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The City of Calgary's Nose Creek Sanitary Sewer Trunk Phase B Contract 4

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Abstract: The City of Calgary's Nose Creek Sanitary Sewer Trunk Phase B project has been constructed over several years to accommodate future population growth and open more developable lands in northern Calgary. The project was divided into three phases, Phase A, B, and C, with each phase delivered by a separate consultant. Phase A was the downstream section of this project and was undertaken by Stantec Consulting. Phase B was the upstream section designed by CH2MHILL (now Jacobs) and further divided into different contracts (1 through 5). Phase C was a separate sewer called the Saddleridge Trunk sewer and this was designed by Associated Engineering. This paper covers Phase B, Contract 4, which had several unique challenges and included many innovative design and procurement solutions. One procurement strategy included a two-phase qualification package, with the initial phase to select a tunnelling contractor with the experience to deliver technical installations under rail and creeks, and the second phase, a RFP (request for proposal), to select a general contractor, with broader experience in open-cut and stormwater drainage, which were other aspects included within the project. This approach ensured that The City had the most qualified team available to complete the project. Technical challenges discussed in this paper include an oblique CPKC (Canadian Pacific Kansas City) rail and Nose Creek crossing that required independent review, and CFD (computational fluid dynamics) and hydrogen sulfide modelling to confirm conditions within the trunk sewer.

Key words: Sanitary sewer, municipal infrastructure, conveyance, upgrades, consulting.

1. Introduction

The City of Calgary (The City) is experiencing continuous development in the northern part of the City. To accommodate new developments and enhance the sanitary sewer capacity, The City started upgrading the existing sewer system in 2011. Overall, the sanitary sewer upgrade is divided into three Phases: Phase A, Phase B, and Phase C.

Phases A and C are built. Phase A involved twinning the existing sanitary sewer trunk along Nose Creek from the south side of the Bow River to 32 Avenue NE. Construction was completed in 2013. Phase C transferred into a new project called the Saddle Ridge Sanitary Sewer Trunk Upgrade. This project added a relief sanitary sewer trunk connection to the Nose Creek sanitary sewer trunk from Fox Hollow Golf Course, under Deerfoot Trail, and into the sanitary system near 11 Street NE and 12 Street NE, which services a large portion of northeast Calgary. The construction was completed in 2017.

Phase B involves twinning over 10 km of sanitary pipe from 32 Avenue NE past Beddington Trail NE. This phase is divided into 5 contracts. Contracts 1, 2, 3, and 5 are built. Contract 4 is under construction. In this paper, we will discuss the overview of the Phase B Contract 4 challenges including geotechnical, topography, CPKC (Canadian Pacific Kansas City) rail crossing, Nose Creek crossing, access to site, and the proximity of a major highway (Deerfoot Trail).

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Contract 4 includes an approximately 2.3 km long reinforced concrete sewer pipe, with a HDPE (High Density Polyethylene) liner, as seen in Figs. 1-3, with two tunnelled sections. One tunnelled section is a 260 m long siphon crossing under Nose Creek and the CPKC rail track. The other tunnelled section is a 1,500 m long section of 1,650 mm lined sewer pipe from the southwest side of the siphon running along the west side of Nose Creek to Laycock Park. The siphon is 1,500 mm in diameter and cased in a 2,400 mm sleeve and liner plates.

The remainder of the lined sewer pipe is beside Deerfoot Trail and is to be installed using open cut methodology. Contract 4 also includes stormwater and other infrastructure improvements within Laycock Park. A riprap revetment, OGS (oil-grit separator) bypass, rain garden, new pathway, and parking lot will be built. The trunk alignment is mostly in green space with irregular topography south of Beddington Trail and west of the CPKC rail tracks along the steep slope of the Nose Creek valley.

Part of the trunk is within the CPKC ROW (right of way) and the Deerfoot Trail TUC (transportation utility corridor). The siphon crossing under Nose Creek is 6.1 m deep from the bed of the creek and under CPKC it is 12.3 m deep from the rail tracks. During construction traffic disruption is expected on Beddington Trail southbound and Deerfoot Trail southbound. Therefore, a traffic safety and accommodation plan from the Contractor is required during construction. A preliminary permit for access and traffic accommodation was acquired before the procurement stage to ensure traffic flow and commuter safety was considered.

2. Design Challenges

2.1 Route Selection

The City's hydraulic model assumed the route for the new sewer trunk would run parallel to the existing sewer trunk, with associated tie-ins between Beddington Trail and 32 Avenue NE. This was the base route used to review potential alternative routes within the area.

An AVM (asset value management) process was undertaken using a route selection tool to rank potential route combinations, weighted for the following five main categories: economic, social, environmental, timescale risk, and technical risk. The tool generated a matrix and provided an associated weighting for each route.

The AVM process provided a guidance framework for selecting the route. The final route was selected after stakeholder input and City review was received and shown in Fig. 1 below. This route was selected for progressing into preliminary design, the alignment was refined further after a constructability review of the major road crossing and depths of excavation. Fig. 2 below shows some of the sections that were refined following this process.

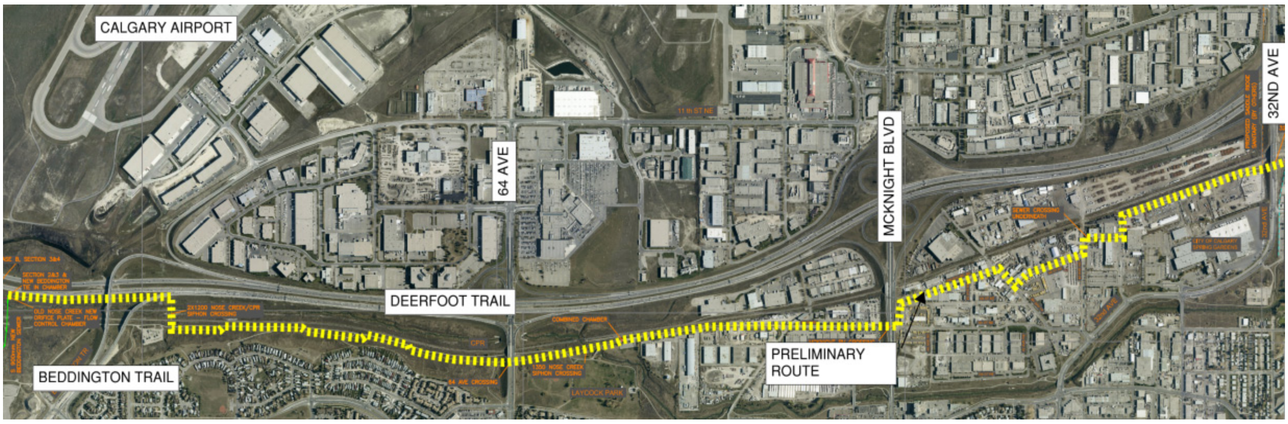

Fig. 1 Preliminary Phase B: route alignment.

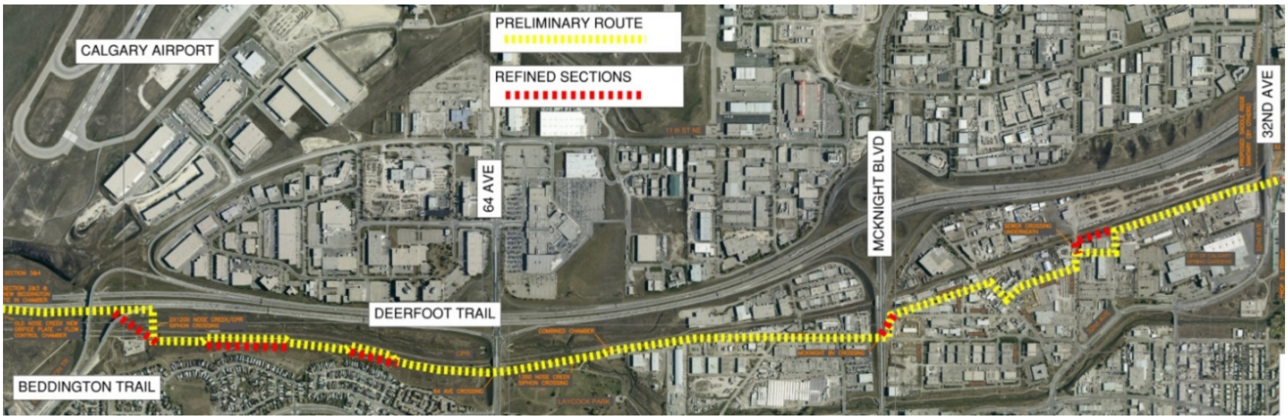

Fig. 2 Preliminary Phase B: route alignment with refinements.

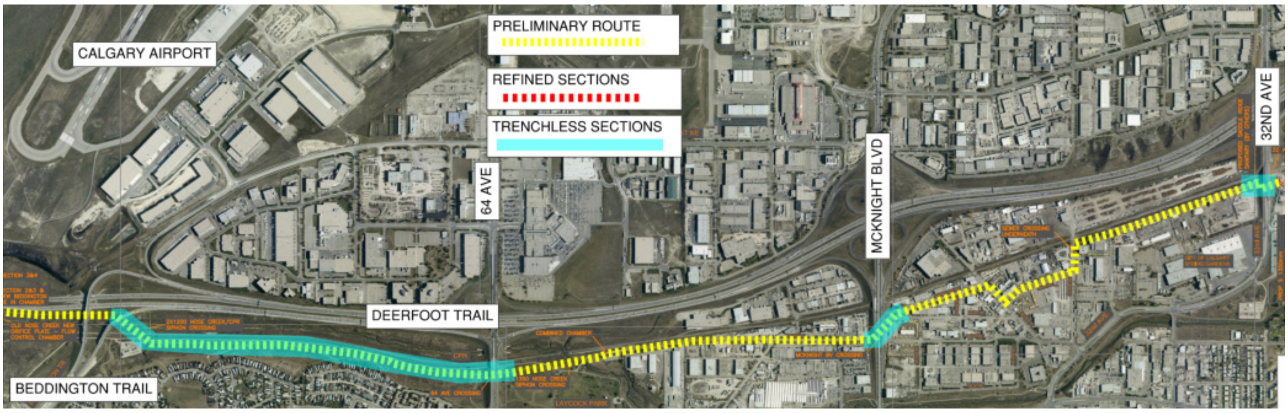

Fig. 3 Trenchless sections.

There are typically two methods used for the installation of large diameter sewer trunks, open cut or trenchless. Open cut installation can be used in conjunction with shoring (trench boxes or slide rail systems), commonly used when space constraints limit the working area available for safely excavating the trench. Open cut was selected for most of the locations where there was sufficient space to install shoring systems, or the depth of cover was not too deep for shoring to be cost effective. Trenchless installation methods were chosen for the locations where open cut was not practical or permitted, such as major road crossings, crossing under Nose Creek, deep sections, and under railroad tracks. Shoring was also used for open cut sections close to the Beddington Trail bridge piers and when the alignment encroached to within 15 m of Deerfoot Trail edge of pavement. Fig. 3 above shows the sections that were designed for open cut and trenchless installations.

2.2 Geotechnical Considerations

Thurber Engineering LTD (Thurber) completed a preliminary geotechnical assessment (commonly referred to as a desktop study) on May 29, 2009, titled *Nose Creek Sanitary Sewer Trunk Upgrades—32 Avenue to 144 Avenue N.E* [1]. The report provided a summary of the geotechnical investigations carried out within the study area and included relevant geotechnical information that was readily available. The study area followed the existing utility ROW along Nose Creek on the east side of Deerfoot Trail.

All available geotechnical information was examined to determine the elevation of the bedrock and groundwater. The borehole information was interpolated to determine the elevations of each strata. The bedrock was typically found to be at an elevation of approximately 1,045 m. At this elevation, in the north end of the route, this would be considered shallow bedrock (only 3 to 4 m deep).

The existing pipe elevation had been laid just above the soil-bedrock interface. Shallow bedrock is probable in the upper 6 m of the alignment. This will present more difficult tunnelling at the CPKC rail track crossings and road crossings where open cut is not an appropriate method of construction. Due to shallow bedrock, the crossing was deepened to avoid the interface. The upper bedrock is weak and weathered but will allow for easy excavation. It was predicted that this will be found along the whole length of the alignment. The upper bedrock is predominantly fine-grained silts and clays. It is predicted there will not be any large areas of sand and gravel except perhaps at the southern portion of the alignment. Boreholes were recommended to be taken to verify if sand and gravel deposits are present along the alignment. The southern section of the alignment has fill and poor ground conditions, which is most likely due to the developments in the area over the last 50 years. Open-cut construction will be relatively easy since it is predicted that the bedrock is sufficiently weak and/or weathered. The data on groundwater levels from the existing test holes and test pits indicate that the groundwater table is within approximately 2.5 to 5 m below grade. At the northern end of the alignment, soft ground was identified along the open cut section. A slope stability analysis was undertaken to identify measures to prevent slope instability from affecting Deerfoot Trail. Shoring was the recommended method of trench support when the center line of the pipeline encroached to within 15 m of Deerfoot Trail. A GBR (geotechnical baseline report) was developed by Jacobs Canada Inc. (Jacobs) for procurement purposes.

2.3 Tunnelling Assessment

Sound, quality bedrock (with at least 3 diameters cover) is typically a good soil condition in which to carry out tunnelling operations; however, it has only been found at depths of 8 m and below and only in one existing borehole location. Tunnelling at depths greater than 8 m would have resulted in siphons being installed at tunnel locations. It is suspected that an inadequate pressure head will be generated for the siphons to function hydraulically.

At shallower depths, risks associated with mixed face conditions will need to be considered and consequences, such as sinkholes, prevented. There have been indications of gravel lenses within the shallow layers and fill has been indicated to depths of up to 6 m. There is a risk that it may not be possible to prevent the flow of these materials into the tunnel.

Ground probing and ground treatment methods should be considered to discover any problem layers and to stabilize and strengthen the ground where required. Further detailed site investigation is to be carried out at each identified tunnel location.

For the preferred diameters of 1,650 mm and 1,500 mm (cw 2,400 mm casing), many trenchless methods are beyond the limits of their proven track record. Microtunnelling, a pressurized face TBM (tunnel boring machine) along with pipe jacking, or pressurized face TBM with tunnel segments, will most likely be the methods used. Depending on the soil conditions for the proposed profile, a specific trenchless method could be proposed.

Initial design options considered a twin barrel siphon under Nose Creek and an analysis undertaken on the cost comparison of tunnelling two separate tunnels for each barrel, or one large tunnel with the twin barrels inside a large casing. Due to the size of the single large tunnel, it was determined not feasible due to permitting requirements. Subsequent value engineering exercises ultimately reduced the twin barrel to a single barrel.

Following on from the desktop study, Thurber Engineering undertook additional geotechnical investigations and produced two Geotechnical Data Reports (GDR) [2, 3]. These reports supplemented a *Geotechnical Baseline Report (GBR)* [4]. This additional investigation included a drilling program for 13 boreholes, SPTs (standard penetration tests) were conducted in the overburden soils at selected depth intervals to assess the relative density and/or consistency of the soils encountered.

Four of the test holes were cored using High Quality (HQ) (nominal 63 mm diameter core) triple-tube wireline equipment, typically in 1.5 m runs. The core was logged in the field and the following diagnostic features were measured before it was transported to Thurber's laboratory for further testing:

- REC (total core recovery)
- SCR (solid core recovery)
- RQD (rock quality designation)

Bedrock was encountered along the entire alignment at a depth ranging from 2.1 to 8.4 m below ground, REC ranged from 39% to 100%, SCR and RQD ranged from 0% to 100%, and fracture index ranged from 0 to 9 with an average of 3 m recovered per core.

UCS (unconfined compressive strength) ranged from 0.1 MPa (stiff clay) to 4 MPa (very weak) and the harder sandstone and siltstone 10 MPa (weak) to 92 MPa (strong); however, it was noted that on other projects in this area UCS up to 150 MPa has been measured.

Hand slotted 25 mm diameter standpipes were installed in all the test holes along the open cut sections of the alignment to measure groundwater levels.

At the trenchless crossings, 50 mm monitoring wells were installed to measure groundwater levels and to conduct in-situ hydraulic conductivity tests. All of the wells were screened across the proposed pipe depth at the time of investigation. The screened portion of each well was backfilled with filter sand, with a 1.5 m thick bentonite seal above the sand. The remaining hole was backfilled with drill cuttings, with another bentonite seal at the surface to prevent infiltration of surface water.

Hydraulic conductivity values, using the in-site rising and falling head tests ranged from 1×10^{-6} cm/s to 4×10^{-2} cm/s.

A geophysical survey using ERT (electrical resistivity tomography) was undertaken at the rail and creek crossing south of the Beddington Trail interchange. The objective of this survey was to map the bedrock surface along this portion of the alignment. The bedrock survey did not identify any concerns or issues with granular material underneath Nose Creek that could have impacted the vertical profile under the Creek.

2.4 Flow Control and Hydraulic Balancing

A flow control assessment was undertaken to ensure an equal flow split between the new and existing sewers at the upstream tie-in at Beddington Trail. It was critical to update the preliminary design modelling assumptions that were made several years ago. Population projections were re-evaluated and revised flows calculated.

These revised flows were modelled under various scenarios in the downstream sewers, to establish a balanced flow regime between the existing and new sewers, this was done to ensure that minimum velocities were achieved in the downstream siphons, to reduce operational impacts. The upstream flow chamber was designed with flow control gates to adjust the flows to achieve the desired balance. Additionally, the flow control gates could be used to divert flows to either the existing or new sewer to increase flushing velocities to remove blockages downstream.

2.5 CFD (Computational Fluid Dynamics) and H_2S (Hydrogen Sulfide) Assessments

The upstream flow chamber was identified as a potential source of turbulence and generator of H_2S. Due to these concerns The City requested that CFD and H_2S assessment be provided to enable safe access for operations to maintain the flow control gates.

The objectives of the study were to validate the concern that H_2S concentrations inside the chamber may exceed allowable limits for occupational safety and determine ventilation strategies to mitigate this concern. A series of CFD models were developed to evaluate the H_2S circulation and ventilation at the proposed Beddington tie-in chamber for the Nose Creek Sanitary Sewer Trunk Phase B Contract 4 project. The model includes liquid flow phenomena that ultimately determines the H_2S gas migration such as hydraulic flow characteristics, turbulence, and flow split at the tie-in chamber. The amount of H_2S stripped to the air will be estimated using WATS (wastewater aerobic/anaerobic transformations in sewers), a sewer process model. The results of WATS will serve as one of the inputs to the CFD model. This computer simulation of the active chamber will inform effective location and sizing of ventilation ductwork and equipment.

A CFD model requires the development of a 3-dimensional solids model that represents the fluid flow space. After development of the fluid model, a suitable finite-volume mesh is created. Mesh refinement techniques are often implemented to resolve computations to a high degree of accuracy in regions where the flow parameters change rapidly. After the volume mesh is created, fluid modeling parameters along with boundary condition information must be assigned. Fluid assignments include parameters such as viscosity, density, velocity, pressures, or other important parameters that influence the flow characteristics being modeled.

CFD results are stored in large binary data files from which data can be extracted and displayed in multiple ways. There is considerable flexibility in reviewing results that aid in interpretation of hydraulic performance and H_2S concentration. Flow pattern visualization includes horizontal and vertical slices showing magnitude contours of various parameters including pressures, velocity, directional velocity components, acceleration, and H_2S concentration. Vectors, streamlines, and particle tracking along streamlines can be added to illustrate the direction of parameters such as velocity. Iso-surfaces can be created to illustrate the water surface or H_2S concentration or temperature. Animations can also be created to show time-dependent system behavior. Well-developed visuals can effectively illustrate the complex flow field so it can be understood.

The WATS model evaluates chemistry; aerobic, anoxic, and anaerobic biological processes; liquid and vapor mass transfer; corrosion; releases of gas to the environment; impact of drop structures; and corrosion. WATS considers many more variables and processes than previous simplified models, allowing the project team to address the challenges of controlling odors in highly dynamic, complex collection systems. The sewer process model will be used to estimate the H_2S generated and stripped into the structure headspace. The WATS model will be used to estimate roughly the ventilation air flow needed to achieve a safe atmosphere for worker safety. If it is believed that the results of the WATS model are overly conservative, a CFD model will be developed with the WATS model. H_2S estimated stripping rate being input into the CFD model. CFD and H_2S modelling is currently underway, and results are expected soon and will be presented at the 2024 conference.

2.6 Construction Phasing

Due to rising construction costs, the construction of Phase B was split into 5 construction contracts as detailed below:

- Contract 1—Laycock Park, including Nose Creek Siphon 64 Street
- Contract 2—32 Street to McKnight Boulevard NE
- Contract 3—Tunnel under 32 Avenue, McKnight Boulevard NE to Laycock Park
- Contract 4—Tunnel under 64 Avenue to Beddington Trail Split Chamber
- Contract 5—Laycock Park Split Chamber

Contracts 1, 2, 3, and 5 have been constructed and Contract 4 construction is ongoing.

3. Regulatory Approvals

The Nose Creek Sanitary Sewer Trunk Phase B Contract 4 required approvals, permits, and notifications under multiple bylaws, policies, and acts from the Municipal, Provincial, and Federal governments prior to construction. Submissions for these regulatory requirements included Calgary Municipal Development Plans, Alberta Highways Development and Protection Act, Transportation and Economic Corridors Permit (previously known as a Roadside Development Permit), Alberta Public Lands Act, Canadian Navigable Waters Act and CPKC Agreement for the Laying of Pipelines on Railway Lands Crossing the Railway.

The project's extents are primarily located in a natural park space beside a waterbody. Not all regulations require submissions, but still need to be followed prior to and during construction activities. Wildlife and environmental protection acts that needed to be considered during project planning included the Migratory Birds Convention Act, Species at Risk Act, Alberta Wildlife Act, and other related acts.

Two regulatory requirements needed additional time and effort to gain approvals than anticipated, which impacted the overall project schedule. The CPKC Agreement for the sanitary siphon underneath the rail tracks took eleven months from initiating the request to receive the agreement. During this period, two supplemental scope and fee agreements were authorized with activities related to the CPKC Agreement. Work included additional geotechnical information, track monitoring details, and engineering drawings. The Transportation and Economic Corridors Permit also required additional time and effort than initially planned. This permit required eleven months from initiation to approval. During this time, two supplemental scope and fee agreements were authorized to with activities related to the Transportation and Economic Corridors Permit. Work included technical memorandums for work beside a Beddington Trail bridge pier and the slope stability of the open cut excavation beside Deerfoot Trail. The outcome of this permit approval also added additional scope and cost to construction, as shoring is required during open cut work beside Deerfoot Trail.

4. Procurement

The procurement methodology used was a combined RFPQ (request for pre-qualification) for tunnelling contractors and RFP (request for proposals) for general contractors. Tunnelling projects from The City of Calgary will typically follow an RFPQ and RFQ (request for quotes) process, expediting the latter part of the procurement to a quote only submission from qualified contractors.

The atypical procurement strategy of an RFPQ then RFP was utilized because the project work is greater than tunnelling only. The scope broadly includes: 1,500 m of tunnelling 1,650 mm pipe, 260 m of tunnelling 1,500 mm pipe for a siphon, 500 m of open cut for 1,650 mm pipe, a split chamber, 2,500 m^2 of parking lot restoration, a 2,500 m^2 rain garden, 100 m of pathway, 220 m of permanent asphalt road construction, 540 m^2 of riverbank restoration and revetment, OGS repairs, 75 m of twinned 1,050 mm pipe for an OGS bypass, and restoration within the environmentally sensitive and highly trafficked area beside Nose Creek and Deerfoot Trail, the primary highway through Calgary.

The project scope is greater than only tunnelling works; therefore, the contractor's team must be competent and have experience with managing multiple work areas for multiple utilities and different types of pipe construction methodologies. Only reviewing qualifications for tunnelling contractors was not enough due diligence to ensure the entirety of the project scope could be handled sufficiently by the selected contractor team.

The upgraded sanitary system capacity of this sanitary sewer trunk is forecasted to be required by the year 2030. Surcharging in the system occurs during severe flow events, and the work was scheduled to be completed prior to the forecasted requirement to resolve surcharging issues and ensure the sanitary system capacity is ready for deviation from the forecasted population growth. The extended procurement timeline was not an issue due to these requirements not being urgent.

4.1 RFPQ

The project personnel evaluated for tunneling contractors were the Project Manager, Superintendent, and Tunnelling Operator. The projects submitted were evaluated based on their relevancy. Table 1 shows a summary of the RFPQ evaluation. A total of nine (9) submissions were received, and seven (7) tunnelling contractors prequalified.

4.2 RFP for General Contractors

The RFP for general contractor's evaluation scoring included the total weight of the price submission at 30% and the remaining 70% evaluated based on the contractor's proposal, as summarized in Table 2. A team of four (4) evaluators reviewed all RFP submissions. One (1) general contractor and their proposed team were awarded the project.

5. Construction and Potential Construction Challenges

After a two-stage procurement using an RFPQ and an RFP, the successful General Contractor and Tunnelling Subcontractor team was chosen. The project was awarded on January 15th, 2024. As per The City of Calgary's RFP obligations, the General Contractor is responsible for submitting an ESC (Erosion and Sediment Control) Plan, an ECO (Environmental Construction Operations) Plan, a Health and Safety Plan and a Traffic Accommodation and Safety Plan. These plans will be reviewed by The City's relevant subject matter experts and are expected to be approved by March 2024. The General Contractor will mobilize on site at the end of March 2024. The shaft construction for the tunnel will begin in April 2024, and simultaneously the open cut excavation is anticipated to start.

Table 1 RFPQ evaluation summary.

Project personnel qualification (50%)	Project experience (50%)
Minimum five (5) years' experience in tunnelling/pipe jacking	Three (3) tunnelling projects have been completed within the last ten (10) years
Relevant experience on three (3) projects of similar scope	At least one (1) project with a minimum drive length of 500 m in similar project soil conditions
Minimum two (2) positive personnel references A "positive personnel reference" means: the reference agrees a collaborative approach was used and are overall satisfied with the personnel's performance on the project	At least one (1) project with equipment size with an internal diameter 2,400 mm or larger At least one (1) project with the tunnel horizon below water table or a water body At least one (1) project utilizing a curved drive At least one (1) project with a rail crossing At least one (1) project with deep well dewatering of the tunnel alignment

Table 2 RFP evaluation summary.

Submission requirements	Evaluation criteria (summary)	Weight
Price	Proposed price compared to other submissions	30%
Project understanding and proposed methodology	Project understanding and methodology are clear. Plans to address quality, constructability, risk, cost control, and innovation.	30%
Construction team	Team has worked together, Project Manager has ten (10) years' experience, Project Superintendent has fifteen (15) years' experience, H&S Manager has ten (10) years' experience, tunnelling team same as RFPQ submission, and these resources will be dedicated and available for work.	15%
Project schedule	Clear schedule in Gantt Chart format, methodology aligns with timelines, risks and material lead times are integrated, winter construction feasible, detours minimized, and other parties considered.	10%
Environment, social, and historical resource management	Display ability to manage environmental regulations, environmental and social risks considered, coordination with historical and other professionals, and demonstrates strategies that have reduced environmental impacts.	5%
Subcontractors management	Information provided about all subcontractors with work exceeding 5% proposal price, and subcontractor management for completed projects.	5%
Social procurement	City of Calgary's Benefit Driven Procurement Leadership Questionnaire completed and rated.	5%

The Nose Creek Sanitary Sewer Trunk Phase B Contract 4 is a large project, with possible impacted areas extending a 3 km linear distance beside an environmentally sensitive area and major highway. The methodology of construction, staging of construction, road and pathway detours, interactions with the public, and interactions with the environment, all provide potential risks to the work. A summary of challenges includes: access from Deerfoot Trail, shafts construction in highly trafficked and environmentally sensitive areas, siphon crossing under creek and CPKC rail tracks, CPKC rail settlement monitoring, groundwater during excavations, contaminated groundwater and soil management, monitoring of Beddington Trail bridge piers for movement, Deerfoot Trail pavement foundation slope stability, wildlife disturbance (Bank Swallow nesting along Nose Creek) and pathway detours for the Trans Canada Trail.

Overall, the teamwork and communication will be essential for addressing issues that will arise, including the deviation of proposed design. When the contractor team is on board, there will be several meetings between The City, Consultant, and the Contractor's teams during the submittal preparation period, so that all parties will be aware of the project specific requirements. The Consultants and The City's Inspection teams will be onsite for quality assurance to ensure the timely addressing of construction issues.

The project communication strategy and team building will also play a positive role. The communication on the project will be open and transparent among all parties involved including the contractor, subcontractors, the client, and the consultant. This will help in building trust among all parties involved which will be the contributors to the success of the project.

6. Conclusions

Nose Creek Sanitary Sewer Trunk Phase B Contract 4 project has experienced technical challenges, but the project is on track for completion before the forecasted sanitary sewer trunk capacity is needed and within the estimated budget. These challenges are being overcome by the project team having a comprehensive understanding of the project and qualifying the contractor through a two-stage procurement process for the work. Including the additional flow control gates at the upstream tie-in, provided the flexibility to adjust flows based to reduce future operational issues with siltation. The H_2S modelling results will lead to improved operations safety for future maintenance activities.

Acknowledgments

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