BRITISH COLUMBIA HIGHWAY REINSTATEMENT PROGRAM

HIGHWAY 5 – CATEGORY B PROJECT

CANADIAN CONSULTING ENGINEERING AWARDS 2024

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PROJECT BACKGROUND

In November 2021, an atmospheric river pummeled British Columbia (BC), and led to devastating flooding throughout the province which significantly damaged critical highway infrastructure. Specifically, the flooding completely closed Highway 5 between Hope and Merritt, BC with six collapsed bridge spans and abutments, multiple undermined bridge abutments, eight culvert washouts, over 1.5 km of highway washouts and 24 sites impacted by slide debris or washouts along the corridor. In response to this catastrophic flooding, Kiewit and Emil Anderson Construction (EAC) provided significant emergency response efforts to safely re-open this critical highway corridor. Mobilizing more than 300 workers, 200 pieces of equipment, and over 80 subcontractors and vendors to repair and re-open Highway 5 to essential commercial vehicles at a reduced lane capacity, in just 35 days – more than six weeks before the Province's expected date.

"The impact of the emergency repair efforts and the speed at which they were completed cannot be understated." British Columbia Transportation Minister Rob Fleming said at a news conference, that the reopening of Highway 5 was **"one of the most remarkable engineering feats in recent memory in the province of British Columbia."**

"We're grateful for the effort that Kiewit put in, pulling people from all over the place to come and work on the Coquihalla," said Jennifer Fraser, Executive Project Director for the Highway Reinstatement Program for the British Columbia Ministry of Transportation and Infrastructure (MoTI). **"Given the fact that we were able to open a month ahead of when we originally anticipated, it is a testament of Kiewit's ability to mobilize at that scope and scale."**

Following the emergency response work, MoTI launched the BC Highway Reinstatement Program to permanently repair the various affected highways across BC. In a departure from tradition, MoTI chose the Alliance delivery model, which is an innovative collaborative contracting approach in which the Owner, Contractor and Designer form an integrated project team and share in project risks and rewards.

The Highway 5 project was executed by the Coquihalla Alliance Team (C.A.T.5) comprised of owner MoTI, and the KEA5 Partnership comprising Kiewit and EAC as the Constructor and Kiewit as the Designer. The Alliance team was supported by BASIS Engineering as design subconsultant and by several construction subcontractors that were aligned to the organization and integrated into the Alliance Team. The overall scope of work for the permanent repairs included the design and construction of six new permanent bridge structures, two temporary bridges and associated 4.53 km highway (two-lane one direction) reconstruction which expanded and strengthened revetments along the rivers near the bridge crossings at three sites along Highway 5 between Hope and Merritt, BC.

MoTI had ambitious schedule targets for reinstating four lanes of traffic before the 2022 Christmas holidays – just seven months after contract award in May 2022 – and to complete all highway reconstruction by December 2023. Due to the impromptu nature of the project, at the time of award there was no reference design concept, design basis, definition of project requirements, stakeholder consultation, construction contract, governance plans, and many other foundational elements typically established before projects are awarded for construction.

INNOVATION

The Alliance Delivery Model

Working Together to Design and Construct under a True Collaborative and Best-for-Project Mentality

The most significant innovation on this project was MoTI's use of the Alliance model for the first time on a transportation project in British Columbia. Much of the innovative design and construction was a direct result of the Alliance approach.

In the Alliance model the Owner, Constructor and Designer sign a joint contract that incentivizes them to set aside their individual interests and to act as a team to make best-for-project decisions. An Alliance aims to achieve positive project outcomes with the following features:

- **It precludes the parties from submitting claims against each other.** The Alliance team is empowered to solve project issues, mitigate risks, capture opportunities and deal with unexpected events without claiming as a recourse.
- **The Alliance team works together to develop preliminary designs, prepare design and construction schedules and cost estimates on an open book basis, which are based on real-time availability of materials, labour, constructability, and optimized design solutions (the Development Phase).**
- **Overruns and underruns of the TOC are shared by the Designer, Constructor and Owner.** The Designer and Constructor are paid for all direct costs by the Owner, irrespective of the Actual Outturn Cost (AOC), however Design and Constructor's overhead and profit are at risk.
- **Designer and Constructor performance are further measured against Key Performance Indicators (KPI) that are established by the Alliance team at the outset of the project, and that are aligned with the project objectives.**

Developing a Feasible Timeline and Achieving Schedule

The Alliance model was instrumental in achieving the project's ambitious schedule goals – a result that a conventional design-bid-build delivery couldn't provide. Use of the collaborative model was critical to the Alliance Team overcoming challenges and meeting schedule objectives through:

- **Mutually identifying and allocating project risks and developing feasible mitigations.**
- **Using a shared risk/reward regime to drive a "best for project" mindset and achieve the project objectives with end-users in mind.**
- **Integrating Designer, Constructor and Owner deliverable reviews to accelerate project schedule, rather than executing them sequentially, as is typically done.**

Embedded Decision-Making Hierarchy to Facilitate Collaboration, Communication and Cooperation

The Alliance model, comprised of representatives from each organization, ensured collaboration and communication not only across entities, but also created a decision-making hierarchy. The Alliance contract governance relies heavily on the active participation of the members named to its governance bodies, the Project Management Team (PMT) and the Senior Leadership Team (SLT), to which the PMT reports. The PMT comprises Project Director, Construction Manager, Design Manager and Owner Representative. The SLT comprises representatives of the Constructor, Designer and Owner (which in this case is represented jointly by individuals from MoTI and Infrastructure BC). All decisions must be made unanimously by each group. The Project Director chairs the PMT and is responsible for interfacing with the SLT, who have the highest level of authority for decision making on the project. This approach facilitated prompt resolution of challenging issues, promoted constructive engagement among team members, and ensured alignment among all project stakeholders.

Overlapping the Development Phase and the Execution Phase

Due to the aggressive schedule, this Alliance project was unique in that the development phase and execution phase overlapped significantly with **approximately 25% of the site work being completed before executing the execution phase agreement.** Activities typically completed before design begins, such as defining the required scope of work, interested party engagement, establishing project requirements and specifications, and completing business cases, moved in parallel with design, construction planning, and early procurement of materials. With each group moving simultaneously, small changes in direction had the potential for large ramifications. This approach involved making decisions based on the best information available at the time that could advance the project and structuring the team's activities to support those, without looking back and second guessing.

The Benefit of Fully-Integrated Taskforces

Discipline-specific taskforces that incorporated design, construction, estimating, procurement, and owner staff were established. Taskforces streamlined review processes to accelerate the release of design materials for construction. Key vendors were engaged early so that readily available materials could be incorporated into designs, shop drawings could proceed in parallel with design, and long lead times in procurement could be avoided.

Involving the Owner in design development as an integral part of the interdisciplinary team, rather than as an external reviewer, facilitated real-time feedback that empowered the Owner to contribute to the evolving design and participate in critical decisions before design deliverables were completed. This departure from the conventional design-build approach significantly reduced the usual back-and-forth exchanges, saving both time and energy and accelerated the overall schedule.

Integration of Procurement and Vendors into Taskforces

Vendor design teams were also integrated into taskforces for items like the pre-engineered retaining walls, structural steel girders, concrete girders, precast concrete deck panels, and bridge bearings so materials that were readily available could be incorporated into the design, shop drawings could proceed in parallel with design, and long lead times could be minimized. This collaboration reduced shop drawing review times and the need for resubmittal or updating IFC drawings to match vendor preferences.

Arranging design deliverables to match the construction sequence. The team worked to identify early procurement packages that were on the critical path, such as steel girders, precast girders, pile installation details, etc. The design team worked to provide Issued for Construction (IFC) or Issued for Procurement (IFP) packages for these specific items with appropriate caveats on the drawings to allow the construction team to begin procurement and, in the case of piling, early piling works before the design was completed.

The design team also worked closely with the construction team to expedite site clearing and grading work while the detailed designs were progressed. Permanent highway and temporary detour alignments at each site were established and agreed to by the Alliance Team early in the design stage, so that clearing and grubbing work could be expedited for site preparation. Following closely was the expedition of highway designs to meet the final design and operational requirements, which permitted efficient transitions from site preparation work to grading work. Where temporary detours and permanent highway alignments overlap, careful design considerations minimized re-work and permitted simple transitions from detour operations to permanent highway operations.

Design and Construction Innovations

Design Innovations

In some cases, innovative approaches were implemented specific to a bridge location, and in others, were implemented project-wide. In many cases, decisions had to be made before the design could be finished. Where possible, solutions were chosen that afforded maximum adjustability, either in the opportunity to increase strength if needed, or modify geometry at a later date. The major innovations implemented on the project were:

Selection of Bridge Type

Design Decision-Making around Material Availability | On-time completion was the Owner's primary project objective. Therefore, taskforce groups analyzed and selected structural solutions that prioritized completion schedule over material cost. As the procurement of bridge construction materials was going to be unusually fast, consideration was also given to availability of key bridge components and the capacity of local suppliers. **The Alliance contract model allowed the team to go directly to suppliers and vendors with authority and engage them in the process early. This allowed design and procurement to work in tandem, and design solutions were developed around those materials that were readily available or that reduced procurement durations**. For example, Rapid-Span, one of the structural steelwork suppliers, rescheduled production of another project with schedule float to provide urgently needed shop space to begin early fabrication.

Structural Forms based on Required Span Arrangements, and Procurement and Schedule Demands | Two structural forms were chosen, partly to match the span arrangements required, but also to meet procurement and schedule demands:

- **Juliet Bridges were designed to use precast concrete box girders.** This was the fastest construction method for the required span lengths. Precast concrete box girders are relatively easy to procure, faster to erect, and once in place acts as a formwork for a quick deck placement. This allowed the team to complete construction of the replacement northbound bridge by the end of 2022, avoiding the requirement for a temporary bridge to facilitate construction staging.
- **Bottletop and Jessica Bridges were designed to use steel girders.** This was in part due to the longer main span required on each bridge: >45 m, too long for precast box girders, but also because much of the complexity of steel bridge construction is dealt with in the fabrication shop, taking time-consuming activities off the critical path. The schedule for preparation of the substructures allowed for the longer duration of steel fabrication.
- Having both Bottletop and Jessica Bridges as steel structures required too much work for a single supplier to meet the aggressive schedule. Therefore, it was decided to engage two steel fabricators – one for each location. This allowed the bridges to be fabricated in parallel. The team used existing Bottletop Bridge steel in the design of the temporary detour bridge at Jessica using a full depth precast panel. Maintaining a clear span using salvaged steel girders allowed for faster construction using precast elements in an extremely constrained site.

Use of Steel Pipe Piles to Address Soil Conditions

An early critical path item was the design and installation of piles. The ground investigation program at each site began within one month of project award and the selection of pile type and diameter was based on what was used for the original bridges and what was readily available in the Lower Mainland. At all three sites, 914 mm diameter by 19 mm wall thickness steel pipe piles were used, however the pile design and installation approach varied between sites based on the local ground conditions, and were refined after selection and purchase of the steel pipes.

At the Jessica Bridge, ground conditions comprised dense to very dense deposits of sand and gravel with cobbles and boulders to depths of about 30 m, underlain by very dense till with cobbles and boulders. As such, the piles were drilled to near the anticipated toe depth, concrete infill plugs were placed, and the piles were finally driven to mobilize the full end bearing capacity.

At the Bottletop Bridge, ground conditions comprised sand and gravel deposits with cobbles near the ground surface underlain by interbedded layers of sand and silt at depth, similar to Juliet. Pilot holes were drilled to clear the cobbles at the pile locations, below which the piles were driven. The Juliet pile design and installation approach was modified to reduce the required toe depth by driving the piles to near the target toe depth, placing concrete infill plugs and then re-driving until the required pile installation termination criteria was achieved.

Revetment Design and Installation

To mitigate future flooding impacts, the riprap revetments comprised self-launching aprons to reduce excavation depth and allow construction to occur offset from the river, minimizing river impacts and limiting dewatering needs during construction. Custom riprap gradations were developed that reduced the maximum rock size within a riprap class, simplifying riprap transport and placement, reducing cost and shortening schedule.

Collaborative Approaches to Traffic Management

Highway 5 is one of the most important transportation corridors in BC and is situated in a topographically challenging area with no nearby alternate route. Any necessary detours in the event of partial or full highway closure would add significant travel time and distance for the public, commercial, and emergency traffic to reach their destinations. The project sites are also adjacent to the Trans Mountain Expansion Project (TMEP) Spread 5A and 5B project alignments; thus, our Traffic Management Plan incorporated provisions to manage the traffic movements to complete Highway 5's scope of work, and coordinated with two separate TMEP contractors to ensure compatibility with the traffic management setups for all projects.

The Alliance Team's collaborative approach facilitated communication and coordination between construction crews, maintenance service providers, MoTI, and the adjacent TMEP teams to ensure traffic would not be disrupted by unexpected maintenance or construction operations. Coordination meetings with the highway maintenance contractors and MoTI representatives were conducted before every switch of traffic, and site drive throughs were conducted to optimize the traffic control layouts with the adjacent projects. Despite the aggressive project schedule, continuous traffic flow was always maintained with effective staging schemes that maximized workspace in the narrow corridor while minimizing traffic disruptions. **Because the traffic management strategy differed at each bridge location, traffic innovations are described below under the bridge-specific innovations.**

Throughout construction, the Alliance Team's traffic management personnel received praise from MoTI and their maintenance contractors for the support provided during emergency responses to traffic incidents that occurred on Highway 5 outside of the project limits. This included partial and full closures of the highway to allow access for emergency responders and to facilitate highway clean-up by maintenance contractors.

Bridge Design Innovations

Jessica Bridge

Innovative Design Elements

The Jessica Bridges cross the Coquihalla River approximately 20 km north of Hope. The new northbound and southbound Jessica Bridges are identical, each comprising three spans of continuous steel plate girders, with abutments and piers skewed to the river. There are four girder lines supported on concrete pier and abutment caps. Each foundation consists of four composite pile/columns, with 19 mm thick steel casing extending up the underside of the cap. The main span is 58 m, 4 m longer than the original span, while the side spans were extended to 36.5 m, increasing the total bridge length from 85.4 m to 131 m. The original structure had discontinuous spans, with short side spans and deck joints at each pier, which were poor for durability.

The longer bridge provides a wider channel opening and shallower revetments, meeting updated 200-year return period river flows and accounting for climate change.

The longer main span allowed the new piers to be placed immediately behind and in line with the original piers. This allowed the original piers to be demolished at the same time that the piling was done on the new piers, overlapping critical path activities and optimizing the schedule.

Innovative Temporary Bridge

At the Jessica site, a temporary bridge was constructed between the two permanent bridge alignments. This detour served dual purpose as the southbound detour first, while the permanent southbound bridge was constructed, then reconfigured to a northbound detour while the permanent northbound bridge was constructed. The design of the detour approach roadways minimized material throwaways and the time required for the detour reconfiguration from southbound to northbound. The traffic control setup also required compatibility with the adjacent TMEP construction, where the traffic was always maintained. The temporary bridge was squeezed into the narrow space between the two existing structures. The gap was too narrow for the more traditional temporary modular truss bridge used at Bottletop. Instead, the girders from the demolished northbound Bottletop Bridge were used to create a custom narrow temporary bridge, with only a metre to spare on either side.

Juliet Bridge

Innovative Design Elements

The Juliet Bridges cross Juliet Creek, a Coldwater River tributary, approximately 55 km south of Merritt. The new Juliet Bridges consist of four spans of pre-cast concrete box girders. Each span includes seven box girder lines with integral piers supported on four columns and semi-integral abutments. All piers and abutments are supported on four concrete-filled steel pipe piles. **An additional side span was added to the north end of the bridge (relative to the original bridge), increasing the total bridge length from 89 m (17.5 m, 36 m, 35.5 m), to 107 m (25.2 m, 30.5 m, 26 m, 25.2 m), providing space for the river to expand under extreme rain events, and adapt to climate change. The spans were kept short, permitting use of precast box girders, a cost effective and fast construction option.**

Innovative Traffic Control

At the Juliet Bridge, capitalizing on the wide separation between the two original bridge alignments, the Alliance Team determined that the most efficient approach was to construct the new northbound bridge in the median and use it temporarily as a southbound detour while the new southbound bridge was under construction. **This approach eliminated the need for temporary detour structures to restore four traffic lanes and expedited the new bridge construction. The result was that four lanes were reinstated by December 2022 and facilitated the new southbound construction early in 2023.** After the new southbound bridge was constructed, northbound traffic was efficiently transitioned to the new northbound bridge, as the temporary southbound detour was constructed with the permanent northbound alignment in mind, such that only the top portion of the pavement structure had to be constructed to suit the new northbound alignment.

Bottletop Bridge

Innovative Design Elements

The Bottletop Bridges cross the Coldwater River approximately 2 km north of the Juliet Bridges. The new Bottletop Bridges consist of four spans of continuous steel plate girders, keeping the existing bridge skew angle. There are four lines of steel plate girders with conventional piers and abutments on four columns on concrete-filled steel pipe piles. **An additional side span was added to the south end of the bridge (relative to the original bridge), increasing the total bridge length from 82.7 m to 156 m (33.4 m, 41.5 m, 48 m, 33 m), providing space for the river to expand under extreme rain events, and adapt to climate change. The additional span provides for the bend migration that was seen during the flood event in 2021. The new structure, like Jessica Bridge, replaced simple spans with continuous span, removing deck joints from the bridge and improving durability.**

At both the Bottletop and Jessica Bridges, the pass-through abutments were located at the expansion joint behind the backwall, significantly reducing the risk of road water runoff draining onto the ends of the girders and the bearings, minimizing the corrosion risk and extending the bearing life. This provides the benefits of semi-integral abutments, commonly used on shorter and less skewed bridges, without the complexity associated with bridge expansion and contraction being carried by the fill and roadway behind the abutments.

Innovative Traffic Control

At the Bottletop Bridge, the Alliance Team reviewed the site constraints and existing highway right-of-way available and determined that an offline detour with a modular temporary bridge would provide the most efficient construction. The modular temporary bridge was erected parallel to the existing highway alignments for use by the southbound traffic to avoid interfering with ongoing construction activities for the new permanent bridges. Once southbound traffic was shifted to the temporary bridge, two lanes of northbound traffic could be restored on the old southbound bridge. Once the new northbound bridge was constructed, northbound traffic was moved to the permanent alignment so that work could start on constructing the new southbound bridge. During this time, southbound traffic continued to operate on the temporary bridge with minimal impacts on traffic.

OUTCOMES

Delivering the project with a tight schedule

In December 2022, just seven months after contract award, all design was complete and one new bridge and two temporary bridges had been constructed, restoring four lanes of traffic between Hope and Merritt. In October 2023, all bridge construction was complete, including six permanent bridges, construction and removal of two temporary bridges, and demolition of six damaged original bridges – two months ahead of target.

This was achieved largely because of the collaborative team-based approach. The Alliance Team assessed the project risks and desired outcomes together, and worked collaboratively to ensure that changes in both temporary detour design and permanent highway/bridge design were minimized. With the project criteria established and agreed to early in the project, the design team could focus on delivering the design packages necessary to facilitate cost estimation, procurement, and construction.

Incorporating Climate Change Resilience

The collaborative nature of the Alliance model allowed Kiewit to incorporate MoTI's goals for climate change resiliency into the designs. Replacement bridges longer in length than the original structures met MoTI's Build Back Better initiative in support of resilient flood planning. **The increased bridge lengths accommodate 200-year return period river flows and provide improved resilience.**

The longer bridges allowed for wider waterway openings that better match the upstream and downstream river geometry. Reducing the river width through a bridge opening, as the original bridges did, alters the erosion and deposition rates of the river. These changes could result in a more active river, including migration of the river, avulsions, and landslides. Matching the existing river geometry through the bridge opening allows the river to maintain its regime and reduces the risks of unintended erosion and deposition upstream and downstream of the bridge. The longer bridges allow for a more natural river design through the opening, consisting of a low flow channel and an overbank. The low flow channel improves the aquatic ecosystem, while the overbanks are used to convey larger floods. To improve the biodiversity in the overbanks, the riprap was set back and buried, allowing for plantings and wildlife passage along the waterway opening. The nature-like overbanks also allow the river to adapt to changing climatological conditions, while the buried riprap revetments will protect the bridge structure in extreme flood conditions. The revetments were designed to withstand maximum scour depths and water levels that could result from increased peak flows due to climate change, and the riprap was sized to provide a stable protection against velocities and turbulence associated with these high flow events.

Benefits to the local area and community

The Team set goals for local participation and input, leading to various economic and social benefits, including:

- Procuring more than $27.8 million of locally sourced material and contracts, including to Indigenous businesses and partners.
- Utilizing more than 28,777 hours of labour from local and Indigenous workers.
- Planted approximately 4,500 native plants at the bridge locations to help return the environment to its natural landscape. These plants will provide habitat for wildlife, encourage the use of the bridges as wildlife underpasses, and enhance fish habitat through shoreline shading.
- Successful participation from the local Indigenous communities resulted in enhanced capacity and further development of a talented and committed workforce with community members and community-owned businesses prepared to participate in future opportunities.

Ability to Merge Owner Needs with Feasibility to Achieve Owner Objectives

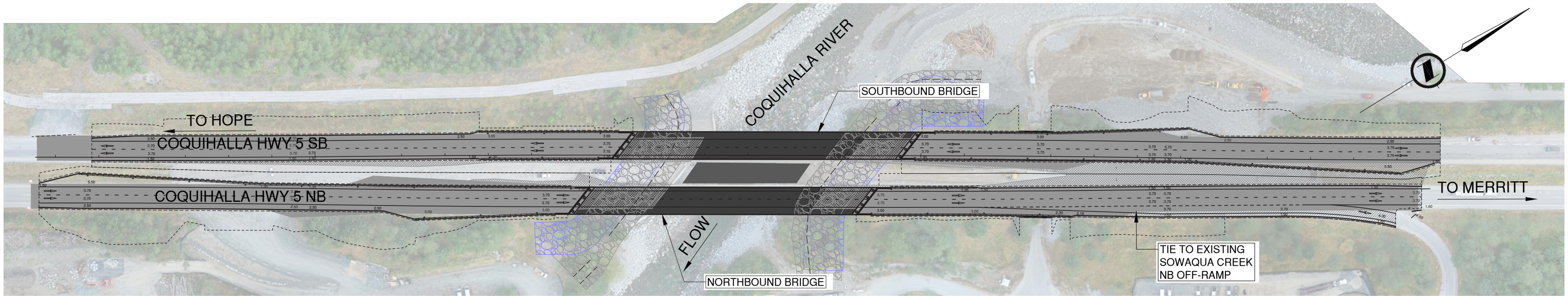
With increasing frequency of extreme weather events and consequently emergency projects across the country, the success of the Highway 5 project demonstrates that the collaborative Alliance delivery model can be utilized to successfully respond to unexpected needs in the transportation market. The collaborative model was key to completing this project ahead of schedule and critical to creating successful relationships between the Owner, Designer, Contractor, and local Indigenous groups affected by the work.

Inherent decision-making hierarchy

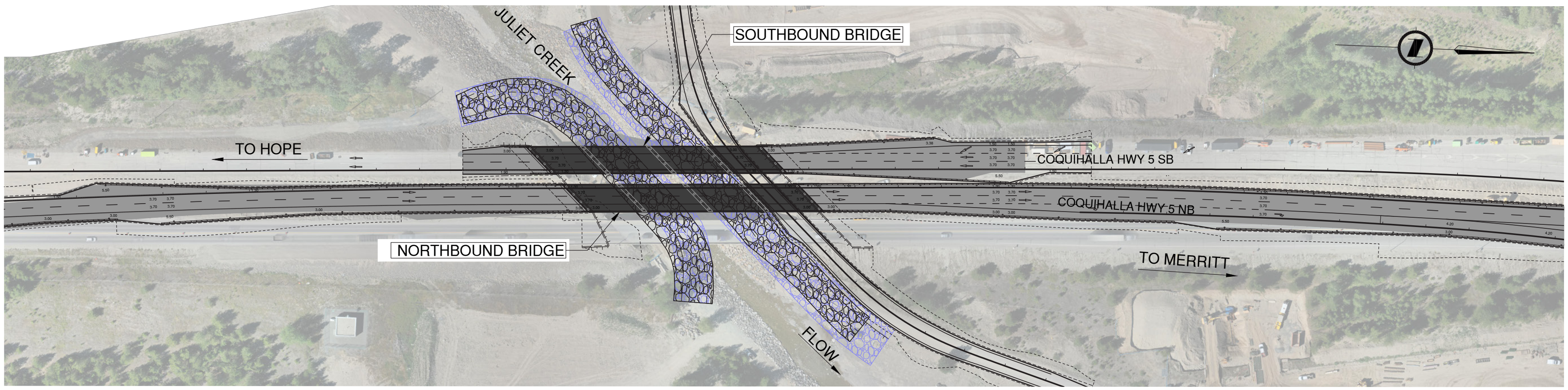
The Alliance Senior Leadership Team (SLT), comprised senior and executive-level representatives from each organization, and the Project Management Team (PMT), comprised project management representatives from each organization, ensured collaboration, communication and implementation of an effective decision-making hierarchy. The Highway 5 project implemented a unified organizational structure, merging personnel from the Owner, Designer and Contractor to streamline tasks like daily reporting. Furthermore, a two-tiered governance model ensured comprehensive input to critical project decisions. This approach facilitated prompt resolution of issues, promoted constructive engagement among team members, and ensured alignment among all project stakeholders. This collaborative model grows trust and understanding between entities and creates relationships built on understanding and trust to deliver positive project outcomes.

![Kiewit]

CANADIAN CONSULTING ENGINEERING AWARDS
TRANSPORTATION CATEGORY
BC HIGHWAY 5 - CATEGORY B PROJECT



HIGHWAY 5 - JESSICA BRIDGE



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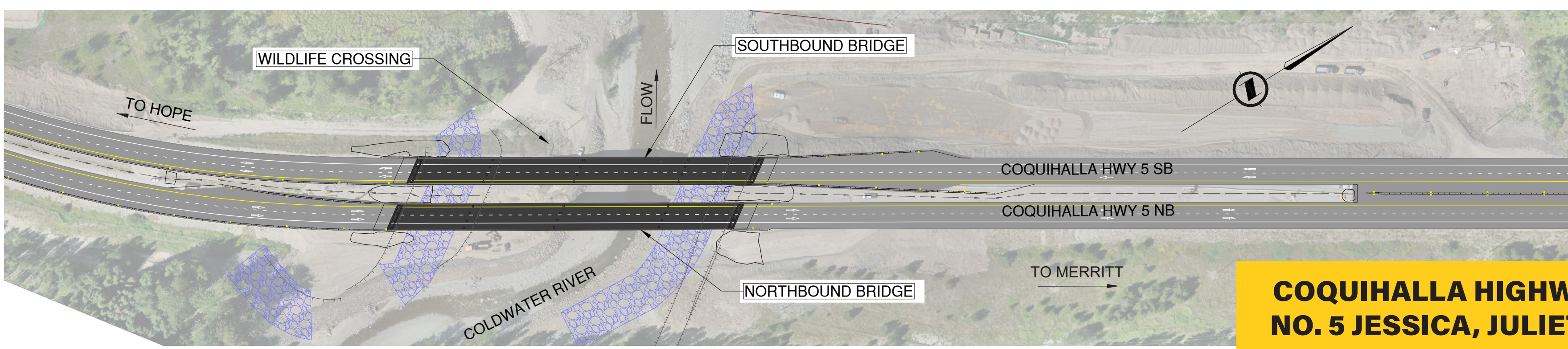

HIGHWAY 5 - BOTTLETOP BRIDGE

COQUIHALLA HIGHWAY NO. 5 JESSICA, JULIET & BOTTLETOP BRIDGES