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CANADA'S JOHN HART GENERATING STATION REPLACEMENT PROJECT

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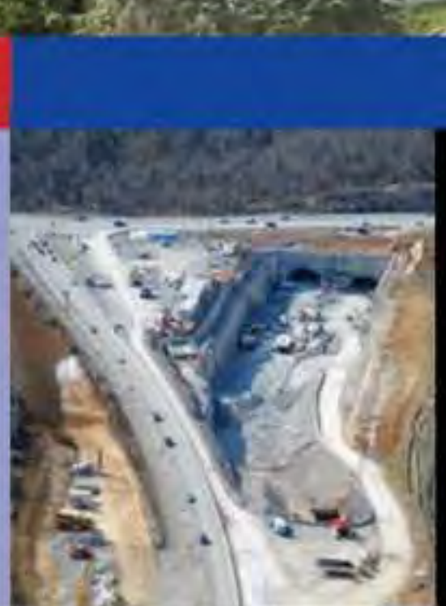

OHIO RIVER BRIDGES EEC

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SIMULTANEOUS DESIGN

SHOULD HARD ROCK TUNNEL SEGMENT & TBM DESIGN BE DONE CONCURRENTLY?


Service and Main Access tunnel portals at the downstream end of the John Hart project

JOHN HART

BC Hydro is breaking new ground by using P3 to procure a new hydroelectric facility on Vancouver Island, Canada. The project has been progressing well, although the discovery of unexpected ground conditions could yet challenge the program partners. Kristina Smith reports

Pioneering P3 power AT JOHN HART


Drilling in the Power tunnel this November


Bench excavation in the Powerhouse cavern

GIVEN THE CHOICE of constructing a huge hydroelectric powerhouse above or below ground, on a virtual greenfield site, conventional wisdom tells us that the surface option would win on cost every time. Yet for BC Hydro's new John Hart Generating Station Replacement Project, near the City of Campbell River, on Vancouver Island, the concessionaire proposed the opposite solution.

"When our designers came up with the idea of looking at an underground powerhouse, our first thought was that it would be more expensive than the reference design," says Alfred Hanna, Vice President of SNC-Lavalin Hydro. "We went into a lot of cost estimating, including independent cost estimates, and the surprise was that an underground powerhouse was cheaper than a surface one."

InPower BC, a special-purpose vehicle owned solely by SNC-Lavalin won the $1.093 billion contract to design, build, partially finance and maintain the new Jon Hart station in February 2014, which will replace an existing 68-year-old surface facility. InPower BC worked with the Design-Builder SNC-Lavalin Hydro, who awarded the civil works contract to a joint venture of Aecon and SNC-Lavalin (ASL-JV). They then employed Frontier-Kemper to carry out the tunneling works.

As well as negating the need for massive concrete foundations, relocating the powerhouse 600m (2,000ft) inland from its proposed riverbank location lengthened the tailrace, which carries water from the turbines into the Campbell River. "This meant that the tailrace tunnel became low pressure instead of high pressure and eliminated the need for around 700m (2,300ft) of steel liners that would have been required to prevent hydrofracture," explains Tony Dell, Lead Geotechnical Engineer for ASL-JV.

There were additional benefits to the underground location that made a compelling case for SNC-Lavalin's design. Surrounded by bedrock, the generators will be protected against the seismic activity experienced in the area, and the visual impact for the many users of the provincial park that surrounds the site will be minimized.

One of the reasons why BC Hydro took a public private partnership (P3) route to procure the station (see box on p12) was that it wanted to encourage alternative ideas in how to carry out the replacement project. "The private sector can bring innovation," says BC Hydro's Project Communications Lead, Stephen Watson. "These companies work on projects around the world and bring with them new knowledge and ideas."

The other main attractions of the P3

procurement route for BC Hydro were the transfer of cost and schedule risk and a 15-year performance warranty while InPower BC maintains the station. InPower BC won't operate the plant, however, that task will be performed by BC Hydro.

The construction and procurement of large projects, especially one as large and complex as John Hart, always present challenges. While the project is going well on various fronts, unexpected ground conditions in the form of a loose area of sand and cobbles (versus mass rock) has been encountered in the main access tunnel. The client and contractor are currently working out how to move through this ground while maintaining schedule. Sustaining good relationships and relying on the comprehensive project agreement between both parties that outlines a processes for these kinds of situations will help.


Pipe arch installation in the Main Access tunnel

Out with the old

The existing John Hart generating station was built in 1947. In poor condition and with its output declining, the facility is threatened by seismic activity. Even a low to moderate earthquake can take out the generating station and the three woodstave and steel penstocks that bring water from the John Hart reservoir to the turbines. Knowledge on ground movements from earthquakes in this area has increased, and from that, the potential for structural damage from shaking and liquefaction.

InPower BC is constructing the new facility alongside and under the old one, which must continue to operate until 2018 when power generation is switched over. With around 2.1km (6,890ft) of tunnels in total, water will be drawn in via a new intake structure in the reservoir, dropping 90m (295ft) down a shaft before running to the powerhouse in a 1.5km (4,920ft) long, 8m (26ft) diameter, power tunnel that passes through the basalt bedrock. A new water bypass facility within the powerhouse will ensure that water can still flow into the river below should one or more turbines shut down, preserving the habitat downstream for fish.

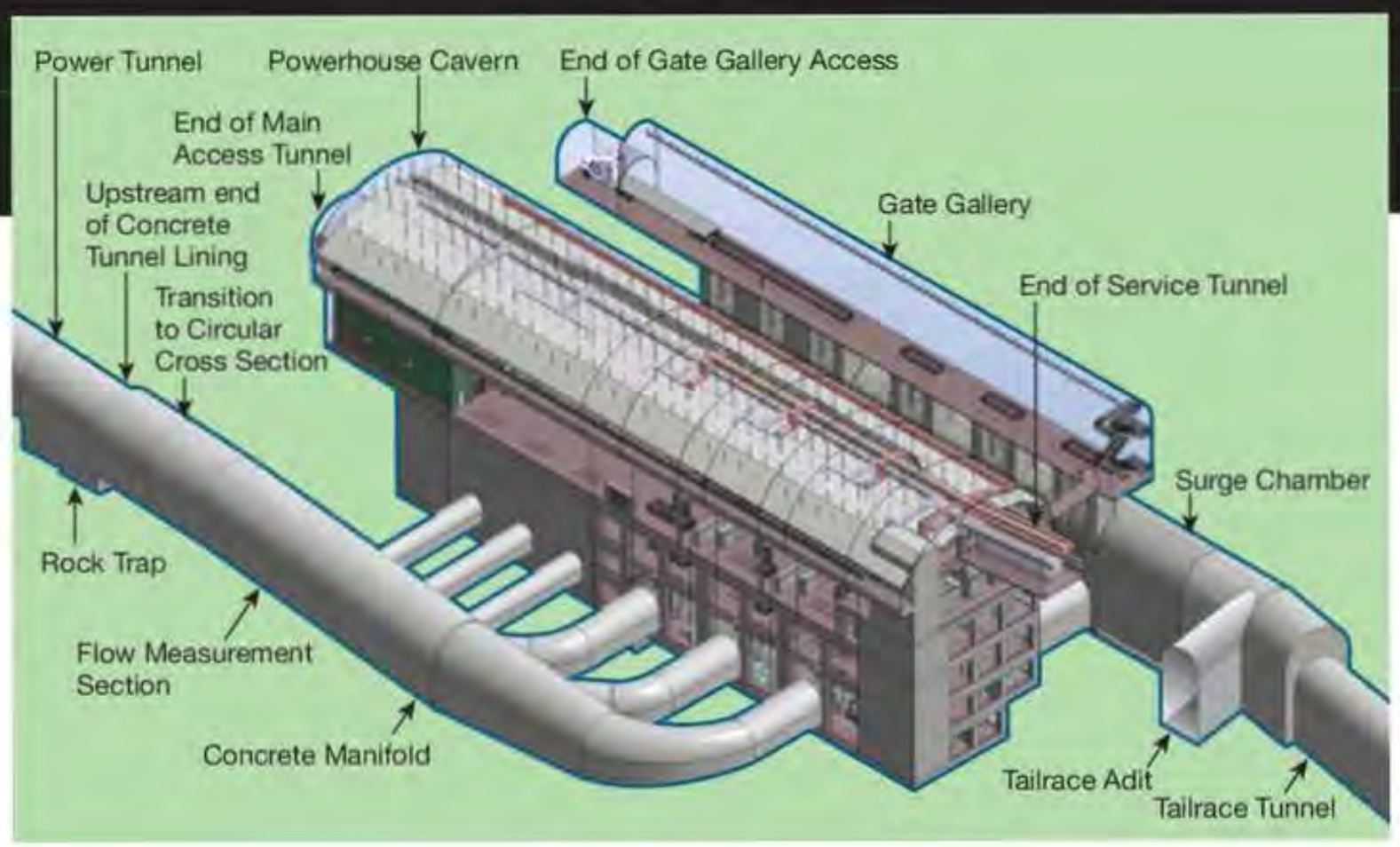
There are two access tunnels from the surface down to the powerhouse. The service tunnel goes in about 116m (380ft) before hitting the powerhouse cavern, and has three tunnel adits that are being used for the rock removal process before later being closed off. Frontier-Kemper is using drill and blast to excavate these tunnels and the 93m (305ft) long x 40m (130ft) high x 23m (75ft) wide powerhouse. The other, main access, tunnel is where the unfavorable loose rock area has been encountered.

The proximity of the existing and sensitive John Hart station to the action does mean that there are vibration constraints on the blasting. BC Hydro has set some limits for peak particle velocity (PPV), to prevent the power plant units going off-line and also to protect the integrity of the earth fill dam, which is holding back the water in the John Hart reservoir. The number and timing of blasts on the various work fronts are carefully controlled and measured – there are nine vibration monitors on site. "We are using techniques such as increasing the number of delays or sometimes decking a single hole," explains Dell. Delay charging sees a number of smaller charges set off at intervals and deck charging aims to distribute the blast energy down the entire length of the drill hole.

An initial blast at the tailrace outlet site, which is adjacent to the existing powerhouse, did trip one of the units and caused flows downstream to decrease for a short time. "We didn't exceed our vibration limits, but there was a mercury switch in the operating system that was very old, so BC Hydro did not know how sensitive it was," says Dell. "Now they override the switch when we are blasting and it doesn't trip the unit."

"These six units are very sensitive even under normal operations and with this work happening we employed further mitigation and contingency plans for each blast. So far, it's been working out well," says Watson.

Up at the intake structure, there are two more things that the ASL-JV must not disturb: the earth fill dam and the water quality within




Temporary support in the Powerhouse cavern

JOHN HART: FAST FACTS

Client: BC Hydro
Concessionaire: InPower BC (owned 100% by SNC-Lavalin)
Civil contractor: ASL-JV (Aecon and SNC-Lavalin)
Tunneling subcontractor: Frontier-Kemper Constructors
Generator supplier: Alstom
Cost: $1.093
Funding: 60% from BC Hydro; 40% from InPower BC
Excavated rock: 300,000m^3
Power from existing station: 121MW
Power from new station: 132MW
February 2014: contract signed
June 2014: construction begins
Spring 2016: all excavation complete; powerhouse construction begins
Fall 2018: operation begins


Cofferdam works for the new intake next to the existing dam and spillway

the reservoir, which is a fish habitat and provides drinking water for the city and over 35,000 people. Silt curtains, hung from a walkway and anchored to the floor of the reservoir, have prevented turbidity from the cofferdam works in the reservoir impacting upon water quality. Protecting the earth fill dam – a critical structure for the whole area – has been an altogether more complex task.

"It's very difficult because we are working with an existing structure, an earth dam that was constructed in the 1940s with few as-built drawings," says Hanna. "We had to take care to ensure the construction of the intake and the power tunnel that passes underneath it would not affect the stability of the dam." The tunnel beneath the dam must be lined with steel reinforced concrete to prevent seepage from the tunnel exerting an upwards pressure on the structure. Though SNC-Lavalin looked at other potential positions for the intake, this was the only point identified by BC Hydro where the tunnel could run entirely through bedrock, avoiding the liquefying soil. However, a significant change, aimed to protect the dam and its stability was made: "We marked the line of the tunnel so that it went under the embankment of the dam, rather than under the center to reduce the risk," says Dell.

Contractor Fraser River Pile & Dredge has installed 57 piles, with the area between the cofferdam and the dam now ready to be drained. Meanwhile Emil Anderson Construction is blasting above ground on the downstream side of the dam, just below the existing spillway gate. This is the location of the new water outlet valves that will provide the environmental flows for fish down Elk Falls Canyon, as well as a road access to the entrance of the power tunnel, connecting the water intake to the generating station.

Frontier-Kemper will construct the 6.5m (22ft) diameter, 90m (295ft) deep shaft for the intake using conventional shaft sinking methods. "We won't have time to complete the power tunnel and then do a raise bore shaft," explains Dell. However, a 4m (13ft) diameter, 130m (425ft) deep surge shaft located 40m (130ft) upstream of the powerhouse will be constructed by raise bore.

Work around the service tunnel, adits, and powerhouse site has been going well. The service tunnel that runs from the south portal reached the location of the future powerhouse in March 2015. By September, the first level of the cavern had also been excavated.

Surprise glacial feature

The 384m (1,260ft) long main access tunnel from the north portal was progressing well until May 2015. However, 100m (330ft) in, the miners encountered unexpected ground conditions. "We found cobbles and boulders where we expected rock," says Dell. "We are 60m (200ft) below the surface and we were expecting hard rock from 10m (33ft) downwards. Instead we encountered some form of glacial feature." Two glacial periods have left their mark on this part of BC, with carbon dating indicating that the feature – which is now densely compacted – dates back to the oldest of these, some 50,000 years ago.

The change in ground conditions required a total change in mining method, switching from rock bolts and fiber-reinforced shotcrete to the sequential excavation method (SEM). Now 12m (39ft) long pipe arches – 5.25-inch steel tubes filled with grout – are providing

PIONEERING P3 IN THE ENERGY SECTOR

Canada is a world leader in public private partnership (P3) financing, attracting attention from governments around the globe that are looking to encourage infrastructure investment. The John Hart Generating Station Replacement Project is breaking new ground, and it's safe to say that the world is watching. "P3 in large infrastructure projects has become a favored model for project delivery in BC, and in Canada, but this will be the first in the energy sector," explains InPower BC CEO Paul Sawyer.

"P3 is a very good system for transit, roads, hospitals, but when it comes to very complicated systems like a generating station it hasn't been done before on a project of this size," says Alfred Hanna, VP of SNC-Lavalin Hydro. "We are the guinea pigs in that respect."

John Hart is also BC Hydro's first foray into P3 and, until its Site C Clean Energy Project on the Peace River started up, it was the company's largest construction project since 1980. "We looked at all types of procurement methods," says BC Hydro's Stephen Watson. "With this project, because it's replacing an existing station but can be built independently, it's a little unique. The design and construction can be carried out by another organization."

BC Hydro worked with specialist organization Partnerships BC to tender the project and to set up the project agreement, which laid down how everything would work. Eight teams from around the world, who submitted prequalification documents, were whittled down to three. The three shortlisted teams were evaluated against four elements: financial capability, the project team leader, design and construction, and the turbine and generator supplier. The winning bidder supplies 40% of the project funding, which is paid back over the 15-year period. An independent 'fairness advisor' monitored the selection process to ensure it was open and transparent.

This is a completely different way of working for BC Hydro and it took some time to get used to, says Watson who has worked at the utility for 25 years. "Within BC Hydro we take a lot of pride in our facilities and in designing upgrades to them. We do Design-Build sometimes, but this is the first time we really took a step back and let someone else take the lead with this procurement model, so it took a few years for us as a company to work though things and hand it over to a third party in this manner. Having said that, once we got those bids, and we saw the details and the designs, we could all see why we were doing it this way."

Where usually BC Hydro would have a big supervisory team with work package managers for design and construction, the team at John Hart is much smaller with a reviewing rather than controlling mandate. "I think it was difficult for BC Hydro to get used to the idea that we were the designer and the constructor at first," says Hanna. "It took a lot of energy in the early days. They wanted lots of deliverables and submittals and to approve every small thing. Now we are working well together."

Would BC Hydro use P3 again? Watson doesn't rule it out but refers back to the uniqueness of John Hart in that it doesn't interface with existing infrastructure. There will be plenty of people interested in the outcome of this pioneering project.

From top: Start of the Service Tunnel, in January 2015; ASL-JV's Project Manager, Scott Marshall, with BC Hydro's Stephen Watson; Close up of the cofferdam works

overhead protection, while the tunnel advances in lengths of 4m (13ft). Lattice girders at 1m (3ft) centers provide additional reinforcement to the fiber-reinforced concrete. ASL-JV and Frontier-Kemper have brought in specialist contractors and designers for this purpose: BeMo Tunneling, with pipe grouting expertise from Shaft Drillers International (SDI), and ILF to carry out the design.

This means that progress is much slower than before, says Dell: "There is a delay because SEM is really time consuming. We have reprogrammed other access adits so we can get into the main service bay level earlier without waiting for the main access tunnel."

Just 8m (26ft) of the SEM tunnel has been built so far. In the meantime, the team is investigating the possibility of moving the tunnel's alignment, but before that happens, it's important to ensure that no similar geological features are lurking elsewhere. "We have to make sure that if we bypass it, we don't end up in another difficult area," says Hanna.

"We have been probing and planning physical work to see if we can go round the glacial feature," says Dell. "We know we have good rock close to the powerhouse and gate chamber and early indications are that we might be able to change the alignment of the access tunnel."

Additional boreholes have been drilled from the surface, although there is limited land to conduct these from since the project must not encroach on parkland. Investigative work from inside the tunnels may be augmented by geophysical methods including seismic reflection and electrical resistivity tomography.

Frontier-Kemper has encountered little groundwater to date, apart from within the highly permeable glacial feature. However, the tunnel will cross a number of faults, with a fault located right under the earth fill dam expected to conduct water." We are anticipating that will have to do pre-grouting and post-grouting to protect the dam from seepage," says Dell.

Even with the challenges encountered in the main access tunnel, InPower BC is still aiming for the fall 2018 start-of-operation date. For the tunneling contract, the power tunnel is the critical path activity. For the civil works package it is the construction of the powerhouse. Alstom will be supplying the generators with InPower BC procuring the E&M work in smaller packages.

"We worked with that system – dividing up the civils, turbine generator and tunnel – on another plant, the Waneta Dam power plant expansion, and it went very well," says Hanna. "Waneta came in ahead of schedule and cost. We have some challenges here already, but we are working hard to make it just as successful."