Knight Piésold used unique and innovative designs when working on the Kokish River hydropower project in Canada.

Knight Piésold recently received an award for engineering excellence from the Association of Canadian Consulting Engineers for the detailed design and construction supervision of the Kokish River hydroelectric project. The award was in recognition of the project’s unique solutions and innovative designs that cater to the sensitive environmental attributes of the site, primarily on the presence of steelhead trout and salmon throughout the diversion reach.

During every step of the project development process the diversity, attributes and value of fish habitats in the Kokish River were considered and design and construction techniques were implemented to safeguard these values. As an example, the diversion weir has one of the largest capacity Coanda screen spillways capable of regulating spillway flow water depth over the screen with one of the smallest Obermeyer crest gates in the world.

A diversion weir with one of the world’s largest capacity Coanda screen spillways capable of regulating spillway flow water depth over the screen with one of the smallest Obermeyer crest gates in the world.

A 70m long vertical slotted fish ladder that wraps around the intake box, allowing continuous fish migration around the diversion structure.

Hydraulic model testing of the entire diversion weir, intake structure and fish ladder to refine the facilities design, configuration and flow requirements.

A 1474m long buried HDPE (Weholite) low pressure penstock connected to a 7703m long buried, high pressure steel penstock, designed using soil restraint to eliminate expensive concrete anchor blocks.

A powerhouse encompassing four vertical axis, six-jet Pelton type turbine-generating units, configured to address the low flow ramping rates associated with the project.

A powerhouse tailrace channel fish fence designed to prevent adult salmon and steelhead trout from entering the tailrace and to encourage them to continue their upstream migration past the powerhouse.

Sophisticated in-stream flow measuring and flow ramping protocols.

The Kokish River hydroelectric project is a 45MW run-of-river scheme located approximately 15km east of Port McNeill, on the northeast coast of Vancouver Island, British Columbia in Canada. Preliminary design and permitting activities were initiated in 2007 and the project was submitted as part of a competitive bid process in BC Hydro’s 2008 Clean Power Call. The Kokish project was awarded an energy purchase agreement in 2010, and detailed design began in 2012. Construction started in May 2012 and ended in April 2014 when commercial operation was achieved.

The project incorporates an intake that diverts a portion of river flows from the Kokish River through a 9.2km long penstock into a surface powerhouse located adjacent to the lower reach of the river, where power is generated with four Pelton turbine-generating units. The project is interconnected to BC Hydro’s transmission system through a 0.65km long, 138kV transmission line and interconnection substation to the BC Hydro grid. Access to the hydroelectric project site was facilitated by existing public roads and forestry roads in the Kokish River Valley.

The terrain, climate, and permitting constraints presented numerous challenges that were all overcome with innovative design solutions and collaborative relationships among the owner, EPC contractor, and design team. These included:

- Temporary diversion designs and construction scheduling to suit migratory salmon and steelhead trout that are present throughout the diversion reach of the project, both during diversion construction and operation.
- A diversion weir with one of the world’s largest capacity Coanda screen spillways capable of regulating spillway flow water depth over the screen with one of the smallest Obermeyer crest gates in the world.
- A 70m long vertical slotted fish ladder that wraps around the intake box, allowing continuous fish migration around the diversion structure.
- Hydraulic model testing of the entire diversion weir, intake structure and fish ladder to refine the facilities design, configuration and flow requirements.
- A 1474m long buried HDPE (Weholite) low pressure penstock connected to a 7703m long buried, high pressure steel penstock, designed using soil restraint to eliminate expensive concrete anchor blocks.
- A powerhouse encompassing four vertical axis, six-jet Pelton type turbine-generating units, configured to address the low flow ramping rates associated with the project.
- A powerhouse tailrace channel fish fence designed to prevent adult salmon and steelhead trout from entering the tailrace and to encourage them to continue their upstream migration past the powerhouse.
- Sophisticated in-stream flow measuring and flow ramping protocols.

General project arrangement

![General project arrangement diagram](image-url)
Project organisation
As the lead design engineer, Knight Piésold worked closely with owner Kwagis Power Limited Partnership (Brookfield Renewable Energy Group and ‘Namgis First Nation) and EPC contractor Peter Kiewit Infrastructure Co to develop innovative and cost-effective solutions that were able to meet the stringent permitting requirements.

Knight Piésold’s team was involved throughout project development and was responsible for project optimisation, permitting assistance, and preliminary engineering before completing the detailed design. Other key project participants included Northwest Hydraulic Consultants for intake scale model testing and Rockwell Automation for the design of electrical components and control system. Brofish Research also assisted with the permitting and fisheries aspects of the project.

Design innovation
Five species of Pacific salmon, summer-run and winter-run steelhead trout, rainbow trout, coastal cutthroat trout, kokanee and Dolly Varden char live in the Kokish River watershed. Salmon migration above the Kokish River intake structure generally occurs between July and November with peak fish counts in September. Design and construction planning focused on limiting impacts to fish habitat during construction – a temporary period of approximately 24 months. Hence, to construct the intake headworks, the Kokish River had to be diverted from the natural channel around the intake site. This temporary diversion channel was constructed to accommodate year-round fish migration past the construction site, with in-stream works constructed during a designated period or ‘fish window’.

Upgraded forest service roads ensured that access to both sides of the site were available after construction of a new bridge across the Kokish River. The temporary diversion channel was constructed on the western side of the river by excavating a trapezoidal-shaped channel. The roughly 240m long temporary diversion channel was sized to pass significant flood flows during a 12-month diversion stage and configured to allow year-round fish passage.

Specific challenges for the temporary diversion works included:
- In-stream construction work planned and performed within short duration seasonal fish windows.
- Temporary access built on the far bank (western side) to accommodate intake construction staging.

The channel was sized to pass significant flood flows during a 12-month diversion stage and configured to allow year-round fish passage.

Hydraulic model
A scaled hydraulic model of the Kokish River intake and diversion structure was tested in a hydraulic laboratory to verify sediment and debris migration downstream of the diversion weir; diversion of generation flows to the intake; penstock submergence requirements; and to confirm permitted operational requirements could be met, namely balancing of fisheries bypass flows and generation flows. The hydraulic model of the headworks was tested in Northwest Hydraulic Consultants’ laboratory facility in North Vancouver, British Columbia.

The primary objective of the diversion works design, as for any run-of-river hydropower facility, is to create sufficient ponding depth to divert a portion of the river flows to the intake structure and penstock, while allowing for large volume flood flows to be safely discharged during the design flood events without major structural damage to any of the permanent works.

The intake structure layout adopted for the project consists of three main components:

<table>
<thead>
<tr>
<th>Project Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Source</td>
</tr>
<tr>
<td>Project Operation</td>
</tr>
<tr>
<td>Nameplate Capacity</td>
</tr>
<tr>
<td>Plant Design Flow</td>
</tr>
<tr>
<td>Design Flood</td>
</tr>
<tr>
<td>Intake</td>
</tr>
<tr>
<td>Powerhouse</td>
</tr>
<tr>
<td>Hydraulic Head</td>
</tr>
<tr>
<td>Environmental Flow</td>
</tr>
<tr>
<td>Headworks</td>
</tr>
<tr>
<td>Penstock</td>
</tr>
<tr>
<td>Powerhouse</td>
</tr>
<tr>
<td>Access</td>
</tr>
<tr>
<td>Turbine</td>
</tr>
<tr>
<td>Generator</td>
</tr>
<tr>
<td>Switchyard</td>
</tr>
<tr>
<td>Transmission Line</td>
</tr>
</tbody>
</table>
diversion weir structure, intake structure, and fish ladder. The primary functions of the intake and diversion structure are:
- Facilitate the reliable extraction of the generation flow into the intake and penstock through a variable range of river flow conditions.
- Prevent debris and larger sediment from entering the generation flow diverted into the penstock.
- Effectively and accurately regulate both generation flow and bypass flow.
- Sustain existing river bed morphology and minimize or eliminate the requirement for dredging of the headpond.
- Allow upstream and downstream passage of fish through the vertical slot fish ladder and bypass flow systems, accepted by a professional fisheries biologist.
- The diversion weir consists of a reinforced concrete overflow weir with an inner spillway section fitted with Coanda screen panels and a collector channel at the toe of the screens. It was connected to the intake structure on the eastern side and bound by an overflow weir wall on the other side.

The diversion weir spillway and overflow weir wall is designed to accommodate the peak instantaneous flow for 1,500-year return period flood (1014m³/sec) without structural damage. Downstream of the diversion weir, riprap was placed and infilled with gravel to protect the structure foundations against scouring and erosion while eliminating holes for fish to hide (ie prevent fish stranding).

Coanda screen panels set within the spillway section are capable of screening generation flows to the collector channel below the spillway section. The collector channel conveys the screened flow from underneath the Coanda spillway and transfer the screened water to the intake box. These screens exclude floating debris, coarse sediment (>2mm) and fish from the generation flow. Screened material and fish pass over the spillway into the river section below the weir. The Coanda screen design follows the design guidance laid out by the US Department of the Interior Bureau of Reclamation (USBR). The slot opening between the Coanda screen wedge wires is 2mm and the screen approach profile was designed to operate efficiently up to the 1.2-year peak instantaneous flood event.

Support structure underneath the screens was designed to withstand impacts from bedload...
materials and floating debris during design flood conditions (i.e. boulders and logs). Screens are installed in separate uniform panels, sloping downstream at an angle that prevent direct impact, reducing the force of boulders or other debris passing over the weir. The total length of the spillway with Coanda screen panels is 58.6m. The throughput capacity of the spillway screens is 25m³/sec, believed to be one of the world’s highest capacity Coanda screen hydroelectric installations.

Located inside the pre-construction river channel, below the diversion weir, a sluice channel was designed to bypass flows underneath the headworks. It was outfitted with two slide gates which were sized to provide a fully redundant environmental in-stream flow release discharge system. The in-stream flow requirements for the project varied from 3.4m³/sec up to 12m³/sec through the year.

Designed to convey the generation flow from the powerhouse back to the Kokish River’s natural watercourse, the powerhouse tailrace channel consists of a riprap armoured channel, bounded by concrete block retaining walls, and a fish screen fence located at the end of the tailrace channel.

The purpose of the fish fence, which is located downstream of the tailrace at the confluence with the river, is to prevent adult fish from entering the tailrace. The fence is designed and orientated to encourage fish to continue their migration upstream, past the powerhouse; whereby the natural river flow conditions provide the necessary upstream attraction flow and white-water noise to encourage fish migration upstream and past the projects tailrace.

The fish screen consists of:
- Reinforced concrete foundation structure.
- Submerged weir on the base slab and intermediate piers.
- HMWPE screen panels located in between the piers.
- 25mm clear spacing between the blades of the screen.
- Supported by structural steel member beams.

**Engineering awards**
Knight Piesold’s work at the project recently gained industry recognition. The Association of Consulting Engineering Companies – British Columbia (ACEC-BC) recognised the project with an Award of Merit in the Energy and Industry Category at the 2015 ACEC-BC Awards for Engineering Excellence. This category included all engineering related to mining, metallurgy, petrochemical, geology, geophysics, forest industry, power and transmission, industrial and related process and systems engineering. The project was also honoured with a second place in ACEC-BC’s 2015 People’s Choice Poll.

Jointly with the Canadian Consulting Engineer magazine, the Association of Consulting Engineering Companies – Canada (ACEC) presented the project with an Award of Excellence at 2015 Canadian Consulting Engineering Awards. A distinguished 12-member panel selected the project from 64 project entries for this prestigious award, honouring engineering innovation and achievements by Canadian firms.

**Author information**
The authors from Knight Piesold are Sam Mottram, Managing Principal, Power Services.
Email: smottram@knightpiesold.com
Egbert Scherman, Specialist Civil/Structural Engineer.
Email: escherman@knightpiesold.com
Travis Brown, Senior Civil Engineer,
Email: tbrown@knightpiesold.com