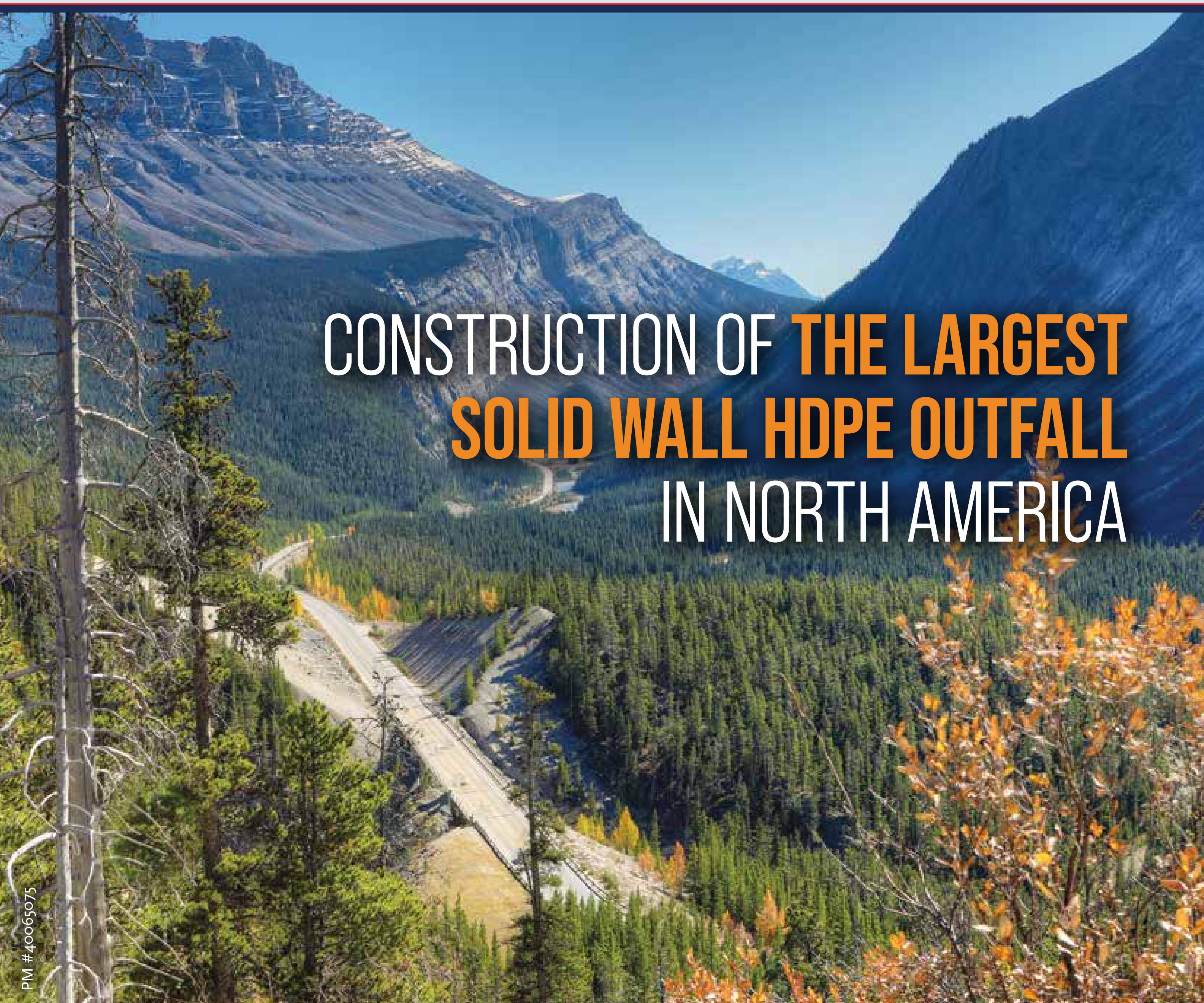
2020 | NORTHWEST FALL/WINTER

# TRENCHLESS JOURNAL

THE OFFICIAL PUBLICATION OF THE NORTHWEST CHAPTER OF
THE NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY



## CONSTRUCTION OF THE LARGEST SOLID WALL HDPE OUTFALL IN NORTH AMERICA

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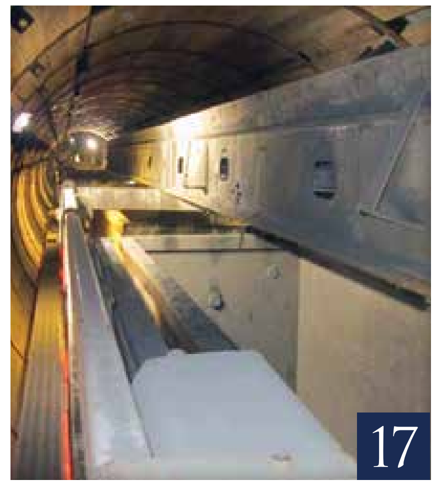
## IN THIS ISSUE:


11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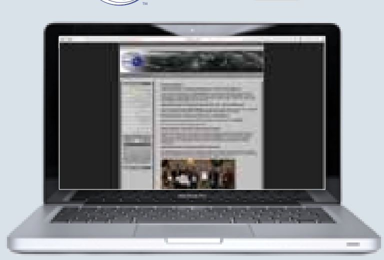



ON THE COVER: The Icefields Highway through the Rocky Mountains. | dreamstime.com

# STRONGER THAN EVER

For everyone 2020 has been quite a whirlwind year! Like the rest of the world, the staff and volunteers here at NASTT have been pivoting and evolving on a near daily basis to changes in how we do business due to the COVID-19 situation.

As this unprecedented year continues to unfold, NASTT is working diligently to continue to provide the training and education you need to do business and stay up to date with innovations in our industry. We are excited to have rolled out virtual events and training opportunities as we fulfill our mission to be the premier trenchless educational society in North America.

In August we launched our NASTT Good Practices Courses as virtual events. These courses are a rescheduling of the 2020 No-Dig Show Good Practices Courses and our entire suite of courses will be available as live training events. Our four-hour courses will take place in one day and our eight-hour courses will be split into two-day sections to allow for schedule flexibility for our attendees. All NASTT Good Practices Courses include Continuing Education Units, a training manual, and the accompanying NASTT Good Practices Guidelines book if applicable. Visit *nastt.org/training/events* for the full schedule and registration details.

"Our goal is to represent our industry and provide valuable initiatives."

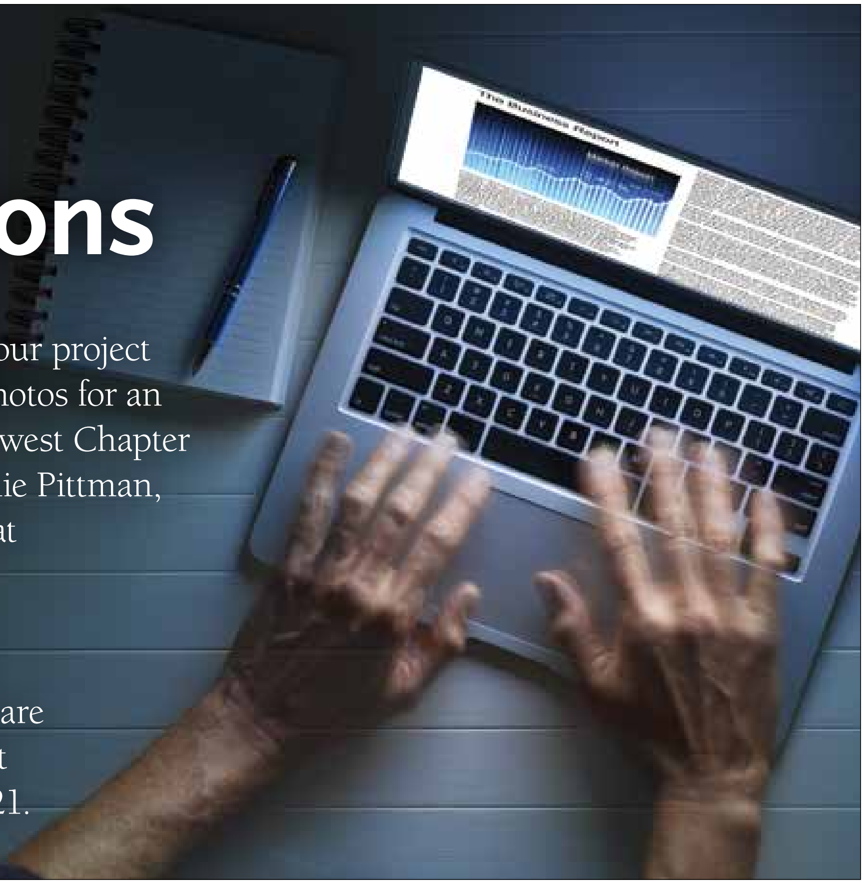
Our goal is to represent our industry and provide valuable initiatives. To do that, we need the involvement and feedback from our members. We are always seeking volunteers for our various committees and programs. If you are interested in more information, please visit our website at *nastt.org/membership/volunteer.* There you can view the committees and learn more about the ways to stay involved with the trenchless community and to have your voice heard. Please consider becoming a volunteer – we would love to tap into your expertise.

We are looking forward to coming together in Orlando next March for the NASTT 2021 No-Dig Show. It will be particularly exciting to come together again as a group and celebrate the trenchless industry in North America as we learn and network together. By all accounts, the NASTT 2019 No-Dig Show in Chicago was a resounding success, hosting a record-breaking 200+ exhibitors and more than 2,200 attendees. We're going to come roaring back strong and break these records at No-Dig 2021 in Orlando!

We look forward to growing and learning from these recent challenges and coming back stronger than ever. Thank you for all your support and dedication to NASTT and the trenchless technology industry. We are only as strong as our Regional Chapters. We are always looking for volunteers and new committee members not only locally but nationally. Don't be afraid to get involved! With the trenchless market growing so fast now is the time to join us!

Thank you for being a part of our organization and for dedicating your careers to the trenchless industry.

***Craig Vandaelle***
NASTT Chair



# Call for Submissions

If you would like to submit your project paper or other content and photos for an upcoming issue of this Northwest Chapter magazine, please contact Carlie Pittman, Magazine Committee Chair, at *pittmanc@ae.ca*.

Editorial submissions for the *Northwest Trenchless Journal* are welcome and due for our next publication by early April 2021.

# IN THIS ISSUE

Welcome to the Fall/Winter issue of the *Northwest Trenchless Journal*, the official publication for members of the NASTT-NW Chapter. In this issue of the magazine, we put the spotlight on the National Project of the Year Winner, the McLoughlin Point WWTP Outfall. To read more about this winning project, see page 11.

In addition, we are pleased to highlight the GLSLA Project of the Year, the Hanlan Feedermain Project, on pages 17–23. And don't miss out on the NASTT 30th anniversary bookstore sale – flip ahead to page 16 to check it out.

Our Chapter magazine is published twice a year. The next issue of the *Northwest Trenchless Journal*, our annual Buyers' Guide issue, is scheduled for distribution in the spring.

We are always interested in relevant, regional content to share with members. We welcome submissions such as technical papers and project profiles. Please contact Carlie Pittman at *pittmanc@ae.ca* before the end of March 2021 if you would like to contribute to the next issue of this magazine.

"WE ARE ALWAYS INTERESTED IN RELEVANT, REGIONAL CONTENT TO SHARE WITH MEMBERS. WE WELCOME SUBMISSIONS SUCH AS TECHNICAL PAPERS AND PROJECT PROFILES."

NO-DIG NORTH

# SPOTLIGHT ON NATIONAL PROJECT OF THE YEAR:

# CONSTRUCTION OF THE LARGEST SOLID WALL HDPE OUTFALL IN NORTH AMERICA – McLoughlin Point WWTP Outfall, Victoria, B.C.

Marvin McDonald, AECOM, Winnipeg, MB; Jordan Thompson, AECOM, Winnipeg, MB; Robin Dill, AECOM, Chelmsford, MA; Chris Macey, AECOM, Winnipeg, MB

## INTRODUCTION

AECOM and its Joint Venture partner, Graham Construction (AGJV), designed and facilitated construction of a new ocean outfall, as part of the new McLoughlin Point Wastewater Treatment Plant in Victoria, B.C. The outfall is 1.92 kilometres (1.2 miles) long, and is primary constructed with 2,250 millimetre DR26 High Density Polyethylene (HDPE) pipe. This is the largest solid wall HDPE outfall in North America. The construction of the project was supported by our subcontracting partners Michels Canada and Vancouver Pile Driving Ltd.

The design and construction of the outfall features several unique and innovative concepts. The outfall was constructed in two distinct segments, a 120 metre long inshore segment, constructed with steel pipe by "wet exit" microtunnelling, and an 1,800 metre long offshore segment, constructed with HDPE pipe and installed by "float and sink" construction. This article will provide an overview of the design considerations utilized for the project, and an overview of the outfall fabrication, assembly, and deployment of the two specialized construction areas: the inshore and offshore segments.

## DESIGN

Performance specifications for the plant required the outfall and diffusers required an ultimate design capacity of 438 mega litres per day (MLd) (5.1 cubic metres per second, [cms]). The range of flows over the life of the outfall, including diurnal and seasonal flow variation is highly variable, as indicated in Table 1. The high range in flow was a design challenge in selecting a pipe size that would provide specified scour velocities through the initial operational periods, and meet the ultimate long-term demands.

Table 1. Design Effluent Flow Rates

| | | Flowrates | |
|---|---|---|---|
| | | MLD | $M^2/s$ |
| Commissioning | Min | 43 | 0.5 |
| | Max | 381 | 4.4 |
| Ultimate | Min | 58 | 0.67 |
| | Max | 438 | 5.1 |

The resulting design resulted in selection of a 2,250 millimetre HDPE pipe, with an internal diameter of 2,076 millimetres. It was imperative through detailed design to ensure headlosses along the pipeline from the plant to the diffusers were minimized.

The maximum available head at the discharge point at the plant was limited due to by-law criteria limiting the building height of the wastewater treatment plant.

Near and far field diffusion modelling resulted in design of a 210 metre long, 36 port diffuser, located in 60 metres of water. Design specifications required a minimum Froude number of 2 to prevent sea water ingestion during lower flows. This would have required initially closing several ports that would need to be open over full effluent flow development. To eliminate the need for sequential port commissioning over time, 200 millimetre wide bill "duckbill" or pinch valves were selected for the diffuser port exits.

The offshore segment was designed to resist movement by hydrodynamic and current forces present at the site. The initial specified valves are presented in Table 2.

Table 2. Hydrodynamic Design Requirements

| Parameter | Value |
|---|---|
| Maximum Wind Speed | 110 kph |
| Significant Wave Height | 4.3 m |
| Wave Period | 7 seconds |
| Current Speed (Maximum) | 1 m/s (2 knots) |
| Current Direction | Generally east or west |

AECOM reviewed the available information and completed a wind hind-cast model, based on 125 years of record at nearby weather stations. Through statistical analysis, a 100 year wind speed and direction joint probability was completed, and displayed in a wind rose.

From this data, a wave estimation was completed using MIKE 21 Spectral Wave Model SW. This wave model resulted in a 100-year return significant wave height of a maximum of 3 metres from the southwest. This reduction in significant wave decreased design weight requirement considerably.

Using the significant wave, plus the specified design currents of 1 metre per second (m/s), a hydrodynamic stability analysis was completed. The analysis was completed generally using DNV F109 On-Bottom Stability Design of Submarine Pipelines. A summary of the hydrodynamic output is provided in Table 3.

## CONSTRUCTION – INSHORE SEGMENT

The inshore section from the new treatment plan to the ocean consisted of a 120-metre (394-ft) long, "wet-exit" microtunnelling drive which was constructed with a 2,120-millimetre (6.95-ft) steel pipe section with a 25 millimetre pipe wall thickness to safely resist installation jacking forces. The pipe was driven through highly abrasive granodiorite bedrock. The pipe selected

Table 3. Hydrodynamic Stability Summary

| Depth | Peak Horizontal Load (Fy) | Peak Vertical Load (Fz) | Friction Factor (μ) 0.6 for Silt 0.43 for Clay | Buoyant Unit Weight of Concrete Required (SF=1.5) | Mass of Pipe per Unit Length (Including Concrete Collars) | Mass of Weight as % Pipe Displacement | % Air to Achieve Neutral Buoyancy |
|---|---|---|---|---|---|---|---|
| (m) | N | N | Unitless | (kg/m) | (kg/m) | % | % |
| 15 | 4554 | 1852 | 0.60 | 1879.33 | 1443.60 | 47% | 54% |
| 20 | 2826 | 1911 | 0.60 | 1466.20 | 1012.46 | 36% | 41% |
| 25 | 2065 | 1572 | 0.60 | 1220.39 | 766.66 | 30% | 34% |
| 30 | 1642 | 1373 | 0.43 | 1247.50 | 793.77 | 31% | 34% |
| 35 | 1433 | 1256 | 0.60 | 1010.87 | 557.14 | 25% | 27% |
| 40 | 1312 | 1181 | 0.60 | 968.62 | 514.88 | 24% | 26% |
| 45 | 1260 | 1134 | 0.60 | 948.05 | 494.31 | 23% | 25% |
| 50 | 1225 | 1102 | 0.43 | 1057.75 | 604.02 | 26% | 29% |
| 55 | 1201 | 1061 | 0.43 | 1046.31 | 592.58 | 26% | 28% |
| 60 | 1186 | 1067 | 0.43 | 1038.70 | 584.97 | 25% | 28% |

Figure 1. Microtunnel Launch

Figure 3. Quality Control Testing

for the jack was Permalok® steel pipe in 3 metre lengths. The Permalok® pipe utilizes a specialized stab fit connection system, which eliminates welding during the jacking process. The pipe was protected from corrosion through use of an abrasion resistant overlay (ARO) epoxy, and the bore annulus was pressure grouted with a specialized grout containing a calcium nitrite corrosion inhibitor. The interior of the pipe was provided with a polyurethane coating conforming to AWWA C222 for corrosion protection. A cathodic monitoring lead was also added to the pipe for long-term monitoring of the steel pipe elements. On completion of the drive, the pipe joints were seal welded to ensure a leak proof product, and the weld holdbacks were repaired.

The drive started from an inshore blasted jacking shaft at a depth of approximately 12 metres (40 feet) below ground as shown in Figure 1, to a blasted offshore marine trench at a water depth of approximately 12 metres (40 feet), Figure 2. This section of pipe was

Figure 2. TBM Exit

installed by a Herrenknecht AVN MTBM. Production was in the order of 3 metres per day, with one shift.

The pipe used in the drive included a custom designed bulkhead door behind the TBM, which allowed for the TBM to be removed in the wet, and floated to surface. The connection of this system required a specialized 3-ring internal flange for connection of the bulkhead pipe to the product pipe to minimize intrusion of the internal flange to approximately 60 millimetres, to reduce headloss. The inshore end on the pipe featured a blind flange which protected the treatment plant site from flooding during constriction. On completion of the plant construction, the outfall chamber was flooded, and the blind removed by divers.

## OFFSHORE SEGMENT

The offshore section of the outfall was comprised of concrete weight ballasted 2,250 millimetre HDPE pipe, installed by “float and sink” methods, in water depths up to 62 metres (203 feet) deep. The float and sink installation was approximately 1,800 metres (5,900 ft) long, and included a 210-metre (690-ft) long, 36 port diffuser. The 2,250 millimetre HDPE pipe consisted of a short inshore section of DR 21 pipe (107 millimetre wall), and the balance utilized DR 26 pipe (87 millimetre wall thickness). This is the largest deployment of solid wall HDPE and the largest solid wall HDPE outfall in North America.

The initial pipe selected for this project during the initial bid was coated, lined, and cathodically protected steel pipe. During the design process, larger diameter, high-performance HDPE pipe, manufactured to European ISO standards, became available in North America in 2018. The change to HDPE pipe was premised on its long-term performance in the corrosive sea water environment, increased seismic resiliency, and its ease of construction.

Figure 4. Ballast Weight Installation

Figure 5. Diffuser Details

The size of solid wall HDPE pipe in North America, until recently, was limited to 1,600 millimetre diameter.

To facilitate the sinking operation, an installation sink analysis was completed to control the radius of the pipe bending during sinking. The analysis indicated that an end pull force of 100 metric tonnes was required, plus a 2 bar internal pressure, to control pipe bending to an acceptable level. A DR 26 pipe was selected after review of the dynamic installation forces required for this project.

The pipe was supplied by ISCO, and manufactured by Agru America in Charleston, SC, in 16 metre sticks. AECOM attended weekly pipe quality assurance sessions through the manufacture process (Figure 3).

The selected pipe ballast was 4.75 cubic metre precast concrete weights, spaced from 4 to 6 metres apart. Overall, a total of 350 ballast weights were installed. The weights were designed for the long-term stability mass required, as well as the installation forces expected during deployment. Each weight design is approximately 11,400 kilograms. The weights were designed to withstand a 2 bar internal pressure during deployment, and a maximum 3 bar test pressure post assembly.

Pipes were transported by truck to the assembly site, in Nanoose Bay, north of Nanaimo, about 180 kilometers by sea from the project site. HDPE fusion was completed on shore in a weather-resistant enclosure. Typically, two segments were fused per day.

The pipe was towed off the fusing machine, into Nanoose Bay, where the ballast weights were installed by crane (Figure 4), using a special frame designed by Vancouver Pile Driving. Each weight has a mass of approximately 11,400 kilograms.

Post pipe assembly, the pipe was pressure tested to ensure hydraulic integrity. The predicted pipe strain during the pressure test phase was an increase of 16 millimetres of pipe diameter, based on an estimated time based elastic modulus of 400 MPa for a four-hour test period. The actual measured pipe strain diameter during the 3 bar pipe expansion phase was an increase of 17 millimetres, which reduced to approximately 11 millimetres when test pressure was reduced to 2 bar. This measured pipe strain closely matched the predicted values.

The diffusers (Figure 5) feature 200 millimetre duckbill valves to prevent sea water intrusion into the outfall. This feature was selected to maintain adequate design diffuser velocities over the time dependent capacity development of the treatment system. The pipe diffuser section designed with a unique port sealing system that allowed it to be installed in one operation as part of the main pipe string. Traditionally, the diffuser section of an outfall is installed as a separate operation. A gasketed internal sealing plate was used to close off the diffuser ports during installation, to allow the pipe to be pressure tight during install. To accommodate the duckbill valves, a unique framing system was constructed to allow the sealing plate to be tensioned to the inside of the pipe. After deployment, the inner plate was removed by an ROV, allowing the diffusers to function as designed.

Materials and hardware for the project, including weight bolts, flanges, and fasteners were selected to provide corrosion resistance and project economies. Flanges included use of super duplex stainless steel flanges and fasteners. Due to the cost of these specialized fasteners, only enough corrosion resistant bolts were used to provide long-term sealing performance on bottom, with the balance of the fasteners being more economical galvanized mild steel. Similarly, bolts used in attaching weighs for pipe included a 50% mix of silicon bronze fasteners and marine-grade cold water anodes, and galvanized mild steel. The mild steel fasteners were required to ensure adequate clamping of weights to the pipe during install, and the silicon bronze to allow for long-term performance to hold the weights in place on bottom for duration of the 75-year design life.

The intertidal and subtidal zone was protected from anchor drag to a depth of 15 metres by installation of a riprap protection system. The riprap was designed as a filtered system progressing in size from a 75 mm sized material around the pipe and anchors to the surface riprap course of 900 mm sized rock.

The project also required habitat compensation due to the construction footprint. This was achieved through construction of intertidal reefs to augment the fish habitat. The berms were partially constructed with blast material from the tunnel exit shaft area. The design also featured installation of 20 bridges across the pipe, to allow for migration sea life across the pipe, should the pipe become embedded in the sea floor and restrict movements of species.

The offshore pipe was fabricated and installed in two segments. A short inshore segment approximately 40 metres in length was installed first. The design alignment required a 30 degree bend just offshore to align the pipe to its final location. This section was sunk as an open-ended pipe, using two cranes with spreader bars to lower the pipe to bottom. The longer second segment was sunk in place, using a "float and sink" operation.

The pipe was towed to site from Nanoose Bay on July 24 and 25, and was successfully deployed on July 25 and 26. The worksite was extremely congested with the Victoria cruise ship dock immediately to the east, and Victoria Harbour sea runway immediately to the north. Initially, the deployment was scheduled to commence at approximately 5 AM on July 25, but several delays resulted in deployment commencing in the late afternoon, which was completed at approximately 5 AM on July 26.

## SUMMARY

AECOM and its Joint Venture partner Graham Construction (AGJV) designed and facilitated construction of a new ocean outfall, as part of the new McLoughlin Point Wastewater Treatment Plant in Victoria, B.C. The construction of the project was supported by our subcontracting partners Michels Canada and Vancouver Pile Driving Ltd.

The project consisted of two unique construction segments. The inshore segment of 2,120 millimetre diameter steel pipe, from the treatment plant to approximately 120 metres offshore, was designed and constructed by microtunnelling through bedrock, using a "wet exit" technique whereby the TBM and carrier pipe were pushed out under the ocean, and the TBM retrieved by diver.

The offshore segment was constructed of 2,250 millimetre diameter HDPE pipe, weighted with precast concrete weights, and installed by a "float and sink" method. The 2,250 millimetre HDPE pipe is the largest solid wall HDPE outfall in North America, and featured a unique diffuser port design that allowed the diffuser to be installed as part of the main pipe.

This project was executed using design-build delivery. The designer, microtunnel, and marine subcontractors closely coordinated and optimized design and construction details to successfully complete the construction.

## REFERENCES


AECOM. (20188) – McLoughlin Point Wastewater Treatment Plant – Basis of Design Report – Outfall

NORTH AMERICAN SOCIETY *FOR* TRENCHLESS TECHNOLOGY

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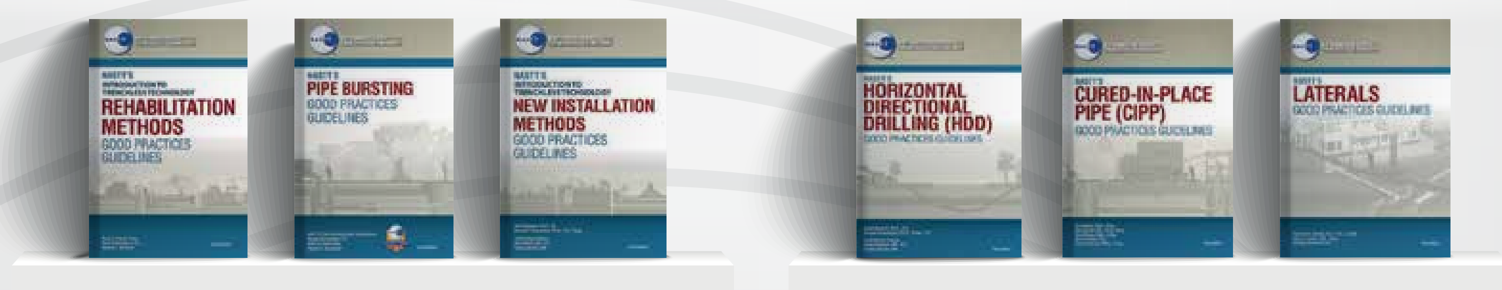


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# SPOTLIGHT ON GLSLA PROJECT OF THE YEAR: HANLAN FEEDERMAIN PROJECT

Eric Wildschut, Jacobs Engineering, Toronto, ON; Camilo Quintero, Jacobs Engineering, Toronto, ON; Justin Wassink, Jacobs Engineering, Toronto, ON

## ABSTRACT

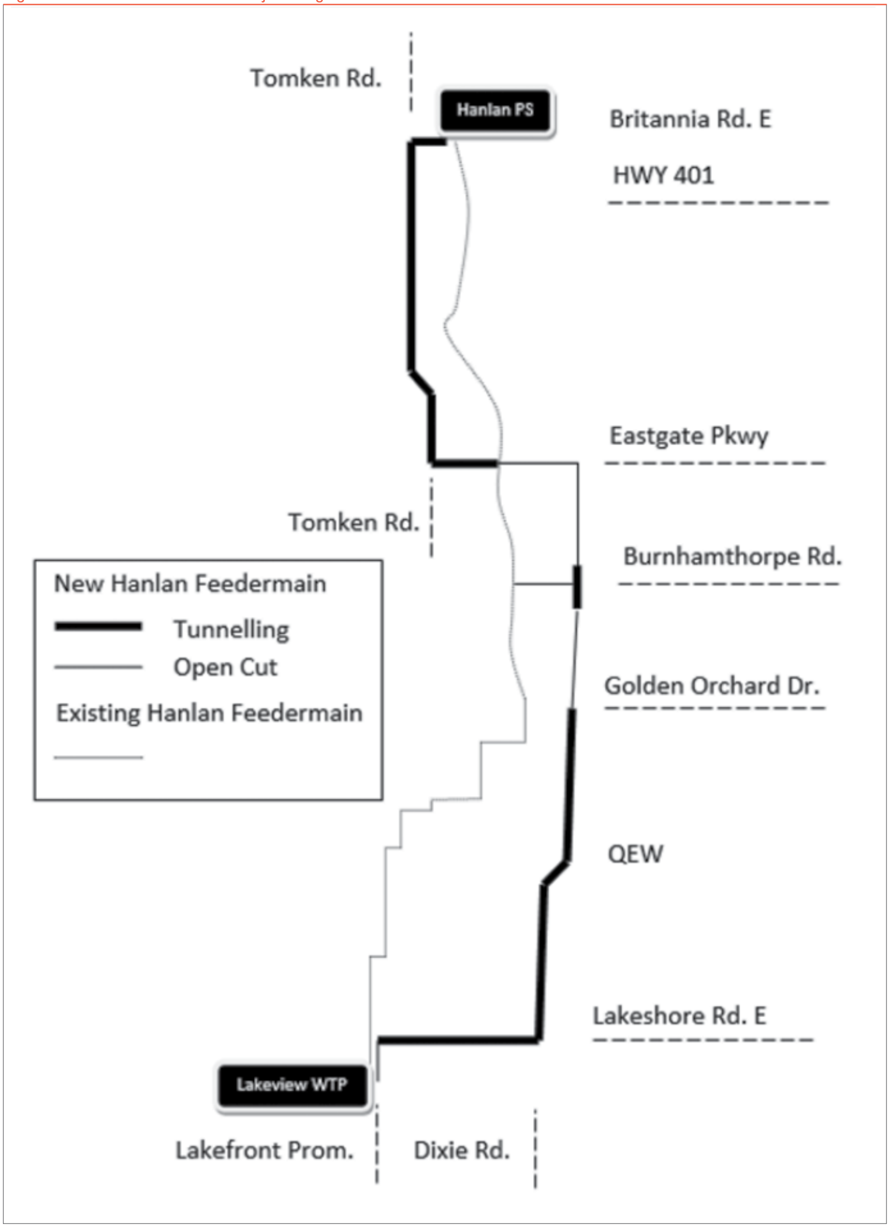
Construction of the Hanlan Feedermain Project, the largest watermain construction project in the history of the Region of Peel, includes the installation of 14 km of 2,400 mm feedermain pipe, 6 km of 1,500 mm sub-transmission watermain, and 13 km of smaller distribution watermains, installed via open cut and tunneling, as well as related sewer, road, and bike path improvements. As construction occurred simultaneously on multiple contracts, there were many challenges to the successful delivery of a multi-faceted construction program of this magnitude, including consistent monitoring of project costs, schedules, quality, safety, and public relations. This paper will focus on best practices and lessons learned for managing the construction of a large-scale conveyance project while meeting the needs of multiple internal and external stakeholders, utilities, and the public, and will also provide background for the design and construction of the tunneled sections of the feedermain.

## INTRODUCTION

The Hanlan Water Project (Hanlan) is a critically important initiative to ensure a reliable and affordable water security of supply for the Region of Peel (the Region), to meet the needs of Region growth and enable the Region to meet water supply commitments made to the neighbouring Regional Municipality of York. It is also the largest and most extensive watermain project that has ever been designed and constructed by the Region. The existing 1,800 mm Hanlan Feedermain was previously not twinned, and any break would have resulted in significant impacts within the Region. The Hanlan Water Project will interconnect the existing and proposed feedermains to allow for the existing feedermain to be taken offline for inspection and repairs.

The Hanlan Water Project consists of approximately 14 km of 2,400 mm feedermain extending from the existing Lakeview Water Treatment Plant on Lake Ontario to the existing Hanlan Reservoir and Pumping Station. The feedermain runs through the City of Mississauga, including residential, commercial, industrial, and recreational land. The project also includes design and construction of the Mississauga City Centre sub-transmission watermain (MCC), which will provide water to facilitate the intensification of the city's core. The 1,500 mm sub-transmission

Figure 1. Overall Hanlan Water Project Alignment




watermain runs 6 km south from the existing Hanlan Reservoir and Pumping Station. Approximately 13 km of water distribution works ranging in size from 150 mm to 600 mm were also be built as part of the project, located intermittently along and surrounding the Hanlan alignment. Additional works were included in some of the contracts to complete upgrades to sewers, roads, signalized intersections, and pedestrian trails. Design and contract administration of the project was divided into two sections, with WSP and Jacobs providing consulting services for the north and south portions, respectively. The feedermain alignment is shown in Figure 1.

## CONTRACT DIVISION

Due to its complexity and size, the feedermain was constructed under multiple contracts by various contractors. The north section (Eastgate Parkway, Tomken Road, and Britannia Road) was constructed via Contract 3 (C3), which also included the MCC and smaller diameter watermains for local distribution, whereas the work within the south section (Lakeshore Road and Dixie Road) was split into several contracts of varying size and scope, initially being divided based on similarity of scope and location. The south section was divided into Contract 1 (C1), which was tunneled and therefore dedicated to feedermain only, and Contract 2 (C2), which was open cut and so also included local watermains. Extensive planning was required for complex surface work through busy intersections, with detailed restraints being built into the contract. The C2 feedermain was constructed through the middle of Dixie Road, one of the busiest arterial roads in the Region, within an 11-meter wide work zone

Table 1. Details of Feedermain Contracts

| Contract | Length (km) | Installation Type | Depth Range (m) | Contractor | Value | Contract Duration |
|---|---|---|---|---|---|---|
| Contract 1 South | 0.3 | Open Cut | 3–7 | Varcon Construction | $4.9 million | November 2011 – July 2013 |
| Contract 1 | 5.8 | Tunnel | 10–27 | McNally Construction | $97.9 million | September 2013 – October 2014 |
| Contract 2 | 2.8 | Open Cut | 3–5 | Joint Venture: TACC, Dufferin, Dibco, Memme & Pachino | $53.4 million* | November 2013 – July 2016 |
| Contract 3 Feedermain | 4.5 | Tunnel | | Joint Venture: Southland, Technicore and Mole | $241.1 million* | April 2014 – September 2019 |
| | 1.0 | Open Cut | | | | |
| Contract 3 MCC | 3.9 | Tunnel | | | | |
| | 1.9 | Open Cut | | | | |
| Contract 4 | N/A (feedermain commissioning) | | | Moretti Excavating | $6.1 million | August 2017 – March 2019 |

*Contract 2 and Contract 3 also included smaller diameter watermains while still maintaining two lanes of traffic in each direction.

Since the overall Hanlan Water Project also included local watermains along the C1 alignment, this work was awarded separately via two smaller contracts with less capital cost, which allowed for the inclusion of smaller local contractors. To address potential issues of time and space separation between surface and tunneling contracts in the same area, a conservative approach was adopted to ensure that no concurrent work look place. It was decided that C1 – the large tunneling contract – would dictate the timing for all of the local distribution contracts. As such, Assignment Z1 for watermain on Lakeshore Road was issued in the fall of 2013, with the intention of being completed before C1 needed to tunnel in that area. Assignment Z2/3 for watermain on Dixie Road was then held for bidding until the C1 schedule could be reviewed and the restraints for Z2/3 could be fully determined.

Another separation occurred when it became apparent that the first 300 m of the feedermain would need to be installed in advance to facilitate other works occurring at the Lakeview Water Treatment Plant. This work was completed under Contract 1 South (C1S). Commencing in 2011 and finishing in 2018, the Hanlan feedermain was under constant construction for approximately seven years. In 2017 a final contract was issued for disinfection and commissioning, and the feedermain was placed into service in February 2019. The details of each feedermain contract are shown in Table 1.


## TUNNELING DESIGN AND CONSTRUCTION

The bedrock underlying the project site is the Georgian Bay Formation, which generally consists of shale with interbedded siltstone and limestone layers. The rock surface generally slopes from north to south within the project area, but several buried valleys are also known to exist within the rock. Geotechnical investigations for the south assignments included 12 boreholes during the Environmental Assessment phase and a total of 51 boreholes during the detailed design phase (see Coffey Geotechnics, 2012). Laboratory tests were also performed to determine properties and geotechnical parameters of the rock. Shale of the Georgian Bay Formation is known to possess high horizontal stresses; in addition, after elastic redistribution of the primary stresses, time-dependent deformation takes place. This deformation has been described in the literature as "swelling" or "squeezing" and is associated with high salt concentration. During the geotechnical investigation for the Hanlan project, free swell tests confirmed the time-dependent deformation of the rock, although the tests could not be extended to the typical 100-day period due to time constraints.

Table 2. Details for Each Shaft and Tunnel Drive

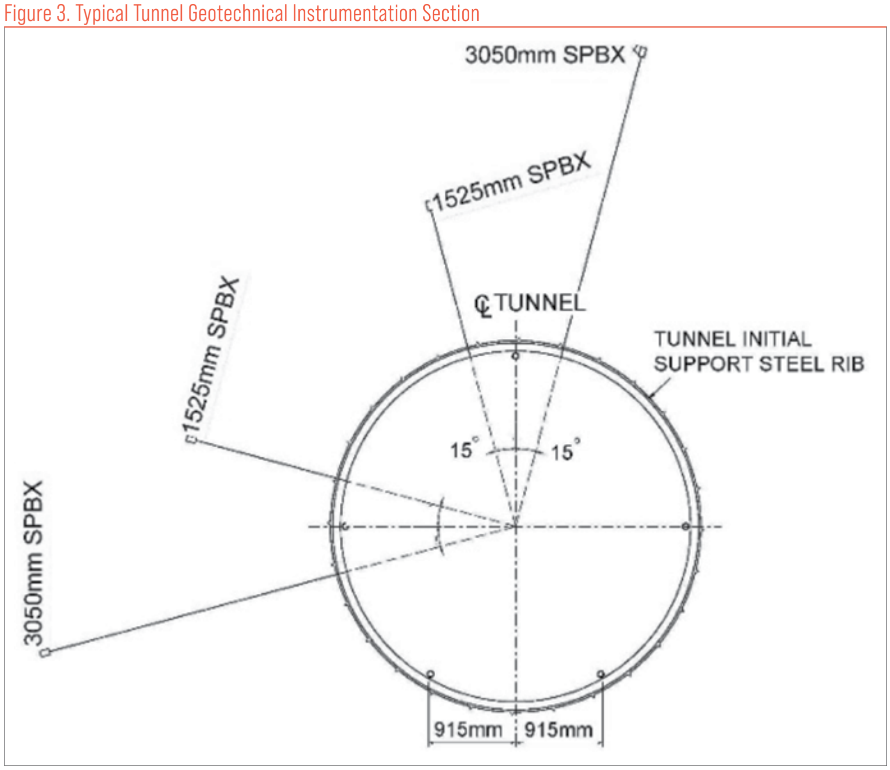
| **Contract 1** | | | | **Contract 3** | | | |
|---|---|---|---|---|---|---|---|
| **Shaft/ Tunnel** | **Location** | **Depth/ Distance (m)** | **Diam. (m)** | **Shaft/ Tunnel** | **Location** | **Depth/ Distance (m)** | **Diam. (m)** |
| Shaft 1 | Lakefront Prom./ Lakeshore Road | 15 | 8 | Shaft 9 | Eastgate Parkway | 44 | 10 |
| Tunnel S2 – S1 | Lakeshore Road | 1,330 | 3.68 | Tunnel S9 – S10 | Eastgate Parkway | 386 | 3.30 |
| Shaft 2 | Lakeshore Road/ Dixie Road | 17 | 18 | Shaft 10 | Eastgate Parkway | 42 | 14 |
| Tunnel S2 – S3 | Dixie Road | 1,975 | 3.68 | Tunnel S10 – S1 | Eastgate Parkway | 276 | 3.30 |
| Shaft 3 | Dixie Road/QEW | 16 | 8 | Shaft 1 | Eastgate Parkway/ Tomken Road | 47 | 12 |
| Tunnel S3 – S4 | QEW Compound | 80 | 3.65 | Tunnel S1 – S5 | Tomken Road | 3,132 | 3.30 |
| Shaft 4 | Dixie Road/QEW | 27 | 12 | Shaft 5 | Tomken Road/Hwy 401 | 25 | 12 |
| Tunnel S4 – S5 | Dixie Road | 2,430 | 3.68 | Tunnel S5 – S7 | Tomken Road | 792 | 3.30 |
| Shaft 5 | Dixie Road/ Golden Orchard | 32 | 8 | Shaft 7 | Tomken Road/ Britannia Road | 21 | 12 |
| | | | | Tunnel S7 – S8 | Britannia Road | 200 | 3.30 |
| | | | | Shaft 8 | Britannia Road (Hanlan PS) | 19 | 10 |

Case history information for other tunnel projects excavated in Georgian Bay shale indicate that overbreak at the tunnel crown has occurred because the combination of redistribution of the primary stresses and the time-dependent deformation creates stresses in the rock that are higher than the unconfined compressive strength of the shale (see Lo et al., 1978.). Overbreak tends to slow down construction because of the need for cleaning the tunnel invert and the need for additional crown and arch support. For Contract 1, due to some rock mass weak zones identified during the geotechnical investigation as well as potential rock mass weakness associated with zones of low rock cover and more deeply weathered rock, it was decided to specify ribs and lagging as the tunnel excavation support system. In addition, because the end product is a feedermain, at all creek crossings and all rail crossings, after the excavation support was installed and before the feedermain pipe installation, a steel casing was installed covering the length of the easement under the creeks and rail tracks respectively, as required by the stakeholders.

The tunneled feedermain sections included a total of eleven shafts and nine separate runs, the longest of which was 3.13 km (10,270 ft) along Tomken Road in Contract 3. Details for each of the shafts and tunnel drives are shown in Table 2. The feedermain alignment required tunneling under the six-lane Queen Elizabeth Way (QEW) highway, ten bridges which make up part of the 401/410 highway interchange (approximately 12 lanes), six river crossings, two rail crossings, and one elevated bus rapid transit crossing, all of which were completed without any issues or interruptions. After tunnel excavation, the 2,400 mm concrete pressure pipe was installed as the carrier pipe inside the tunnel. The annulus between the carrier pipe and the excavation support system and the steel casing and the excavation support was grouted with cellular grout.

To verify that tunnel and shaft wall deformations decrease with time, instrumentation sections were defined for the tunnel drives. In each instrumentation section, four single point extensometers were installed, two at 1.5 m and the other two at 3 m from the wall. At each location, extensometers were installed in pairs (one long and one short) at 30 degrees from each other, with each pair to be installed at 90 degrees from the previous pair. Figure 3 shows a typical geotechnical instrumentation section for the tunnel.

Figure 3. Typical Tunnel Geotechnical Instrumentation Section




Similar instrumentation sections were defined for the shafts due to concerns of damage to utilities in proximity to shaft excavations. Two instrumentation sections were defined at different depths for each shaft and high-level triggers (review level and alert level) were established. The review level is an instrumentation measurement value at which it is necessary to alter methods, rate or sequence of construction to control the effects of the construction. The alert level is an instrumentation measurement value at which construction may be stopped, the site and affected properties are to be secured, unacceptable ground or structure movements mitigated by necessary measures, and safety of public and work area ensured. The review level and alert levels for subsurface settlement points due to tunneling were defined at 10 mm and 15 mm, respectively; for instrumentation within the shafts, the review and alert levels were defined at 12 mm and 25 mm, respectively. During construction, there were only two


incidences of review levels for settlement points, and only one for shaft instruments, with no alert levels occurring.

## CONSTRUCTION MANAGEMENT

The construction management plan was set up to share responsibilities and take advantage of the strengths from both the Region and Consultant, with administration tasks handled primarily by the consultant and shared inspection duties. Inspectors were assigned so to have a consultant inspector and a Regional inspector on each contract, to allow sharing and separation of tasks. For technical issues on site, consultant inspectors are able to more easily tap into the design expertise of their firm, and Regional inspectors were better able to access Regional resources and coordinate Regional assets.

As part of the initial roll-out of the construction management plan, two items are of note. First is that the staggered deployment of contracts allowed for the management and site coverage plans to be adjusted prior to full scale deployment, i.e., establishment of clearer roles and responsibilities for consultant and Regional staff sharing inspection responsibilities, and for administration staff to establish standards and procedures for the remainder of the project. Second is that issues during initial contracts regarding constructability of the feedermain were instructive during design of subsequent contracts, so that the expectations and projections could be adjusted accordingly. It should not be understated how beneficial this was, as the constructability of a 2,400 mm concrete pressure pipe in an open cut manner within an urbanized area had only, until that point, been theoretically determined.

Once construction was underway for multiple contracts simultaneously, the contract administration and inspection teams collocated into project offices within the general work area. Although the inspection staff also worked out of the trailers provided at each contractor's site, it was also important to assemble all of the management staff in one location. The benefits of this were several. First, collocation allowed for faster decision making, as administration and managerial staff were able to immediately meet, investigate, and resolve problems as they occurred. Second, collocation allowed for multiple meetings to be held one after another between the same and different contracts, which increased the efficiency of the team and reduced any downtime lost between meetings for administration staff. Since each project required multiple bi-weekly site and coordination meetings, collocation provided increased productivity for the administration staff who would otherwise have had to drive to multiple constructions sites. Third, it allowed for consistency in a great accumulation of project materials in one place that was accessible to the entire project team. Although project materials were all stored electronically online for all team members to access, having hard copies of project documents in one location allowed for a greater efficiency by providing a collaborative, problem-solving space for members of the construction management team.

During construction, the constant monitoring of construction costs, schedule, quality and contract compliance, and safety is paramount for ensuring that the projects are delivered on time and within budget. Understandably, this becomes more complex as multiple contracts are simultaneously underway, all with different contractors working on different parts of the overall project. To best manage this, weekly progress meetings were held for each project to discuss the previous week's production, the next week's plans, projections of production to evaluate how realistic contractors' schedules are, contract compliance with specific monitoring (dewatering, settlement, vibration, noise, etc.), public relations issues, and potential upcoming conflicts and concerns. These meetings were held with only Regional and consultant management staff to ensure that all parties were up to date and to deal with issues and concerns quickly and effectively. It is critical that this meeting is held weekly, as onsite conditions can change quickly, and to ensure that the members of the construction management team are all on the same page to maintain consistency and fairness with how each contract is managed.

Just as it is important to deal fairly and consistently between each contract, it is important to also do so with the public. Stakeholder management has always been key to the success of the program and has required considerable attention for a project of this size. Design included the coordination of twelve sub-consultants, eight environmental/cultural regulatory bodies, four transportation/railway regulatory bodies, seven utility companies and multiple impacted landowners that all needed to be consulted and managed. As part of the overall Hanlan feedermain project, the Region instituted an extensive public relations program and hired multiple Project Ambassadors to inform, respond to, and champion the public's interests and complaints within the project team, and generally serve as a link between the construction teams and the community. This program also manages the advance notification of the public for issues that affect them, such as road closures, service interruptions, and night works. As the works can involve multiple road interruptions and closures all occurring simultaneously along a short stretch of a heavily traveled arterial road, disruptions to the public are an unfortunate byproduct of the work, but one that can be mitigated with the proper management and oversight. As part of the overall public relations program, the Region instituted a contractor awareness training that was given to each crew upon their first mobilization to site, to discuss and cover the Region's expectations and procedures if approached by the public with a complaint. It is important to track incidents and public complaints and hold contractors accountable where complaints are the result of actions that could have been prevented.

In addition to making it the largest watermain project in the Region, the size of the Hanlan Feedermain meant that additional effort was required during the commissioning process. Coordination between all the ongoing Contracts was required to ensure the operation went smoothly. The feedermain was disinfected using spray disinfection, a first known application of the method on this scale worldwide since AWWA allowed the rules to change in 2014. This required a detailed review of the contractor's proposed methodology and all health and safety considerations, as manned entries were required for the entire length of the feedermain. This methodology was highly successful and the main passed all required bacteriological testing the first time.


## LESSONS LEARNED AND CONCLUSION

There have been several lessons learned from the design and delivery of the Hanlan Feedermain Project. First, it is important to have a detailed plan of execution for the work, and to have that plan fully vetted and discussed in Value Engineering sessions, but also to be willing to change the anticipated sequencing once construction commences. This is important because once the Contractor is on board, they are going to bring their own skills, experience, and preferences into the equation. Site conditions and unexpected issues may require modifications to the anticipated construction sequencing. A strong contract framework is more important than the rigid timing and ordering of events. Without a strong plan, the Contractor would be able to claim additional funds, or successfully argue that certain contract requirements be ignored in the delivery of the work. It is important to have a strong plan in place, such that the work as bid is constructible in a means that meets the contract requirements. Once a change is proposed or becomes necessary, the framework provided in the contract can be leaned on to ensure that the overall goals of the project are maintained and that all parties are satisfied.

One of the ways that this played out on the Hanlan program is the restrictions and timing regarding open cut installation of the feedermain in Contract 2 along Dixie Road, but particularly through the Dixie Road and Bloor Street intersection. As Dixie Road is one of the major arterials in Mississauga, several construction constraints were developed to protect the public's interest. To accomplish this, and to complete the work in a timely manner and with minimal impact to the public, a detailed constructability plan was developed during the design phase. Once under contract, the contractor developed an alternative plan that matched their preferred methods for the installation. Although in some cases the contractor chose to follow the contract plan, in most others they diverged. Where they opted to diverge, the contractor chose their own productivity and construction preferences over contract provisions that were designed to ease the impact of construction on the public. This was allowed where feasible, however as a strong framework existed in the contract that was constructible, in some cases they were held to the contract provisions.

Second, it is important to take a partnering approach immediately at the start of the project, and to maintain that approach even while dealing with major issues. At the start of each of the main feedermain projects, a partnering meeting was held with the entire management team from the Region, consultant, and contractor to get everyone on the same page as to what each party's goals were. Periodic meetings were then held by upper management of all parties to ensure that these goals were being accomplished. This allowed for more direct lines of communication between the different project management teams, and has reduced contract change negotiations, reduced the average length of meetings, and allowed for a non-adversarial approach to exist.

Third, as this was a large capital project with construction through an election cycle, an increased level of scrutiny was required in the lead up to and during an election campaign to ensure that the political aspects and public relations goals of the project were achieved. While these issues were a priority for the entire duration of the project, additional time and energy were spent during the election period to ensure that these goals were met. As the public's expectations and direct access to projects and politicians increase via social media, it can only be expected that this will become more and more an area of focus for construction projects in the future.

Finally, it is important that the project management team be regularly cross-training and ensuring staff engagement on the projects they are working on. With a multi-year delivery plan of any project, it should be assumed that there will be staff turnover in all parties, so it is important to ensure that cross-training of roles and skills is completed so that the project management can continue uninterrupted when staffing changes do inevitably occur.

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