2024 Canadian Consulting Engineering Awards

HIGHWAY 29 REALIGNMENT

Transportation

wsp

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA

HIGHWAY 29 REALIGNMENT

30km Highway + Five Major Bridges

ABOUT THE PROJECT

The creation of a reservoir for BC Hydro's Site C Clean Energy Project will widen the Peace River by two to three times, significantly inundating sections of Highway 29. The highway, tracing the north bank of the Peace River in Northeastern BC, is a crucial link between Hudson's Hope with the Alaska Highway and Fort St. John.

To mitigate impacts to the local community and improve transportation links in the area, BC Hydro partnered with the BC Ministry of Transportation and Infrastructure (BCMOTI) to realign segments of Highway 29, which involved designing and constructing 30km of highway, including **five major highway bridges** at **Cache Creek** (590m long & 43m high), **Halfway River** (1,042m long & 45m high), **Farrell Creek** (411m long & 30m high), **Dry Creek** (160m long & 23m high), and **Lynx Creek** (150m long & 17m high).

Key Project Objectives

45m Pier Columns at Halfway River Bridge

1 To **meet project timelines** to ensure all bridge sites were ready for milestones in the Site C Clean Energy Project timeline, such as the **reservoir filling** in September 2023.

2 To design infrastructure with a 75-year service life and **minimal maintenance needs to provide a sustainable asset for the client.**

3 To **minimize impact** to surrounding land including archaeological sites, agricultural lands, and private properties.

4 To **mitigate geo-hazards** such as **landslide generated waves (LGW)** resulting from large slope failure of the Peace River valley walls.

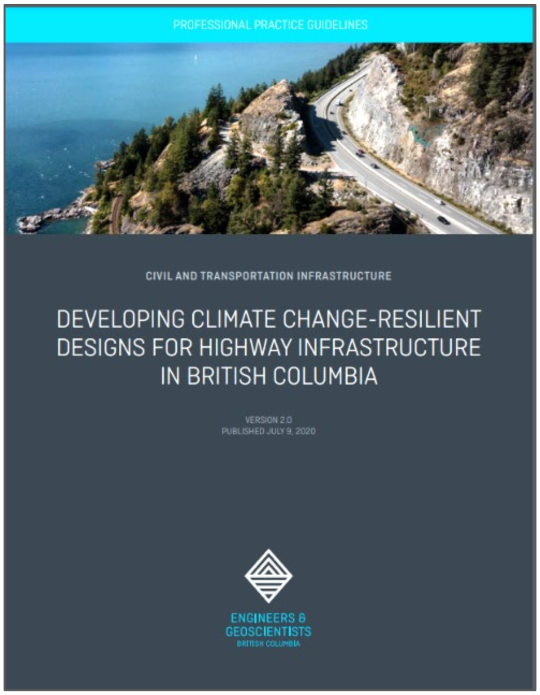
WSP was the lead bridge and geotechnical consultant for the design of the new highway bridges from definition, functional, preliminary, to detailed design. WSP also provided engineering services and fulfilled the role of Engineer of Record during the construction of the new bridges.

Ensuring timely completion was paramount for the project, aligning with critical milestones in the Site C Project timeline. Equally important was the safety, community benefit, sustainability, and resilience of new bridges as mandated by the project-specific design objectives.

Completed Halfway River Bridge

INNOVATION

British Columbians expect that the new Highway 29 bridges will be safe, resilient, and able to serve BC communities for years to come, and withstand extreme weather conditions and the effects of climate change. To address this expectation, WSP prioritized safety and resilience in every step of the bridges' design and construction.



EGBC Professional Practice Guidelines

Design Criteria Sheet for Climate Change Resilience
Highway Infrastructure Engineering Design and Climate Change Adaptation
BC Ministry of Transportation and Infrastructure
(Separate Criteria Sheet per Discipline)
(Submit all sheets to the Chief Engineers Office at: BCMOTI-ChiefEngineersOffice@gov.bc.ca)

BCMOTI Climate Change Technical Circular

To ensure the safe and reliable performance of the bridges during their 75-year design life, WSP carefully designed all of the new bridge components with **durable materials and innovative structural details** to meet or exceed the performance criteria as specified in the ***Canadian Highway Bridge Design Code* (CHBDC)** and also to fully account for all anticipated adverse effects of climate change on the long-term performance of the bridges as required by the BCMOTI Technical Circular T-04-19 - ***Resilient Infrastructure Engineering Design–Adaptation to the Impacts of Climate Change and Weather Extremes, 2019,*** and Engineers and Geoscientists British Columbia (EGBC) Professional Practice Guidelines - ***Developing Climate Change-Resilient Designs for Highway Infrastructure in British Columbia, 2020***. The *2022 Canada New Report on Climate Change* clearly states that "**Canada's North is experiencing a range of climate change-related impacts such as rising temperatures, changing sea levels, and the loss of ice and permafrost, which deeply affect all aspects of life in the North and will require unprecedented action**".

The Highway 29 bridges are subject to environmental conditions inherent to the northern climate and are expected to experience a similar range of climate change-related impacts as seen in Canada's North. Fortunately, because of the resilient approach taken to design them, these bridges will be able to reasonably withstand future climate changes and weather extremes across various scenarios.

In addition to climate change-related resilient designs, the project team **raised the bar for resilient designs to a new level** by identifying and defining additional project-specific design and performance criteria that further enhanced the resilience of bridges and their major components under a range of "unusual loads" or "extreme events" beyond the prescribed loads or events in CHBDC. Details on how the project team implemented these additional project-specific design and performance criteria are provided in this report's Complexity section.

Farrell Creek Bridge Opening

Each bridge crossing has unique site conditions and its design and construction must be completed by the predefined end date, which links to the Site C Project timeline. **The main innovative design approach was to create an engineering design solution that is adaptable to five unique sites, consistent in aesthetical appearance and performance, cost-effective and time-efficient for construction, sustainable for climate change, and resilient for extreme events.**

Notable Design Innovations Stemming from this Approach

Pier Columns | Use of non-uniform circular pier columns supported on octagon-shaped concrete caps, with drilled large-diameter steel pipe piles socked to shale bedrock and placed in an axisymmetric formation, to withstand large ice loads and impacts from landslide-generated waves (LGW) while addressing the directional uncertainty of those loads.

Steel Plate Girders | Use of a fixed set (three lines) of steel plate girders designed with a constant girder depth, and as one continuous structure from abutment to abutment to greatly simplify steel girder design, fabrication, and erection.

Finger Expansion Joints | Use of large finger expansion joints only at abutments to significantly enhance bridge structural durability and minimize future deck maintenance.

Spherical Bearings | Use of special spherical bearings with purposely designed low friction sliding interfaces, installed on selected tall piers to accommodate large thermal movements up to 1,000mm.

Environmental Enhancements | Provision of environmental enhancements wherever feasible for fish, snakes, and amphibians, along with safety features for cyclists and motorcycles.

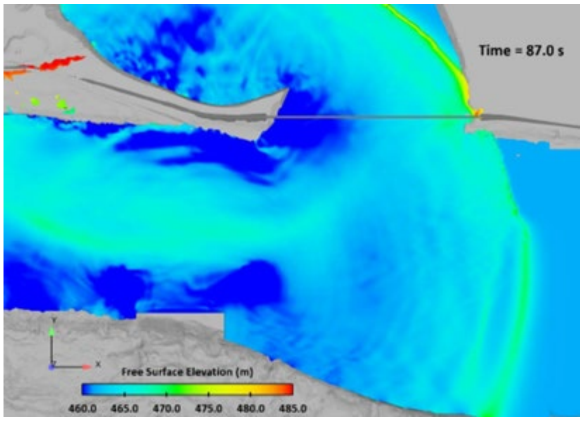
Construction of the Halfway River Bridge in Cold Northern Climate

COMPLEXITY

Highway 29 traverses an area characterized by poor ground conditions prone to debris flows and slides. Additionally, the region experiences significant fluctuations in local climate, wind patterns, and hydrology before and after reservoir formation. Consequently, the bridge design must overcome many complex and difficult technical challenges.

Several new design loads / conditions that are unique to this project include:

a) Exceptionally large and heavy EPLL2 truck loads.
b) Earthquakes induced by hydraulic fracturing (fracking) in the oil and gas industry.
c) Large ice force induced by large ice floes on open water in the reservoir mobilized by high winds.
d) Landslide-Generated Wave (LGW) impact loading.



CFD Simulation of Potential LGW

The design loads (b) to (d) are beyond the mandates of the current bridge design codes.

EPLL2 Special Truck

Highway 29 is required to carry exceptionally large and heavy truck loads for future maintenance and improvements to the hydroelectric facilities, as well as serve the needs of the future and ongoing oil and gas industry. Therefore, all bridges had to be designed for the **EPLL2 Special Truck with a gross load of 2,346kN (275% heavier than normal design CL-625 truck in CHBDC)** defined in the *BC Supplement* to CHBDC. The EPLL2 vehicle is only permitted to travel under supervision while on Highway 29 bridges, and may only travel within 600mm of the bridge centreline at speeds of less than 10km/h.

Large Ice Force Induced by Large Ice Floes in Open Water Mobilized by High Winds

This unique load case was considered in the design of bridge piers by defining a completely new Ultimate Limit State (ULS) load combination where **50-year ice load is combined with 50-year wind load** using a load factor of 1.0 for both loads.

Fracking Induced Earthquakes

A set of project-specific design response spectra for the fracking-induced earthquakes was used in the design. **Design spectral accelerations from the fracking induced earthquakes are higher than that from the natural earthquakes for the short periods at the project location**.

Landslide Generated Wave Loading

Four bridges are susceptible to catastrophic landslide events, which may cause large volumes of material (up to 10+ million m3) to slide into the reservoir, generating tsunami-intensity (**up to 18m high**) waves,

Tall Piers of the Halfway River Bridge before Site C Reservoir Filling

and impinging large dynamic forces (**close to 6,000kN per column**) to pier columns. No design codes and criteria are available. The traditional approach (uniform hazards) was cost-prohibitive. **A risk-based approach was adopted**, e.g. higher risk elements (pier columns and foundations) were designed for high hazard level (1:10,000 years) & high-performance level (minimum damage), and lower risk elements (abutments and superstructure) were designed for low hazard level (1:2,500 years) & low-performance level (repairable damage).

To quantify the LGW impact loading on bridges, **3D Computational Fluid Dynamics** (CFD) analyses were performed to simulate wave propagations in the reservoir caused by the landslides. In turn, **3D structural Time-History Analyses** (THA) were then performed by applying the LGW loading time histories to individual piers following the LGW propagation in the reservoir as predicted by CFD. **Both analyses are time-consuming and extremely complicated**. Many innovative techniques were used in both analyses for practical applications.

Extreme Temperature Conditions

The climatic conditions in the Peace River Valley, where warm summer weather is followed by blasts of cold Arctic fronts through the winter, resulted in some complex and unique project challenges. **Extreme temperatures vary between +30°C and -50°C**, with new temperature records being recorded recently due to climate change. Cold temperatures in the winter months are expected to build up thick layers of ice on the reservoir around the bridge piers.

Thermal effects on the bridge structures must be adequately addressed in the design. As all bridges were designed as one continuous structure between abutments, seasonal and daily temperature changes would result in large thermal movements for the design of expansion joints and bearings.

Pier Construction in Harsh Northern Climate

The ultimate limit state joint design movements for the three longest bridges **is between 600mm and 1,000mm**. The longest, Halfway River Bridge, having a total length of 1,042m requires its expansion joints installed at abutment locations to accommodate a horizontal movement greater than 1,000mm at each joint. Cantilever expansion joints are rarely used for movements exceeding 600mm. To ensure an optimal solution for the joint design, a comprehensive assessment of numerous superstructure articulations, as well as different types and number of joints was performed by closely analysing the joint construction cost, long-term performance, and potential impact on bridge durability. The assessment led to the rational selection of the most optimal type and number of expansion joints for each bridge crossing. To overcome unusually large thermal movements and forces in the bearing design for the three longest bridges, numerous bridge articulations for each bridge were investigated

Concrete Deck Construction on Cache Creek Bridge

to balance the overall performance of the bridge. **The optimal articulation, such as the locations of fixed and expansion bearings, was confirmed by performing the 3D structural analysis**. The conventional pot bearings with a sliding interface made of polytetrafluoroethylene (PTFE) and stainless-steel plate were assessed, and it was found that significantly large frictional forces from the bearings resulted in large load demands on foundations and at the base of the tall expansion piers. **To resolve the large frictional forces associated with pot bearings, spherical bearings with sliding interfaces comprised of ultra-high molecular polyethylene (UHMWPE) were evaluated and adopted**.

Changing River Hydraulics

Before reservoir formation, the bridges are subjected to streamflow scenarios including freshet floods resulting in significant scour protection for piers. **After reservoir formation, submerged piers are exposed to large ice loads by ice floes on open water during spring breakups of ice sheet in the reservoir**.

SOCIAL AND/OR ECONOMIC BENEFITS

Highway 29 is situated within the traditional territories of the Treaty 8 First Nations, which encompass distinct cultures and histories deeply connected to the Peace River. From the beginning of the project, **the design aimed to reduce the impact of this project on local communities and value Indigenous contributions to the project**. For example:

- The alignment of the highway and bridges were informed by avoiding all cultural and historical sites that were identified through consultations with local communities and interest groups, including affected First Nations, in the planning phase.
- During the detailed design phase, one of the bridges was moved twice to avoid a site of cultural significance that was identified after the detailed design commenced.

Indigenous Names for Crossings

Bridge design also focused on enhancing the experience of residents and recreational users of this essential link between the small communities in the Peace River Valley. **The safety of all users was enhanced** by increasing the shoulder width of the highway and bridges, introducing climbing lanes on steep vertical grades, and allowing for ample sightlines along the straight sections of the highway to facilitate safer passing. To support future recreational use of the reservoir, the bridges were designed with adequate vertical clearance to accommodate different leisure water vessels and provided with clear navigational signages on bridge piers in the reservoir to safely guide boat users.

Benefit agreements were reached with several Treaty 8 First Nations impacted by the construction and operation of the project. Agreements ensure Indigenous communities benefit from the project through employment and business opportunities.

Completed Halfway River Bridge Rising Above the Morning Mist

ENVIRONMENTAL BENEFITS

In preparation for the Site C project, BC Hydro conducted years of comprehensive studies to understand the effects of the project, and the potential mitigation measures. These resulted in the *Environmental Impact Statement*, which was used in the environmental assessment. **The adopted environment programs focused on protecting wildlife, fish, vegetation, air, water, the aquatic environment, as well as heritage and archaeology by working closely with Indigenous groups to ensure programs are built on their knowledge and understanding**.

The Peace Valley is rich in highly valued, fertile, agricultural lands. To protect this regional asset, **sustainability was a key consideration behind major decisions that shaped the project**. **Valuable environmental habitats at each site were protected and preserved during and after construction** by avoiding permanent and temporary works in the watercourse and any environmentally sensitive areas, using diversion channels, temporary culverts, and bridges as required. **The bridge design also incorporated environmental enhancements for fish, snakes, and amphibians**.

Sustainable design also focused on the effective use of locally available materials and method of construction to minimize impacts on the environment while not compromising the functionality, safety, and resilience of the bridges.

Throughout the construction period, BC Hydro continued to conduct environmental and engineering field work on and around the Peace River between the Williston Reservoir and the Alberta border to inform construction plans, mitigation and monitoring programs.

MEETING THE NEEDS OF BC HYDRO

The main goals for the Highway 29 Realignment project as mandated by BC Hydro are centered on the following:

1. Meeting specified project timelines to ensure bridges and highway are completed ahead of key milestones in the Site C Clean Energy Project timeline, such as the start of reservoir filling in September 2023.
2. Designing new bridges that are cost effective, and have a 75-year service life with minimum maintenance needs to provide a sustainable bridge asset for BCMOTI.
3. Minimizing impacts to surrounding lands including archaeological sites, agricultural lands and private properties.
4. Mitigating all geo-hazards including landslide generated waves resulting from large slope failure of the Peace River banks and valley walls.

Final Deck Pour on Halfway River Bridge

Goals No.1 and No. 2 were primarily achieved by selecting an optimal bridge configuration that is commonly used in BC and has proven to be cost-effective, and by implementing standard and durable design details for all five bridges whenever possible to streamline design process and production, as well as to allow for efficiencies during construction and minimum maintenance needs during operations. Additionally, the use of precast concrete components improved concrete quality by shifting on-site construction to shop fabrication in a controlled environment.

Goal No. 3 was a key consideration behind all major decisions that shaped the project, such as selecting highway / bridge alignments to completely avoid interferences with cultural and historical sites, protecting valuable environmental habitats during and after construction, and minimizing impacts to agricultural lands and private properties.

Goal No. 4 was achieved by using a risk-based design approach as described in the Complexity section of the report.

PROJECT SUCCESS

Three project benefits to the community and BC Hydro successfully achieved by WSP are:

1

SITE C CLEAN ENERGY

All bridges and approaches were completed and opened to public on time as determined by Site C overall project timeline. The on-time completion of Highway 29 bridges facilitated one of the last steps in building Site C, that is, to fill the reservoir, which allowed BC Hydro to put the generation station, spillways, turbines, and generators into operation. This will provide 1,100 megawatts of capacity and produce about 5,100 gigawatt hours of electricity each year – enough to power 450,000 homes or 1.7 million electric vehicles.

2

SUSTAINABILITY

All valuable environmental habitats at each site were protected and preserved during and after construction by avoiding permanent and temporary works in watercourse and any environmental sensitive areas, using diversion channels, temporary culverts, and bridges as required.

3

COMMUNITY

Bridge alignments and crossing locations were thoroughly studied and carefully selected to minimize impacts on agricultural lands, private properties, cultural and historical sites, and to enhance recreation and tourism opportunities for local communities. The realigned highway and bridges are safer and more reliable for local residents and heavy trucking industry and shall serve the communities for years to come.

WSP is one of the world's leading professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, architects, planners, surveyors, environmental specialists, and other design, program and construction management professionals. We design lasting solutions in the Transportation & Infrastructure, Property & Buildings, Environment, Power & Energy, Resources and Industry sectors and offer strategic advisory services. With approximately 66,500 talented people globally, including more than 12,200 in Canada, we engineer projects that will help societies grow for lifetimes to come.