Golder Associates

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Vancouver City Central Transmission
Vancouver, British Columbia

PRECEDENT SETTING
HDD & GROUTING
APPLICATION

OVER
$3 MILLION
COST SAVINGS

CANADIAN CONSULTING engineer

Project Summary

Conduits to house 230 kV electrical cables were installed across False Creek by Horizontal Directional Drilling method at a capital cost saving of $3 million compared to the next nearest feasible installation option. Golder designed a unique conduit bundle configuration, collaborated with BC Hydro electrical engineers and with grouting specialists to replace the drilling mud surrounding the installed bundle with purpose designed thermal grout. The grout placement required a method with no prior industry experience.

Project Highlights

Innovation and New Applications of Existing Techniques

The Vancouver City Central Transmission (VCCT) Project was constructed to add to BC Hydro's electricity distribution capacity and improve system reliability in the Vancouver area. This is BC Hydro's most significant investment in central Vancouver's electrical grid in almost 30 years. A vital component of the VCCT project is installation of three 850-m-long 230 kV transmission cables across False Creek inlet (the Inlet). The successful completion of this project required two major breakthroughs through the application of existing technologies to new and complex challenges. Meeting these challenges required bringing together skills from a wide range of disciplines and the development of processes to provide assurance that this application could successfully be brought to completion.

The major breakthroughs were the successful completion of a large diameter Horizontally Directionally Drilled (HDD) bore through glacial till soils and the installation of a grouted conduit bundle system and transmission cables which had to conform to very strict seismic and thermal dissipation requirements. Neither of these had been achieved before in Canada. The adopted solution met the owner's requirements and was the most cost effective and schedule efficient construction of the options considered. Additionally this approach reduced adverse environmental effects that would have resulted from the adoption of other options.

Geotechnical Challenges and Innovation

Detailed geotechnical investigations showed that nearly 230 m of the borepath for the HDD would traverse through glacial soils. During the design of the project, there was no prior experience in Vancouver of successfully drilling a large diameter HDD bore through glacial soils. The novel approach adopted for this project to confirm the viability of the HDD through glacial soils was to pre-drill the full diameter HDD hole through the glacial till and some 25 m into the bedrock as pre-works prior to completion of design and fabrication of the bundled pipes for the pull. Whilst this was a considerable at-risk upfront cost should the drive not have proved successful, it was an acceptable investment to mitigate this risk in advance of the main contract.

Thermal Design Challenges and Innovation

BC Hydro required the three electrical cables to be physically separated by a minimum specified centre to centre distance and the annular space between the ducts and the HDD bored hole to be filled with a grout complying with specified thermal resistivity characteristics. Compliance with these requirements meant designing a grout which was at the same time flowable, dense, stable and capable of replacing the drilling fluid (mud) in the HDD bored hole.

The ability to successfully displace the mud from the 50-m-deep, 850-m-long HDD bore was critical to the success of the project and of major concern, since similar project case histories and prior industry experience were sparse and mostly documented as less than successful. An innovative solution to complete this successfully needed to be developed. The grout mix was designed prior to the tendering of the works. This required testing of a number of potential mix designs. The proposed mud replacement/grout placement technique was confirmed by conducting a large scale pre-production grouting field trial. The experience gained from the grouting trial provided an effective means of identifying production grout quality assurance issues and the feasibility of achieving 90% mud replacement as required by BC Hydro. The production grouting was completed successfully.

Although only three cables were to be installed, a relatively simple and efficient multi-pipe conduit bundle design comprising seven pipes was adopted. This allowed for ease of field construction, conduit redundancy (in case of damage to one or more of the pipes during pullback), and for possible incorporation of a cable cooling system should the grouting operation not meet full success. The completed work proved for the first time that HDD can be successfully carried out in glacial soils. It is also the first mud replacement grouting to the scale of this project known to have been successfully carried out anywhere in the world.

Complexity

The owner's required the new cable system meet the Institute of Electrical and Electronic Engineers (IEEE) seismic standard (IEEE693) and the cables carry the rated load current without overheating. This significantly added to the complexity of the project. Maintaining the integrity of the HDPE pipes through the pulling process without adversely affecting them as a consequence of the heat of hydration during grout replacement required considerable modeling, prior testing and detailed and extensive monitoring during the operation. To arrive at a design that met all criteria required a stringent level of coordination and interaction between the pipe designers, geotechnical engineers, BC Hydro electrical engineers and the grouting specialists before finalization.

On the logistics side, the prefabricated 850-m-long, 140,000 kg pre-strapped bundle required transporting over a distance of 1.3 km including negotiating three 90 degree bends. The bundle had to rest in the streets for the period of the pull. We achieved the pull in seven days. Informing the public of the anticipated disruptions, providing alternative transportation to affected residents of these city blocks and coordinating the works with the public required an effective communication plan and considerable skill.

Environmental Impact

The HDD method is one of the least disruptive pipe installation methods because it does not require trench excavation, sea bed dredging or large entry and exit shafts. The HDD entry site work area was in David Lam Park adjacent to False Creek, a high public use area located near residential towers, a school and daycare centre. The park was a gathering place and celebration site during the 2010 Winter Olympics. The overall project construction schedule was strategically planned to allow the HDD exploratory program to be completed prior to this event, with the final construction of the crossing resuming the following winter. The choice of conduit installation using the HDD method resulted in a reduced carbon footprint and minimized environmental impact as compared to dredging or tunnelling options. The impact on the environment and water quality was minimized by active implementation of an environmental management plan. David Lam Park is now fully restored with an upgraded electrical supply system.

Social and Economic Benefits

The project will provide assurance of reliable electricity supply to Vancouver into the future, as the new installation is resistant against earthquake damage and heat damage. Demonstration that bundled pipes installed by HDD can be achieved for installation of large electricity cables will allow future works to adopt this cheaper, faster and more reliable methodology. The direct savings to the client in this case of not adopting a more conventional shaft and tunnel option were six months in construction time and $3 million in capital cost.

Meeting and Exceeding Owner's / Client Needs

This project proved the feasibility of completing large diameter bores using the HDD method within dense glacial soils, which have historically been considered as high risk and potential "show stopper" ground conditions. It also represents the largest scale known application of thermal grouting to accomplish full displacement of drilling fluid within an uncased HDD bore anywhere in the world. The savings from the project exceeded the owners' expectation.

Introduction

The Vancouver City Central Transmission (VCCT) Project is the most significant investment in central Vancouver's electrical system in almost 30 years. Once completed, it will increase reliability of electrical supply throughout Vancouver and meet the growing demand for power in South False Creek and Mount Pleasant.

BC Hydro supplies electricity to the City of Vancouver through a network of underground and overhead power lines and substations. An existing 230 kV underground transmission line in the City and the electricity distribution system in Mount Pleasant and South False Creek have aged and need replacement. To meet the future demand for power in this densely populated area, the VCCT Project was approved by the BC Utilities Commission in June 2010 and includes three main components:

- a new electrical substation in the Mount Pleasant area, planned to be the first Leadership in Energy and Environmental Design (LEED) standard substation in BC Hydro's system;
- 8 km of new 230 kV transmission line under city streets connecting the new substation to two existing substations; and
- the drilling of an 850-m-long bore under the bed of False Creek and installation of a conduit bundle in the bore to connect the new infrastructure in the Fairview Slopes to the Yaletown area and downtown core.

Golder provided design and environmental services on all aspects of the project. This submission focuses on the crossing under the bed of False Creek as it was the most technically complex and logistically challenging component of the project in terms of Golder's role and level of involvement. Golder acted as prime consultant throughout the design and was responsible for overall construction management.

Objectives and Solutions

BC Hydro identified several engineering design objectives that needed to be accounted for in the design and construction of the cable crossing under the bed of False Creek:

- System Life – The cable system (power cables, conduit material, and grout) needed to remain stable and functional for a design life in excess of 40 years.
- Seismic Performance – The cables needed to remain serviceable following the design earthquake (1 in 2,475 year return period) event. A study of the response of the power cables to dynamic forces was conducted by BC Hydro and it was deemed necessary to limit the approach angles for the crossing to 10 and 13 degrees below the horizontal on the north and south sides of False Creek, respectively.
- Thermal Performance – The cable system needed to reliably carry the rated current load without overheating (i.e. maximum conductor temperature of 90°C).

Golder's task was to provide an engineering solution for the crossing that would meet the stringent cable performance requirements, while at the same time addressing project geotechnical risks and environmental sensitivities associated with construction. Golder evaluated alternative crossing locations and construction methods, with two trenchless options being considered to minimize the potential for impact to the marine environment: construction of a tunnel that would accommodate the cables, and a HDD bore. The HDD method presented a number of design and construction challenges which, if they could be overcome, would significantly reduce the cost; better meet BC Hydro's operational performance requirements; and reduce the length of the crossing construction time by an estimated six months. After careful consideration and a test HDD to mitigate risk, the HDD option was selected for detailed design.

Design Challenges and Innovation

Seismic

To meet the seismic performance criteria, the cables could not be installed at an angle greater than 13 degrees to the horizontal. This requirement would be difficult to meet as the cables rising along the shaft of the tunnel would be near vertical unless they were coiled around the circumference of the shaft. The coiling around the shafts would be both expensive due to the significantly greater total length of the cables as compared to cables installed in a HDD bored hole and would also be difficult to construct. The integrity of the cables could also be compromised should the shaft fail due to a seismic event. Installation of the cables in a HDD bored hole which has no sharp bends and can be designed to less than 13 degrees bend angle thus, provided the best solution from seismic considerations. Installation of the cables in a HDD bored hole was the preferred method of design.

Geotechnical

The results of site-specific detailed geotechnical investigations indicated that nearly 230 m of the borepath for the HDD would traverse through glacial soils. HDD is considered risky within glacial material because it can contain random boulders, cobbles and gravel. An exploratory HDD bore was successfully completed through the high risk soils to assess and confirm feasibility of drilling through glacial soils prior to confirmation of the approach and completion of final design. The success of the drilling proved the feasibility of drilling through glacial soils at the site. Due to the proposed use of David Lam Park as a celebration site during the 2010 Winter Olympics, the exploratory drilling work was strategically scheduled in advance of the Olympics. The resulting bore hole was suitably protected from deterioration in the intervening months while design tasks were conducted and the production HDD bore tendered, as the design intent was to use as much of the exploratory bore as possible.

Overheating Challenges

BC Hydro required the three electrical cables to be physically separated a minimum centre-to-centre distance of 356 mm to meet thermal performance objectives. The cables needed to be contained in separate ducts forming a bundle. The duct material properties needed careful consideration so as not to act as thermal insulators. The bundle configuration had to be maintained during the pipe pulling operation and could not suffer excessive installation damage. The design solution offered by Golder was for the cables to be installed in a bundle of high-density polyethylene (HDPE) pipes installed in an uncased HDD bore. The bundle consisted of seven 209 mm inside diameter ducts for electrical cables and possible future cooling, and eleven 100 to 125 mm diameter grout pipes. All of the pipes were strapped together using non-magnetic material to form the design bundle configuration and comply with electrical requirements. The specifications required the contractor, Michels Canada Co. (Michels) to pull a minimum 20-m-length bundle test section through the entire length of the borehole to demonstrate minimal damage to the bundle and adequacy of the banding immediately prior to the production pullback.

The HDD borepath traversed up to 50-m-below the existing ground level and was approximately 850 m in length. BC Hydro's electrical engineers required up to 90% of the drilling fluid remaining in the bored hole after the installation of the bundle to be replaced by a grout with low thermal resistivity to aid in heat dissipation of the cable system. The grout was custom designed to meet demanding thermal performance characteristics. It possesses various properties such as high density, low shrinkage, low heat of hydration, as well as suitable flow and pumping characteristics to achieve a high degree of drilling fluid displacement without causing heat or distortion damage to the installed conduit bundle. The grout was also designed such that its physical properties remain stable in the long term (in excess of 40 years).

Construction Challenges

Alignment Incompatibilities

Construction difficulties arose early on during drilling of the HDD pilot bore due to alignment incompatibilities between the exploratory HDD borehole completed in 2010 and Michels production borepath. Michels, BC Hydro and Golder worked collaboratively on an innovative solution involving grouting of a portion of the exploratory borehole. This allowed pilot bore drilling to continue until drilling fluid loss to ground surface was experienced within Charleson Park on the south side of False Creek. The fluid was quickly contained and a solution to complete the pilot bore using the drill intersect method was proposed and successfully completed by Michels. The remaining hole opening passes to obtain a final HDD bore diameter of 1,176 mm were completed without incident.

Duct Fusion and Transport

The HDPE pipe sections forming the bundle had to be fused in a Heritage Railway corridor and transported approximately 1.3 km to the laydown area, which was a busy road spanning five Vancouver City blocks. The bundle conveyance required 24 hour operations to minimize traffic impacts within a major commuting corridor. The bundle move and pull route had a total of three 90 degree turns. The 860 mm outside diameter, 140,000 kg pre-strapped bundle had to negotiate these bends during the pull, involving use of a significant amount of heavy construction equipment within confined street corridors. At one point during the operation, significant twisting of the individual pipes occurred, and alternative methods of pipe handling and conveyance needed to be quickly assessed in the field to minimize schedule delays and risk of damage to the pipes.

Drilling Mud Replacement Grouting Trial

Compliance with the thermal performance of the new cable system required 90% of the drilling mud surrounding the conduit bundle installed inside the HDD bore to be replaced by purpose designed grout. There was no industry precedence of such work to the scale of this project. Published literature of smaller installations indicated either partial success of the replacement effort or failure. To confirm or otherwise reject the viability of mud replacement, the contractor was required to drill a 50-m-deep (same depth as the maximum depth of the HDD borepath), 300 mm diameter cased vertical borehole off-site; fill the borehole with drilling fluid of the same consistency and density as the drilling fluid used for production of HDD; install a mini-bundle inside this hole and, pump pre-designed thermal grout in it. Sensors were attached to the bundle to monitor the pressure and temperature inside the hole during grouting. The temperature and pressure monitoring was essential so that the HDPE pipes in the bundle did not melt or deform due to grouting pressure or to the heat of hydration generated by the grout. Upon completion of the grouting, the near surface soil column surrounding the borehole was excavated to examine the extent of grout displacement. It was evident that the trial grouting was highly successful and that replacing mud in the 50-m-deep, 850-m-long HDD bore with the product bundle in place was feasible. Replacing the drilling mud with the grout was essential to the success of the project and the grouting trial provided the confidence that it can be successfully accomplished.

Environmental

The HDD method is one of the most environmentally friendly methods of underground pipe installation, including across river channels. The choice of conduit installation using the HDD method resulted in a reduced carbon footprint and minimized environmental impact as compared to dredging or tunnelling options.

Maintenance of environmental control during construction was enforced through an Environmental Management Plan (EMP) developed by Golder. The EMP also addressed environmental considerations such as noise and dust generation, traffic management, treatment and proper disposal of potentially contaminated soil and groundwater, spill prevention and sediment and erosion control. Michels had a qualified environmental monitor on site to observe construction activities that had a potential to affect the environment. In addition, Golder, on behalf of BC Hydro, performed regular environmental audits at the construction site to evaluate the Contractor's adherence to the EMP.

The HDD entry site work area was in David Lam Park adjacent to False Creek, a high public use area located near residential towers, a school and daycare centre. The park was a gathering place and celebration site during the 2010 Winter Olympics. The overall project construction schedule was strategically planned such that the HDD exploratory program was completed prior to this event, with the final construction of the crossing resuming the following winter. BC Hydro, Golder and Michels also worked closely with City of Vancouver Parks staff and event organizers to reduce the footprint of the active HDD work area to allow unimpeded access to one of the International Jazz Festival main venue sites within the park. The site restoration works in the park included upgrading of the existing electrical supply system to better facilitate future events.

Archaeological

The historical shoreline of False Creek is located near the drill exit point, with potential archaeological sites associated with former settlements of First Nations communities in the vicinity. As part of the comprehensive Environmental Management Plan (EMP), Archaeological Chance Find Management procedures were included, in the event that ground disturbance activities during construction encountered any items of historical or archaeological significance.

Public Relations

To mitigate the impact of the conduit bundle move from the Heritage Railway Corridor to the HDD borehole exit on Laurel Street and the pullback operation, BC Hydro organized and Golder participated in several neighbourhood advisory committee meetings well in advance of the operations to inform and engage residents and stakeholders in the affected area. The unavoidable disruption to an urban area of mixed residential and commercial use spanning 16 city blocks long by eight blocks wide for seven days was completed successfully. It was recognized early during construction, that this work activity would be highly disruptive and would require much of it to be carried out as a 24-hour-a-day operation. Significant coordination efforts were required to maintain local pedestrian and vehicle access to the extent possible and provide for emergency services access. Mitigation measures implemented by Michels included setting up an on-site Emergency Services Response command centre, involving 20 police and traffic authority officers to assist with traffic control and using a shuttle bus service to assist movement of pedestrians around the conduit bundle as it moved along the city streets.

The David Lam Park area has been fully restored following construction, with improvements made to field drainage and irrigation systems. Considerable effort was made to re-instate the impacted portions of terraced walkways with matching brickwork to maintain the beauty and aesthetic appeal of this urban park.

Socio Economic Impact

The project was completed at less than $3 million estimated for next feasible option, which was installation of the conduits in a purpose built tunnel. The successful application of HDD method in this project has set a precedence case of an economic method of installation of high voltage electrical cables, with potential to generate significant cumulative savings from future projects. The successful completion of the project has provided the Vancouver public with a reliable electricity supply for the coming 40 years.

Achievements

This project proved the feasibility of completing large diameter bores using the HDD method within dense glacial soils, which have historically been considered as high risk and potential "show stopper" ground conditions. It also represents the largest scale known application of thermal grouting to accomplish full displacement of drilling fluid within an uncased HDD bore anywhere in the world.

Successes

Our involvement in the VCCT project earned recognition by the Association of Consulting Engineering of British Columbia and received an Award of Merit. It was also named 2011 Project of the Year Runner-up in the October issue of Trenchless Technology.

Vancouver City Central Transmission — Vancouver, British Columbia

David Lam Park Drill Entry Work Area

HDD Drill Rig at David Lam Park

Conduit Bundle Fusing and Temporary Laydown Area in Heritage Railway Corridor

Duct bundle transported from Railway Heritage Corridor to the Pipe Laydown area in downtown Vancouver.

Batching of Thermal Grout for Pre-Production Field Trial

Grout placement in the 50-m-deep grouting trial hole in progress.

Grout trial showing a cross section of the grout surrounding the trial pipe bundle.

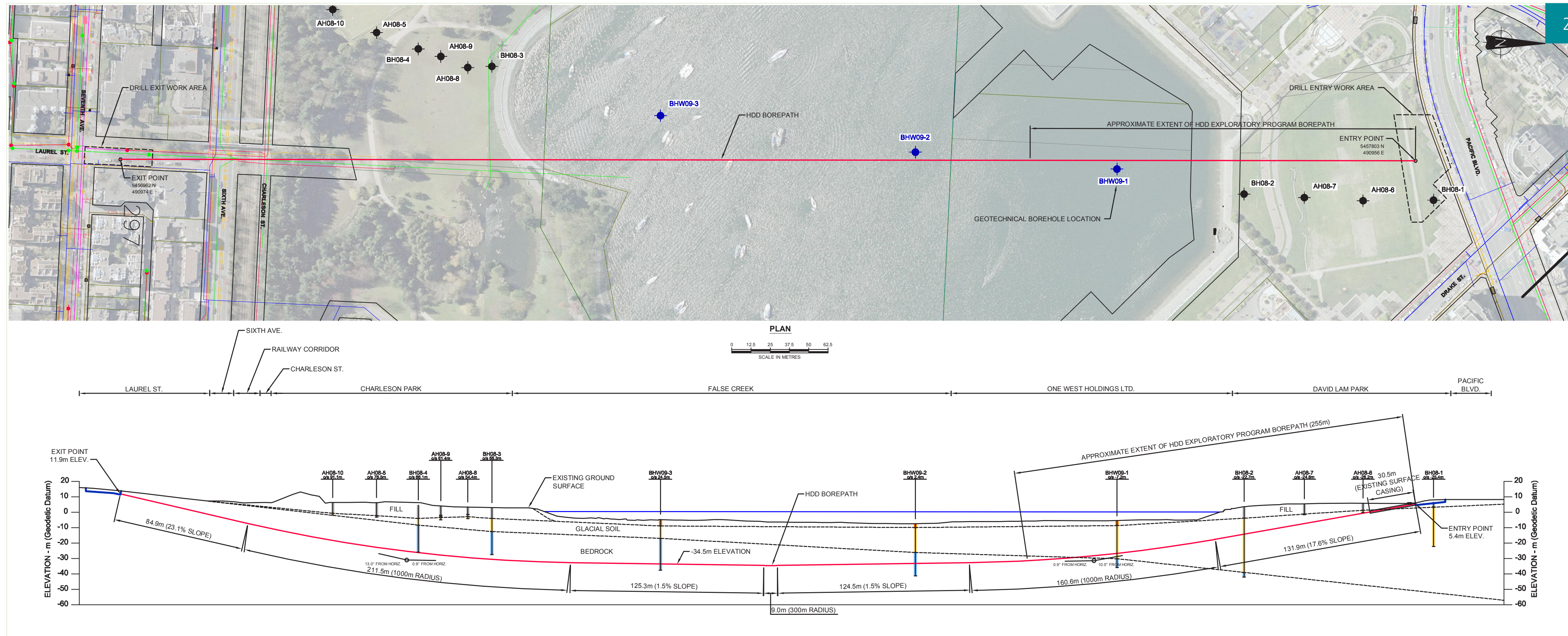
Bundle Conveyance along 8th Avenue

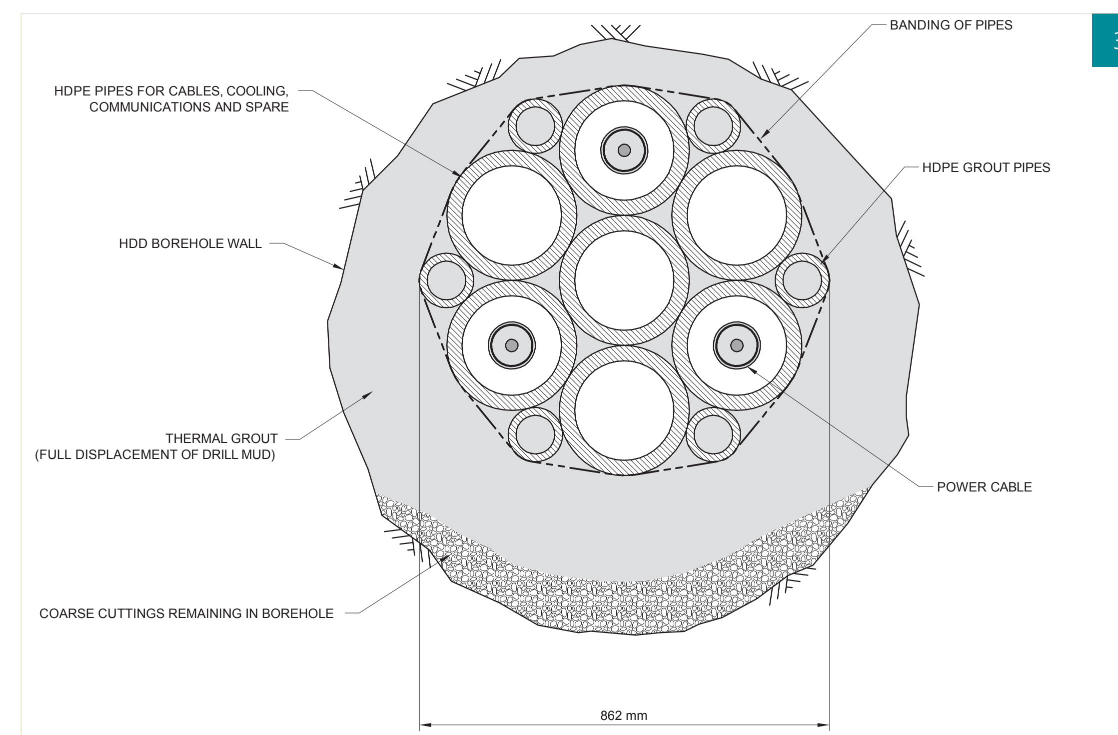
Pull Head at Drill Exit after Successful Pullback

Duct Bank Construction at Laurel Street Transition Tie-in to Manhole

David Lam Park Work Area Restoration

Vancouver City Central Transmission — Vancouver, BC





1. Map of VCCT Transmission Route.
2. HDD Borepath Plan and Profile.
3. Cross Section of Conduit Bundle in HDD Borehole.

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2012 AWARDS FOR ENGINEERING EXCELLENCE

Award of Merit

Vancouver City Central Transmission

Consultant

Golder Associates Ltd.

Owner/Client

BC Hydro and Power Authority

Category

Natural Resource, Energy & Industry

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The Vancouver City Central Transmission (VCCT) Project is BC Hydro's most significant investment in central Vancouver's electrical grid in almost 30 years. It will add needed capacity and improve system reliability. A vital component of the VCCT project is the 1-km transmission line section crossing False Creek inlet and linking the new system upgrades.

The technically challenging nature of the False Creek crossing, within a densely populated, environmentally sensitive and highly utilized park area, demanded innovative design solutions and effective construction management. Golder Associates Ltd. (Golder) provided geotechnical and environmental services throughout the permit application, and design and construction process. The construction contract to complete the False Creek crossing by Horizontal Directional Drilling (HDD) method was awarded to Michels Canada Co. (Michels). Golder managed the technical design aspects and construction contract of the HDD crossing, including Quality Assurance/Quality Control (QA/QC) and environmental auditing.

The construction of the HDD crossing including installation of the conduits was completed on schedule. The successful installation resulted in a savings of approximately $3 million to the overall VCCT project.

This project demonstrates engineering achievement, as it proves the feasibility of completing large diameter bores using the HDD method within dense glacial soils, historically considered as high risk. It also represents the largest scale known application of thermal grouting to accomplish full displacement of drilling fluid within an uncased HDD bore anywhere in the world.

20 Trenchless TECHNOLOGY 20th anniversary

New Install Runner Up

Vancouver City Central Transmission Project – HDD & HDPE

< All stories in this sectic

— Oct 27, 2011

As the third-largest film production center in North America, Vancouver is a rapidly growing hub that has showcased the best and brightest the world has had to offer in the last few years, from the 2010 Winter Olympics to the Stanley Cup Playoffs. Through it all, Vancouver has been on the world's stage.

And in the thick of it all is Michels Canada, the prime contractor on the Vancouver City Central Transmission (VCCT) Project, a complicated job that required the use of HDD to install a power cable duct bank under False Creek in the heart of downtown Vancouver. Despite all the activity in downtown Vancouver, the high-voltage installation wa the most significant power project to be built in Vancouver in the last 30 years and was necessary to meet deman and strengthen reliability in the city's fast-growing neighborhoods. The project, owned by BC Hydro and engineered by Golder & Associates, consisted of nearly five miles of 230 kV underground transmission circuits, including the 2,789-ft HDD crossing. The 44-in. diameter crossing housed a duct bank consisting of seven 10-in. HDPE ducts, five 4-in. grout pipes and one 5-in. grout pipe. Michels was responsible for the supply and assembly of the ducts and grout pipes, which ultimately weighed 342,000 lbs.

Additionally, Michels grouted the annular space between the borehole walls and the bundle and constructed a transition on either end of the crossing from an HDPE to a PVC duct system, which then was terminated in cable vaults. One of the project's major milestones was the move of the 342,000-lb product bundle from the pipe make-up location on the Heritage Railway Corridor through nearly one mile of city streets to the pullback location. Durin this move and subsequent pullback, 14 city blocks in the downtown area were closed or partially closed to traffic. The exit side was located at the intersection of two narrow streets on a seven-degree hillside. The work area was small at just 130-ft by 26-ft, and it was nearly within arm's reach of adjacent apartment buildings.

While it was one of the most challenging pipe pulls achieved by Michels and the biggest duct bundle grouting job ever undertaken in North America, the logistical and public relations issues may have posed the highest hurdles. The entry side was located in David Lam Park, which was a popular Olympic celebration site during the games. T mitigate noise, Michels used sound mats and hospital mufflers on equipment and shut down non-essential equipment whenever possible.

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The small work area on the exit side meant that Michels crews often found themselves on a first-name basis with the area residents and stopping operations in order to allow a resident to access a parking garage. It was this type of attitude that resulted in Elsie Roy Elementary School, the City of Vancouver Fire Chief and the Vancouver Police Department recognizing Michels for its community involvement.

BC Hydro showed its pride in the project by inviting British Columbia Minister of Energy Richard Coleman to visit the sit during the pullback stage and showcased the project to CEOs of various electric utilities from across Canada. Throughout the pipe pullback, Michels continued to look out for local residents by providing shuttles for pedestriar who were trapped on one side of the six-block length of pipe so that they could more quickly get to their destination. The pullback was successfully concluded on May 31, 2011.

A varied and diverse management team was selected from across Michels, including Michels Canada, Michels Pipeline Construction, Michels Directional Crossings, Michels Power, Michels Tunneling, Michels Environmental Resources Group and Pilchuck.

Owner: BC Hydro
Engineer: Golder Associates Ltd.
Contractor: Michels Canada