Option 3 Short Bridge was the lowest cost option at [redacted]. An additional benefit of this option is that it is located outside the Landslide Generate Wave Impact Line which is preferable. However, a couple of concerns were identified with this option from a property and bridge perspective. This alignment option would sever an existing active farm and the bridge crossing would be located closer to the mouth of the creek and may be subject to increased sedimentation and debris accumulations thus increasing bridge maintenance costs.

The Option 4 Short and Long Bridge had the highest capital costs of any of the options. In addition, this option has the highest exposure to Landslide Generated Wave impacts since the alignment is immediately adjacent to the proposed reservoir. A large amount of riprap material would be required for this option to protect the slope against wind generated waves which would increase annual maintenance efforts. The high capital costs and the increased risk due to exposure to a landslide generated wave resulted in this option being eliminated from further consideration.

Option 5 Short Bridge was the second lowest cost option coming in approximately [redacted] higher than Option 3 Short at [redacted]. This option however has several benefits when compared to Option 3 Short Bridge. It has the least amount of property impacts and severances partly because it utilizes a portion of the Millar Road alignment. The use of the Millar Road alignment was suggested by local residents during the 2008 public consultation process. As with Option 3, the Option 5 alignment is located entirely outside the Landslide Generated Wave Impact Line which eliminates the risk associated with a landslide generated wave. From a bridge perspective, this option is preferred because it provides the shortest bridge length and the bridge crossing is located far enough away from the mouth of the creek to minimize debris and sedimentation. Lower annual bridge maintenance is expected with this option when compared to Option 3. Even though the capital cost for Option 5 was slightly higher than the capital cost for Option 3, the additional benefits described above were considered significant and therefore Option 5 Short Bridge was selected as the preferred option to advance through the Definition Design stage.

Refer to **Section 5** for details on the preferred option for Lynx Creek.

4.2 DRY CREEK

As discussed in **Section 2**, the existing culvert at Dry Creek is a 2.4 metre diameter steel multi-plate culvert that lacks capacity to handle the Q200 Instantaneous Flow and will be fully submerged after construction of the Proposed Dam. The existing highway alignment and profile at Dry Creek are a concern to the BCMOT due to the poor geometry created by the combination of the tight horizontal curves and the steep grade.

Given these concerns, the Binnie Design Team was asked to explore options to replace the culvert at Dry Creek. Several options were prepared for consideration and review by the IET. The options included both bridge and culvert structures. These options were subject to a design review and refinement process not a formal MAE in selecting the preferred alignment to advance to the Definition Design stage.

4.2.1 Conceptual Dry Creek Options

An Option 4 alignment and profile was prepared and presented at a design review session held on October 14, 2011. The horizontal alignment consisted of a 380 metre radius curve which meets a 90 kilometres per hour design speed. The vertical alignment consisted of a sag vertical curve with 4 percent and 5 percent approach grades. Three different structures including a bridge, a pre-cast concrete arch culvert and a multi-plate arch culvert were considered.

Option 4 Bridge Option – The bridge option consisted of an 18 metre single span incorporating precast concrete box girders. The bridge concept assumed cast-in place concrete abutments founded on piles with MSE wing walls that begin above the full supply level elevation of 461.8 metres. The bridge option provided a Navigable Water Clearance Envelope of 3 metres high by 10 metres wide and also allowed for a 2.0 metre animal pathway adjacent to the east abutment at an elevation 462.3 metres. An MSE wall was provided on the upstream side to minimize environmental and property impacts. An MSE wall was also provided on the downstream side because it was assumed that it would withstand the impacts of a landslide generated wave better than a typical embankment fill with riprap although no detailed analysis was done to confirm this assumption. The total cost of the bridge structure was estimated to be [redacted] and the total estimated project cost was [redacted].

Option 4 Precast Concrete Arch Option - A precast concrete arch structure, with a span of 13 metres and rise of 8.5 metres, was also considered. In the absence of any detailed geotechnical investigation a conservative approach was used for the foundation design with the concrete arch being founded on piles with MSE wing walls beginning above the full supply level of 461.8 metre. MSE walls were assumed on both the upstream and downstream sides for the same reasons mentioned above. The concrete arch option was sized to provide a Navigable Water Clearance Envelope of 3 metres high by 10 metres wide. The total cost of the concrete arch was estimated to be [redacted] and the total estimated project cost was [redacted]

Option 4 Multi-plate Culvert Option – A multi-plate high profile arch culvert with a span of 6.3 metres and a rise of 3.68 metres was the final structure considered. This option did not consider the need for a Navigable Water Clearance Envelope and the only design consideration was that the pipe conveys the Q200 Instantaneous Flow which is estimated to be 44.3 cubic metres per second. Embankment side slopes of 2H:1V were provided for this option instead of MSE walls which increased impacts to adjacent private properties. Similar to the other options and in the absence of any detailed geotechnical investigations, a conservative foundation design was assumed with the culvert being founded on piles. The total cost of the culvert was estimated to be [redacted] and the total estimated project cost was [redacted].

The preferred option that was selected to be advanced through the Definition Design Stage was essentially Option 4 Multi-plate Culvert Option with a Precast Arch as the preferred structure instead of the multi-plate. This option was selected because preliminary discussions with Transport Canada indicated that a Navigational Clearance Envelope may not be required at Dry Creek and therefore a smaller and lower cost structure could be used. The Precast Concrete Arch was preferred over the multi-plate structure because it was thought to be more robust although other structure types can also be considered in subsequent design stages.

Refer to **Section 5** for details on the preferred option for Dry Creek.

4.3 FARRELL CREEK

Farrell Creek was subject to a design review and refinement process not a formal MAE process to select the preferred option to advance through the Definition Design stage.

4.3.1 Farrell Creek Options

A single alignment and profile option, Option 1, was considered at Farrell Creek including short and long bridge variants. The proposed alignment is generally tangential with the exception of three large radius curves of 5,000 metres, 2,000 metres and 1,000 metre radii which are well above the requirements for a 90 kilometres per hour design speed. The vertical profile consists of gently rolling vertical curves with grades under 3 percent. The exception to this is at the east project limit where a 4.3 percent grade is required to match the existing highway. This horizontal and vertical alignment for Option 1 provides a significant improvement over the existing alignment. The total length of the Option 1 alignment is 1.97 kilometres. A short bridge option with a causeway and a long bridge option with no causeway were considered. The short bridge option included a 160 metres long bridge and a 150 metres causeway. The bridge configuration consisted of 2 spans 80 metres long and one pier. The estimated total cost of the bridge structure only was [redacted] and the estimated total project cost of the short bridge variant was [redacted]. The long bridge option included a 310 metres bridge with no causeway. The bridge configuration consisted of 3 spans of 80 metres and one end span of 70 metres with three piers. The estimated total cost of the bridge structure only was [redacted] and the estimated total project cost of the long bridge variant was [redacted].

Based on costs, the long bridge variant was eliminated from further consideration. The short bridge variant with some revisions to the horizontal alignment was selected as the preferred option to advance through Definition Design.

Refer to **Section 5** for details on the preferred option at Farrell Creek.

4.4 Km 21 to Km 26.5

The Km 21 to Km 26.5 segment is in an area where the preliminary erosion and stability impact lines extend beyond the existing highway. This indicated that some form of slope protection may be required to protect the embankment from erosion and prevent a slope failure. Alternately, the highway alignment may need to be relocated outside of the erosion and stability impact lines. The landslide generated wave is not a concern within the Km 21 to Km 26.5 segment.

4.4.1 Km 21 to Km 26.5 Options

Slope Protection Plan – This option investigated the feasibility of providing slope protection by placing riprap along the embankment slopes adjacent to the proposed reservoir. The riprap was only to be placed between elevations 459.6 metres and 464.5 metres with the intent of providing erosion protection from wind induced waves. Riprap of 100 Kg Class and 1 metre thick was assumed. The total estimated project cost of the slope protection plan was [redacted]. This option only provided localized protection from wind induced waves and did not address the overall global stability of the embankment slopes. In addition the construction of this option would be difficult because of the high and steep embankment slopes which are as steep as 1.25H:1V and as high as 65 metres. For these reasons, this option was not considered feasible and it was eliminated from further consideration.

Highway 29 Realignment Option – This option investigated the feasibility of relocating the highway further inland and beyond the erosion and stability impact lines. A conceptual design was prepared assuming a 90 kilometres per hour design speed. The total length of the relocation was 6.4 kilometres and the total estimated project cost was [redacted]. The relocation option addressed the global stability concerns by relocating the highway beyond the stability impact line and is significantly less expensive and easier to construct than the slope protection option but it does have a greater impact on private properties. The realignment option was selected as the preferred option to advance through Definition Design.

Refer to **Section 5** for details on the preferred option for Km 21 to Km 26.5.

4.5 HALFWAY RIVER

The Halfway River segment, similar to Lynx Creek, underwent two levels of Options Analysis including a pre-screening MAE and a Final MAE prior to selecting a preferred alignment.

4.5.1 Pre-screening MAE Process – Halfway River

The pre-screening MAE took place over three days on July 22, 2011 (Meeting No. 1), July 28, 2011 (Meeting No. 2) and September 23, 2011 (Meeting No. 3). The purpose of Meeting No. 1 was to allow the Binnie Design Team an opportunity to present the different alignment options to the IET and BCMOT for their review and consideration. The purpose of Meeting No. 2 was to review the indicator data compiled for each alignment option and eliminate alignment options that were considered less feasible from further consideration. A third meeting, Meeting No. 3 was held to consider changes to the vertical profile and cost estimates that were suggested during Meeting No. 2.

Three alignment options were evaluated during the pre-screening MAE process. These three alignment options were enhancements of previous alignment options developed by Graeme & Murray Consultants Ltd. in 1982 and subsequently updated by Urban Systems in 2008. These previous alignment options can be found in the following reports:

- Highway 29 – Hudson Hope to Charlie Lake Environmental Impact and Engineering Study of Highway #29 Relocation Section 1, prepared by Graeme & Murray Consultants Ltd., dated January, 1982
- Peace River Site C Hydro Project Highway 29 Relocation Hudson Hope to Charlie Lake, prepared by Urban Systems, dated November 2008

These three alignment options generally followed three main corridors. An inland-corridor located away from the reservoir, a shoreline-corridor located adjacent to and in close proximity to the reservoir and a mid-corridor. A brief description of the three options is provided below. A short bridge with a causeway and a long bridge with no causeway were considered for all alignment options.

Option 1 – This is similar to the previous alignment Option C from the 2008 Urban Systems report. The total length of this option is 4.7 kilometres and can be considered a mid-corridor option. The short bridge option included a 640 metre long bridge and a 320 metre causeway. The long bridge option included of a 960 metre bridge with no causeway. The total estimated project cost of the short bridge option was [redacted] and the total estimated project cost of the long bridge option was [redacted]

Option 2 - This is similar to the previous alignment Option A from the 2008 Urban Systems report. The total length of this option is 4.5 kilometres and can be considered an inland-corridor option. The short bridge option included a 305 metre long bridge and a 1,367 metre causeway. The long bridge option included a 1,672 metre bridge with no causeway. The total estimated project cost of the short bridge option was [redacted] and the total estimated project cost of the long bridge option was [redacted]

Option 3 - This is similar to the previous alignment Option B from the 2008 Urban Systems report. The total length of this option is 3.4 kilometres and can be considered the shoreline-corridor option. The short bridge option included a 305 metre long bridge with a 695 metre causeway. The long bridge option included a 1,000 metre long bridge with no causeway. The total estimated project cost of the short bridge option was [redacted] and the total estimated project cost of the long bridge option was [redacted]

As noted, after Meeting No.2, refinements were made to the Option 2 Short Bridge profile to reduce the amount of imported fill material required for the causeway construction. The unit rates for imported fill and riprap were also modified. The initial cost estimates assumed a unit rate of [redacted] per cubic metre for riprap and [redacted] per cubic metres for imported fill material which were based on historical typical highway unit rates but were later revised to [redacted] per cubic metre and [redacted] per cubic metre respectively for the final MAE process. These lower unit rates assumed that the riprap could be produced and hauled from the West Pine Quarry and that the imported fill could be sourced from the existing gravel islands located within inundated areas adjacent each segment. **Table 4.5.1** below summarizes the effects of changes to these unit rates.

Table: 4.5.1: Halfway River costs with changes to riprap and imported fill unit rates

Option	With [redacted]/m³ for riprap and [redacted]/m³ for imported fill	With [redacted]/m³ for riprap and [redacted]/m³ for imported fill
Option 1 Short (C)	[redacted]	[redacted]
Option 1 Long (C)	[redacted]	[redacted]
Option 2 Short (A)	[redacted]	[redacted]
Option 2 Short Revised (A)	[redacted]	[redacted]
Option 2 Long (A)	[redacted]	[redacted]
Option 3 Short (B)	[redacted]	[redacted]
Option 3 Long (B)	[redacted]	[redacted]

After the MAE process, these rates were again revised to [redacted] per cubic metre for riprap and [redacted] per cubic metre for imported fill and these rates were used in the determination of the final Definition Design cost estimates for all segments. The [redacted] per cubic metre for riprap was based on the assumption that riprap could be produced and hauled from Portage Mountain instead of the West Pine Quarry which reduces the haul distance. There is a risk that this assumption is proven wrong in subsequent design stages then increased project costs could result. The imported fill unit rate of [redacted] per cubic metre was determined by estimating loading times, hauling distance and equipment rates to calculate an appropriate rate.

The three alignment options were evaluated based on a series of key accounts and indicators as described earlier in **Section 4.0**.

After the pre-screening session, Option 2 Short Bridge and Long Bridge were eliminated and Option 1 Short, Option 1 Long, Option 2 Short Revised, Option 3 Short and Option 3 Long were selected to advance to the final MAE process. The pre-screening MAE report containing all the indicator data and the meeting minutes can be found in **Volume 3**.

Minor revisions were made to all horizontal and vertical alignments between the pre-screening and final MAE sessions. A sacrificial breakwater berm was considered for all three alignment options in order to protect the bridge structure against impacts from a landslide generated wave. The sacrificial berm was conceptual only and based on a previous study titled "**Peace River Site C Project Model of Landslide Waves at Attachie and Bear Flat Areas**", prepared by Northwest Hydraulic Consultants Ltd. and dated June, 1983.

4.5.2 Final MAE Process – Halfway River

The final MAE process for Halfway River took place on October 28th, 2011 (Meeting No. 4). At the meeting the Binnie Design Team provided an overview of the five remaining options. An updated list of indicators was provided at the meeting for review and discussion. The strategy used to select the preferred alignment was to look at the lowest cost option first and determine if there were any significant concerns with any of the accounts. If no significant concerns were identified by the Project Team, or the impacts were comparable, then the low cost option was considered the preferred option.

The estimated total project costs for the five options evaluated during the Final MAE session, including the berm costs, were as follows:

- Option 1 Short [redacted]
- Option 1 Long – [redacted]
- Option 2 Short Revised – [redacted]
- Option 3 Short – [redacted]
- Option 3 Long – [redacted]

Based on these estimates, all the long bridge options were eliminated from further consideration because they were substantially higher in cost than the short bridge options.

Option 1 Short Bridge was the highest cost option of all of the short bridge options. This option had the longest bridge at 640 metre long which resulted in the much higher costs. The causeway length for this option was 320 metres. The entire length of the Option 1 alignment is within the 10,000 year Wave Impact Line (WIL) however the east end of the alignment is near the outer limits of the WIL which will reduce the risk to the highway from a landslide generated wave.

Option 2 Short Bridge is the second highest cost option costing [redacted] less than the Option 1 Short Bridge. It is the furthest inland and offers the greatest protection from a landslide generated wave. This option, along with Option 3 had the shortest bridge at 305 metres but a causeway that was 1,367 metre long. The length of the causeway required large quantities of imported fill which resulted in the high costs associated with this option. Similar to Option 1, the entire length of the Option 2 alignment is within the 10,000 year Landslide Generated Wave however the east end of the alignment is near the outer limits of the WIL which would limit the risk to the highway from a landslide generated wave.

Option 3 Short Bridge is the lowest cost of all the three short bridge options coming in approximately [redacted] less than Options 1 and 2. This option, like Option 2 has the shortest bridge at 305 metres long but its causeway is 695 metres long. The short bridge and the relatively short causeway resulted in the lower costs associated with this option. The entire alignment for this Option is within the 10,000 year Wave Impact Line however unlike Option 1 and Option 2, the east end of the alignment is near the proposed reservoir shoreline and may be exposed to higher risks in the event of a landslide generated wave event. This option is preferable from a properties perspective because it has the least impacts and least amount of agricultural severances.

Option 3 short bridge was selected as the preferred alignment option to proceed with through Definition Design even though it was at the greatest risk from a landslide generated wave. BC Hydro and BCMOT have not reached agreement on whether the highway and bridge will be designed to accommodate potential 1,000 year and 10,000 year return periods however, with BCMOTs agreement, Definition Design has been concluded by proposing highway and causeway grades so that the 1,000 year return period landslide generated wave does not overtop the highway embankment, raising the bridge so that the 10,000 year return period wave amplitude passes under the proposed bridge, and by proposing a bridge that can withstand the forces induced by the 10,000 year return period landslide generated wave

As previously noted the capital costs used during the MAE process were intended for comparison purposes only and should not be considered absolute or final.

Refer to **Section 5** for details on the preferred option for Halfway River.

4.6 BEAR FLAT / CACHE CREEK

The Bear Flat / Cache Creek segment was subjected to an MAE process to select an alignment and then to a design review, refinement and optimization process prior to selecting a preferred alignment.

4.6.1 Final MAE Process – Bear Flat / Cache Creek

Two alignment options (Options D and E) were evaluated during the MAE process. These were enhancements of previous alignment options developed by Graeme & Murray Consultants Ltd. in 1982 and subsequently updated by Urban Systems in 2008. These previous alignment options can be found in the following reports:

- Highway 29 – Hudson Hope to Charlie Lake Environmental Impact and Engineering Study of Highway #29 Relocation Section 1, prepared by Graeme & Murray Consultants Ltd., dated January, 1982
- Peace River Site C Hydro Project Highway 29 Relocation Hudson Hope to Charlie Lake, prepared by Urban Systems, dated November 2008

The final MAE process for Cache Creek took place on October 28th, 2011 (Meeting No. 4). At the meeting the Binnie Design Team provided an overview of the two alignment options. An updated list of indicators was provided at the meeting for review and discussion. The strategy used to select the preferred alignment was to look at the lowest cost option first and determine if there were any significant concerns with any of the accounts. If no significant concerns were identified by the Project Team, or the impacts were comparable, then the low cost option was considered the preferred option.

A short bridge with a causeway and a long bridge with no causeway were considered for both alignment options.

Option D - The Option D alignment is similar to the previous alignment Option D-D1 from the 2008 Urban Systems report. The alignment is located at the base of an existing escarpment which poses significant geotechnical concerns. The total estimated project cost estimate for the Option D alignment option was [redacted] for the short bridge option and [redacted] for the long bridge option. These are both significantly higher than the Option E cost estimates and because of this and the increased geotechnical challenges associated with this option, both the short and long bridge Option D alignments were eliminated from further consideration.

Option E - The Option E alignment is similar to the previous alignment Option E from the 2008 Urban Systems report. This option follows the proposed reservoir shoreline and is in an area with fewer geotechnical challenges. The total estimated project cost estimate for the Option E alignment was [redacted] for the short bridge option and [redacted] for the long bridge option. Due to the higher cost and the increased maintenance and icing concerns associated with a longer bridge, the long bridge option was eliminated from further consideration and the Option E short bridge option was selected for further refinement.

4.6.2 Post MAE Refinement Process – Bear Flat / Cache Creek

A collaborative effort between the BC Hydro Site C IET and the Binnie design team resulted in the development of four new alignment options which were all refinements to the preferred Option E alignment. These alignment options are called Option B, Option F, Option B Modified and Option F Modified. The horizontal alignment was adjusted for all the four options to avoid impacts to a property containing a gravel pit. Cost and property impacts, particularly east of Cache Creek were the determining factors in the selection of the preferred alignment. A brief description of the four alignment options is provided below and drawings of the options can be found in **Volume 3**.

Option B - The Option B alignment deviates from the Option E alignment at the Cache Creek crossing impacting the residential property immediately east of crossing. This option requires high embankments approaching the east tie in. The total estimated project cost for the Option B alignment was [redacted] for the short bridge option and [redacted] for the long bridge option.

Option B Modified - The Option B Modified alignment is similar to Option B but deviates from it east of Cache Creek by tying back into the Option E alignment which reduces the embankment height approaching the east tie in. The total estimated project cost for the Option B Modified alignment was [redacted] for the short bridge option. A long bridge option was not considered for Option B Modified.

Option F - The Option F alignment deviates from the Option E alignment at the Cache Creek crossing and passes behind the residential property immediately east of Cache Creek. This option utilizes an existing road allowance and requires high embankments at the east tie in. The total estimated project cost for the

Option F alignment was [redacted] for the short bridge option and [redacted] for the long bridge option.

Option F Modified - The Option F Modified alignment is similar to Option F but deviates from it east of Cache Creek by tying back into the Option E alignment rather than using the existing road allowance. This results in reduced embankment heights approaching the east tie in. The total estimated project cost for the Option F Modified alignment was [redacted] for the short bridge option. A long bridge option was not considered for Option F Modified.

Due to the lowest cost, Option F Modified was selected as the preferred alignment to advance through the Definition Design phase.

Refer to **Section 5** for details on the preferred option for Bear Flat / Cache Creek.

5.0 PREFERRED OPTIONS

5.1 LYNX CREEK

The preferred option at Lynx Creek is Option 5 Modified - Short Bridge which is one of the Millar Road options and is shown in **Figure 5.1.1**. The total length of this Option is 8.22 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.1.1 Scope

The horizontal and vertical alignment for the Preferred Option 5 Modified – Short Bridge complies with the Design Criteria and has a 90 kilometres per hour design speed. It also utilizes approximately 1.2 kilometres of the existing Millar Road right of way although further refinements may be done in subsequent design stages to utilize more of the existing Millar Road corridor.

The horizontal alignment begins at the west project limit with a short tangent section that is followed by a 1,000 metre radius left hand curve and is followed 635 metre radius right hand curve. An 830 metre radius left hand curve is followed by a tangent section across the proposed new bridge crossing. Immediately east of the bridge a 425 metre radius right hand curve is followed closely by a 425 metre radius left hand curve. These two reverse curves are the lowest radius curves along the alignment but are still above the minimum radius of 340 metres that is required for a 90 kilometres per hour design. The reverse curves minimize the impacts to the private property located northeast of the proposed bridge. Just beyond these curves the alignment becomes tangential and follows the existing Millar Road alignment for approximately 1.2 kilometres. A 600 metre radius right hand curve is followed by a short tangent and then a 4,500 metre radius left hand curve. This large 4,500 metre curve shifts the alignment south avoiding impacts to the existing farm field north of the alignment. Reversing 550 metre radius curves are followed by a 1,700 metre radius right hand curve at the eastern project limit.

The vertical profile is generally flat with grades between 0.5 percent and 1.1 percent throughout the segment except at the project limits and the west approach to the bridge. At the west project limit the profile matches the existing highway with a grade of 3.6 percent. At the east end of the project the profile climbs at 4.0 percent and matches the existing highway with a 2.5 percent grade. At the west approach to the bridge the grade is 5.6 percent. Concrete roadside barrier will be placed on the causeway and in areas of high fill.

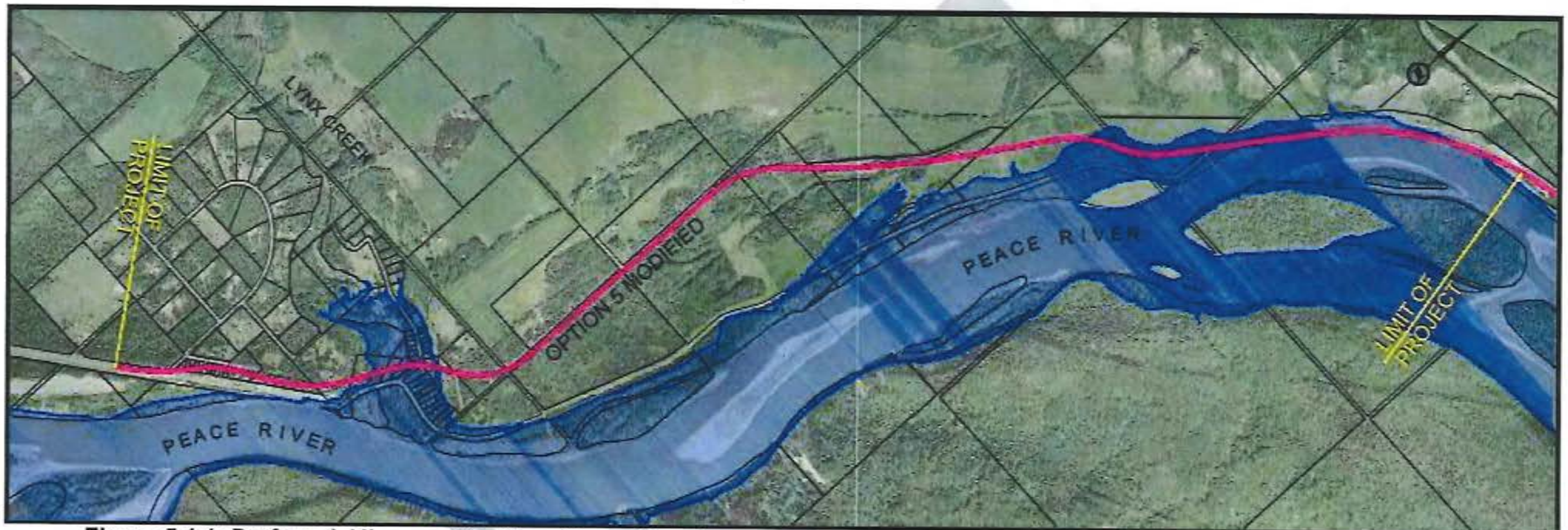


Figure 5.1.1: Preferred Alignment Option at Lynx Creek

For the last 2.5 kilometres between Station 1005+000 and 1007+540, the alignment traverses an area of unstable ground. The existing highway embankment slopes adjacent to the Peace River show signs of instability and have failed in the past. The slopes above the existing highway also show signs of instability and failures. This unstable area cannot be avoided and measures will be incorporated into the design to reduce the risk of failures. Construction of the highway through this section will be challenging and a detailed geotechnical investigation will be required to determine the optimized design alignment. For the purpose of the Definition Design and to provide a conservative footprint, the alignment through this section has been shifted away from the unstable valley slope and is located entirely within the reservoir. A granular embankment fill with riprap protection of the slope has been assumed. When further geotechnical information becomes available it may be possible to shift the alignment closer to the existing valley slope to minimize the footprint and reduce encroachment into the reservoir. The minimum highway elevation through this section has been set at 468 metre which is 2 metres above the flood impact level and will ensure that the highway pavement structure remains dry. During subsequent design stages, there may be opportunities to optimize the alignment through this challenging eastern section. A Preliminary Geotechnical Assessment report for the Proposed Lynx Creek segment report is included in **Volume 3** of the report and provides additional details.

The cut slopes have been designed at 3H:1V however the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable subject to more detailed investigation. Similarly, all the fill slopes have been designed at 2H:1V however the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable depending on the material used to construct them.

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm Well Graded Base Course (WGB) and 600 millimetres of Select Granular Sub-base (SGSB) but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

The proposed crossing of the Lynx Creek channel includes a 160 metre bridge and a 290 metre causeway. A Navigable Water Clearance envelope in excess of 8 metre high by 25 metre wide has been provided under the structure. The landslide generated wave amplitude, assuming a 10,000 year return period landslide is estimated to be 3 metres at Lynx Creek based on the most current wave modelling results from BGC provided in January 2012.

Preliminary wave modelling results indicated landslide generated wave amplitudes to be 9 metres and 14 metres for the 1,000 year and 10,000 year return period landslide generated wave respectively at Lynx Creek. The Definition Design bridge elevations were established to allow the 9 metre wave amplitudes to pass under the structure assuming a 3.3 metres superstructure depth. The most current modelling results, at the time of writing, indicated significantly lower wave amplitudes than previously anticipated, and there will be opportunity to lower the elevation of the bridge during subsequent design stages which will reduce impacts and costs. The Navigable Water Clearance Envelope will now govern the bridge elevation at Lynx Creek.

The causeway has been designed assuming 2H:1V granular embankment slopes. The causeway slopes would be armoured with riprap between the elevations of 459.0 metres and 464.0 metres to protect against wind induced wave action. Riprap will also be required at the east end of the proposed alignment where the new embankment slopes are within the proposed reservoir. The bridge abutments will also be protected with riprap. Details of the riprap design can be found in the Final Hydraulics Report for Definition Design contained in **Volume 3**.

Potential new intersections, field accesses and driveway accesses have been shown along the preferred alignment. These are conceptual only and subject to change based on consultation with affected property owners.

The culverts shown on the Definition Design drawings are conceptual only and not based on a detailed drainage study. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BCMOT Supplement to TAC Geometric Design Guide.

The location of utility poles and an underground telephone line within this segment of Highway 29 will need to be confirmed during subsequent design stages. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawings can be found in **Volume 2**. The properties that are impacted by this proposed alignment include Private Land, Crown

Land, BC Hydro Owned and BC Hydro Owned lands that are currently leased to local residents (BC Hydro Leased). There also appears to be some existing road / utility allowances that will be impacted. **Table 5.1.1** below summarizes the amount of new right of way required based on the Option 5 Modified – Short Bridge preferred alignment. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.1.1: New right of way required at Lynx Creek

Description	New Right of Way Required
Existing Road / Utility Allowance	3.5 ha
Private Land	15.9 ha
BCH Owned	2.2 ha
BCH Leased	13.4 ha
Crown Land	2.3 ha
Total	**37.3 ha**

5.1.2 Geotechnical

As previously mentioned the proposed Lynx Creek highway relocation segment can be generally divided into two distinct sections.

From the western extent of the proposed relocation extending approximately 6.5 kilometres towards the east (from Station 999+540 to 1006+000) cuts and fills should be designed with maximum slopes of 2H:1V, although there may be an opportunity to steepen cuts to 1.5H:1V in granular soils, or alternately, flatten them for additional borrow opportunity. The foundation conditions for the bridge and the causeway fill at Lynx Creek itself are anticipated to be favourable, as the ground conditions appear to consist primarily of granular floodplain soils over shale and possibly sandstone bedrock. Such ground conditions would provide good bearing resistance and likely minimal settlement issues, although a geotechnical investigation will be required to better assess the foundation conditions and to confirm the absence of any soft or weak subsurface layers. Foundations for a bridge are expected to encounter granular floodplain soils over sedimentary bedrock (shale, siltstone and minor sandstone) and rock-socketed piles are likely a suitable foundation option. The causeway embankment is unavoidably within the reservoir footprint and will require erosion protection, as will some of the steep natural slopes of the Lynx Creek valley and north bank of the Peace River that are in close proximity to the bridge abutment and causeway approaches.

From Station 1006+000 to 1007+774, the proposed highway alignment option is required to traverse a tightly constricted slope area, where the Peace River impinges directly on the lower portion of the north Peace River valley sidewall slope. This is a geologically active area, where a number of pre-existing slope failures are located both above and below the current alignment of Highway 29 and construction will be more challenging. A very robust solution is envisioned for this area – likely incorporating extensive replacement or berming of existing poor quality (failing) fills, widening/constructing a new armoured granular highway fill partly or entirely within the reservoir, and/or possibly some local structural solutions (retaining structures) while minimizing cut slopes. The preferred alignment contemplates a large armoured granular highway fill being constructed in the Peace River adjacent to the existing Highway 29 alignment. Significant additional geotechnical investigation and stability modeling will be required in future project phases to develop the optimal alignment solution through this tightly constricted area.

A Preliminary Geotechnical Assessment report for the Proposed Lynx Creek segment report is included in **Volume 3** of the report and provides additional details.

5.1.3 Constructability

The Lynx Creek alignment is primarily off-line and away from the existing Highway 29 alignment which should allow for easy construction. The exception to this is at the project limits and along Millar Road where single lane alternating traffic with delays will be required during construction.

One challenging area will be near Station 1005+840 where the proposed alignment crosses the existing highway at an elevation approximately 15 metres higher than existing. In this area, a detour alignment of approximately 500 metres in length may be required. The detour begins at Station 1005+500 on the proposed new alignment and continues east for 500 metres before tying back to the existing highway alignment near Station 1006+000. A 70 kilometres per hour design speed and an 8.0 metre top pavement width has been assumed for this detour road. A temporary licence for construction access (TLCA) has been shown for this detour road and has been included as part of the right of way Definition Design drawings. The detour design alignment and profile drawings have been included with the Definition Design highway drawings. Both of these drawing packages can be found in **Volume 2**.

Construction of the proposed bridge will not require a detour or the construction of a temporary bridge as it is located away from the existing highway. The proposed central pier is located outside the wetted perimeter of the creek and all pile installations and substructure construction can be carried out without the use of a cofferdam or temporary berm.

Temporary gravel construction access roads will be required to access the abutments and central pier. To access the west abutment and pier, a temporary construction access road can be provide approximately 100 metres west of the existing Lynx Creek Bridge. Access to the east abutment will be from the existing Highway 29 and Backman Road intersection. Drawings of the proposed construction access roads are included with the Definition Design highway drawings in **Volume 2**.

5.1.4 Material Sources

It is estimated that approximately 3.5 million cubic metres of imported fill and 45,000 cubic metres of riprap will be required for the Lynx Creek Segment.

Within the Lynx Creek Segment relatively favourable granular borrow opportunities will likely be available along the fluvial terraces, including areas that will be inundated by the reservoir. For Definition Design purposes, it is assumed that areas of the fluvial terraces, fluvial plains, and in-stream gravel bars that are located below the reservoir's FSL, as shown in **Figure 5.1.2**, would be considered a potential and first priority gravel source, leaving those areas above FSL for later use by others.

Harder Associates (2010) outlined two potential borrow sources: one below the FSL and east of Lynx Creek and the BCMOTs Rieske Pit located above the FSL west of Lynx Creek (discussed below in more detail after AMEC, May 2005). The first source potentially contains a horizon, between 5 and 20 metres thick, of sandy, cobbly gravels. Limited subsurface investigation and laboratory testing has been completed to date but they indicated that the aggregate quality was poor and contained too many fines and sand. Further investigation should be considered prior to eliminating this as a borrow source. The second source, BCMOTs Rieske Pit is located between the highway and the Peace River, to the west of Lynx Creek. Although it has been assumed that deposits below the reservoir's FSL would be considered for use as a first priority rather than Rieske Pit, the character of the deposit in the Rieske Pit may be typical of others in the vicinity. The Rieske Pit reserve is approximately 50 hectares in area and has previously been used for borrow and highway construction. A BCMOT gravel pit investigation found that much of the material in the pit could be crushed into SGSB, 25-mm WGB and medium asphalt mix aggregates. Further investigation would be required to determine remaining aggregate volumes and quality.

In addition to the above noted areas, granular borrow may be found along the majority of the proposed option alignments across the fluvial terrace terrain areas, particularly in cut slopes to the west of Lynx Creek. A detailed sub-surface investigation, including sampling and lab testing should be carried out for granular cut areas along the alignment and for granular areas adjacent to the alignment, but below the reservoir FSL in future design phases.

There were no suitable riprap sources within or in close proximity to Lynx Creek. Portage Mountain is a potential source of riprap but further geotechnical investigations, drilling and material testing will be required to confirm the suitability of the site.

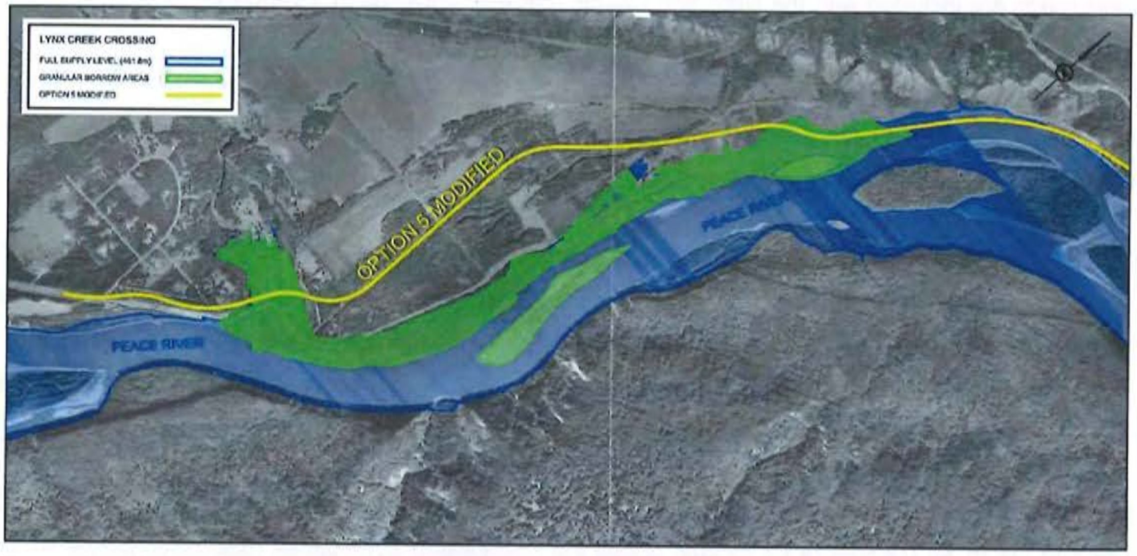


Figure 5.1.2: Potential Granular Borrow Sources at Lynx Creek

5.1.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. Within Lynx Creek, two potential wetland sites have been identified. These sites are described in the document "**Meeting Minutes – Opening discussions between engineering and environmental groups on wetland opportunities at the proposed reservoir**" dated October 12, 2011. This document can be found in **Volume 3** of this report.

5.1.6 Recreation Sites

The potential for a recreation site and possible boat launch at Lynx Creek is being explored. The proposed location for the recreation site is south of the proposed new alignment and east of Lynx Creek near Station 1001+670. The proximity to Hudson's Hope makes this a desirable location. Further information on potential recreation sites along the corridor is included in **Volume 3** of this report in the document titled "**Recreational Access Mitigation Concepts Review**" dated October 6, 2011.

5.1.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

Travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing conditions and the assumption that vehicles slow down at the sharper horizontal curves. An average speed was estimated along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometres per hour throughout the segment because all the curves meet the 90 kilometre per hour design speed. Based on this approach 45 seconds of travel time savings has been estimated at Lynx Creek.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Lynx Creek the passing opportunities remained the same at 2,300 metres in both the eastbound and westbound directions.

The travel time savings and increase in passing opportunities between the existing alignment and the preferred alignment are approximate only and based on a desktop exercise.

5.1.8 Schedule

Due to the long winters experienced in the north, the construction season has been assumed to be 7 months from April to October. It is anticipated that the Lynx Creek Option can be completed within two to three construction seasons, with rough grading and bridge approach fills completed in the first year. The bridge construction can begin once access to the bridge sites and lay down areas have been secured. Bridge construction may be completed in one year if work is permitted in winter months otherwise two seasons may be required to complete the bridge construction.

Some of the critical items that will enable successful completion of the project include:

- Securing the required right of way prior to the construction start;
- Providing access at mid-points along the alignment to minimize haul routes;

- Ensuring a suitable source of riprap is available near the project site or that alternate products can be used;
- Confirmation of aggregate quality and quantity

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Lynx Creek segment is far enough away from the proposed dam site that impacts to the segment would not occur during Stage 1 and Stage 2 construction. The construction of the Lynx Creek segment would need to be completed prior to the completion of the proposed dam but not prior to Stage 1 or Stage 2.

5.1.9 Cost Estimate

The total estimated construction cost for the preferred Option 5 Modified – Short Bridge at Lynx Creek is [redacted] with a total estimated project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Lynx Creek due to advancement of the design and refinements to some of the unit rates. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize over time or may be due to an overall increase in activity in the area caused by the dam construction. **Table 5.1.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.1.2: Summary of Estimated Construction Costs at Lynx Creek

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - STRUCTURAL	[redacted]	
SECTION 5 – CONSTRUCTION DETOUR AND CONSTRUCTION ACCESS ROAD	[redacted]	
SECTION 6 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 7 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 8 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 9 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.1.10 Risks

Some potential risks include the following:

- Increased Navigational Water Envelope requirement that may alter design;
- Changes to the Impact Lines that may alter the design alignment and bridge concepts;
- Changes to the design due to the Public Consultation Process;
- Unknown geotechnical conditions at the east end of Lynx Creek;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the construction start;
- Lack of quality riprap and aggregate sources.

5.2 DRY CREEK

The preferred option at Dry Creek is called Option 7 and is shown in yellow in **Figure 5.2.1** and includes an 8.2 metre span by 4.1 metre rise Precast Concrete Arch culvert. The total length of the Dry Creek segment is 1.4 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.2.1 Scope

Several alignment options were considered prior to selecting a preferred option. The preferred alignment is further south than previous alignment options to minimize the effects on the farm fields east and west of Dry Creek. The horizontal alignment for the preferred Option 7 begins at the west project limit with a 550 metre radius right hand curve followed by a 485 metre radius left hand curve. East of the proposed culvert location, the alignment consists of a large 1,400 metre radius right hand curve followed by a 5,000 metre radius left hand curve that ties back to the existing highway alignment. The vertical profile for the preferred option consists of a short 3.2 percent downhill grade near the western project limit that is reduced to the minimum 0.5 percent grade approaching Dry Creek. From Dry Creek to the east project limits, the grades are all below 2 percent. Crest and sag vertical curves have been provided between changes in grade. The horizontal and vertical alignments achieve a 90 kilometres per hour design speed and are a significant improvement over the current conditions.

Concrete roadside barrier will be placed on both sides of the highway and the proposed embankment slopes are 2H:1V throughout the segment.

The cut slopes have been designed at 3H:1V even though the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable subject to a detailed geotechnical investigation. Similarly, all the fill slopes have been designed at 2H:1V even though the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable subject to the materials used for construction.

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm-WGB and 600 millimetres of SGSB but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

The proposed structure is a precast concrete arch with a span of 8.2 metres and a rise of 4.1 metres and it is located approximately 5 metres west of the existing culvert. The concrete arch structure is founded on piles with concrete headwalls and aprons provided at the inlet and outlet of the culvert. Riprap of 250 Kg Class will be placed at the inlet and outlet of the structure. The riprap will be placed between the elevations of 459.0 metres and 463.0 metres. The total length of the precast concrete arch is 113 metres and the grade is 0.9 percent. Refer to the Bridge Definition Design Report for details on the structure and to the Final Hydraulics Report for Definition Design for details on the riprap requirements. Both of these reports can be found in **Volume 3**.

The precast concrete arch has been sized to accommodate the 200 year instantaneous flow which is estimated to be 44.3 cubic metres per second. The inlet invert of the culvert has been set at an elevation of 461.3 metres and the 200 year water elevation at the inlet is estimated at 463.8 metres which allows a 1.6 metre freeboard at the inlet. The outlet invert of the culvert has been set at an elevation of 460.3 metres and the 200 year water elevation at the outlet is estimated to be at the same elevation as the normal reservoir operating level of 461.8 metres which allows a 2.6 metre freeboard at the outlet. The freeboard provided will allow debris to pass through the culvert during peak flow events.

Two gravels driveways will be impacted with this preferred option. One of the driveways is located west of Dry Creek near Station 5000+400 and accesses a private property to the north. The other impacted driveway is located just east of Dry Creek at Station 5001+100 and also accesses a private property to the north. The proposed new driveways are shown on the Definition Design drawings and are conceptual only and subject to change based on consultation with affected property owners.

The culverts shown on the Definition Design drawings are conceptual only and not based on any detailed drainage study. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BC Supplement to TAC Geometric Design Guide.

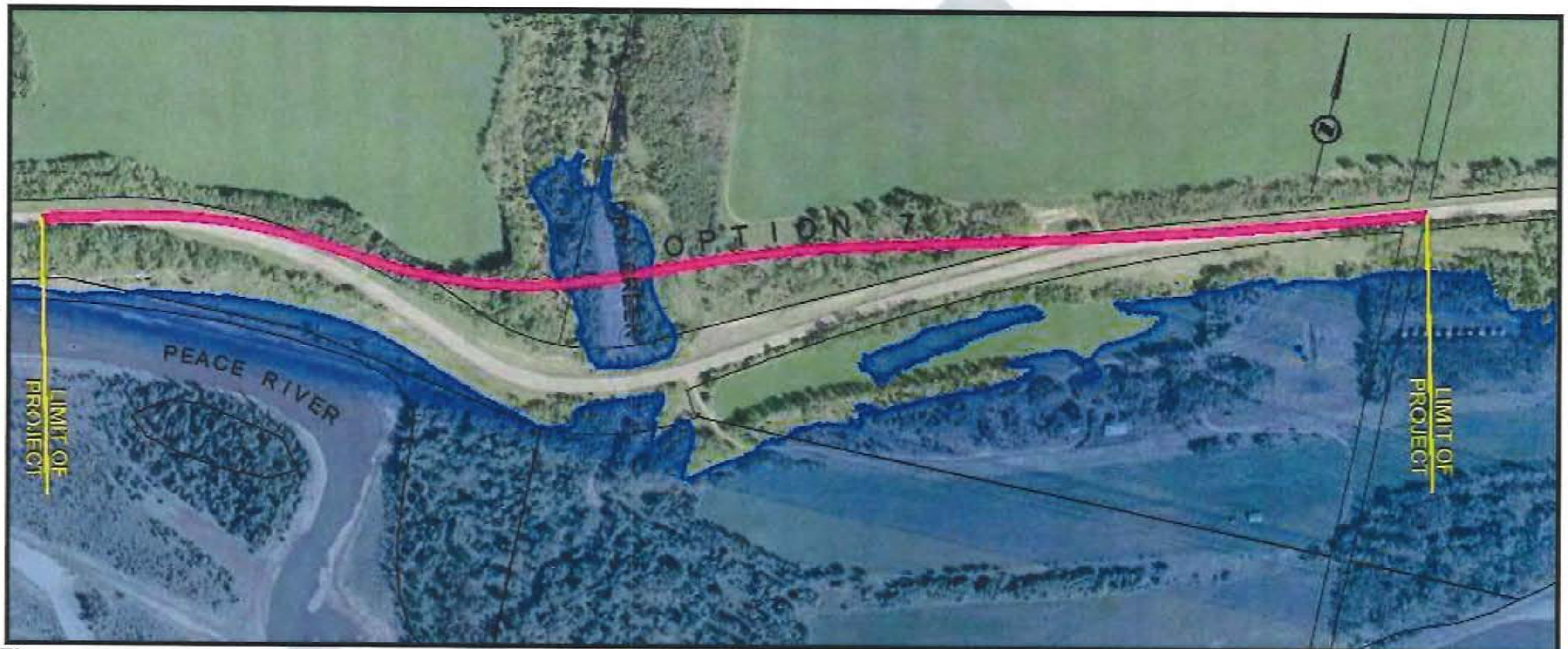


Figure 5.2.1: Preferred Alignment Option at Dry Creek

There are utility poles located adjacent to the existing highway through this section. While these poles could remain at their current location because they are located beyond the inundation area, it is anticipated that they will likely be moved adjacent to the new alignment. This will allow easier access for maintenance work and will also allow the existing highway to be decommissioned and restored to a natural condition. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawing can be found in **Volume 2**. The properties that are impacted by this proposed alignment include Private Land only. **Table 5.2.1** below summarizes the amount of new right of way required based on the preferred alignment option. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.2.1: New right of way required at Dry Creek

Description	New Right of Way Required
Private Land	4.9 ha
Total	**4.9 ha**

5.2.2 Geotechnical

In the absence of subsurface investigations, new crossing alternatives should be designed with consideration of either pile foundations or a relatively deep sub excavation and replacement of unsuitable foundation materials beneath the Dry Creek channel and the existing highway embankment. Cut slope approaches on the north side of the existing alignment will likely be in relatively dry, stable materials consisting of shale bedrock overlain by sand and gravel with a silty topsoil cap. These materials could be excavated at angles as steep as 1.5H:1V.

5.2.3 Constructability

The Dry Creek alignment is primarily off-line and away from the existing Highway 29 which should allow for easy construction. The exception to this is at the project limits where single lane alternating traffic will likely be required to complete the construction.

The proposed new culvert is located west of the existing Dry Creek channel. A temporary berm and dewatering may be required during the construction of the new culvert so that it can be constructed in the dry. Once the culvert installation is complete, flow from the creek can be diverted to the new culvert and backfilling can begin. Flow from the outlet of the new culvert will need to be diverted to the inlet of the existing culvert until the highway construction is complete. Traffic can then be diverted onto the new alignment.

A temporary gravel construction access road will be required to access the new culvert location. The construction access road is proposed to be located adjacent to the existing side slope east of the channel. A temporary culvert will be required to cross the existing creek channel. Drawings of the proposed construction access roads are included with the Definition Design highway drawings in **Volume 2.**

5.2.4 Material Sources

It is estimated that approximately 175,000 cubic metres of imported fill and 5,000 cubic metres of riprap will be required for the Dry Creek Segment.

Within the Dry Creek Segment relatively favourable granular borrow opportunities will likely be available along the fluvial terraces, including areas that will be inundated by the reservoir. For Definition Design purposes, it is assumed that areas of the fluvial terraces, fluvial plains, and in-stream gravel bars that are located below the reservoir's FSL, as shown in **Figure 5.2.2**, would be considered a potential and first priority gravel source, leaving those areas above FSL for later use by others.

There were no suitable riprap sources within or in close proximity to Dry Creek. Portage Mountain is a potential source of riprap but further geotechnical investigations, drilling and material testing will be required to confirm the suitability of the site.

Since this segment is relatively short, the production of paving aggregate and crushed base material will likely come from a pit established for the Lynx Creek or Km 21 to Km 26.5 segment.

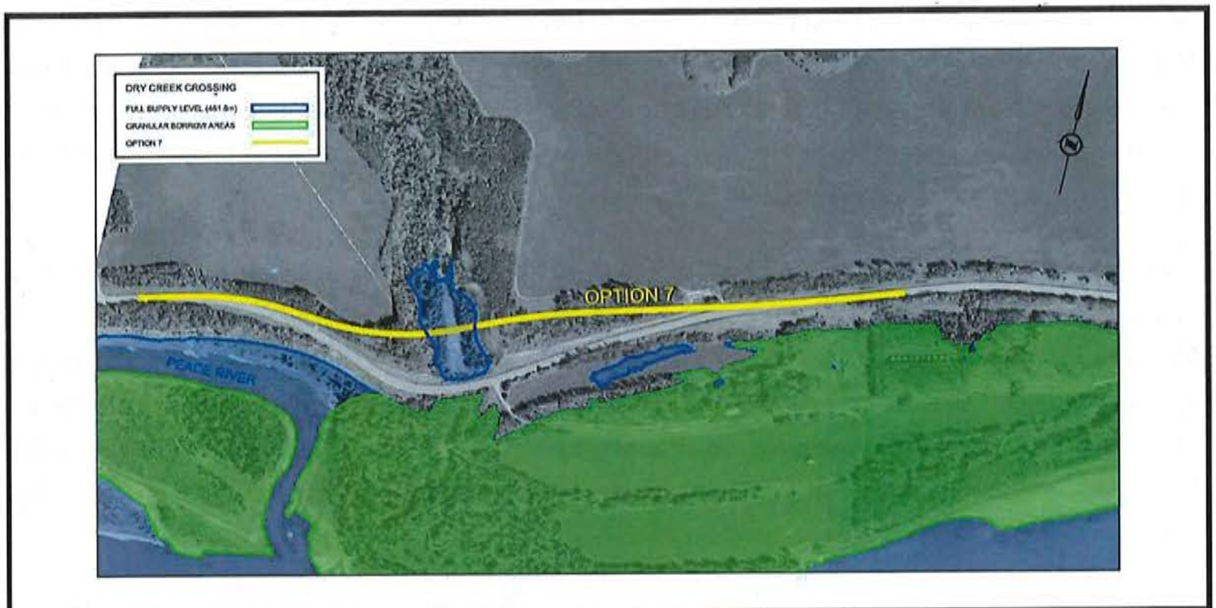


Figure 5.2.2: Potential Granular Borrow Sources at Dry Creek

5.2.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. The north side of the highway at Dry Creek has been identified as a potential wetland site. This site is identified and described in the document "**Meeting Minutes – Opening discussions between engineering and environmental groups on wetland opportunities at the proposed reservoir**" dated October 12, 2011. This document can be found in Volume 3 of this report.

5.2.6 Recreation Sites

No recreation sites are currently being considered within the Dry Creek Segment.

5.2.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

The travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing curve radii and assumed vehicles would need to slow down at the sharper horizontal curves. An average speed was then determined along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometre per hour throughout the segment because all the curves meet the 90 kilometre per hour design speed. Based on this approach 4 seconds of travel time savings has been estimated at Dry Creek.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Dry Creek the passing opportunities increased from 0 metres to 500 metres in both the eastbound and westbound directions.

The travel time savings and increase in passing opportunities are approximate only and based on a desktop exercise.

5.2.8 Schedule

The construction season has been assumed to be 7 months from April to October. It is anticipated that the Dry Creek Option can be completed in one construction season.

Some of the critical items that will enable successful completion of the project include:

- Securing the required right of way prior to the construction start;
- Ensuring a suitable source of riprap is available near the project site or that alternate products can be used;
- Confirmation of aggregate quality and quantity.

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Dry Creek segment is far enough away from the proposed dam site that impacts to the segment would not occur during Stage 1 and Stage 2 construction. The construction of the Dry Creek segment would need to be completed prior to the completion of the proposed dam but not prior to Stage 1 or Stage 2.

5.2.9 Cost Estimate

The total construction cost for the preferred option at Dry Creek is estimated to be [redacted] with a total project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Dry Creek due to advancement of the design, changes to the culvert type and size and refinements to some of the unit rates. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize due to an overall increase in activity in the area caused by the dam construction. **Table 5.2.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.2.2: Summary of Estimated Construction Costs at Dry Creek

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - STRUCTURAL	[redacted]	
SECTION 5 – CONSTRUCTION ACCESS ROAD	[redacted]	
SECTION 6 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 7 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 8 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 9 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.2.10 Risks

Some potential risks include the following:

- A requirement to provide a Navigational Water Envelope which would alter the design;
- Changes to the Impact Lines that may alter the design alignment;
- Changes to the design due to the Public Consultation Process;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the construction start.

5.3 Farrell Creek

The preferred option at Farrell Creek is Option 2 - Short Bridge and is shown in **Figure 5.3.1**. The total length of the preferred alignment is 2.12 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.3.1 Scope

The preferred alignment was shifted south from the previous alignment options to stay outside of the existing wetted perimeter of the creek. The horizontal alignment for the preferred option is generally tangential consisting of a large 8,000 metre radius right hand curve on the west side of the bridge and 3,600 metre radius left hand curve east of the bridge. The proposed bridge crossing is tangent.

The vertical profile consists of a short 3.2 percent grade at the west end of the segment and a 4.3 percent grade at the eastern project limit that matches existing grade. All other vertical grades within the segment are under 1.5 percent.

Concrete roadside barrier will be placed on the causeway and in areas of high fill.

The cut slopes have been designed at 3H:1V even though the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable subject to a detailed geotechnical investigation. Similarly, all the fill slopes have been designed at 2H:1V even though the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable subject to a detailed geotechnical investigation.

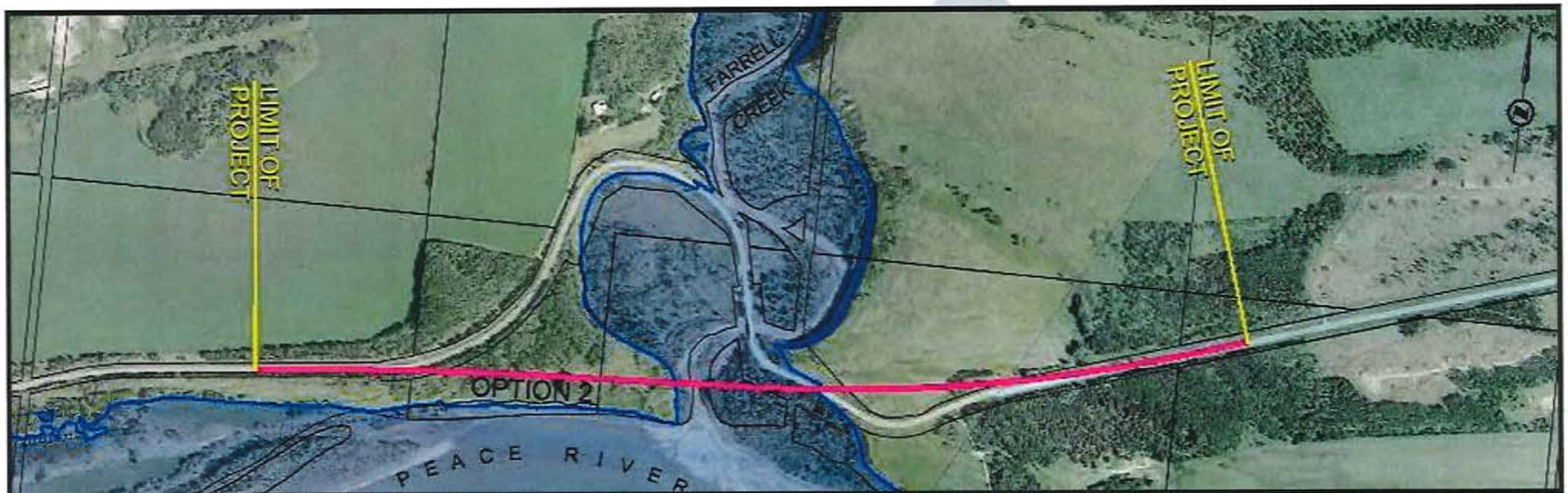


Figure 5.3.1: Preferred Alignment Option at Farrell Creek

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm-WGB Course and 600 millimetres of SGSB but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

The proposed crossing of the Farrell Creek channel includes a 170 metre long bridge and a 150 metre causeway. A Navigable Water Clearance envelope in excess of 8 metres high by 25 metres wide has been provided under the structure. The landslide generated wave amplitude, assuming a 10,000 year return period landslide is estimated at 3 metres at Farrell Creek based on the most current wave modelling results from BGC provided in January 2012.

Preliminary wave modelling results indicated landslide generated wave amplitudes to be 9 metres and 14 metres for the 1,000 year and 10,000 year return period landslide generated wave respectively at Farrell Creek. The Definition Design bridge elevations were established to allow the 9 metre wave amplitude to pass under the structure assuming a 3.3 metres superstructure depth. The most current modelling results, at the time of writing, indicated significantly lower wave amplitudes than previously anticipated, and there will be opportunity to lower the elevation of the bridge during subsequent design stages which will reduce impacts and costs. The Navigable Water Clearance Envelope will now govern the bridge elevation at Farrell Creek.

The causeway has been designed assuming 2H:1V granular embankment slopes. The causeway slopes are armoured with riprap between the elevations of 459.0 metres and 464.0 metres to protect against wind induced wave action. The bridge abutments will also be protected with riprap. For details on the riprap design refer to the Final Hydraulics Report for Definition Design found in **Volume 3**.

Potential new intersections and driveway accesses have been shown along the alignment. These are conceptual only and subject to change based on consultation with affected property owners. A low volume road has been shown at Station 2000+420 that provides access to private properties northwest of Farrell Creek. This low volume access road is approximately 300 metres long and is located within the existing Highway 29 corridor. A 15 metre radius cul-de-sac is provided at the end of the access road to provide a turn-around facility for maintenance vehicles as it is anticipated that this will be a public road.

The culverts shown on the Definition Design drawings are conceptual only and not based on any detailed drainage study. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BC Supplement to TAC Geometric Design Guide.

Utility poles are located within this section and will need to be identified for relocation during subsequent design stages. There is also an overhead crossing of the proposed highway near Station 2000+250 whose location will need to be confirmed. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawing can be found in **Volume 2**. The properties that are impacted by this proposed alignment include Private Land and BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased). There also appears to be some existing road / utility allowances that will be impacted. The existing ownership of the Farrell Creek channel is undetermined but a property taking has been identified in the Definition Design. **Table 5.3.1** below summarizes the amount of new right of way required based on the preferred alignment option. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.3.1: New right of way required at Farrell Creek

Description	New RoW Area Required
Existing Road / Utility Allowance	0.1 ha
Existing Watercourse	0.5 ha
Private Land	3.3 ha
BCH Leased	2.8 ha
Total	**6.7 ha**

5.3.2 Geotechnical

Beginning at the western end, the proposed new 2.5 kilometres long highway alignment would diverge from the current Highway 29 alignment towards the south and extend generally straight in an easterly direction into and across the Farrell Creek valley, making use of the relatively short direct route across the creek between two raised terraces on either side of the valley. Construction across the fluvial terrace areas on either side of the valley is expected to encounter primarily granular soils overlying the bedrock, with variable but generally minimal thicknesses of surficial silt and organic soils requiring sub-excavation or stripping. Conventional cuts and fills and a pavement structure based on primarily non-frost susceptible subgrade soils can be applied in the design. Cuts and fills should be designed with maximum slopes of 2H:1V, although there may be an opportunity to steepen cuts to 1.5H:1V in granular soils, or alternately, flatten them for additional borrow opportunity.

The foundation conditions for the bridge and the causeway fill for the crossing of Farrell Creek are anticipated to be favourable, as the ground conditions appear to consist primarily of granular floodplain soils over shale and possibly sandstone bedrock. Such ground conditions would provide good bearing resistance and likely minimal settlement issues, although a geotechnical investigation will be required to better assess the foundation conditions and to confirm the absence of any soft or weak subsurface layers. Foundations for a bridge are expected to encounter granular floodplain soils over sedimentary bedrock (shale and minor sandstone) and rock-socketed piles are likely a suitable foundation option. The causeway embankment is unavoidably within the reservoir footprint and will require erosion protection, as will some of the steep natural slopes of the Farrell Creek valley and north bank of the Peace River that are in close proximity to the bridge abutment and causeway approaches.

A Preliminary Geotechnical Assessment report for the Proposed Farrell Creek segment report is included in **Volume 3** of the report and provides additional details.

5.3.3 Constructability

The Farrell Creek alignment is primarily off-line and away from the existing Highway 29 which should allow for easy construction. The exception to this is at the project limits where single lane alternating traffic with delays will likely be required to complete the construction.

A detour alignment is shown where the proposed causeway embankment slope covers the existing highway alignment at Station 2001+200. The detour option shown is a 30 kilometres per hour design alignment that begins at the east end of the existing Farrell Creek Bridge, passes between the proposed pier and bridge fill and then ties back to the existing alignment approximately 300 metres east of the bridge. The detour alignment has a maximum grade of 10.5 percent. The proposed width of the detour road is 8.0 metres paved but may need to be widened to accommodate large trucks and construction equipment especially around the 35 metre radius curve at the east end of the existing bridge and will need to be evaluated further at subsequent design stages. A temporary licence for construction access (TLCA) has been shown for this detour road and included as part of the right of way Definition Design drawings. Drawings of the detour design alignment and profile is included with the Definition Design highway drawings included as part of **Volume 2**.

Temporary gravel construction access roads will be required to access the abutments and central pier. To access the west abutment a temporary driveway access can be constructed near Station 2000+350 and access to the west abutment can be gained along the proposed new alignment. To access the pier and east abutment, a temporary driveway access can be constructed approximately 400 metres east of the existing Farrell Creek Bridge. A construction access road can then be provided down to the pier and east abutment. This construction access road will become part of the detour alignment during construction of the causeway. A temporary licence for construction access (TLCA) has been shown for the construction access roads. Drawings of the proposed construction access roads are included with the Definition Design highway drawings **in Volume 2**.

5.3.4 Material Sources

It is estimated that approximately 700,000 cubic metres of imported fill and 7,000 cubic metres of riprap will be required for the Farrell Creek Segment.

Within the vicinity of the Farrell Creek project segment gravel terrace deposits to the east and west of Farrell Creek have been identified as areas for potential development of fill borrow sites. Borrow sourcing from the Farrell Creek Valley is not expected to produce significant amounts of material above the existing water table elevations. The elevated terrace deposits are laterally extensive across the project area. The areas of elevated terraces below the planned reservoir flood limits, such as on the east side of the project segment, would likely be favorable from the perspective of overall footprint, groundwater management and productivity due to the potential for developing thicker sequences as compared to the lower elevation areas near Farrell Creek that would potentially encounter groundwater at shallow depth. A detailed study based on initial projected volume requirements should be undertaken at the detailed design stage to examine the most suitable area(s) to develop. Material from the local granular deposits would likely need to be screened for use as fill to remove oversize boulders and cobbles. Areas of potential borrow material that will fall below the final reservoir level should be used where possible and are shown in **Figure 5.3.2**.

There were no suitable riprap sources within or in close proximity to Farrell Creek. Portage Mountain is a potential source of riprap but further geotechnical investigations, drilling and material testing will be required to confirm the suitability of the site.

Since this segment is relatively short, the production of paving aggregate and crushed base material will likely come from a pit established for the Lynx Creek or Km 21 to Km 26.5 segment.

Figure 5.3.2: Potential Granular Borrow Sources at Farrell Creek

5.3.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. No wetland sites are currently being considered within the Farrell Creek Segment.

5.3.6 Recreation Sites

No recreation sites are currently being considered within the Farrell Creek Segment.

5.3.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

The travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing curve radii and assumed vehicles would need to slow down at the sharper horizontal curves. An average speed was then determined along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometres per hour throughout the segment because all the curves meet the 90 kilometres per hour design speed. Based on this approach 52 seconds of travel time savings has been estimated at Farrell Creek.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Farrell Creek the passing opportunities increased from 0 metres to 1,600 metres in both the eastbound direction and 2,200 metres in the westbound direction.

The travel time savings and increase in passing opportunities are approximate only and based on a desktop exercise.

5.3.8 Schedule

The construction season has been assumed to be 7 months from April to October. It is anticipated that the Farrell Creek Segment can be completed within one to two construction seasons, with rough grading and bridge approach fills completed in the first year. The bridge construction can begin once access to the bridge sites and laydown areas have been obtained and the bridge construction may be completed in one year if work is permitted in winter months otherwise two seasons may be needed to complete the bridge construction.

Some of the critical items that will enable successful completion of the project include:

- Securing the required right of way prior to the project start including the bridge laydown area;
- Ensuring a suitable source of riprap is available near the project site or that alternate products can be used;
- Confirmation of aggregate quality and quantity.

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Farrell Creek segment is far enough away from the proposed dam site that impacts to the segment would not occur during Stage 1 and Stage 2 construction. The construction of the Farrell Creek segment would need to be completed prior to the completion of the proposed dam but not prior to Stage 1 or Stage 2.

5.3.9 Cost Estimate

The total construction cost for the preferred option at Farrell Creek is estimated to be [redacted] with a total project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Farrell Creek due to advancement of the design and refinements to some of the unit rates. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize due to an overall increase in activity in the area caused by the dam construction. **Table 5.3.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.3.2: Summary of Estimated Construction Costs at Farrell Creek

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - STRUCTURAL	[redacted]	
SECTION 5 – CONSTRUCTION DETOUR AND CONSTRUCTION ACCESS ROAD	[redacted]	
SECTION 6 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 7 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 8 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 9 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.3.10 Risks

Some potential risks include the following:

- Increased Navigational Water Envelope requirement that may alter design;
- Changes to the Impact Lines that may alter the design alignment and bridge concepts;
- Changes to the design due to the Public Consultation Process;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the construction start;
- Lack of quality riprap and aggregate sources.

5.4 KM 21 TO KM 26.5

The preferred option at Km 21 to Km 26.5 is Option 3 – Realignment and is shown in **Figure 5.4.1**. The total length of the preferred highway realignment option is 5.85 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.4.1 Scope

With this option the highway alignment is shifted north and outside of the preliminary stability impact lines. The alignment was designed to achieve a 90 kilometres per hour design speed and consists of several curves with radii that are at or above 800 metres which is well above the minimum requirements for a 90 kilometres per hour design speed.

The vertical profile follows the existing terrain closely and is slightly undulating. The vertical grades are generally under 2.5 percent with the exception at the east end where a 5.2 percent grade is required to tie back to the existing highway.

The cut slopes have been designed at 3H:1V even though the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable. Similarly, all the fill slopes have been designed at 2H:1V even though the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable.

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm-WGB and 600 millimetres of SGSB but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

Figure 5.4.1: Preferred Alignment Option at Km 21 to Km 26.5

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

Driveway accesses will be re-established at their current location along the proposed alignment. As well additional driveway accesses have been shown on the Definition Design drawings based on previous consultation with affected property owners. These are conceptual only and subject to change based on further consultation with affected property owners.

There is a watercourse that crosses the proposed alignment at Station 6000+450. The size and flow of this watercourse and the type of culvert structure required is not known at this time. The culverts shown on the Definition Design drawings are conceptual only and not based on any detailed drainage study. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BC Supplement to TAC Geometric Design Guide.

There are no known utilities within this section although this will need to be confirmed with detailed ground survey during subsequent design stages. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages if required.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawing can be found in **Volume 2**. The properties that are impacted by the preferred alignment option are Private and Crown Land. There also appears to be some existing road / utility allowances that will be impacted. **Table 5.4.1** below summarizes the amount of new right of way required based on the preferred alignment. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.4.1: New right of Way required at Km 21 to Km 26.5

Description	New Right of Way Required
Existing Road / Utility Allowance	0.4 ha
Private Land	21.8 ha
Crown Land	0.9 ha
Total	**23.1 ha**

5.4.2 Geotechnical

In terms of geotechnical conditions for new construction designed to provide set back of the highway from potential reservoir shoreline induced stability issues along the Km 21 to Km 26.5 segment; new alignments shifted northwards from the existing Highway 29 location are anticipated to encounter quite favourable, well drained granular soil conditions. Cut slopes as steep as 1.5H:1V can likely be used, along with pavement structures that consider relatively well drained non-frost susceptible subgrades. Some attention will need to be given to drainage and erosion control; particularly where crossing previous drainage channels and where new cross- drainage will discharge into already eroded and incised gullies located along the crest of the slope adjacent to and south of the existing Highway 29 alignment.

5.4.3 Constructability

The Km 21 to Km 26.5 segment is primarily off-line and away from the existing Highway 29 which should allow for easy construction. The exception to this is at the project limits where single lane alternating traffic may be required to complete the construction. No constructability issues are anticipated through this segment and construction access can be gained are various locations along Highway 29.

5.4.4 Material Sources

Based on the current design, no imported fill will be required for the Km 21 to Km 26.5 segment. The total Type-D excavation quantity is estimated to be 182,000 cubic metres (neat line) and the total Type-D embankment quantity is estimated to be 106,000 cubic metres which will result in a surplus of 76,000 cubic metres of material. The Type-D excavated material within this segment is expected to be suitable for use as Type-D embankment. The riprap requirements within this segment will be minimal and will only be required at the inlets and outlets of the proposed culverts.

However, if needed favourable granular borrow opportunities will likely be available along the fluvial terraces, including areas that will be inundated by the reservoir. For Definition Design purposes, it is assumed that areas of the fluvial terraces, fluvial plains, and in-stream gravel bars that are located below the reservoir's FSL would be considered a potential and first priority gravel source, leaving those areas above FSL for later use by others.

There were no suitable riprap sources within or in close proximity to Km 21 to Km 26.5 segment. Portage Mountain is the most likely source of riprap but further geotechnical investigations, drilling and material testing will be required to determine the suitable of the material.

It is likely that a sufficiently large source of paving aggregates and base course material could be established within the project segment to supply the Km 21 to Km 26.5 segment as well as other project segments to the west or east if needed. As well areas above the inundation line within this segment would also be more suitable and attractive for production of base and asphalt aggregates however additional geotechnical investigation and testing of prospects above and below inundation line will be required for confirmation.

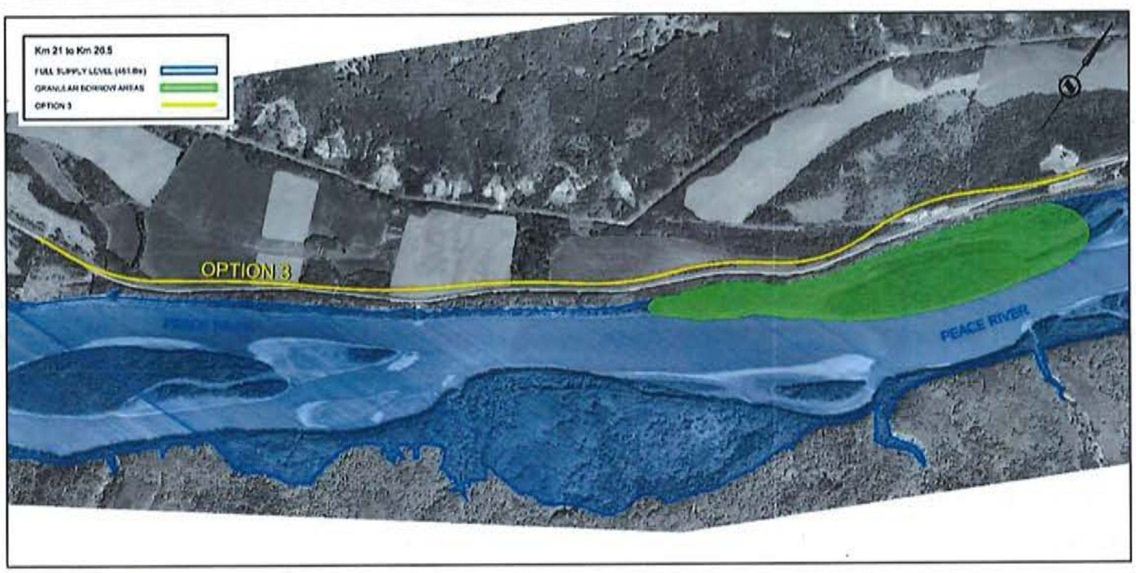


Figure 5.4.2: Potential Granular Borrow Sources at Km 21 to Km 26.5

5.4.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. No wetland sites are currently being considered within the Km 21 to Km 26.5 Segment.

5.4.6 Recreation Sites

No recreation sites are currently being considered within the Km 21 to Km 26.5 Segment.

5.4.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

The travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing curve radii and assumed vehicles would need to slow down at the sharper horizontal curves. An average speed was then determined along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometre per hour throughout the segment because all the curves meet the 90 kilometre per hour design speed. Based on this approach 1 second of travel time savings has been estimated at Km 21 to Km 26.5.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Km 21 to Km 26.5 the passing opportunities increased from 1,800 metres to 3,300 metres in the eastbound direction and from 1,500 metres to 3,000 metres in the westbound direction.

The travel time savings and increase in passing opportunities are approximate only and based on a desktop exercise.

5.4.8 Schedule

It is anticipated that the Km 21 to Km 26.5 segment can be completed within one to two construction seasons, with rough grading completed in the first year and paving later that year or early the following year.

Some of the critical items that will enable successful completion of the project include:

- Securing the required right of way prior to the construction start;
- Providing access at mid-points along the alignment to minimize haul routes;
- Confirmation of aggregate quality and quantity.

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Km 21 to Km 26.5 segment is far enough away from the proposed dam site that impacts to the segment would not occur during Stage 1 and Stage 2 construction. The construction of the Km 21 to Km 26.5 segment would need to be completed prior to the completion of the proposed dam but not prior to Stage 1 or Stage 2.

5.4.9 Cost Estimate

The total construction cost for the preferred option at Km 21 to Km 26.5 is estimated to be [redacted] with a total project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Km 21 to Km 26.5 due to advancement of the design and refinements to some of the unit rates. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize due to an overall increase in activity in the area caused by the dam construction. **Table 5.4.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.4.2: Summary of Estimated Construction Costs at Km 21 to Km 26.5

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 5 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 6 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 7 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.4.10 Risks

Some potential risks include the following:

- Changes to the Impact Lines that may alter the design alignment and bridge concepts;
- Changes to the design due to the Public Consultation Process;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the construction start.

5.5 HALFWAY RIVER

The preferred option at Halfway River is Option 4 - Short and is shown in **Figure 5.5.1**. The total length of Option 4- Short is 3.7 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.5.1 Scope

The horizontal and vertical alignment for the Preferred Option 4 – Short has been established to meet a 90 kilometres per hour design speed. The horizontal alignment begins at the west project limit with a large 800 metre radius right hand curve followed by approximately 500 metres of tangent section and then another 800 metre radius left hand curve followed by an 8,000 metre radius left hand curve. The alignment is then tangent for another 1.0 kilometres including across the causeway and bridge structure. Just east of the bridge the alignment curves to the right with a 1,000 metre radius curve before tying back to the existing alignment with a 450 metre radius left hand curve.

The vertical profile is generally flat with grades under 1.1 percent throughout the segment with the exception of the two tie-in locations. At the west project limit the profile matches the existing highway with a grade of 3.8 percent and at the east end of the project the profile climbs at a 2.2 percent grade to match existing highway.

The cut slopes have been designed at 3H:1V even though the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable. Similarly, all the fill slopes have been designed at 2H:1V even though the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable.

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm-WGB and 600 millimetres of SGSB but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

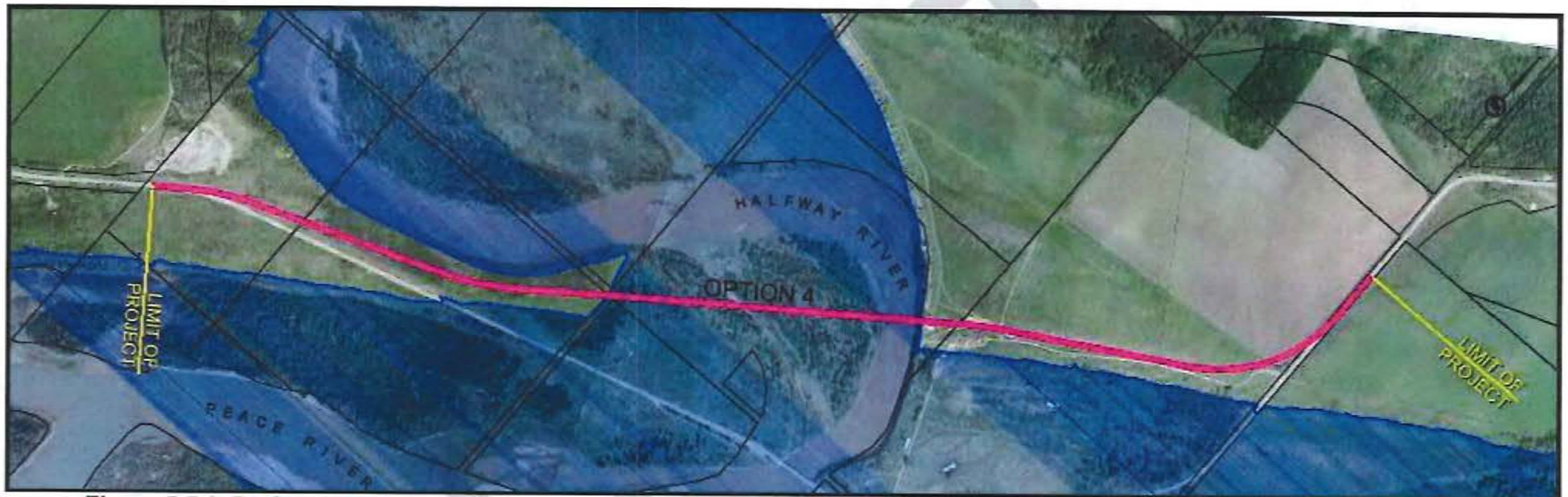


Figure 5.5.1: Preferred Alignment Option at Halfway River

The Halfway River segment is located across from the Attachie Slide area and is the segment along Highway 29 that is the most susceptible to a large landslide generated wave. A quantitative risk assessment (QRA) is currently underway at Halfway River that will provide guidance on the most appropriate landslide return period to design for. For the purpose of the Definition Design and in the absence of the recommendations from the QRA, a 10,000 year return period landslide generated wave was assumed for the bridge design and a 1,000 year landslide generated wave was assumed for the highway approach and causeway.

The proposed crossing of the Halfway River channel includes a 305 metres bridge and a 695 metre causeway. A Navigable Water Clearance envelope in excess of 8 metres high by 25 metres wide has been provided under the structure. The landslide generated wave amplitude, assuming a 10,000 year return period landslide is estimated at 14 metres at Halfway River. The current design elevation of the bridge structure is high enough to allow the 14 metre wave amplitude to pass under the structure assuming a 3.3 metres superstructure depth. The design proceeded with the assumption that the bridge foundations and piers could be designed to withstand the forces created by a 10,000 year landslide generated wave however more detailed engineering is required at the subsequent design stages to confirm this assumption. The preliminary loads on the bridge structure from a 10,000 year landslide generated wave have been estimated by Klohn Crippen Berger Ltd. and presented to the IET team in a letter memorandum dated January 31, 2012. This letter memorandum is included in Appendix F of the Bridge Definition Design Report that can be found in **Volume 3**.

The elevation of the west approach and causeway has been established so that a 1,000 year landslide generated wave would not run up and overtop the existing highway. This resulted in the west approach and causeway being raised to a minimum elevation of approximately 481 metres which significantly increased the imported fill requirements from previous options. This elevation was based on modeling work performed by BGC to determine how far a wave would run up the proposed highway embankment assuming a 1,000 year landslide generated wave. The modeling was based on the preferred Definition Design alignment and assumed 2H:1V embankment slopes. During subsequent design stages, refinements to the preferred alignment will be explored to reduce the height of the highway at the west approach and causeway by mitigating the effects of the wave run up. Some refinements include providing a steeper and rougher embankment slope, providing a vertical retaining wall instead of an embankment slope or providing a large ditch adjacent to the highway. These refinements will help to reduce the height of the wave run-up which may allow a lowering of the west approach and causeway resulting in a reduced quantity of imported fill and cost.

Raising the west approach and causeway above a 10,000 year wave run up would require a significant increase in elevation and was not considered to be feasible and was not considered any further.

The causeway has been designed assuming 2H:1V granular embankment slopes. The causeway slopes are armoured with riprap between the elevations of 459.0 metres and 464.0 metres to protect against wind induced wave action. Riprap or other slope protection will also be required along the existing steep slopes on the west approach to protect against wind induced waves. Riprap has been shown for the purpose of the Definition Design but the feasibility and constructability of providing riprap on the existing steep slopes will need to be further investigated in subsequent stages. The bridge abutments will also be protected with riprap. For details on the riprap design refer to the Final Hydraulics Report for Definition Design found in **Volume 3**.

Potential new intersections and driveway accesses have been shown along the alignment. These are conceptual only and subject to change based on consultation with affected property owners.

The culverts shown on the Definition Design drawings are conceptual only and not based on any detailed drainage study. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BC Supplement to TAC Geometric Design Guide.

Utility poles and an underground telephone line are located within this section and will need to be identified for relocation or protection during subsequent design stages. There is an overhead crossing at Station 3000+300 and an underground telephone line crossing near Station 2999+800 that will need to be confirmed. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawing can be found in **Volume 2**. The properties that are impacted by the preferred alignment include BC Hydro Owned land that is currently leased to local residents (BC Hydro Leased) and Crown Land. There also appears to be some existing road / utility allowances that will be impacted. The existing ownership of the Halfway River channel is undetermined but a property taking has been identified in the Definition Design. **Table 5.5.1** summarizes the amount of new right of way required based on the preferred alignment option. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.5.1: New right of Way required at Halfway River

Description	New Right of Way Required
Existing Road / Utility Allowance	0.4 ha
Existing Watercourse	17.4 ha
BCH Leased	6.1 ha
Crown Land	11.9 ha
Total	**35.8 ha**

5.5.2 Geotechnical

The western section of proposed new highway alignment diverges from Highway 29 near Thompkins Pit and would traverse a remnant raised fluvial terrace or 'spur' between the Halfway River and the existing Highway 29 alignment. Construction across this area is expected to encounter primarily granular soils overlying the bedrock, with variable but generally minimal thicknesses of surficial silt and organic soils requiring sub-excavation or stripping. Conventional cuts and fills and a pavement structure based on primarily non-frost susceptible subgrade soils can be applied in the design. Cuts and fills should be designed with maximum slopes of 2H:1V, although there may be an opportunity to steepen cuts to 1.5H:1V in granular soils, or alternately, flatten them for additional borrow opportunity. The natural slope along the south side of the Halfway River, and north of the proposed alignment, should be considered potentially unstable and will require detailed geotechnical investigation to confirm slope stability conditions and investigate the requirement for erosion protection.

An approximately perpendicular crossing of the Halfway River floodplain and channel will be via a causeway embankment and new bridge to be located about 600 metres north (upstream) of the existing Highway 29 bridge crossing. The foundation conditions for the bridge and the causeway fill for the crossing are anticipated to be relatively favourable, as the ground conditions appear to consist primarily of granular floodplain soils over bedrock. Such ground conditions would provide good bearing resistance and likely minimal settlement issues, although a geotechnical investigation will be required to better assess the foundation conditions and to confirm the absence of any soft or weak subsurface layers. Foundations for a bridge are expected to encounter granular floodplain soils over sedimentary bedrock (shale and minor sandstone) and rock-socketed piles are likely a suitable foundation option. The causeway embankment is unavoidably within the reservoir footprint and will require erosion protection, as will some of the steep natural slopes of the Halfway River valley and north shoreline of the reservoir that will be in close proximity to the bridge abutment and causeway approaches. The natural slope on the east side of the Halfway River, below the proposed bridge abutment location, should be considered potentially unstable and will require detailed geotechnical investigation to confirm slope stability conditions and investigate the requirement for erosion protection.

East of the Halfway River channel, the proposed new alignment follows flat lying terrain just to the north of a sloping terrace face prior to rejoining Highway 29 about 700 metres south of the toe of Halfway Hill. Construction across this area is expected to encounter primarily sands and gravels or silty sands overlying bedrock. However, much of the granular soils may be overlain by a silt cap of variable thickness which may require sub-excavation in excess of normal stripping. Conventional cuts and fills and a pavement structure based on primarily non-frost susceptible subgrade soils can be applied in the design where the silt cap absent or is removed. Further investigation to delineate the thickness and characteristics of the silt cap is required. Cuts and fills should be designed with maximum slopes of 2H:1V, although there may be an opportunity to steepen cuts to 1.5H:1V in granular soils, or alternately, flatten them for additional borrow opportunity.

A Preliminary Geotechnical Assessment report for the Proposed Halfway River segment report is included in **Volume 3** of the report and provides additional details.

5.5.3 Constructability

The Halfway River alignment is primarily off-line and away from the existing Highway 29 which should allow for easy construction. The exception to this is at the project limits where single lane alternating traffic may be required to complete the construction.

The bridge construction will not require a detour or the construction of a temporary bridge since it is located away from the existing highway. The location of Pier 1 and Pier 2 are located outside the wetted perimeter of the creek and the pile installations and substructure construction can be carried out without the use of a cofferdam or temporary berm. Pier 3 however is located within the existing river channel and will require a cofferdam and dewatering for the pile installation.

Temporary gravel construction access roads will be required to access the abutments and piers. To access the west abutment and Pier 1 and Pier 2, a temporary construction access can be provided approximately 600 metres west of the existing Halfway River Bridge. From there an access road can be constructed to the proposed new highway alignment which can then be used to access the west abutment and Pier 1 and Pier 2.

To access the north abutment, a temporary access can be provided off the existing intersection immediately east of the existing Halfway River Bridge. From here a temporary construction access road can be constructed to the abutment.

Access to Pier 3 is the most challenging. A temporary access can be provided off the existing intersection immediately east of the Halfway River Bridge. From here a 450 metre long temporary construction access road would need to be constructed along the existing east bank of the Halfway River to navigate down to the pier. An alternate option could be to build a temporary working platform at the pier and barge equipment and machinery from the west side of the river channel.

5.5.4 Material Sources

It is estimated that approximately 4.0 million cubic metres of imported fill and 20,000 cubic metres of riprap will be required for the Halfway River Segment.

Within the area of the Halfway River project segment the gravel terraces deposits either in the elevated areas associated with the ancient Peace River Valley, or in the lower portions of the Halfway River Valley represent areas for development of potential fill borrow sites. These deposits are laterally extensive across the project area. The low elevation areas such as in the Halfway River Valley include extensive gravel deposits, although the thickness of the deposits in this part of the site is comparatively shallow, and is effectively limited to areas above the water table for the purposes of constructability. The elevated terraces elsewhere at the site, below the planned reservoir flood limits would likely be favorable from the perspective of overall footprint, groundwater management and productivity due to the potential for developing thicker sequences as compared to the lower elevation areas near the Halfway River. The potential granular borrow sites located below the reservoir FSL are shown in **Figure 5.5.2**.

A detailed study based on initial projected volume requirements should be undertaken at the detailed design stage, to identify the most suitable area(s) to develop.

Material from the local granular deposits would likely need to be screened for boulders and cobbles for use as embankment fill. Areas of potential borrow material that will fall below the final reservoir level should be used where possible.

There were no suitable riprap sources within or in close proximity to the Halfway River segment. Portage Mountain is the most likely source of riprap but further geotechnical investigations, drilling and material testing will be required to determine the suitable of the material.

It is likely that a sufficiently large source of paving aggregates and base course material could be established within the project segment however additional geotechnical investigation and testing of prospects above and below inundation line will be required for confirmation.

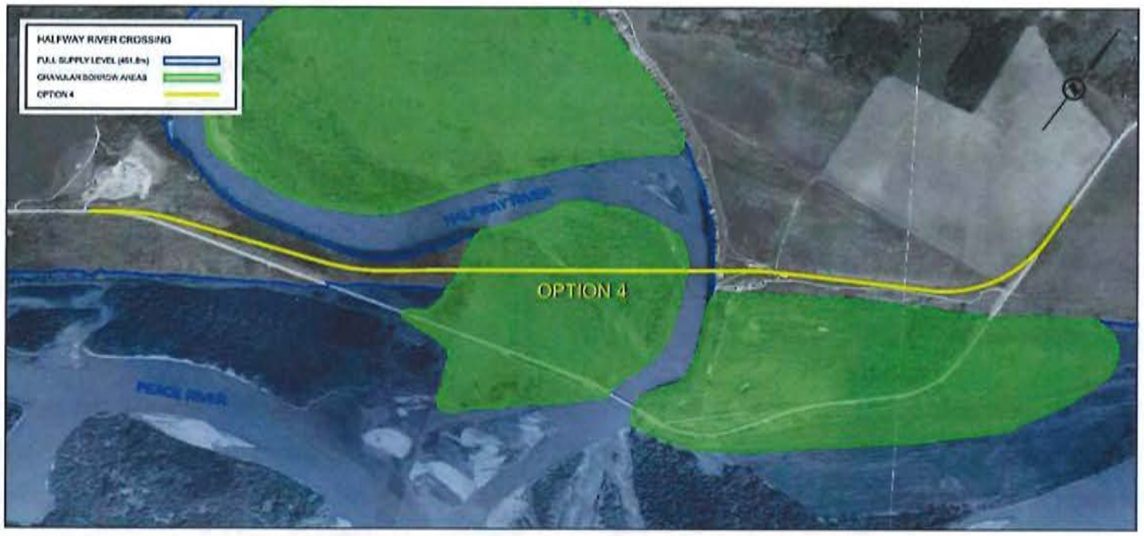


Figure 5.5.2: Potential Granular Borrow Sources at Halfway River

5.5.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. No wetland sites are currently being considered within the Halfway River Segment.

5.5.6 Recreation Sites

No recreation sites are currently being proposed within the Halfway River segment. This is a departure from earlier considerations by BC Hydro, as suggested in the document titled "**Recreational Access Mitigation Concepts Review**" dated October 6, 2011 and available in **Volume 3**.

5.5.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

The travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing curve radii and assumed vehicles would need to slow down at the sharper horizontal curves. An average speed was then determined along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometres per hour throughout the segment because all the curves meet the 90 kilometres per hour design speed. Based on this approach 14 seconds of travel time savings has been estimated at Halfway River.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Halfway River the passing opportunities remained the same at 1,000 metres in both the eastbound and westbound directions.

The travel time savings and increase in passing opportunities are approximate only and based on a desktop exercise.

5.5.8 Schedule

The construction season has been assumed to be 7 months from April to October. It is anticipated that the Halfway River Option can be completed within two to three construction seasons, with rough grading and bridge approach fills completed in the first year. The bridge construction can begin once access to the bridge sites and laydown areas have been obtained and the bridge construction is expected to be completed in two construction seasons.

Some of the critical items that will enable successful completion of the project include:

- Completing the QRA to determine the appropriate landslide generated wave return period that should be designed for;
- Ensuring that the bridge can be designed to withstand the forces of the landslide generated waves;

- Securing the required right of way prior to the construction start;
- Providing access at mid-points along the alignment to minimize haul routes;
- Ensuring a suitable source of riprap is available near the project site or that alternate products can be used;
- Confirmation of aggregate quality and quantity.

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Halfway River segment is far enough away from the proposed dam site that impacts to the segment would not occur during Stage 1 and Stage 2 construction. The construction of the Halfway River segment would need to be completed prior to the completion of the proposed dam but not prior to Stage 1 or Stage 2.

5.5.9 Cost Estimate

The total construction cost for the preferred option at Halfway River is estimated to be [redacted] with a total project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Halfway River due to advancement of the design and refinements to some of the unit rates. A significant increase in the estimated cost resulted from raising the west causeway and bridge to withstand a 1,000 year and 10,000 year landslide generated wave event which resulted in increased imported fill quantities and a more robust pier and abutment design for the bridge structure. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed and efforts will be made to optimize the design. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize due to an overall increase in activity in the area caused by the dam construction. **Table 5.1.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.5.2: Summary of Estimated Construction Costs at Halfway River

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - STRUCTURAL	[redacted]	
SECTION 5 –CONSTRUCTION ACCESS ROAD	[redacted]	
SECTION 6 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 7 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 8 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 9 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.5.10 Risks

Some potential risks include the following:

- The results from the QRA differing from the assumptions used during the Definition Design which could affect the west approach, causeway and bridge designs;
- The Landslide Generated Wave amplitude increases;
- Changes to the Impact Lines that may alter the design alignment and bridge concepts;
- Increased Navigational Water Envelope requirement that may alter design;
- Changes to the design due to the Public Consultation Process;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the construction start;
- Lack of quality riprap and aggregate sources.

5.6 Bear Flat/Cache Creek

The preferred option at Bear Flat / Cache Creek is Option F Modified and is shown in **Figure 5.6.1**. The total length of Option F Modified is 8.36 kilometres. The design drawings for the preferred alignment can be found in **Volume 2** of the report.

5.6.1 Scope

The preferred alignment has been developed to minimize the effects on heritage and archaeological sites. The horizontal and vertical alignment for the Preferred Option F Modified has been established to meet a 90 kilometres per hour design speed.

The horizontal alignment begins at the west project limit with sweeping reverse curves of 440 metres taking the alignment to the top of the lower escarpment. It then follows a generally tangential alignment paralleling the future reservoir shoreline, with minor deviations to avoid impacts to private properties and archaeological sites. Immediately following the Cache Creek crossing, and avoiding the nearby residences, the alignment follows reverse right and left hand curves of 650 metre and 440 metre radii, tying into the existing Highway 29 at the eastern limit of the project.

The vertical profile is generally flat with grades under 1.5 percent throughout the corridor with the exception of the two tie-in locations. At the west project limit the profile matches the existing highway grade on Watson Hill at 8.2 percent with a 6 percent and 2.4 percent approach to this grade. At the east project limit the existing highway grade of 8.6 percent is met again with a new 6 percent approach grade.

The cut slopes have been designed at 3H:1V even though the initial geotechnical assessment indicates that cut slopes of 2H:1V and even 1.5H:1V may be acceptable. Similarly, all the fill slopes west of Cache Creek have been designed at 2H:1V even though the initial geotechnical assessment indicates that some 1.5H:1V slopes may be acceptable. East of Cache Creek fill slopes of 3H:1V have been used in the design owing to the knowledge that the insitu material is of a silty nature, with potentially poor load bearing characteristics.

The pavement structure for the Definition Design was assumed to be 125 millimetres of asphalt, 300 millimetres of 25 mm-WGB and 600 millimetres of SGSB but there may be opportunity to reduce the thickness of the SGSB layer to 300 millimetres depending on existing soil conditions.

One of the purposes of the Definition Design is to establish the Highway 29 relocation project footprint so that all the impacts can be included as part of the overall project Environmental Assessment. Therefore in the absence of detailed geotechnical investigations, conservative cut and fill slopes were assumed for the Definition Design so that the largest impact would be included as part of the Environmental Assessment. The cut and fill slopes and the pavement structure design will be refined and optimized in subsequent design stages when detailed geotechnical investigations are completed.

The proposed crossing of the Cache Creek channel includes a 200 metre bridge and a 240 metre causeway. A Navigable Water Clearance envelope in excess of 8 metres high by 25 metres wide has been provided under the structure. The landslide generated wave amplitude, assuming a 10,000 year return period landslide is estimated to be 3 metres at Cache Creek based on the most current wave modelling results from BGC provided in January 2012.

Preliminary wave modelling results indicated landslide generated wave amplitudes to be 8 metres and 13 metres for the 1,000 year and 10,000 year return period landslide generated wave respectively at Cache Creek. The most current modelling results, at the time of writing, indicated significantly lower wave amplitudes than previously anticipated, and there will be opportunity to lower the elevation of the bridge during subsequent design stages which will reduce impacts and costs. The Navigable Water Clearance Envelope will now govern the bridge elevation at Cache Creek.

The causeway has been designed assuming 2H:1V granular embankment slopes. The causeway slopes are armoured with riprap between the elevations of 459.0 metres and 464.0 metres to protect against wind induced wave action. Riprap is also required at the east end of the proposed alignment where the new embankment slopes are within the proposed reservoir. The bridge abutments will also be protected with riprap. For details on the riprap design refer to the Final Hydraulics Report for Definition Design found in **Volume 3**.

Potential new intersection and driveway accesses have been shown along the preferred alignment. These are conceptual only and subject to change based on consultation with affected property owners.

The culverts shown on the Definition Design drawings are conceptual only and not based on any detailed drainage study. A large gulley is located approximately 400 metres east of the western project limits at Station 400+920 and for the Definition Design a 3.6 metres by 3.1 metres concrete box culvert 122 metres long has been assumed. A hydrology study will be completed in subsequent design stages to confirm the culvert requirements. The surface drainage design will also be completed at subsequent design stages to determine spillway and catch basin requirements. The hydrology and surface drainage designs will follow the guidelines from Section 1000 from the BC Supplement to TAC Geometric Design Guide.

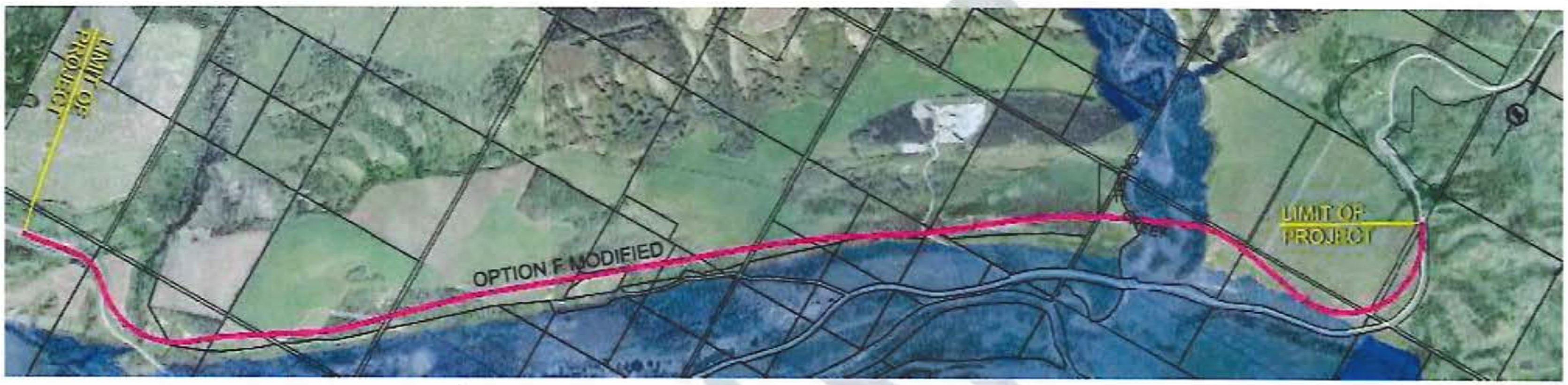


Figure 5.6.1: Preferred Alignment Option at Bear Flat / Cache Creek

Utility poles are located within this segment of Highway 29 and will need to be identified for relocation or protection during subsequent design stages. Consultation with utility owners along the corridor and the preparation of utility relocation drawings will be completed in subsequent design stages.

Option F Modified attempts to minimize impacts to the residential property east of Cache Creek. The alignment is upslope from the residence and thus does not interfere with the future view of the proposed reservoir.

Proposed right of way limits have been established assuming a minimum horizontal distance of 5.0 metres from the proposed top of cut or bottom of fill. The Right of Way Definition Drawing can be found in **Volume 2**. The properties that are impacted by this proposed alignment include Private Land, Crown Land and BC Hydro Owned and BC Hydro Owned land that are currently leased to local residents (BC Hydro Leased). There also appears to be some existing road / utility that will be impacted. The existing ownership of the Cache Creek channel is undetermined but a property taking has been identified in the Definition Design. **Table 5.6.1** below summarizes the amount of new right of way required based on the preferred alignment option. It does not include the right of way inside the existing highway that will still be required nor does it identify any surplus highway right of way.

Table 5.6.1: New right of Way required at Bear Flat /Cache Creek

Description	New Right of Way Required
Existing Road / Utility Allowance	1.1 ha
Existing Watercourse	10.9 ha
Private Land	35.3 ha
BCH Leased	5.7 ha
Crown Land	0.8 ha
Total	**53.8 ha**

5.6.2 Geotechnical

From the western extent of the proposed highway relocation segment extending approximately 6.2 kilometres towards the east (from Station 400+500 to 406+710), the proposed realignment (Option F Modified Short) is primarily located near the edge of the upper fluvial terrace that consists predominantly of sands and gravels. These are post-glacial fluvial deposits, formed as part of the down-cutting of the Peace River, and appear to be underlain by till and/or bedrock. Construction along the fluvial terrace is expected to encounter primarily granular soils, with variable but generally minimal thicknesses of surficial silt and organic soils requiring sub-excavation or stripping, although the possibility of encountering till soils or a perched water table cannot be discounted. Conventional cuts and fills and a pavement structure based on primarily non-frost susceptible subgrade soils can be applied in the design. Cuts and fills should be designed with maximum slopes of 2H:1V, although there may be an opportunity to steepen cuts to

1.5H:1V in granular soils, or alternately flatten them for additional borrow opportunity. Several small draws are crossed and will require full embankment fills with toes close to reservoir impact lines. Additional geotechnical investigation to confirm embankment fill conditions are required, particularly for crossing of the unnamed stream gulley at the western end of the segment.

The foundation conditions for the bridge and the causeway fill at Cache Creek are anticipated to be favourable, as the ground conditions appear to consist primarily of granular floodplain soils over shale at a shallow depth. Such ground conditions would provide good bearing resistance and likely present minimal settlement issues, although a geotechnical investigation will be required to better assess the foundation conditions and to confirm the absence of any soft or weak subsurface layers. Foundations for a bridge are expected to encounter granular floodplain soils over sedimentary bedrock (shale and minor sandstone) and rock-socketed piles are likely a suitable foundation option. The causeway embankment is unavoidably within the reservoir footprint and will require erosion protection. The natural slopes on the west side of the valley, below the proposed bridge abutment location, should be considered potentially unstable and will require detailed geotechnical investigation to confirm slope stability conditions and investigate the requirement for erosion protection.

East of Cache Creek, the existing highway and proposed alignment option cross a broad fluvial fan overlying fluvial terrace deposits. Existing information suggests the possible presence of soft clay at the surface in some areas, or silty or clayey sand and gravel in others. The proposed alignment option includes fills up to about 15 metres above existing grade. Construction of the fills will require detailed geotechnical investigation and analysis to confirm stability of the fills. The toe of these high fills would be located below Full Supply Level and will require erosion protection.

The east end of the segment ties into the existing highway part way up Cache Creek Hill, an area that has a long history of terrain instability, landsliding, and erosion. Tie in to the existing highway may require reconstruction of existing fill slopes leading up to the last several hundred metres to the limit of realignment, where the proposed alignment overlaps the existing highway footprint.

Within the Bear Flat / Cache Creek segment, relatively favourable granular borrow opportunities will likely be available along the fluvial terraces, including areas that will be inundated by the reservoir. The upper terrace surface typically has a surface cover of mixed alluvial material that would need to be stripped. An aggregate investigation would be required to collect samples and conduct appropriate laboratory tests on the soil. For Definition Design purposes, it is assumed that areas of the fluvial terraces that are located below the FSL would be considered as the primary potential gravel sources, although a field investigation and laboratory testing would be required to confirm suitable quantity and quality of material.

No areas were noted within the Bear Flat segment that may be suitable for borrow of riprap. An existing BCMOT prospect for riprap is present just east of the end of the project segment (Bear Flat Quarry), where Dunvegan sandstone outcrops north of the highway. The rock was tested and deemed unsuitable for riprap production due to poor durability and small fragment size.

A Preliminary Geotechnical Assessment report for the Proposed Bear Flat segment report is included in **Volume 3** of the report and provides additional details.

5.6.3 Constructability

Access to Option F Modified from the existing highway is quite straight forward with direct access from the existing highway at the west and east extremities and Watson Road in the central portion. For the majority of Option D alignment construction access would need to be gained from new roadways across ALR land.

The Bear Flat/ Cache Creek alignment is primarily off-line and away from the existing Highway 29 alignment which should allow for easy construction. The exception to this is at the project limits.

The bridge construction will not require a detour or the construction of a temporary bridge since it is located away from the existing highway. The proposed central pier is located outside the wetted perimeter of the creek and all pile installations and substructure construction can be carried out without the use of a cofferdam or temporary berm.

Temporary gravel construction access road from Highway 29 will be required to access the central pier. To access the west abutment, use of Watson Road and clearing the alignment to the west bank will be necessary. Access to the east abutment and causeway can be made from either the aforementioned construction access road or along the alignment from the east tie in point to Highway 29. The construction access road is included within the Definition Design highway drawings included in **Volume 2**.

5.6.4 Material Sources

It is estimated that approximately 2.1 million cubic metres of imported fill and 20,000 cubic metres of riprap will be required for the Bear Flat / Cache Creek Segment.

Within the Bear Flat / Cache Creek Segment relatively favourable granular borrow opportunities will likely be available along the fluvial terraces, including areas that will be inundated by the reservoir as shown in **Figure 5.6.2**. For Definition Design purposes, it is assumed that areas of the fluvial terraces, fluvial plains, and in-stream gravel bars that are located below the reservoir's FSL would be considered a potential and first priority gravel source, leaving those areas above FSL for later use by others.

There were no suitable riprap sources within or in close proximity to the Bear Flat / Cache Creek Segment. Portage Mountain is the most likely source of riprap but further geotechnical investigations, drilling and material testing will be required to determine the suitable of the material.

It is likely that a sufficiently large source of paving aggregates and base course material could be established within the project segment however additional geotechnical investigation and testing of prospects above and below inundation line will be required for confirmation.

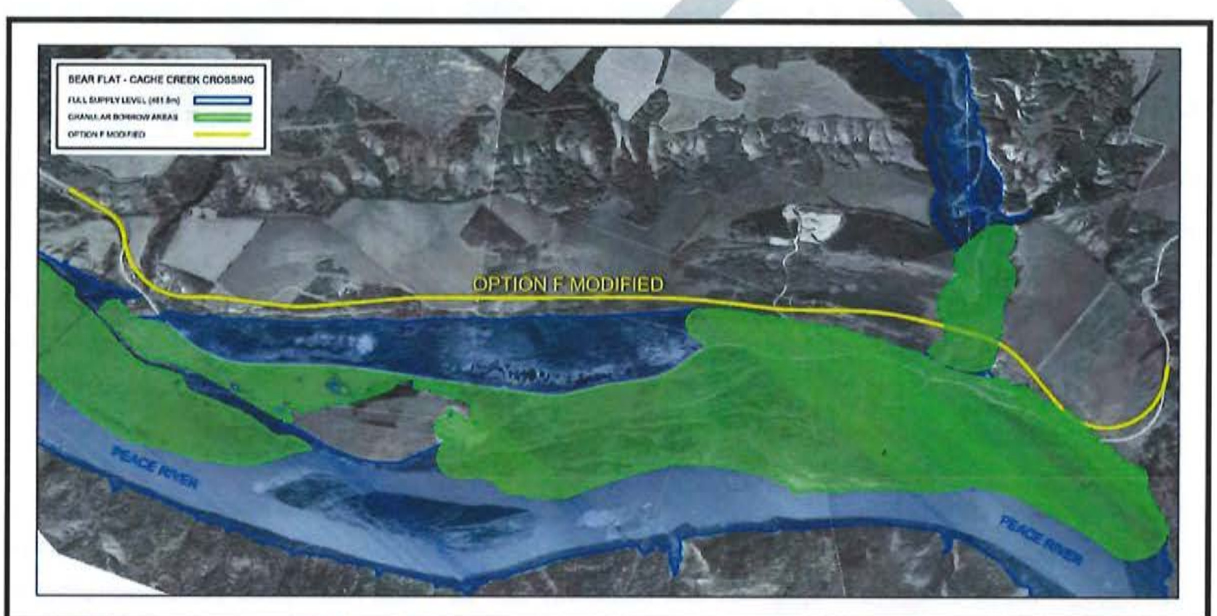


Figure 5.6.2: Potential Granular Borrow Sources at Bear Flat / Cache Creek

5.6.5 Environmental Mitigation and Compensation

Environmental mitigation and compensation will be required for wildlife and fisheries habitats impacted by the proposed Highway 29 relocation. The IET and the BC Hydro environmental groups have been assessing potential wetlands sites along the Highway 29 corridor that could be included as part of the mitigation and compensation areas. A potential wetland site has been identified west of Cache Creek on an existing island that is currently being investigated as a source of gravel. This site is identified and described in the document **Meeting Minutes – Opening discussions between engineering and environmental groups on wetland opportunities at the proposed reservoir** dated October 12, 2011. This document can be found in Volume 3 of this report.

5.6.6 Recreation Sites

Due to the proximity to Fort St. John, the Bear Flat / Cache Creek segment was considered an ideal location for a boat launch site. BC Hydro is considering a possible recreation site outside of the scope of this Definition Design report, and subsequent design stages may have to include provision for access between the realigned highway and the potential recreation site.

5.6.7 Travel Time Savings and Passing Opportunities

The preferred alignment options are generally more tangential and shorter than the existing current highway alignment. This results in travel time savings when compared to the existing current highway alignment as well as a potential increase in passing opportunities.

The travel time savings were calculated based on an estimated average travel speed and travel distance. The estimated average travel speed along the existing alignment was based on the existing curve radii and assumed vehicles would need to slow down at the sharper horizontal curves. An average speed was then determined along the existing highway using this approach. The estimated average travel speed along the preferred alignment was estimated to be 90 kilometre per hour throughout the segment because all the curves meet the 90 kilometre per hour design speed. Based on this approach 35 seconds of travel time savings has been estimated at Bear Flat / Cache Creek.

Section 7.10.1 from the BCMOT Manual of Standard Traffic Signs and Pavement Marking Manual indicates that passing is allowed where the sight distance ahead is greater than 330 metres for a 90 kilometre per hour design speed. A driver eye height of 1.05 metres and a vehicle height of 1.15 metres were used to determine potential passing opportunities. Sight distances were checked along the existing alignment and compared with the preferred alignment taking into consideration the existing and proposed horizontal and vertical curves. At Bear Flat / Cache Creek the passing opportunities increased from 1,700 metres to 3,200 metres in both the eastbound direction and westbound directions.

The travel time savings and increase in passing opportunities are approximate only and based on a desktop exercise.

5.6.8 Schedule

The construction season has been assumed to be 7 months from April to October. It is anticipated that Option F modified could be completed within two construction seasons, with rough grading completed in the first year along with the Cache Creek bridge approach fills being placed in the first summer environmental window. Construction of the bridge could continue throughout the year with the highway gravelling and paving operations completed the following summer. Relocation of the BC Hydro line to the new route should occur during this second construction year. Once the required right of way has been defined for the preferred option, the property acquisition process should commence to avoid construction delays to construction commencement.

Some of the critical items that will enable successful completion of the project include:

- Securing the required right of way prior to the construction start;
- Providing access at mid-points along the alignment to minimize haul routes;
- Ensuring a suitable source of riprap is available near the project site or that alternate products can be used;
- Confirmation of aggregate quality and quantity.

It is contemplated that the construction of the dam would begin in 2015 with the construction of coffer dams during Stage 1 and the diversion tunnels during Stage 2. After construction of the diversion tunnels are completed, the construction of the dam itself will begin during Stage 3. It is expected that the total dam construction period from Stage 1 to Stage 3 is to last approximately seven years. The Bear Flat / Cache Creek segment is close to the proposed dam site and low enough that it will be flooded during Stage 1 and Stage 2 of the dam construction. Therefore the construction of the Bear Flat / Cache Creek segment would need to be completed prior to Stage 1 and Stage 2 of the dam construction.

5.6.9 Cost Estimate

The total construction cost for the preferred Option F Modified at Bear Flat / Cache Creek is estimated to be [redacted] with a total project cost of [redacted]. The Definition Design cost estimates for the preferred alignment differed from earlier estimates at Bear Flat / Cache Creek due to advancement of the design and refinements to some of the unit rates. The estimates are subject to change as the design progresses into a more detailed design stage when topographic survey and geotechnical field investigations are completed. The estimates are based on 2011 dollars and have not considered inflation or an increase in general construction costs that may materialize due to an overall increase in activity in the area caused by the dam construction. **Table 5.6.2** provides a summary of the cost breakdown and a more detailed cost estimate can be found in **Volume 3**.

Table 5.6.2: Summary of Estimated Construction Costs at Bear Flat / Cache Creek

ITEM	COST	DESCRIPTION
SECTION 1 - GENERAL	[redacted]	Includes Mobilization, Traffic Management and Quality Management
SECTION 2 - SITE PREPARATION AND ROAD GRADE	[redacted]	
SECTION 3 - PAVING CONSTRUCTION	[redacted]	
SECTION 4 - STRUCTURAL	[redacted]	Includes [redacted] for the bridge and [redacted] for the box culvert
SECTION 5 –CONSTRUCTION ACCESS ROAD	[redacted]	
SECTION 6 - PROVISIONAL SUMS	[redacted]	Site Modification (5%)
SECTION 7 - MISCELLANEOUS ITEMS	[redacted]	Items not yet quantified such as fencing, signing and drainage features
SUB-TOTAL CONSTRUCTION COST	[redacted]	
Contingency	[redacted]	20% assumed
TOTAL CONSTRUCTION COST	[redacted]	Rounded Total
SECTION 8 – WORK BY OTHERS	[redacted]	Pavement removal and utility relocation
SECTION 9 – OTHER PROJECT COSTS (NON-CONSTRUCTION)	[redacted]	Project Management, Engineering, Construction Supervision, Environmental Mitigation, Property acquisition
TOTAL PROJECT COST	[redacted]	Rounded Total

5.6.10 Risks

Some potential risks include the following:

- Increased Navigational Water Envelope requirement that may alter design;
- Changes to the Impact Lines that may alter the design alignment and bridge concepts;
- Changes to the design due to the Public Consultation Process;
- Unexpected ground conditions encountered during subsequent design stages and during construction;
- Not securing the required right of way prior to the project start;
- Lack of quality riprap and aggregate sources.

6.0 SUBSEQUENT DESIGN

6.1 ITEMS TO BE COMPLETED

Key items that will need to be completed during the subsequent preliminary design stage include the following items:

- Geotechnical field investigations at all bridge sites, at the east end of the Lynx Creek Segment, at Dry Creek and to prove out suitable aggregate and riprap sources;
- Structural design solutions to withstand the impact of a Landslide Generated Wave at the proposed Halfway River crossing to offset the requirement of a berm;
- Detailed ground survey at all bridge sites;
- Detailed ground survey at all watercourses;
- Confirmation of Navigable Water Clearance Envelopes;
- Confirmation of the Landslide Generated Wave Amplitudes and all impact lines;
- Confirmation of an appropriate level of risk acceptable to both BCMOT and BC Hydro with respect to Landslide Generated Waves. This is especially critical at Halfway River;
- Identification of recreation and wetlands areas and incorporate them into the design;
- Identify local borrow pits and waste disposal sites;
- Drainage design;
- Armoring requirements for reservoir drawdown periods have not been addressed in this stage of the design. It is expected that the frequency and extent of reservoir drawdowns will need to be determined in subsequent design stages. Frequent and long term reservoir drawdown may necessitate the need for additional armoring at elevations below the locations shown on the drawings;
- Identification of which accesses will need to be maintained and or replaced and which ones can be eliminated, which may depend on existing BC Hydro lease arrangements and property negotiations;
- Preparation of public consultation material;
- Incorporating environmental mitigation and compensation measures into the design;

6.2 POTENTIAL COST SAVING MEASURES:

During the subsequent design stage, efforts will be made to optimize the design to minimize costs. Some potential cost saving measures that will be explored during the preliminary design stage include the following:

- Optimizing all the bridge crossings by either lowering the elevation of the crossing, shortening the bridge span as much as possible while still maintaining an opening wide enough to satisfy Navigable Water and hydraulic requirements and re-examining the foundation designs when the topographical survey and detailed geotechnical field investigations are completed:
- Optimizing the roadway design to minimize excavation and embankment quantities;
- Refining the pavement structure design to minimize the thickness of the base and sub-base based on the finding of detailed geotechnical investigations;
- Refining the roadway cut and fill slopes based on the finding of detailed geotechnical investigations to minimize embankment and excavation quantities;
- Adjusting the alignment and vertical profile at the east of Lynx Creek to minimize imported fill quantities;
- Refining the detour alignment and profile at Farrell Creek;
- Working with BGC to explore options at Halfway River that will allow a lowering of the west approach and causeway (e.g. a rougher and steeper embankment slope, a wide ditch and a vertical wall instead of an embankment).

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