Rainbow Road Sanitary Trunk Microtunnel

Project Information

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- Project design work began in June 2017 and was completed in September 2017.
- Construction commenced on October 23, 2017 and was successfully completed on April 1, 2018

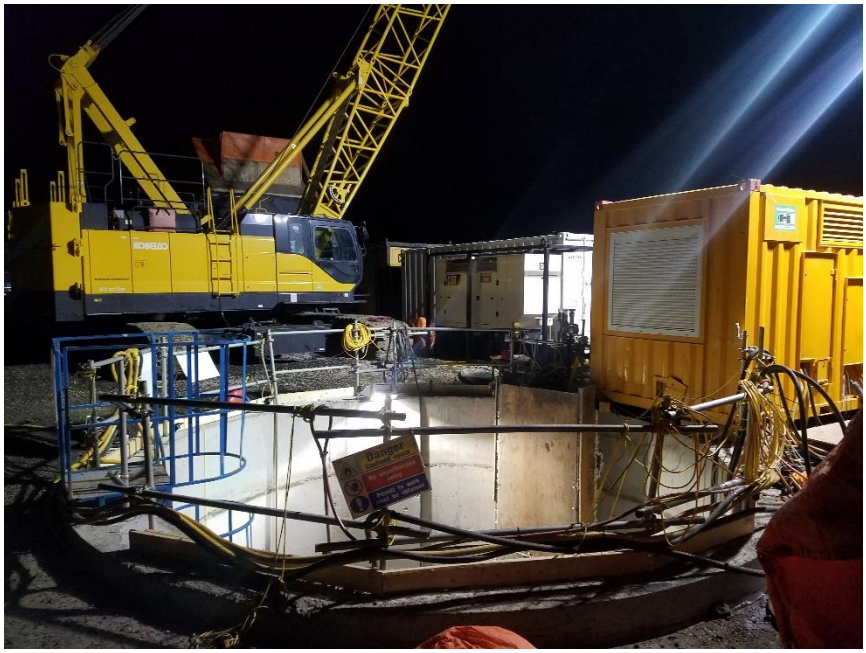
Project Summary

Chestermere Utilities provides safe and efficient utility services to the City of Chestermere, AB. It is dedicated to continuous improvement and developing innovative solutions to provide the highest value to its customers. Chestermere is one of the Canada's fastest growing communities and requires additional sanitary sewer servicing capacity to support future development. CIMA+ was retained as the prime civil consultant, with BlueFox as the trenchless consultant. Two multi-curve microtunnels were installed to provide the required solution.

Innovation

Phase 1 of the Rainbow Road Sanitary Trunk entailed the installation of approximately 900m of sanitary sewer from Rainbow Falls Gate, to the newly constructed Lift Station on the southeast side of Rainbow Road.

As the project developed, it became clear that due to existing infrastructure including a 400/500mm diameter water pipeline running parallel to the proposed alignment, Canadian National Railway, Alberta Environment Irrigation Canal, and newly installed road surface and sidewalks, that a conventional open-cut solution would not only be very difficult and disruptive but also very costly to the project owner.



Innovative thinking and alternatives analysis by CIMA+ included the discussion of trenchless options which led to the retaining of BlueFox Engineering as a trenchless engineering consultant. Together, BlueFox and CIMA+

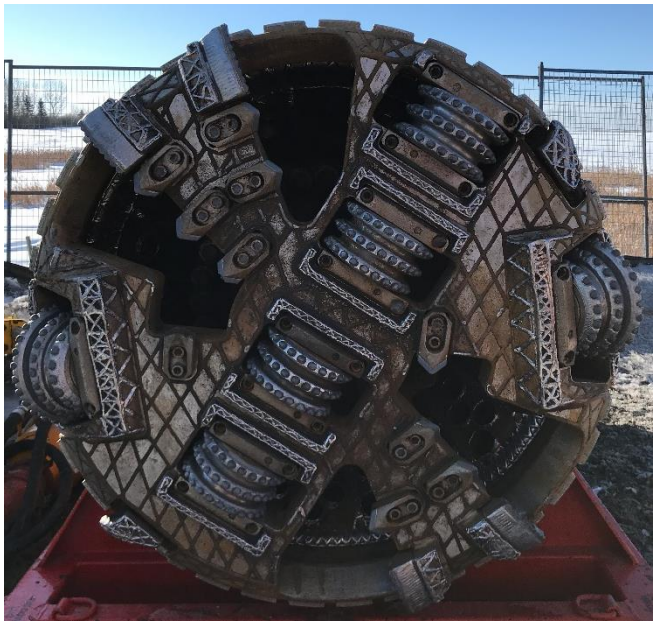
investigated solutions including: Horizontal Directional Drilling an inverted siphon, Pipe Jacking, Auger Boring, and Closed Face Slurry Microtunneling.

To meet the vertical clearance requirements from the Canal and to be able to service all developable area within the City's boundary to the west of Chestermere, the Rainbow Road Sanitary Trunk needed to be up to 14m deep in Phase 1. Due to the depth, a preference for an on grade installation method and following geotechnical investigations – Microtunneling was selected as the optimal solution.

This unique application is distinguishable from other projects in that we were able to install an on-grade sanitary sewer at much greater depths (up to 14m) than what would be easily achievable by conventional means, considering the nearby obstacles and existing utilities. We were able to navigate without impact, below, alongside, and underneath all of the existing infrastructure such as, overhead powerlines along the alignment, existing roadways, The City's water supply main, canal, and a CN railway. Once the project workspace was setup, the noise and construction traffic had minimal impact to nearby residents, as the tunnel progressed continuously for 24hours per day, 7 days per week.

Environmental Benefits

Surface disturbance was minimized by using specialized microtunnel equipment to install underground infrastructure. The new sanitary sewer pipeline infrastructure was installed under O/H power lines, a canal, roadway, railway, agricultural lands and a wetland without any surface disruption along the trajectory.

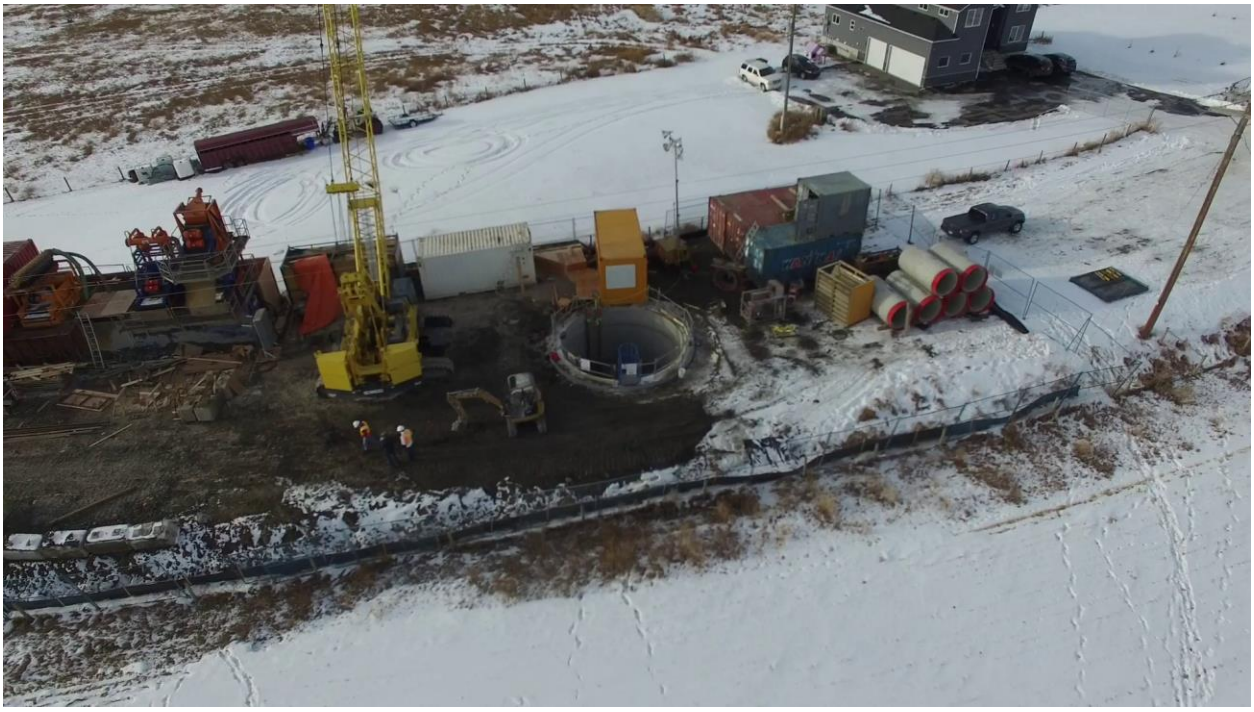


Because the MTBM only excavates the area required to install the pipeline, excavation equipment and spoils removal volume is reduced when compared to conventional methods that require significant large vehicle movement. As an example, for each linear meter of tunnel approximately 2 m^3 of excavation was required. Compare this to an open excavation that is 14m deep which requires approximately 200 m^3 of excavation per linear meter of pipe. The 100:1 savings in excavated material realized my microtunneling translates to a vast reduction in the amount of fossil fuels consumed to install the Rainbow Road Sanitary Trunk at its design depth.

Complexity

The Rainbow Road Sanitary Trunk was required to maintain an alignment within the 20m wide road right of way. Given the required depth of approximately 14m, a trench with side slopes of 1:1 would mean a 28m wide excavation at the surface, not including working space and benching to enable safe excavation. This combined with the fact the City's main water supply pipeline was located within the potential open-cut trench zone meant that standard construction methods would be very costly, if not impossible.

After deciding on microtunneling as the basis to overcome the majority of the obstacles on this project, the design proceeded with a central, bi-directional microtunnel launch shaft constructed as a concrete caisson with two reception shafts on either end. This particular microtunnel is more complex than traditional microtunnels, as it needed to be designed on-grade, and included two horizontal curves for the south drive, which totaled 390m in length. The north drive amounted to 490m length and had 1 horizontal curve. The curves were required in order for the tunnel trajectory to follow the existing road-utility right-of-way without affecting adjacent developments or residents.



The drive length of the north microtunnel required the use of two intermediate-jacking-station (IJS), and the south tunnel required one IJS to provide the required thrust force. Local geotechnical investigations encountered sandy gravel and silty clay, underlain by the mudstone part of the Paleocene Paskapoo Formation. A mixed-face Microtunnel boring machine (MTBM) face was specified for execution in order to process both overburden deposits and bedrock geology.

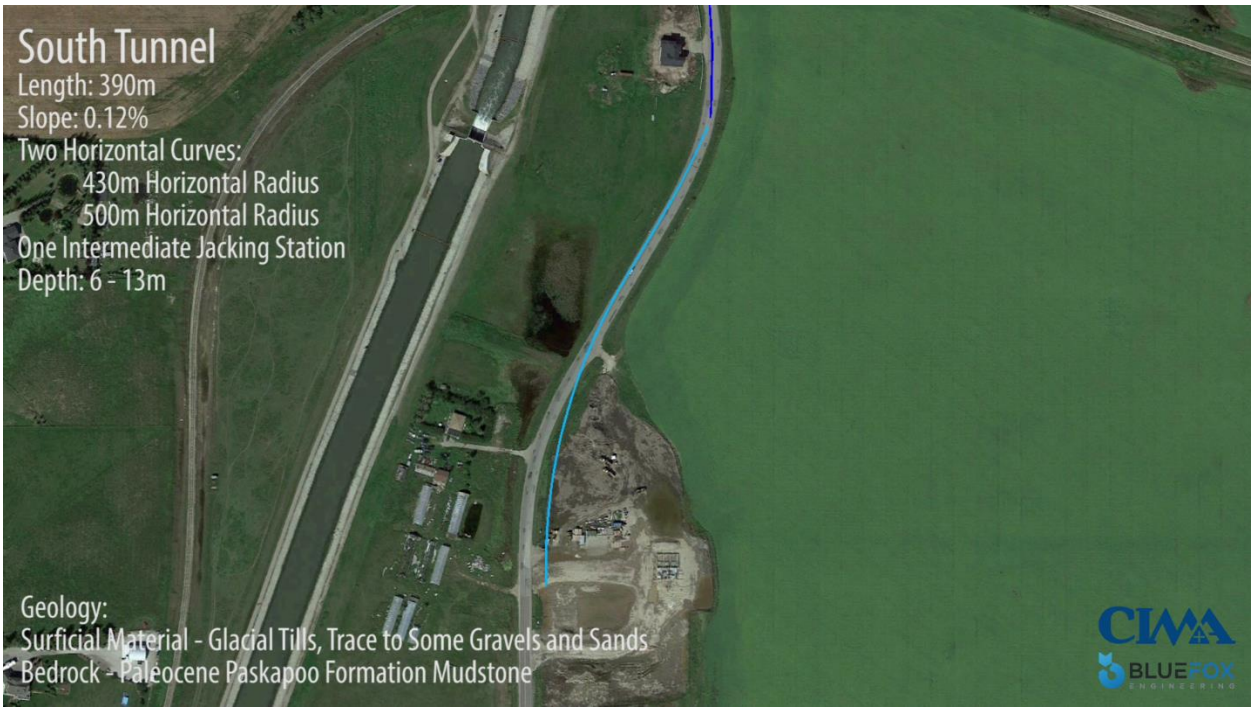
Alignment

South Tunnel

The South Tunnel was designed with a total length of 390m at a constant vertical slope of 0.12%. The design depth of the gravity sewer pipe varied from 13m deep at the north to 6m deep at the south. The alignment starts at the central launch shaft and includes two horizontal curves as it continues south. The two horizontal curves were designed with a 430m and 500m radaii to ensure that the alignment of the sanitary trunk remained within the 20m wide road right of way. This section of the tunnel terminates at a reception shaft that was constructed over top of the downstream connection, a 1050 PVC pipe, that was stubbed out from an existing lift station.

The decision to design a microtunnel for this section of the alignment was due to four primary reasons:

1. Existing Water Main – On the west side of the 20m wide road right of way exists a 500mm water main that is the primary water supply pipe for the City of Chestermere. An opencut excavation if at 13m depth would interfere with the integrity of the water main requiring it to be temporarily relocated prior to the start of construction for this project.
2. Existing Overhead Power – On the east side of the 20m wide road right of way existing 25kV overhead power lines. Discussions with the local utility indicated that temporary relocating these lines would be expensive and time consuming.
3. Environmentally Sensitive Areas – On both sides of the 20m wide road right of way exist wetlands that would be difficult to work around using an open cut installation method.
4. Safe Trench – Common safe trench practice requires 1:1 trench back sloping to be considered safe. This means that a 10m deep installation by open trench would require the full width of the 20m wide road of way. This doesn't include working space or room for a spill pile.



North Tunnel

The North Tunnel was designed with a total length of 490m at a constant vertical slope of 0.12%. The design depth of the gravity sewer pipe varied from 14m and 10m deep. The alignment starts at the central launch shaft and includes one horizontal curve as it continues north. The horizontal curve was designed with a 500m radius curve to ensure that the alignment of the sanitary trunk remained within the 20m wide road right of way and to avoid the bridge crossing the canal. This section of the tunnel terminates at a reception shaft that was constructed with approximately 1.0m separation from an active roadway.

The decision to design a microtunnel for this section of the alignment was due to five primary reasons:

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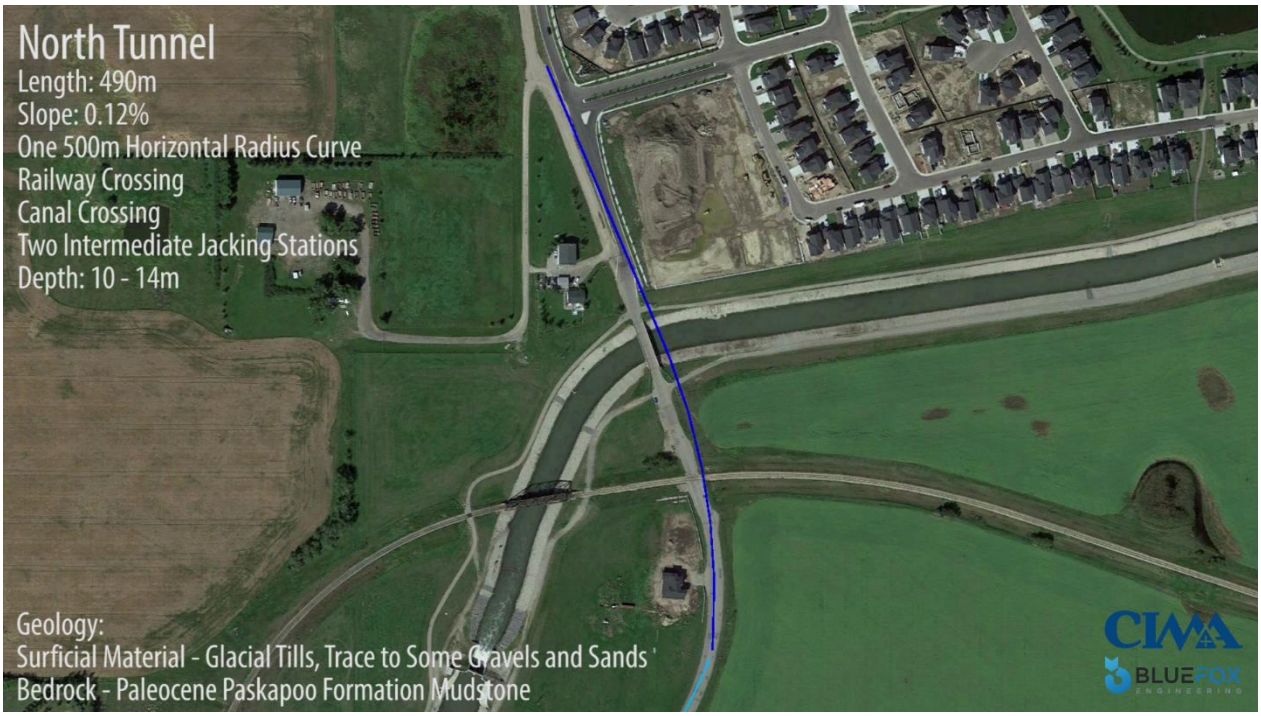
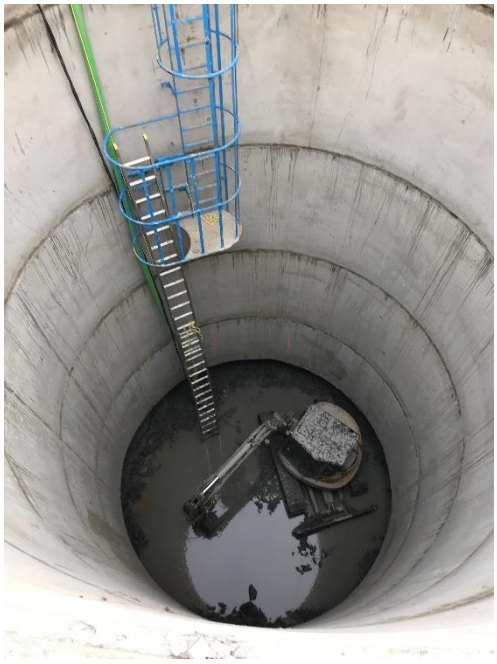
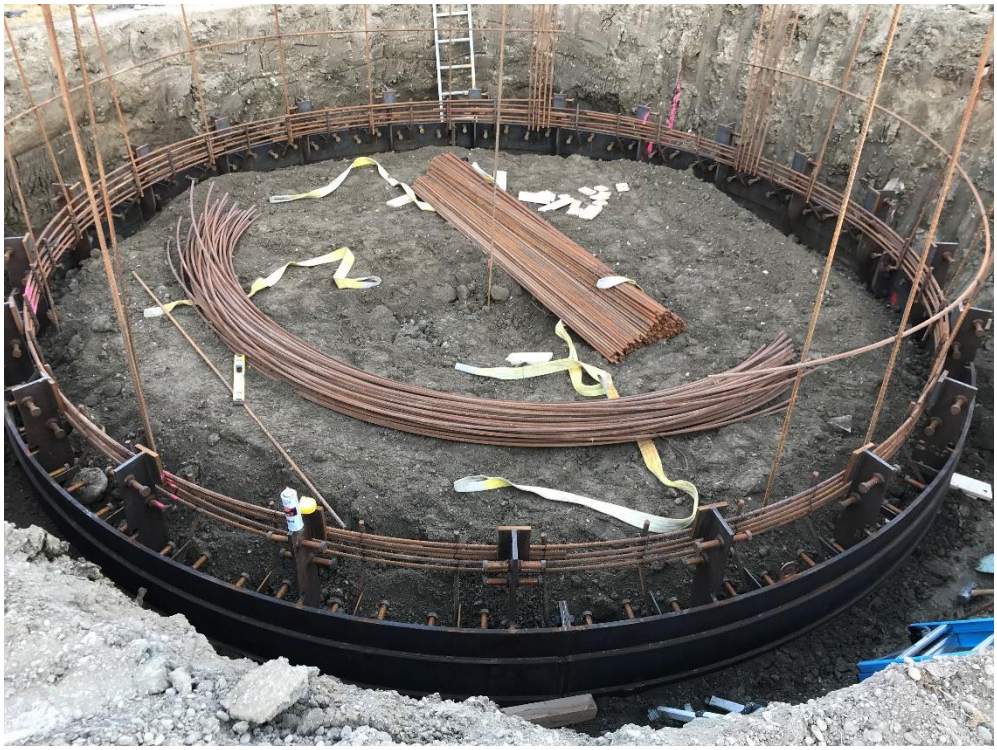
2. Existing Overhead Power – On the east side of the 20m wide road right of way existing 25kV overhead power lines. Discussions with the local utility indicated that temporary relocating these lines would be expensive and time consuming.
3. Canal Crossing – The owner of the canal required the Rainbow Road Sanitary Trunk to be 5m below the bottom of the canal.
4. Railway Crossing – The railway required a crossing that would be self supporting that was sufficiently deep to prevent settlement of the rail in the future.
5. Safe Trench – Common safe trench practice requires 1:1 trench back sloping to be considered safe. This means that a 10m deep installation by open trench would require the full width of the 20m wide road of way. This doesn't include working space or room for a spill pile.



Caisson Microtunnel Shafts

The Rainbow Road Sanitary Trunk project includes three shafts designed for caisson construction method. Using this method, a steel cutting shoe is formed at existing ground elevation and the first pour of concrete is formed on top of it. The shaft is excavated from inside until the entire structure sinks into the ground under its own weight. Each concrete pour is approximately 2.5m in height and the wall thickness is approximately 700mm. Once the caisson is sufficiently sunk, the second pour is added and excavation continues. A waterproofing barrier is placed between each pour to ensure that the shaft is water tight upon completion. This sequence is repeated until the caisson shaft is sunk to the design elevation. The north reception shaft and the launch shaft were designed and constructed to be 6.0m inside diameter while the south shaft was designed and constructed to be 5.0m inside diameter.



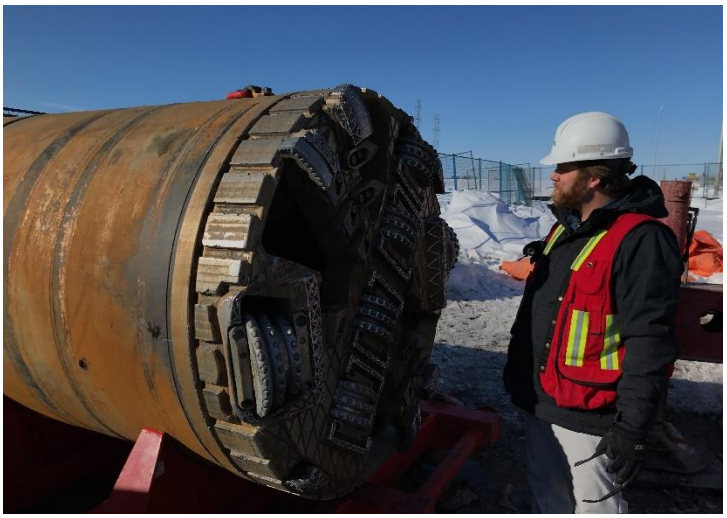


Microtunnel Pipe

The microtunnel pipe was specified as a wet-cast reinforced concrete pipe. Wetcast was specified due to its smooth outer finish that significantly affects the total jacking forces required to install the pipe by microtunnel. Each pipe sement is approximately 3m long and weighs around 4,200 kg. The inside diameter of the pipe is 1200mm and the outside diameter is 1490mm. The pipe was specified with an HDPE liner that was cast into the concrete at the time of manufacturing. Once the tunnel was completed, each joint had to be sealed with a cap strip. This resulted in a sanitary sewer pipe that had the benefits of being essentially jointless with the corrosion resistance and flow characteristics of a typical HDPE or PVC pipe.

Microtunnel Boring Machine

Microtunneling is a process of remote-controlled, continuously supported pipe jacking method whereby soil excavation takes place by way of infusing the soil with slurry at the face of the microtunnel boring machine (MTBM) which is excavated by picks at the machine head and high pressure jets which cut soils in the excavation chamber. The cuttings are forced into the slurry inlet holes and pumped to the fluid separation plant and back to the machine head through a closed-loop system. Due to the local geology encountered, a mixed-face MTBM was specified which is able to excavate soils, as well as bedrock formations. The mixed face MTBM is equipped with a cutterhead consisting of picks and jets for soils, along with roller cones and cutting disks for bedrock. Along with excavated soils, granular deposits or bedrock fragments are also forced through a crushing cone before entering into the closed loop slurry circuit.



The complete microtunnel operation is comprised of the MTBM, control container, guidance system, remote hydraulic power pack, jacking frame and slurry separation plant. The three-piece articulating MTBM and 3m pipe segments allow for both horizontal and vertical curvature which was required on this project to maintain the alignment. The borehole overcut was specified at 1541mm, allowing for 50mm overcut from the outside diameter of the pipeline being installed. The overcut area is filled with a bentonite slurry which acts as a lubricant as the pipe advances.

The bentonite slurry also acts to cool the machine face while excavating and acts to stabilize the formation. The slurry supported excavation and pressurized face requires no dewatering activities during excavation.

Hydraulic jacks within the launch shaft push the MTBM and pipe segments through the ground at the same time as excavation is taking place at the machine face in a single pass. The machine size specified was able to exert up 5,000kN of thrust force. Due to the require drive lengths of the project, 1 intermediate jacking station was installed on the south drive, and 2 intermediate jacking stations were installed on the north drive. Following tunnel completion, the intermediate jacking stations are collapsed, removed and the space is closed.

The MTBM is guided by a motorized total station and laser target unit which is able to determine the horizontal and vertical position, pitch and roll of MTBM at any point. Surface placed prisms at the top of the launch shaft, and prisms placed throughout the installed pipe segments are able to bounce the laser beam from the total station to the target for progression and calibration. This system was selected for its advantages in longer and curved microtunneling projects, the ability to determine and continually update and display the MTBM position, independent of drift or refraction was required for the more complex curvature associated with this project.

The guidance system employs a self referencing algorithm that uses measured system points to create a whole, uninterrupted representation of the actual pipe string position. The motorized laser total station is mounted in a fixed position in the pipe. The system measurements are carried out during the machine's on-going advance, meaning there is no interruption to the production.

Geotechnical Investigations

The project area is located at the boundary of the Southern Alberta Uplands and the Western Alberta Plains. The terrain is characterized by level to very gentle undulating, locally hummocky, plains. Slopes are typically in the 3degree range or less. Elevations along the trenchless route are in the order of 1105 meters above sea level.

Bedrock of the Paleocene Paskapoo formation underlies the Chestermere area. The primary lithological units consist of nonmarine sandstone, siltstone and mudstone. Glacial till, a heterogenous mixture of clay including cobbles forming draped moraine is considered to be the predominant surficial material in the area.

A local field investigation program was completed in September 2017 consisting of three test holes located in close proximity to the shaft sites for microtunnel launch and reception. The drilling and sampling work was undertaken by a truck-mounted M10 drilling rig. The boreholes were advanced by means of continuous flight, solid stem auger drilling.

The stratigraphic profile along the microtunnel alignment remained fairly consistent, comprised of a relatively thin mantle of glacial silty clay till, underlain by weak mudstone bedrock. Surficial gravel deposits were also noted toward the south end of southern alignment. Moisture contents within the clay till ranged from 12 to 18 percent, with liquid limits 31 to 34 and plastic limits between 13 and 15, corresponding to material of medium plasticity. SPT blow counts ranged from 7 to 28 blows / 0.3m, indicative of stiff to very stiff consistency. A 2.3m thick layer of sandy gravel was encountered and described as wet, fine to coarse grained and poorly graded. The moisture content was noted at 16.5 percent and SPT blow count value of 16 blows / 0.3m, indicative of material of compact relative density. Mudstone bedrock was penetrated at all three test holes, described as damp to moist, highly weathered, extremely weak to weak.

Social/Economic Benefits

The consideration to implement microtunneling for this project was initiated by the technical hurdles that had to be overcome, and was supported by social and economic benefits, such as:

- Minimal Disturbance to Surroundings – The footprint for the microtunnel construction zone was much smaller compared to a conventional solution and completed within the existing right of way (5,000 m^2 vs 70,000 m^2).
- Noise and Dust – The microtunnel launch site was located approximately 250m for the developed part of chestermere (there was a single residence within 25m of the launch site). The type of equipment required and the distance from the developed part of the City meant there was practically no impact to existing residents due to noise, even considering the 24-7 nature of the tunneling operations. Microtunneling creates a very low amount of air-borne dust compared to traditional open trench construction meaning that existing properties were not affected by dust from this project.
- Decreased Time – By confining the project to the 20m wide road, time-consuming approvals and land agreements for working space were avoided. The project was completed in April by microtunnel whereby a traditional open cut installation could not have even started until April due to winter conditions.
- Less Money – Because this project was completed in less time – including preparation and restoration – with decreased disturbance, this project was more economical than the open cut alternative at 14m depth when you consider the costs of shoring or relocating the existing water supply main and overhead power lines.

Meeting the Client's Needs

The objective of this project was to expand the City's sanitary sewer servicing capacity along its western boundary in an efficient, cost-effective manner with minimal impact to the environment and residents. The Rainbow Road Sanitary Trunk Microtunnel project delivered a solution that met the client's needs by:

- Capacity - Delivering the required servicing volume to unlock development along the western boundary of the City of Chestermere
- Maintenance - Providing an on-grade solution that minimizes future operational costs (for example flushing of an inverted siphon). This Rainbow Road Sanitary Trunk also does not require any future additional lift stations within the proposed servicing area, again reducing future operational costs.
- Schedule - The project's budget and timeline requirements were met.

CUI is currently considering the approach to take on the second phase of the Rainbow Road Sanitary Trunk where the depth is slightly deeper, but there are no curves, canals or railways to consider.