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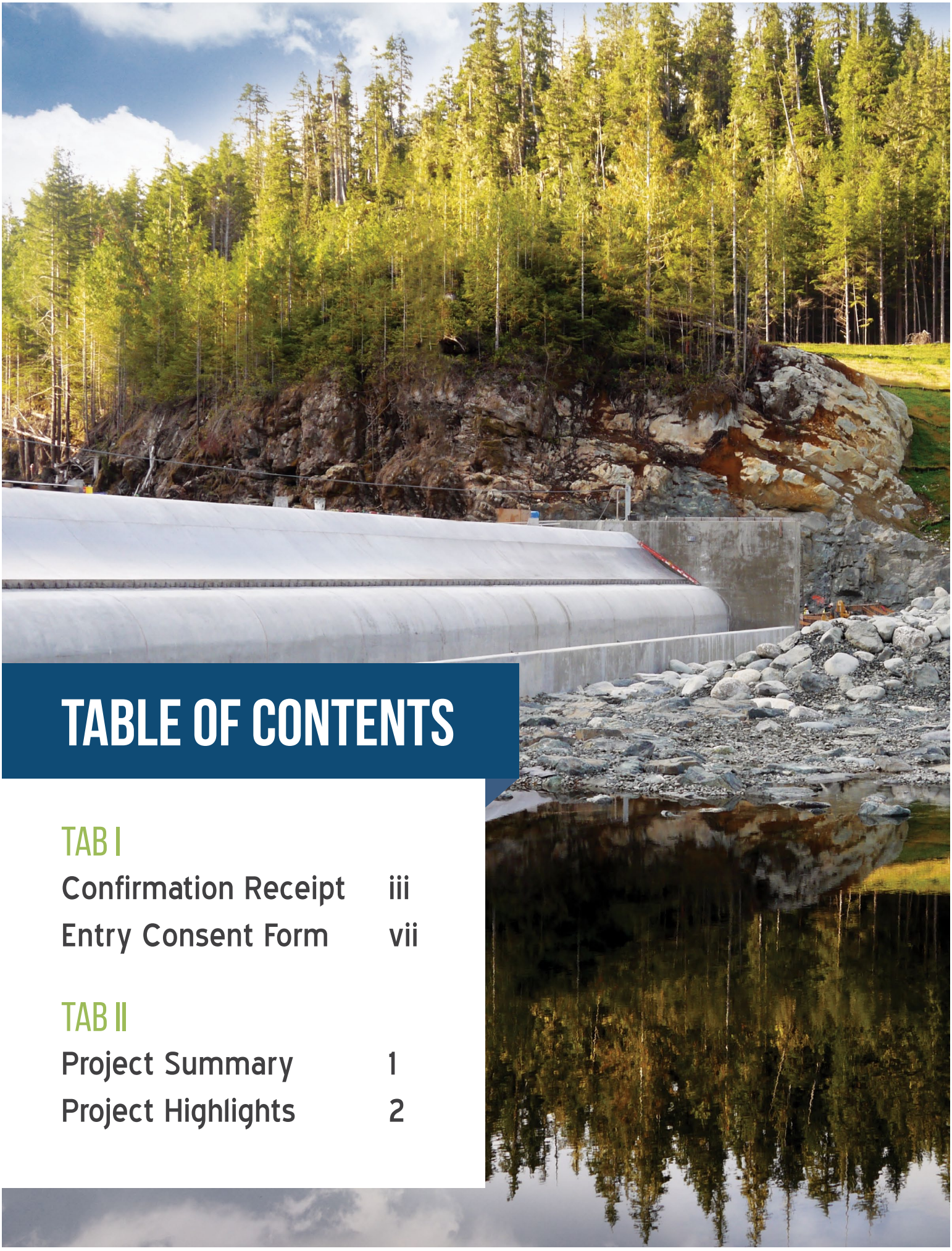
CANADIAN CONSULTING engineer

KOKISH RIVER HYDROELECTRIC PROJECT

Canadian Consulting Engineering Awards 2015

Technical Category E: Natural Resources, Mining, Industry, Energy

VA103-18/15



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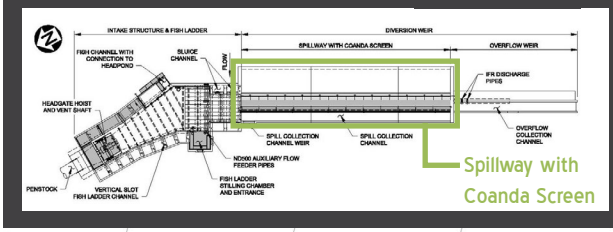
KOKISH RIVER HYDROELECTRIC PROJECT

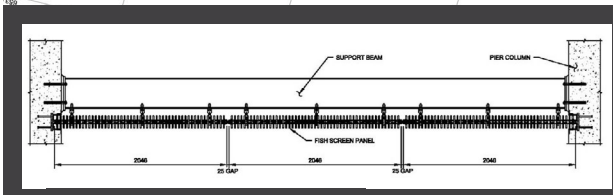
TECHNICAL CATEGORY E: NATURAL RESOURCES, MINING, INDUSTRY, ENERGY

Project Summary

The Kokish River Hydroelectric Project is a 45 MW run-of-river facility near Port McNeill, BC. As the lead Design Engineer, Knight Piésold Ltd. worked closely with Kwagis Power Limited Partnership (Owner) and Peter Kiewit Infrastructure Co. (EPC Contractor) to develop innovative and cost-effective solutions that exceeded fisheries permitting requirements, through a temporary river diversion during construction, a wrap-around fish ladder, a diversion weir and Coanda screen arrangement, and a tailrace fish screen.

Headworks

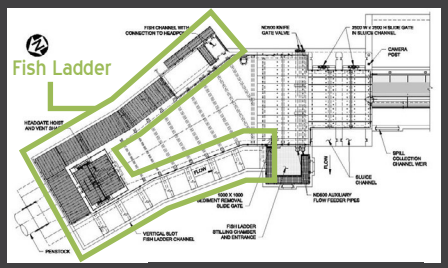




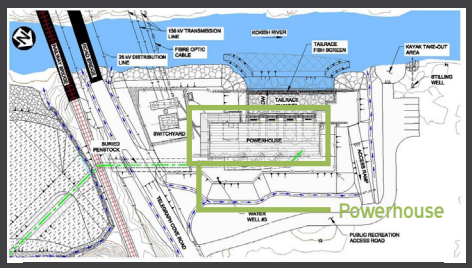
Fish Screen: Typical Detail

General Arrangement Project Overview Plan

Temporary Diversion Channel Plan



Intake Structure Plan



Powerhouse and Switchyard Overall Layout

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KOKISH RIVER HYDROELECTRIC PROJECT

TECHNICAL CATEGORY E: NATURAL RESOURCES, MINING, INDUSTRY, ENERGY

Project Highlights

INNOVATION

The Contractor, Peter Kiewit Infrastructure Co. (Kiewit) completed the design and construction of the Kokish River Hydroelectric Project in an Engineer-Procure-and-Construct (EPC) venture with the Owner, Kwagis Power Limited Partnership (Kwagis). As the lead Design Engineer, Knight Piésold Ltd. (KP) worked closely with Kiewit and Kwagis in a collaborative design-build environment that guaranteed plant performance, construction schedule, and price. KP designed a project that included many unique and innovative details that catered to the sensitive environmental attributes of the site; primarily the presence of steelhead trout and salmon throughout the diversion reach. The design included one of the largest capacity Coanda screen intakes in the world, combined with probably the smallest Obermeyer crest gate in the world, and a vertical slotted fish ladder, to allow for the safe passage of adult and juvenile salmon and steelhead trout past the structure.

> “. . . designed a project that included many unique and innovative details that catered to the sensitive environmental attributes of the site . . .”

Headworks general arrangement

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Intake and Diversion Weir

The intake and diversion weir were designed to provide the following functions:

- Divert a portion of the natural stream flow to the water conveyance system, while excluding large sediment and debris to limit damage to the pipe and turbine generating equipment.
- Provide safe passage for both adult and juvenile salmon and steelhead trout past the intake and diversion weir for upstream and downstream migration. The innovative design included a large vertical slotted fish ladder for upstream migration of adult fish and a small Obermeyer crest gate to facilitate safe downstream migration of juvenile fish.
- Provide the instream flow release (IFR) downstream of the intake to maintain natural aquatic ecology. IFRs varied by season and month from 3.4 m^3/s to 12 m^3/s.
- Allow passage of flood flows without damage to the structure.

Vertical slotted fish ladder, operation of downstream section

Diversion weir with sluice channel outlet and fish ladder entrance nearside, possibly one of the world's largest capacity Coanda screen spillway

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Water Conveyance System

The water conveyance system for the project is long compared to typical run-of-river projects. This necessitated special design consideration for pipe material selection, routing, and installation. Over its entire length, the thin walled pipe sections were designed to be directly buried in the natural ground making use of engineered fills to restrain pipe movement and thus eliminating the need for concrete anchor blocks.

9,300 m long, large diameter penstock buried using soil restraint to eliminate concrete anchor blocks

Powerhouse

A unique feature of the powerhouse design is the fish fence across the tailrace outlet to prevent adult salmon and steelhead trout from entering the tailrace, and to generate flow patterns that would encourage the fish to continue on their upstream migration.

The project has been successfully completed and salient details for the major components of the project are summarized to the right:

Rated Plant Capacity
45 MW

Design Flow
25 m^3/s

Penstock Length
9.2 km with a diameter of 3.05 m HDPE to 2.73 m Steel

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Gross Head

238 m

Turbine(s)

Four 6-Jet Vertical Axis Pelton Units

Switchyard

13.8 kV to 138 kV Transformers

Transmission Line

138 kV Transmission Line

Surface powerhouse housing four vertical axis multi-jet Pelton type turbine generator units

COMPLEXITY

The variable IFRs for the project are larger and more varied than most run-of-river projects in BC due to the presence of salmon and steelhead trout throughout the diversion reach. The IFR release system design allows for precise control and real-time flow monitoring.

A purpose-built 1:12 scale **hydraulic model of the intake and diversion weir** was tested in Northwest Hydraulic Consultants' hydraulic laboratory to verify sediment and debris migration past the diversion weir and to confirm operational requirements, such as the balancing of fisheries bypass flows and diversion of generation flows. The hydraulic model also evaluated flow patterns entering the penstock, through the vertical slot fishway, approach channels, and downstream waterfalls and rapids to protect the natural river geomorphology and flows from being altered, ensuring fish migration as in pre-project conditions.

Headworks, physical hydraulic model, 1:12 scale

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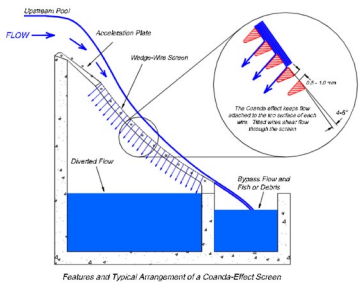
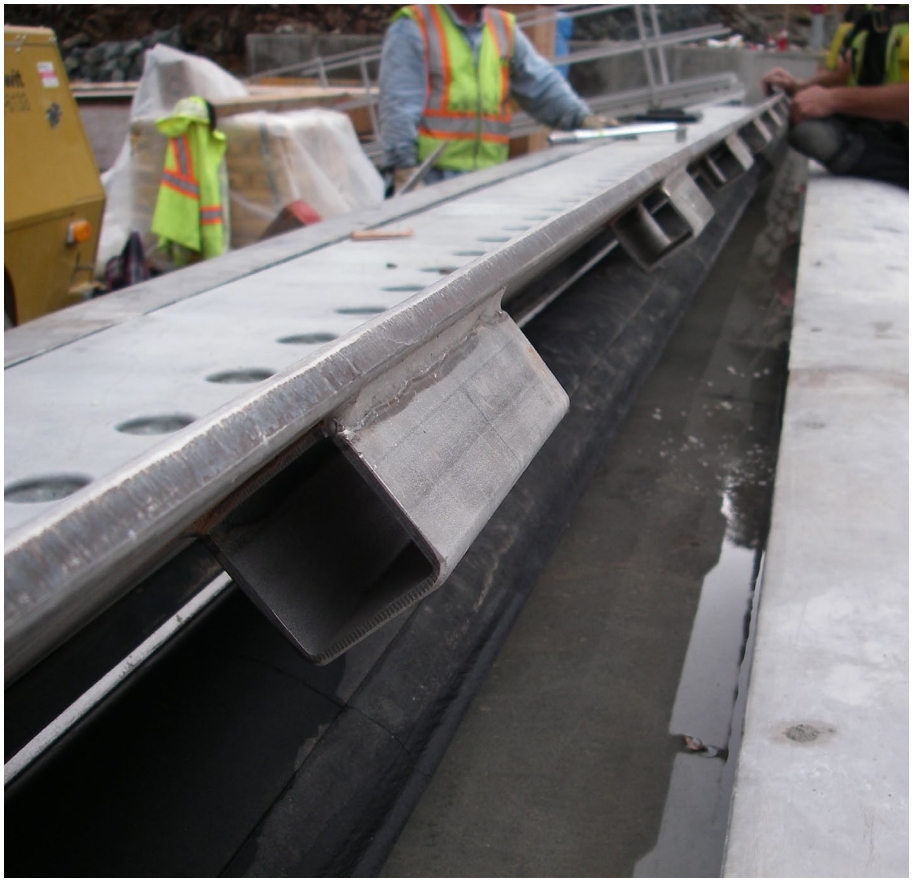
TECHNICAL CATEGORY E: NATURAL RESOURCES, MINING, INDUSTRY, ENERGY

The diversion weir arrangement incorporates **Coanda Shear Effect screens** that pass generation flows, while preventing debris, course sediment, and fish from entering the generation stream. The KP team completed extensive research and model testing to optimize the Coanda screen configuration, including length, width, shape, slope angles, and wedge wire spacing. The throughput capacity of the spillway screens is one of the highest capacity installations in the world for a hydropower project.

To the best of our knowledge, the world's first **multi-segmented small Obermeyer crest gate** was added immediately upstream of the Coanda screen to allow the concentration of low flows over the weir and prevent fish stranding on a seasonally dry screen surface.



Features and typical arrangement of a Coanda-Effect Screen



Possibly the world's first multi-segmented small Obermeyer crest gate

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KOKISH RIVER HYDROELECTRIC PROJECT

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SOCIAL AND/OR ECONOMIC BENEFITS

The project is located 15 km east of Port McNeill, on the northern region of Vancouver Island, BC. The North Island's economy has experienced short-term cycles of recession, superimposed over longer term downward cycles related to the decline of local resource industries, such as mining, fishing, and forestry. With the decline in economic opportunity, there has been an exodus of residents from the region that will likely continue given the economic outlook. The 28-month construction of the project has provided direct and indirect socio-economic benefits to the regional economy and community, including approximately 75 person-years of labour and technical trades, nearly $30 million in goods and services related to heavy industry, as well as housing and accommodation, restaurants, grocery stores, etc.

Having the local First Nations as part of the Owner's development team provided a significant benefit to the project team, with the 'Namgis First Nation being able to share their in-depth knowledge of the site and surrounding environment, and traditional use of the area. All of these aspects were taken into consideration with the project's design, construction, and now operation.

The project was designed and constructed on time and on budget, and will generate clean renewable energy to power 13,000 homes in BC annually.

'NAMGIS FIRST NATION

The Owner, Kwagis Power Limited Partnership, is a partnership between Brookfield Renewable Energy Group and 'Namgis First Nation.

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ENVIRONMENTAL BENEFITS

The KP team has been involved throughout project development and was responsible for project optimization, permitting assistance, and preliminary engineering prior to completing the detailed design. Every step during the development process has taken into consideration the diversity of fish habitats in Kokish River. This diversity is due, in part, to the wide range of natural flows, which vary between over 300 m^3/s in the winter and 2 m^3/s during a dry summer. High flows flush organic debris and gravel from upper watershed sections into lower sections and replenish spawning gravel, but also remove fine sediments from existing spawning gravel beds. The diversion weir and intake structures were designed and constructed to ensure that during operations natural long-term sediment transport rates are maintained over the life of the project. Design considerations included:

- **Temporary river diversion during construction //** channel design focused on unique fisheries constraints, including:
  - High value fish habitat of the river section
  - Construction work had to be performed in a short duration fish window
  - Designed to pass Kokish River's naturally high flood flows
  - Facilitate year-round fish passage
- **Intake model testing //** purpose-built 1:12 scale hydraulic model of the intake and diversion weir was tested in Northwest Hydraulic Consultants' hydraulic laboratory to:
  - Verify sediment and debris migration past the diversion weir
  - Balance fisheries bypass flows and divert flows towards the intake
  - Penstock submergence requirements
  - Flow patterns through the vertical slot fishway, approach channels, and downstream waterfalls and rapids
- **Tailrace fish screen**

Juvenile fish allowed safe passage past the intake and diversion weir for downstream migration

The project area has a diverse habitat. Aside from fish, it is also home to other animals.

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Temporary diversion channel during construction of intake

Powerhouse tailrace channel fish fence

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MEETING CLIENT'S NEEDS

As the lead Design Engineer, KP partnered with Kiewit under an EPC contract for the design and construction of the project. The collaborative design-build environment allowed the Owner, EPC Contractor, and KP to design a project that guaranteed performance, schedule, and price. Customized project management tools, innovative design concepts, project optimization studies, and strong teamwork all played significant roles in the project's success. Some of these aspects included:

- Coanda ("shear-effect") intake screens are self-cleaning and prevent sediment inclusion into the penstock. The addition of a small Obermeyer gate on the crest of the Coanda screen allows for the safe passage of both adult and juvenile salmon and steelhead trout downstream from the diversion weir.
- A large vertical slot fish ladder to allow safe passage of adult salmon and steelhead trout past the diversion weir.
- Intake model testing for hydraulic design and optimization.
- Designing facilities and installing instrumentation to allow accurate and real-time regulation and measurement of generation and ecological bypass flows.
- Designing the facilities to sustain existing river bed morphology and minimizing the need for dredging or other mechanical sediment removal methods.
- Designing a cost-effective and robust large diameter penstock that is over 9,000 m in length and exposed to hydraulic transient pressures internally and logging road traffic and natural forces externally.
- Designing a tailrace channel and fish fence to prevent adult salmon and steelhead trout from entering the tailrace, and generate flow patterns to encourage fish to continue on their upstream migration.

> The partnership of Kiewit and Knight Piésold Ltd. played a significant role in the development and design of this project, particularly for the Intake Structure and Powerhouse Tailrace, which achieved fish passage and fish exclusion as required by the Environmental Assessment Certificate.
>
> Bill Payne, Director, Project Development, Brookfield Renewable Energy Group

KWAGIS POWER

Owner

Kiewit

Client and EPC Contractor

Knight Piésold CONSULTING