Narragansett Bay Commission

OF-217 Consolidation Conduit

Phase III CSO Plan: Contract IIIA-5

December 2020

BASIS OF DESIGN REPORT

DRAFT – 30% Design

60% Design

Version 3

BETA

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OF-217 Consolidation Conduit

Narragansett Bay Commission

Phase III CSO Plan: Contract IIIA-5

BASIS OF DESIGN REPORT

Prepared by: BETA GROUP, INC.
Prepared for: Stantec

December 2020
Version 3

Revisions

Revision History

DATE	VERSION	DESCRIPTION	AUTHOR(s)	REVIEWER(s)	Date of Review(s)
April 10, 2020	1	Basis of Design Report – 30%	BETA/McMillen Jacobs/SAR	Stantec – Feeney / Olson	4-30-2020
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3) Geotechnical Data Report (GDR), NBC Phase III CSO Program, Consolidation Conduits IIIA-4 and IIIA-5, McMillen Jacobs Associates, Burlington, Massachusetts, dated 10 April 2020. (Not included-See 30% Submission)
4) Calculations
5) Easement Drawings (Pending, Not Included)
6) Environmental Technical Memo (Not Included-See 30% Submission)
7) Risk Register
8) Opinion of Probable Construction Cost (Class 4)
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1.0 INTRODUCTION

The Narragansett Bay Commission (NBC) embarked on a three-phase Combined Sewer Overflow (CSO) control program in 1998, aimed at lowering annual CSO volumes and reducing annual shellfish bed closures in accordance with a 1992 Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). The Phase III CSO Control Program focuses on the Bucklin Point Service Area (BPSA) in Pawtucket and Central Falls and includes the design and construction of large diameter conduits consolidating flows from the existing CSO outfalls to the proposed Pawtucket Tunnel (Stantec/Pare, CSO Control Facilities Phase III Amended Reevaluation Report; prepared for NBC, 2017).

The goal of the project (and the program as a whole) is to limit the number of CSOs within the NBC system such that no overflows occur during the three-month storm event and no more than four CSOs occur for the typical year. The consolidation conduits are designed to have capacity for the peak hourly flow from a 2-year design storm to meet the project goals.

This Basis of Design Report (BDR) presents the design criteria and approach for the OF-217 consolidation conduit as defined in the "Phase III CSO Program, Conceptual Design for Consolidation Conduits and Regulator Modifications, Technical Memorandum, January 25, 2019". The project consolidation conduit will direct flow from the OF-217 outfall (i.e. "overflows" or OFs) to the tunnel via Drop Shaft 213 (DS-213).

The conduit and regulator modifications for OF-217 are the subject of this "Basis of Design Report" and are associated with the Contract IIIA-5 OF-217 Facilities package, as referenced in the Technical Memorandum. The OF-217 facilities will tie into the downstream Contract IIIA-4 Facilities. Although the Contract IIIA-4 Facilities are not addressed in this BDR they include a Gate and Screenings Structure (GSS) and Junction Chamber (JC), which are located immediately upstream of DS-213, and a connecting portion of consolidation conduit for which the upstream OF-217 consolidation conduit will connect.

Additionally, the OF-217 outfall shall be relocated as part of Contract IIIA-5. A significant portion of the existing OF-217 outfall currently runs directly beneath and within the secured confines of the existing National Grid Electrical Substation located at the end of Tidewater Street. Under this Contract, the OF-217 outfall pipe will be intercepted prior to the Substation and redirected to a discharge point to the Seekonk River just north of the Substation.

This BDR will present the hydraulic, geotechnical, and designs of the diversion structure, consolidation conduits, and associated connection structures and relief operation. Drawings that accompany the BDR are included under separate cover and include plans and profiles of the consolidation conduits, structural design layouts for the diversion structure and connection/relocation structure. A list of the Drawings is included as Appendix 1 and a list of specifications has been included as Appendix 2.

1.1 CONSOLIDATION CONDUITS

Consolidation conduits are relief sewers designed to convey wet weather flow (up to the peak hourly flow from a 2-year storm event) to downstream gate and screening structures and drop shafts. Diversion structures are installed over existing CSO pipes to direct flow to the consolidation conduits. The drop shafts bring the flow from the surface to the tunnel for storage. The consolidation conduits are designed to fully drain into the Pawtucket Tunnel (Tunnel) following each storm event.

1.1.1 Alignment

Alignment of the consolidation conduits is driven by the location of the Tunnel drop shaft and the related gate and screening structure. The site selected for Drop Shaft 213 (DS-213) is 50 Pleasant Street in Pawtucket. 50 Pleasant Street (Parcel 53-551) is the site of the former Pawtucket Masonic Temple. This parcel was specifically purchased by the NBC for this project, and will be the location for DS-213 and the upstream gate and screening structure (GSS). The GSS is being constructed under Contract IIIA-4, while DS-213 and the Tunnel are part of a separate design/build construction project.

OF-217 and the proposed diversion structure are located approximately 2,800 feet south of DS-213 on property commonly referred to as "Tidewater" and is owned by National Grid. The property is the site of a former coal gas manufacturing facility and is well documented to have residual soil and groundwater contamination. Routing of the consolidation conduit through the Tidewater property is necessary to intercept OF-217 flow and convey such flow to the DS-213 location. Provisions for management of contaminated soil and groundwater will be required for construction at this location.

Contract IIIA-5 includes the construction of approximately 1,900-feet of 48-inch diameter consolidation conduit, the OF-217 Diversion Structure, a connection/tie-in structure and approximately 450-feet of 42-inch diameter pipe for the relocation of outfall OF-217, to be located approximately 450 feet north of the current discharge point.

1.1.2 Construction

The consolidation conduit is recommended to be installed using a combination of trenchless construction and traditional open-cut excavation techniques. Microtunneling is the preferred and recommended trenchless method to be used for installing the consolidation conduits through the Tidewater site and towards the northern limit of the project in the vicinity of the City of Pawtucket's Town Landing Boat Ramp, approximately 1,500 linear feet. Approximately 400-feet of the total 1,500-feet will be installed adjacent to Tidewater Street within the Tidewater property and approximately 1,100-feet will be within and parallel to Taft Street. Pipeline installation using open-cut trenching methods are proposed within the Tidewater property, however only in those limited areas where abandoned subsurface foundations, and potentially demolition rubble, are known and expected to be encountered. These areas of open-cut trenching are relatively shallow and will provide an acceptable means to remove underground obstructions that exist and are problematic and/or non-conducive to trenchless techniques (whether by size, composition or amount). The segment of consolidation conduit to be constructed with open-cut trenching methods is approximately 300-feet. For the same reasons stated above, the relocated OF-217outfall pipe shall also be constructed using traditional open-cut trenching techniques within the Tidewater property.

Depths of excavation in open-cut areas will range from 9.5 to 18-feet for the consolidation conduit and 7 to 10-feet for the relocated outfall. Both operations will require temporary support of excavation systems. Jacking and receiving pits will function as working shafts associated with the microtunneling operations and will require excavations to depths up to 40-feet with support of excavation systems. Construction will require staging of excavated soil for disposal and treatment of dewatering discharges prior to disposal to NBC's sanitary sewer system. Based on borings completed for the project, excavations are anticipated to extend below the bedrock surface at one of the two drive shaft locations.

Deep excavations associated with the microtunnel drive shafts will require major excavation and support equipment all of which is intended to be maintained off the adjacent roadways. The goal is to allow uninterrupted traffic to the surrounding residential neighborhoods andthe Blackstone Academy Charter School, which is located at the intersection of Taft Street and Tidewater Street, as well as to National Grid for servicing the Tidewater site. Impacts upon pedestrian traffic will also be limited.

1.2 Structures

Project structures include the consolidation conduit manholes, the diversion structure at OF-217, and the relocation structure for rerouting the OF-217 outfall. The consolidation conduit manholes and diversion and relocation structures are planned to be prefabricated precast concrete. Support of excavation and dewatering systems will be required for the installation. The Diversion Structure will be constructed within the alignment of the newly constructed pipeline for OF-217. The Diversion Structure will contain a weir on the downstream end of the structure to divert wet weather flows to the consolidation conduit. The relocated OF-217 outfall pipe will function to provide system relief. Flows that overtop the diversion weir will discharge to the Seekonk River through the new OF-217 outfall pipe. Flow is intended to overtop the weir when wet weather flow rates exceed the 2-year peak hourly flow rate and/or when the Tunnel is full and the gates to the Tunnel are closed. Relief of the consolidation conduit is necessary to avoid surcharge and flooding.

A fiberglass reinforced plastic (FRP) trash rack with a 3-inch apparent opening size (AOS) will be installed above the weir at the diversion structure for floatables control. A flap gate will also be constructed within the diversion structure to limit flood waters from entering the tunnel system.

1.3 Relocation of OF-217

Approximately 300-feet of the existing OF-217 pipe system resides within a secured area, directly beneath an active Electric Substation located on the Tidewater Property. The CSO pipe, which is currently the property of the City of Pawtucket, recently underwent some structural repair to fix a collapsed section located immediately upstream of the outfall discharge. Because of its existing location being beneath the secured electrical Substation, combined with its age and deteriorating condition, the NBC and National Grid mutually agreed that the CSO flow be redirected . Therefore, the scope for a new CSO discharge pipe has been incorporated into this Project. The pipeline is approximately 500 linear feet in total length and will be positioned just north of the Substation, within the proposed cap area for the Tidewater site. The existing pipe will remain in service to manage on site drainage.

2.0 Project Coordination and Preliminary Investigations

2.1 Project Coordination

Below is a summary of project coordination that has taken place in preparation of the design to date. Coordination has taken place with the City of Pawtucket, and National Grid and utility agencies.

2.1.1 City of Pawtucket:

Drainage Plan Information: The City Department of Public Works and the Engineering Department were contacted to access available roadway and drainage plans in the area.

Source: New England Real Estate Journal, 12-13-2019

Economic Development: The City has a vision for significant economic development along the Seekonk River, and the Tidewater parcel is integral to the City's plans. The Tidewater parcel abuts a City owned parcel to the north, often referred to as "Town Landing". The Town Landing and Tidewater parcels are currently part of a development proposal called "Tidewater Landing". The proposed project includes expanded waterfront access through a river walk park connecting downtown Pawtucket to the riverfront, a new pedestrian bridge, and other significant infrastructure upgrades. In addition, the project reportedly will include construction of a new multi-use sports stadium, a new indoor sports complex, a parking garage, a hotel, and commercial office space and residential housing. Although there has been some coordination between involved parties the details of the proposed development and related design plans beyond conceptual plans shared with the media, are still being developed. Therefore, such specifics are not available at the time of this Report. The developer's engineer has shared AutoCad files that define approximate development limits and boundaries of proposed infrastructure. The Design Consultant has utilized the conceptual plan information in the preparation of the design.

The NBC directed the Design Consultant (BETA or as also referred to "DC") to evaluate several different pipe alignments to accommodate these future development opportunities. The effort was focused on creating more development space that would avoid conflicting with the NBC's proposed pipe alignment. Several alignment alternatives were reviewed, however all had similar pros and cons. One alignment that was seriously considered was running in the northly direction, parallel to and along the shoreline of the Seekonk River. However, this alternative needed to be abandoned due to concerns related to the predicted hydraulic grade lines of the NBC's operating system.

The recommended alignment, as presented in the design favors the more westerly upland topography of the area. This alignment favors Tidewater Street to the west before turning north and running along the eastern side of Taft Street. The pipeline alignment has been presented and coordinated with the City's developer for their review and agreement.

Further coordination with the City, the City's developer and National Grid is anticipated as they further develop the "Tidewater Landing" plans for the property. Coordination will be required as it relates to the consolidation conduit alignment, as well as the timing of its construction. The developer's construction and the remediation construction being completed by National Grid as described below, as well as the construction of the consolidation conduit, preliminarily have overlapping construction schedules. Timing and coordination of the construction will be critical in reducing conflicts and delays.

Bike Path: The City has a bike path project in the design stage, and a portion of the bike path extends within the Tidewater Parcel. This bike path project is also an element of the Tidewater Landing development discussed earlier. Coordination with the bike path project was an element of the alternative alignment that paralleled the shoreline. Although the bike path, as currently proposed, does cross the current pipeline alignment in certain areas, the need for coordination appears limited at this time. Impacted areas are part of the developers surface restorations, and along Taft Street are within the current right-of-way where bike path features are anticipated to be limited to pavement striping.

2.1.2 National Grid

Tidewater: National Grid owns Parcels 54-826 and 65-662 and the consolidation conduit will be located within portions of both properties. The subject parcels, located east of Taft Street and north of Tidewater Street, are the site of a former manufactured gas plant (MGP), and often referred to as the "Tidewater" property. The properties are known to have soil and groundwater contamination associated with its former use and are listed as a "State Site" under RIDEM's Remediation Regulations (RIDEM Case No. 95-022). The former MGP operated from the 1880s until 1954 and coal was used as the principal fuel to produce coal gas. In the later years of operation (1954 until the late 1960s), the MGP produced gas using oil and propane.

The Site is generally vacant except for:

- Active natural gas regulating station located on the southeast end of Tidewater Street on its south side,
- Former Power Plant currently used as an active switching station, and
- Electric substation on the central portion of the Site.

The Site is secured with a locked perimeter chain-link fence.

National Grid is currently progressing forward with a plan to construct a cap over the site as part of their Sitewide Remedy Design project. The design was submitted to RIDEM for review in August 2019. The project is expected to be an 18-month, six-phase project scheduled to commence in late Fall 2020 and be completed by Fall of 2022. A second project includes substation construction. That project is estimated to start in Spring 2021. Demolition of the existing buildings is scheduled for July 2022. Upon completion of these projects, it is the DC's understanding that the National Grid parcels, or a portion thereof, will be leased to the City. These parcels are part of the potential development vision noted above (Tidewater Landing).

Initiated by the NBC, the DC has provided design support and resources for communication with National Grid throughout development of this design. It is anticipated that further coordination is required as their closure project advances, specifically with respect to closure phasing and provisions to allow construction of the NBC facilities and to limit cap disturbances. The DC will continue to provide design information as the NBC continues this coordination.

At the request of National Grid, no environmental investigations were conducted on the site as part of this Project. Numerous investigations previously completed by National Grid are available for review. It is anticipated that National Grid will dictate requirements associated with health and safety, soil management, dewatering treatment, and material disposal. These requirements will be developed in the final design and incorporated as contract requirements for the NBC Project.

Gas Infrastructure: The alignment takes into consideration minimum separation clearances with an existing 16-inch cast iron gas main that runs parallel to the alignment of the consolidation conduit for the length of Contract IIIA-5. The condition of the gas main has reportedly been reviewed by National Grid and there is no plan for its rehabilitation or replacement. National Grid has provided their requirements for work in the vicinity of cast iron gas mains and the requirements have been incorporated into the design documents. National Grid requires a minimum separation distance of ten (10) feet for excavation activities and that criteria was a prominent element in the alignment design.

2.2 Survey

Survey for the project was completed by Bryant Engineering, Inc. in accordance with the following datum:

Horizontal Datum: RI State Plane Coordinate System (NAD '83)

Vertical Datum: National Geodetic Vertical Datum 1929 (NGVD 29)

The survey included topographic survey, location of edges of vegetation, wetland flagging, visible utility covers and inverts for drain and sewer pipes.

2.3 Geotechnical

This section presents a high-level overview of the subsurface conditions in the vicinity of the Project and the geotechnical investigations performed.

2.3.1 Geologic Setting

The Project is in the New England physiographic province of the Appalachian Highland physiographic division, lying within the Seaboard lowland section (Denny 1982). The physiographic area is referred to as the Narragansett Basin, the result of a complex sequence of a combination of geosynclinal sedimentation, volcanism, plutonism, and erosion (Quinn 1971). The basin is made up of several thousand feet of non-marine sedimentary rock that has been folded, faulted, and slightly to moderately metamorphosed.

The geologic history of the proposed project area is one of weathering, erosion, and deposition. Periods of glaciation have shaped much of the visible landscape and the Project area is characterized by the adjacent river valley. Glacial and post glacial deposits dominate the landscape and generally consist of stratified layers of sand, silt, gravel, cobbles and boulders.

Drainage in the area is by the Blackstone River/Seekonk River, which trends north south.

2.3.2 Topography and Land Use

The topography in the area is the result of a long and complex history of glaciation and site filling, which has had an influence on the current site and subsurface conditions. The topography is generally rolling to flat, with less than 200-feet of relief, sloping towards the east. The ground surface along the Project alignment varies from about Elevation 16 to Elevation 38-feet, with a slight rise just south of the Division Street overpass before sloping gradually back down towards the south. The bedrock surface topography is irregular and is expected to range from about 10-feet to 30-feet below existing grade with the highest rock in the area adjacent to the National Grid building located at the end of Tidewater Street.

Land use along the Project alignment varies from residential, public land, a high school, and a utility company. South of the Pawtucket Boat Landing, the alignment traverses the Tidewater Site, a former MGP and power plant site currently owned by National Grid that is classified as a superfund site.

2.3.3 Geotechnical Investigations

A geotechnical investigation program, consisting of borings and groundwater monitoring wells has been completed to obtain information on the subsurface conditions for the Project. The geotechnical investigation program has been augmented by a laboratory testing program. The objective of these programs was to provide an interpretation of the ground and groundwater expected to be encountered during construction of the Project's consolidation sewers, shafts, and near-surface structures. This information will be used by the Design Team to design the underground elements of the Project, and by the contractor to plan, price, and schedule the work. A summary of the subsurface exploration program completed for this project is included as Table 2-1. A figure depicting the approximate locations of the borings is provided in Figure 2-1.

Table 2-1: Summary of Subsurface Exploration Program

Test Boring Designation	Total Depth (ft)	Depth Drilled in Soil (ft)	Depth Drilled in Rock (ft)	No. of Split Spoon Samples	No. of Rock Cores	Observation Wells
B-1	22	10	12	3	2	0
B-2	34	29	5	9	1	1
B-3	37	27	10	5	2	1
B-9	39	28.8	10.3	9	2	1
B-10	31	21	10	8	2	1
B-11	39	29	10	10	2	0
B-12	51	28.8	22.3	7	5	0
B-13	21	21	n/e	5	0	0

Notes
1. Refer to 30% Design Plans for the location of test borings.
2. Test borings were vacuum excavated to a depth of 6 feet below the existing ground surface.

Details of the procedures used for conducting the field work and laboratory testing, and the factual results are summarized in the report found in Appendix 3. Geotechnical Data Report (GDR), NBC Phase III CSO Program, Consolidation Conduits IIIA-4 and IIIA-5, McMillen Jacobs Associates, Burlington, Massachusetts, dated 10 April 2020.

In addition to the new data being collected by the Design Team, a geotechnical investigation program was completed for a planning-level geotechnical study of the Project (Stantec and Pare 2019). Data from that study were incorporated into the interpretation of the ground conditions in the Project area and were used to plan this geotechnical exploration program. Existing data relevant to the Project alignment will be included in the GDR.

2.4 Subsurface Utility Engineering / Test Pits

Subsurface Utility Engineering (SUE) efforts were conducted as part of the conceptual design, and is specific to Taft Street. Based on the current horizontal and vertical alignment additional SUE is not anticipated for Taft Street.

Legend

- B-1 BORINGS COMPLETED FOR CONTRACT IIIA-4/IIIA-5
- BH-35 BORINGS PREVIOUSLY COMPLETED FOR OTHER PROJECTS
- B17-45 BORINGS COMPLETED FOR CONTRACT IIIA-4/IIIA-5 BY PARE CORP.

SCALE
1"=200'

NBC CONTRACT NO 308.05C
CIVIL

IIIA-5
BASIS OF DESIGN

SHEET
FIG. 2-1

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Test pitting on the Tidewater site is not proposed. National Grid provided utility information for the property. Utilities on the Tidewater property, north of Tidewater Street, have reportedly been abandoned except for an existing 16-inch cast iron gas main that runs adjacent and parallel to the north side of the roadway. The gas main reportedly has been leak tested and found to be of adequate condition to remain in service. The gas main and its proximity to the NBC construction has been reviewed by National Grid. Utility locations within the proposed location of the Relocation Structure have been investigated by National Grid at the request of the DC. The position of the Relocation Structure has subsequently been revised to reduce utility conflicts. National Grid has cautioned that, due to the age of the facility and lack of documentation, unidentified underground pipes may be encountered during construction. National Grid should be notified if this occurs to help identify the source of the pipe.

It is noted that multiple test pits were conducted by National Grid on the Tidewater Site. The test pits appear to have been conducted to obtain information on surficial soils as part of their environmental investigations and for developing remediation strategies.

3.0 Design Criteria

This section presents the overall Design Criteria for the project to achieve the desired program goals. In addition, it provides a discussion relative to different construction methods that will be employed in the construction of the new OF-217 facilities considering geotechnical factors associated with the existing geologic conditions.

3.1 Hydraulics

A hydraulic analysis of localized level of service (LOS) has been assessed, by the Program Manager (Stantec), using the BPSA InfoWorks Integrated Catchment Model (ICM) software, calibrated through December 2017. Hydraulic grade lines (HGL) were developed for the 2-year design storm. The model estimates and the resulting hydraulic grade lines are the basis for the consolidation conduit design criteria.

The horizontal alignment and profile of the consolidation conduit were developed to achieve the specified hydraulic requirements. Table 3-1, below summarizes the design capacity and the required minimum slopes for the consolidation conduit, as provided by the Program Manager. Peak hourly flow is presented as the peak hourly flow discharging from the structure.

Table 3-1: Consolidation Conduit Summary and Design Peak Flow

Diversion Structure		Peak Hourly Flow	Consolidation Conduit				Overflow Pipe
	Weir Elevation (ft)	2-year (MGD)	Size (in)	Min Slope (ft/ft)	Capacity (MGD)	Velocity (FPS)	Size (in)
OF-217	10.5	39	48	.0018	39.5	4.9	42
Junction Chamber	NA	155.2	72	.0032	155.2	8.5	NA

OF-217 Consolidation conduit will flow towards facilities constructed under Contract IIIA-4 including the Junction Chamber (JC) where flow will combine with consolidation conduits from OF-210, OF-213, and OF-214 before it flows into the Gate and Screening Structure (GSS) and ultimately to the Tunnel via Drop Shaft 213. Figure 3-1 depicts a general layout of the consolidation conduit.

Consolidation Conduit sizes were presented in the "Phase III CSO Program, Conceptual Design for Consolidation Conduit and Regulator Modifications – Technical Memorandum". Pipe sizes were confirmed based on an analysis using the Manning Equation and Calculations are provided in Appendix 4. The minimum slope presented considers gravity flow without surcharging. The pipeline profile presented in the design documents takes into consideration minimum slopes, existing topography, and utility clearances and are adjusted accordingly.

Additional considerations incorporated into the design of the consolidation conduit system include:

- Conduits and structures conveying the 2-year Peak hour flow at a velocity of 10 fps or greater will consider special design consideration for protection against displacement by erosion and impact. Manhole and pipe lining will be considerations for protection against scour and manhole anchoring will be considered for protection against displacement.
- Manholes are designed with minimum 0.1-foot elevation difference between inlet and outlet pipes
- Manholes are spaced every 300 to 500-feet and at changes in alignment, in areas where the consolidation conduit is to be installed with traditional open-cut. In areas where the pipe is to be installed using microtunneling techniques, manhole spacing is increased to up to 1,000-feet.

3.2 Geotechnical Considerations

This section presents a high-level overview of the subsurface conditions in the Project Area. This information is based on the subsurface investigation programs described above. In addition, interpreted subsurface conditions and preliminary soil and rock engineering parameters will be provided in the Geotechnical Design Summary Report (GDSR).

3.2.1 Subsurface Conditions

The subsurface materials in the Project Area are anticipated to consist of the following geologic units from top downward (i.e., from youngest to oldest):

- Fill
- Alluvium Deposits
- Glacial Deposits
- Bedrock

All geology units may not be encountered at all locations along the Project alignment.

The Fill consists of variable composition, uncontrolled man-made materials and other construction debris. The nature, quality, and thickness of the fill is expected to vary and includes fragments of glass, brick, and concrete.

More recent deposits of Alluvium are expected beneath the Fill and consist of medium dense, silty sand to stiff clayey silt. The Alluvium is discontinuous and is not expected in all areas of the Project.

SCALE 1"=200'	NBC CONTRACT NO 308.05C CIVIL IIIA-5 BASIS OF DESIGN	SHEET FIG. 3-1

DWG FILE: J:\6412 NBC CSO Consolidation Conduits\Drawing Files\Acad - Misc\PAWT_FIG_IIIA-5_BASIS OF DESIGN.dwg PLOT DATE: 12/22/2020 10:49 AM BY: JAIMIE PAYNE

Glacial Deposits lie directly over the bedrock and is variable in nature due to the complex process of deposition either by retreating glaciers (glaciofluvial/outwash) or directly beneath the glacial ice (lodgment till). The Glacial Deposits consist of a medium dense to very dense, unsorted mix of sand and gravel and includes occurrences of cobbles, boulders and rock fragments from the underlying bedrock.

The bedrock consists of the Rhode Island Formation of the Narragansett Bay Group. The Rhode Island Formation consists of predominantly sandstone with lesser amounts of conglomerate sandstone and siltstone. Minor occurrences of mudstone, shale, and coal are also present along with discontinuous short intervals of the Wamsutta Formation at shallow depths which appear as dark red in color. The bedrock is generally described as strong, slightly weathered to fresh, sandstone to siltstone, laminated, with joints ranging from 20 degrees to 50 degrees from the horizontal. Quartz filled fractures are common. Evidence of faulting in the wider area is present but not expected along this Project alignment.

3.2.2 Preliminary Soil and Rock Engineering Properties

Soil and rock engineering parameters will be determined based on the results of empirical correlations to standard penetration testing, laboratory index test results, and engineering judgment. The geotechnical design parameters needed by the Design Team to complete their work will be provided in the Geotechnical Data Summary Report. The geotechnical data required by the contractor will be provided in the Geotechnical Data Report (GDR).

3.3 Trenchless Construction

The current plan is to install the majority of the OF-217 consolidation conduit using trenchless construction methods. Trenchless methods result in less disruption and are cost-effective beyond a certain depth of installation or in adverse ground conditions below the groundwater.

In selecting trenchless methods for this Project, consideration was focused on line and grade requirements, depth of installation, pipe size, installation lengths, presence of glacial soils and bedrock, groundwater table above pipe invert, ground cover, presence of contaminated soil and groundwater, impacts to adjacent structures and managing surface disruptions. Table 3-2 lists the approximate length and range of installation depth anticipated for IIIA-5 trenchless construction.

Table 3-2: Trenchless Summary for Consolidation Conduits IIIA-5

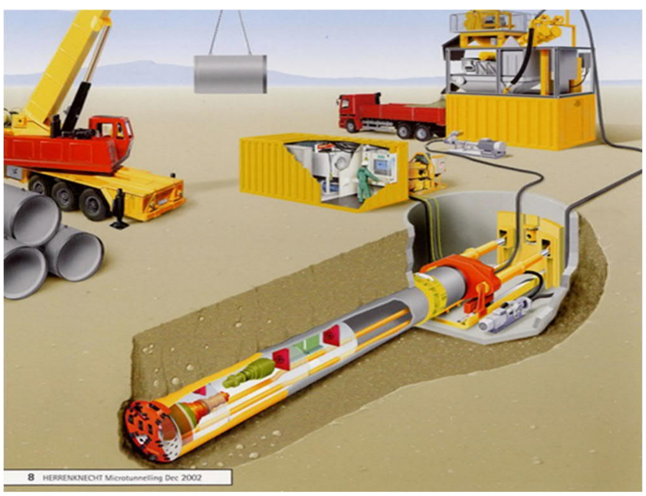
Trenchless Installation Reach	Location	Trenchless Method	Nominal Diameter of Pipe (inches)	Approximate Length (ft)	Approximate Depth Range to Invert (ft)
MH217-5 to MH217-6	Sta. 1+26 to 7+90	Microtunneling	48	664	17 to 36
MH217-6 to MH217-7	Sta. 7+90 to 12+40	Microtunneling	48	450	25 to 36
MH217-7 to Sta. 14+55	Sta. 12+40 to 16+65	Microtunneling	48	395	18 to 25

3.3.1 Alignment Discussion

As indicated in Table 3-2 above, the alignment is broken down into three drives that will require four shafts – one jacking shaft, two receiving shafts and one receiving/jacking shaft. Manhole structure are typically provided upon completion of jacking pipe into place to accommodate changes in alignment and connect pipes at the jacking pit locations. The plan alignment has a very slight change in direction at MH 217-6 and a much more pronounced change in direction at MH 217-7. A preliminary evaluation of the potential to lengthen drill lengths and eliminate structures has been conducted but resulted in no significant change to the design. Soil and mixed face conditions, as described below, limit the opportunities for lengthening the drives and any potential for applying curved methods. The alignment and the positioning of the structures are also dictated by the proposed development. .

3.3.2 Microtunneling

Microtunneling is a slurry-based pipe jacking process that employs a remotely controlled, closed face tunneling shield, also commonly referred to as a Microtunnel Boring Machine (MTBM). Closed face slurry-based shields can exert a positive pressure against the excavation face to maintain face stability and the pressurized slurry counterbalances the hydrostatic head to prevent uncontrolled ground and groundwater inflow that can lead to over-excavation and ground settlement. Because a pressurized slurry is used to counterbalance groundwater, contaminant migration can be mitigated with pressurized slurry and subsequently the pressurized lubricant. The remote-control nature of the system does not require personnel entry for the tunneling operations. The pipe diameter range for microtunneling is generally from 36 to 144-inches, however the most common pipe diameter range for microtunneling is between 42 to 72-inches.



Microtunneling Layout

The primary advantages of microtunneling are that the product pipe is often installed directly behind the machine in a one-pass installation, and the depth of the tunnel can be adapted to the subsurface conditions. Considerations for microtunneling pipe selection and cutter head design include, but are not limited to soil type, strength, consistency, potential for encountering obstructions or cobbles and boulders, groundwater levels, and drive distance. Subsurface explorations along the microtunnel alignment and material laboratory testing have been completed along the alignment.

Based on those subsurface explorations, portions of the alignments are expected to encounter mixed ground conditions, such as soil and bedrock or glacial deposits overlying rock, which can be very challenging and cause difficulty in maintaining line and grade of the pipeline. The risks associated with mining and controlling line and grade in these varied ground conditions can be minimized by selecting a vertical and plan alignment that places the alignment in similar ground type to avoid mixed ground or mixed face conditions. Where the vertical alignment cannot be adjusted to avoid mixed ground or mixed face conditions, the risk can be reduced by utilizing appropriate cutterhead tooling that is adaptable to the anticipated ground conditions and tunneling from hard to soft ground (bedrock to soil). The disadvantage to that is different tooling is required for the rock and the soil and that can impact the efficiency in mining through those conditions.

Another advantage of microtunneling is that advanced guidance coupled with sophisticated steering allows the method to develop horizontal curves to optimize alignments and overcome constraints inherent with straight alignments. Because of the short drive lengths for the three reaches, there should be no need to utilize Intermediate Jacking Stations along the pipe string to distribute jacking loads and keep them within acceptable limits.

3.4 Pipe Considerations

With the new 48-inch diameter consolidation conduit and a new 42-inch diameter CSO outfall (OF-217) proposed to be located on the Tidewater property, National Grid expressed their concern relative to the subsurface contaminants that exist. They indicated that the pipelines installed below the groundwater table must be constructed watertight to reduce the potential migration of contaminants from the site. They identified concerns relative to the contaminants potentially impacting the plastic pipe material, as well as their standard gaskets. They indicated that the specified pipe and related gaskets proposed for this area must be resistant to the existing contaminants.

Residual contamination from the MGP operation is consistent with coal tar and includes volatile organic compounds (Benzene, Toluene, Ethylbenzene and Xylene) and semi-volatile organic compounds (polycyclic aromatic hydrocarbons). These constituents in their pure form can degrade certain pipe and gasket materials. When reviewing material compatibility charts with contaminants, it is important to note that the tests are completed with contaminants in their pure form, while the contaminants present at the site are diluted. It is recognized, however that it is important to be conservative considering the lifespan of the proposed infrastructure.

The impact to pipe joints will be the greatest in a one pass installation where the carrier pipe is installed directly behind the microtunnel machine placing the joints in direct contact with the contaminated ground and groundwater. Plastic or fiberglass material types of pipe are typically inert to many types of contamination, but the pipe manufacturers would need to address performance of their pipe and the identified contaminants. The weak point in a one pass approach are the joints themselves, as the joint seals will be exposed to the contaminants in the groundwater and possibly the soil that may find its way into a joint. Consequently, seal manufacturers will need to address the performance of their seals for the anticipated contaminants.

The impact to pipe joints can be eliminated with a two-pass installation where the carrier pipe is installed in a casing, most often steel, that isolates the carrier pipe from any external contamination.

Unfortunately, this has an appreciable cost on microtunneling as the carrier pipe must be sleeved inside the casing and grouted in place, which are added costs over a one pass installation.

The consolidation conduit is anticipated to be below the groundwater table, but the outfall pipe is expected to be above the groundwater table. It is anticipated that no special considerations are required for pipe systems that are above the groundwater table.

3.4.1 GASKETS

Based on a review of gasket materials and the contaminants present, FKM gaskets (common trade name Viton) is the most suitable pipe gasket for the application. FKM gaskets provide a resistance to volatile and semi-volatile organic compounds, petroleum products, and many chemicals and solvents. Their chemical resistant properties differentiate them from other common types of gaskets. The Table below published by the American Ductile Iron Pipe summarizes the gasket materials and their suitable applications.

Common Name or Trade Name*	Chemical Name	Maximum Service Temperature**		Common Uses
		Water & Sewer	Air	
Plain Rubber	Styrene Butadiene Copolymer(SBR)	150°F	150°F	Fresh Water, Salt Water, Sanitary Sewage
Plain Rubber (conductive)	Styrene Butadiene Copolymer(SBR)	150°F	150°F	Electrical continuity for thawing of Service Water and Sewage
EPDM	Ethylene Propylene Diene Monomer	212°F	200°F	Water, Sewage, Ketones, Dilute Acids and Alkalies, Vegetable Oil, Alcohols, Air
Neoprene	Polychloroprene(CR)	200°F	180°F	Fresh Water, Sewage
Nitrile Buna-N	Acrylonitrile Butadiene(NBR)	150°F	150°F	Non-Aromatic Hydrocarbons, Petroleum Oil, Hydraulic Fluids, Fuel Oil, Fats, Oil, Grease†
Fluoroelastomer Fluorel Viton®***	FKM	212°F	300°F	Aromatic Hydrocarbons, Gasoline, Refined Petroleum Products, most Chemicals and Solvents, High Temp., Air (Least permeable of all available Fastite gasket rubbers)

*AMERICAN reserves the right to furnish any Trade or Brand rubber for the chemical formulation specified.
Temperature is in reference to conveyed fluid. **Lubricating oil in air can adversely affect SBR and EPDM performance. SBR, Nitrile and Neoprene are not recommended for hot air exposure in wastewater treatment systems.
***Viton® is a registered trademark of DuPont Dow Elastomers.
Refer to Section 11 for temperature and service capabilities of pipe linings.
Refer higher temperatures or other special requirements to AMERICAN for recommendations regarding suitable gasket material.
†This gasket rubber is chemically resistant in the non-potable water uses shown but is not as resistant to permeation in potable water applications as FKM.
All Fastite gaskets made from the materials in the above table are suitable for use with water containing normal concentrations of chloramine. Where increased resistance to chloramine is desired, neoprene or fluoroelastomer materials should be considered.

A source from the state of Washington documented similar and consistent information and is provided in the table below.

ENVIRONMENTAL CONSIDERATION MATRIX FOR PIPELINE DESIGN THROUGH IMPACTED MEDIA

Contaminant of Concern	Screening Criteria Reference			Environmental Monitoring Reference	Compatible Materials*				O&M
	Soil	Groundwater	Air		Piping	Gaskets	Trench Lining	Trench Backfill**	
Volatile Organic Compounds	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	Epoxy-coated Ductile Iron Pipe (hydrocarbons) Steel casing	NBR FKM EPDM (MEK, acetone)	Flowable Fill	Flowable Fill Bentonite	Venting Liquid Monitoring Groundwater Treatment Dewatering Health and Safety Plan
Semi-volatile Organic Compounds	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	PVC HDPE	Neoprene (heat and oil only) FKM	Overexcavate Geotextile fabric Warning layer	Clean Fill	Health and Safety Plan
Polychlorinated Biphenyls and Pesticides	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	PVC HDPE	NBR FKM	Overexcavate Geotextile fabric Warning layer	Clean Fill	Health and Safety Plan
Corrosive Soil/Groundwater	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	PVC HDPE	EPDM (dilute acids) FKM	Overexcavate Geotextile fabric Warning layer	Clean Fill	Health and Safety Plan
Mixed Impacts (Landfills)	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	Epoxy-coated Ductile Iron Pipe Steel casing	NBR FKM EPDM	Flowable Fill Bentonite	Flowable Fill Bentonite	Venting Liquid Monitoring Groundwater Treatment Dewatering Health and Safety Plan
Metals	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	PVC HDPE	NBR FKM	Overexcavate Geotextile fabric Warning layer	Clean Fill	Health and Safety Plan
Asbestos	MDE Cleanup Standards USEPA RBCs	MDE Cleanup Standards USEPA MCLs	PEL or TLV/STEL IDLH	NIOSH OSHA	***	***	***	***	Health and Safety Plan

Source: Washington Suburban Sanitary Commission: Common Design Guidelines, Pipelines crossing contaminated areas.

The Viton gaskets are widely used on PVC and ductile iron pipe, however based on our research, are not commonly used on pipe systems installed utilizing microtunneling techniques. The cost for the Viton gasket is approximately $6,900 per gasket for a 48-inch diameter pipe (for PVC or ductile iron pipe).

A review of pipe materials and their suitability for use with Viton Gaskets is provided below.

3.4.2 48-INCH CONSOLIDATION CONDUIT

The consolidation conduit through the Tidewater property will be installed with traditional open-cut methods (approximately 230 linear feet) and microtunneling methods (approximately 815 Linear feet). Trenchless construction is proposed due to the depth of the installation and to limit exposure and effort related to contaminated soil and groundwater management. Pipe material options for use in microtunneling include reinforced concrete pipe (RCP), reinforced concrete cylinder pipe (RCCP), ductile iron (DI), centrifugally cast fiberglass reinforced plastic pipe (CCFRPP or "FRP"), vitrified clay pipe (VCP), and polymer concrete pipe (PCP).

Of the pipe options presented, only ductile Iron pipe is available for use with FKM (Viton) gaskets, however U.S. Pipe does not recommend Ductile Iron Pipe with this application, due to the distance. Concerns include:

- Pipe will have flexible joints and pipe could stray from the required alignment
- The cost of welding steel push bars to a thick pipe will be cost-prohibitive

If ductile iron pipe were to be pursued as an option, the pipe would need to be installed within a steel casing pipe. The cost for the ductile Iron pipe with the Viton gasket is estimated to be $708 per linear foot. The cost for the ductile iron pipe does not include the cost for the steel sleeve. The cost for a two pass microtunneling approach would be on the order of 2.5 times that of a single pass system. At this time ductile iron pipe is not being recommended.

Below is a description of the other types of pipe considered.

Reinforced Concrete Pipe (RCP): RCP that is manufactured specifically for jacking and adheres to strict manufacturing tolerances and is considered the only kind of pipe to use for such a microtunneling application. It has added strength and if applicable, the joints allow for the pipeline to curve. FKM gaskets are not an available option, the gasket is relatively stiff and difficult to stretch into position. It is the suppliers experience that the gasket can also come apart during the stretching process.

In a typical gravity sewer application, RCP would require protection against sulfide corrosion; however, sulfide corrosion is not anticipated to be a concern with this application because sanitary flow will be diluted by the storm flow, and the consolidation conduit system is designed to drain. The cost of this pipe material is approximately $400 per linear foot. In this application however, National Grid has expressed concern with reinforced concrete pipe in that concrete is inherently porous, and therefore the pipe and joints would require additional protection. See Section 4.4.3 Pipe Joint Protection.

Reinforced Concrete Cylinder Pipe (RCCP): RCCP is a reinforced concrete pipe that has a welded steel cylinder encased in concrete. Joints are typically both rubber and steel to provide water-tightness. The concrete provides corrosion resistance for the steel. Sulfide corrosion of the concrete is not anticipated to be a concern with this application as noted above. In this application the general concern is the long-term integrity of the pipe joint considering the contaminants in the soil and groundwater. The cost of this pipe material is approximately $400 per linear foot, but provisions to further protect the joints are warranted. This pipe can only be used in a two-pass installation as there is too much risk to damaging the concrete encasement during the microtunnel jacking process (as related to the jacking forces required to install such lengthy runs). This pipe is therefore not recommended.

Centrifugally Cast Fiberglass Reinforced Plastic Pipe (CCFRPP): CCFRPP, commonly referred to as Hobas Pipe or FlowTite pipe, is equipped with a structural sleeve coupling that provides a gasket sealed connection. EPDM and Nitrile gaskets are available, and the coupling allows a few degrees of angular deflection to allow simple grade and line corrections. CCFRPP can be installed in a one pass installation, but the pipe is not used to develop tunnel curves because it is easily damaged from point loading that develops around radius curves. The cost of this pipe material is on the order of $555 per linear foot, but provisions to further protect the joints are warranted.

Vitrified Clay Pipe (VCP): VCP is not an option for this application since the pipe is not available in 48-inch diameter.

Polymer Concrete Pipe (PCP): The polymer concrete technology provides high compressive strength that resists higher jacking forces for longer stretches of pipes and provides watertight joints with a gasket seal and stainless-steel collar. A vinyl Esther resin coating was recommended based on the contaminants present on site. The cost of this pipe material is approximately $1,250 per linear foot, but provisions to further protect the joints are warranted.

3.4.3 Pipe Joint Protection

Another option to address the existing contaminants would be to use a traditional pipe and gasket material followed by installing an interior coating system that seals off the sewer from external contaminants. Epoxy coating, geopolymer concrete, and resin impregnated polyester tube systems were reviewed.

Epoxy Coating: The epoxy coating system would be spray applied once the pipe is installed and could be applied either for the entire pipe length or limited to the pipe joints only. The installation would require man-entry into the pipeline along with the required equipment and materials. The estimated cost associated with lining the size and length of the pipe under this application is approximately $400 per linear foot. The cost for lining the joints is approximately $3,000 per joint. The estimated level of effort required to complete this application is approximately two (2) weeks, 6 days per week with 10-hour workdays.

Geopolymer lining: Based on manufacturer's information, geopolymer is a formulated mortar comprised of aluminosilicate powder with an alkaline activator to form a monolithic mineral polymer with ceramic properties. Like epoxy coating, the geopolymer is spray applied to the interior of the pipe system. The NBC has recent experience with use of this material as it was the selected material for their rehabilitation of the brick interceptor located within the RIDOT Route 6 and 10 Interchange. The estimated cost for lining the pipe is approximately $440 per linear foot.

Insituform CIPP lining: Based on conversations with the installer, the cost associated with lining the pipe is approximately $1,000 per linear foot. Factors impacting cost include onsite wet-out restriction for the liner and resin selection. The liner cannot be wet-out at the manufacturer's facility since the liner will be too heavy to ship. The wetting out process will need to occur onsite, which results in a significant cost associated with mobilization of the equipment, materials, and resources. Also, a more costly vinyl ester resin is recommended over the standard polyester resin due to its resistance to the site contaminants.

3.4.4 Recommendation:

Each of the viable pipe systems requires additional protection, it is therefore recommended that RCP pipe be utilized for all consolidation conduit installed by both microtunneling, with additional protection installed between MH217-6 and the OF-217 Diversion Structure. Calculations supporting use of RCP are included in Appendix 4. The geopolymer lining and the epoxy coating systems are feasible alternatives and are comparable in cost. Further development of the cost information is warranted as the project progresses and specifications for use of the geopolymer are included in the 60% submission.

3.4.5 42-Inch Outfall Pipe (OF-217)

Gasketed reinforced concrete drainpipe is recommended for construction of the OF-217 outfall pipe. Based on information reviewed, the depth of the outfall pipe should be above the groundwater table thereby eliminating any pipe material or gasket concerns.

3.5 Shafts

Excavation support to accommodate construction of MH217-6 and MH217-7 will be provided by 20-foot inside diameter circular secant pile shafts designed by the contractor in accordance with criteria provided by the EOR. Secant pile or slurry diaphragm wall method may be used. Depending on method used, secant piles or diaphragm wall panels with piles will be drilled-into sound rock for water tightness. Depending on the rock quality at the base, permeation grouting may be required to create a plug to cut-off water inflows. Efforts to reduce or eliminate Inflow into these shafts is considered critical due to the existing ground contamination. MH217-6 and MH217-7 will serve as launching pits for the deep MTBM drives necessary to complete the trenchless reaches. The circular secant pile shaft resists lateral loads through ring compression and could therefore be designed as unreinforced without any internal bracing. Maximum installation tolerances of 1-inch within in-plan design location and 1% out-of-verticality are recommended to ensure contact between adjacent piles for water cut-off and effective bearing area to act as a compression ring. The secant pile concrete circular shaft will be designed in accordance with ACI 318.

Earth pressures acting on the circular shaft will be derived from effective at-rest pressures based on soil parameters from the GDSR. This will be used to design the excavation support system for strength. Lateral loads to be considered in the design include earth, groundwater and construction surcharge based on a vertical surface load of 600-psf. Unbalanced loading to the shaft due to construction surcharge should be considered. The design should also consider temperature effects where applicable. Secant pile circular shafts are inherently stiff such that lateral deformations are expected to be negligible.

3.6 Open-Cuts

Temporary earth support for installation of diversion structure, Relocation Structure MH-217-8, 8-foot diameter precast concrete manholes and RCP consolidation conduits and outfall pipes, will also be the responsibility of the contractor. Performance specifications will be provided by the DC and will require that his SOE system be fully coordinated with his dewatering and treatment system plans. The Contractor will present his SOE design plan with his dewatering plan in the Shop Drawing review process. To evaluate clearances and construction costs, it has been assumed for the purposes of this report that excavation support will consist of steel soldier piles and timber lagging. Trench box for earth support may be considered when excavations for outfall and consolation conduits are 10-feet in depth or less, however, with the man-made obstructions expected below grade, this may be prohibitive, and the contractor may elect to utilize a soldier pile and lagging system

A steel soldier pile and timber lagging system would be designed by the Contractor in accordance with criteria established and provided by the DC. Drill-holes are to be backfilled with concrete to final excavation subgrade after each soldier pile is in-place. Above the excavation subgrade the drill holes will be backfilled with lean mix concrete to the existing site grade. The excavation support system will be internally braced with steel struts and walers and arranged to accommodate easy installation of the permanent concrete structures and RCP carrier pipe.

The excavation width for the consolidation conduit and outlet pipe should be 3-feet wider than the outside diameter of the RCP carrier pipe. The excavation width for precast concrete manholes should be 3-feet wider than the manhole base diameter. Where the manhole braced excavation is also being used to support MTBM operations, (MH-217-5), the footprint size will be adjusted accordingly. Soldier piles, struts and walers are to be designed in accordance with AISC 360 ASD.

Limit Equilibrium Method using appropriate apparent earth pressure diagrams derived from effective active pressures based on soil parameters from the GDSR, will be incorporated into the performance specifications and utilized by the Contractor for the SOE design. Lateral loads to be considered in the design include earth and construction surcharge based on a vertical surface load of 600-psf. The design should also consider temperature effects where applicable and protections against surface settlements. To limit surface settlement and protect adjacent structures, nonlinear analysis using beams on elastoplastic Winkler springs will be performed to check and limit lateral deformations to response level criteria

Pile toe embedment is to be determined using a reduced passive earth pressure coefficient (Kp/1.5). To account for soil disturbance at excavation depth, passive resistance will be ignored or discounted 2-feet immediately below that depth.

Active site dewatering will be necessary to install the RCP pipe. Permeation grouting may be necessary to improve ground conditions to reduce permeability in certain areas. Provisions related to groundwater controls will be provided in the contract documents. Utilities not being relocated prior to excavation will be supported in-place keeping deflections to within allowable criteria as dictated by the utility owner.

4.0 CONSOLIDATION CONDUIT

Wet weather flow from the regulators Reg-217T and Reg-217M will be diverted from the 42-inch OF-217 CSO pipe and will be conveyed through a new 48-inch diameter RCP consolidation conduit to Drop Shaft 213. The OF-217 Diversion Structure will be located at the south east corner of the Tidewater property owned by National Grid. The Consolidation conduit extends west and then to the north to Drop Shaft 213, located at the Masonic Temple property, Parcel 53-551. The OF-217 consolidation conduit is:

- Approximately 2,700 linear feet
- 48-inch diameter RCP
- Designed to convey a peak flow of approximately 39 MGD
- minimum slope of 0.0018 ft/ft.

The portion of OF-217 consolidation conduit to be constructed under this Contract is 1,900 linear feet. The downstream section of 800 linear feet that extends within the limits of Taft Street, beneath the Interstate Rte. 95 bridge and the Division Street bridge to the Junction Chamber, upstream of the GSS is to be constructed under Contract IIIA-4.

Relocation of OF-217 is also a part of this Project. The outfall location will remain on the Tidewater property but will be relocated approximately 450-feet to the north along the river.

4.1 TIDEWATER PROPERTY

Approximately 1,000 linear feet of consolidation conduit with two (2) associated structures, and 470 linear feet of outfall pipe with two (2) associated structures, will be constructed within National Grid's Tidewater property. Tidewater is a former MGP site and is known to have soil and groundwater contamination associated with its former use. The MGP operated from the 1880s until 1954 and coal was used as the principal fuel to produce coal gas. In the later years of operation (1954 until the late 1960s), the MGP produced gas using oil and propane.

National Grid is currently progressing forward with a plan to construct a cap over the site. The project is an 18-month project scheduled to commence in the late fall of 2020 and be completed by late fall 2021. A second project includes substation construction and is estimated to start in July 2020, with demolition of the existing substation building scheduled for July 2022.

4.1.1 Alternatives

The conceptual design for the OF-217 consolidation conduit depicted an alignment that bisected the Tidewater property to the northwest before turning to the north running parallel to Taft Street toward Drop Shaft 213. However, recent information about the Tidewater parcel's development potential warranted review of alternative alignments within the Tidewater property. Development plans include both the Tidewater parcel and the City's Town Landing parcel that is adjacent to the Tidewater property to the north.

The alternatives focused on creating more development space that would avoid conflict with the pipeline alignment. Two alternatives to the conceptual design alignment were developed for review, a "shoreline" alignment and a tidewater property "perimeter" routing. Below is a discussion of the alternatives.

Shoreline: The shoreline alignment considers routing the consolidation conduit from the OF-217 Diversion Structure to the north, parallel to the shoreline, through the Tidewater property and the City's Town Landing property. This alignment runs approximately fifty (50) feet east of the river wall and was coordinated with the City's proposed bike path along the same route. The pipe would reside within the velocity zone of the flood plain. As such it would require placing additional fill above the pipe to provide protection and maintain structure heights above the flood plain. This fill would also be necessary to maintain the system's hydraulic grade line. The advantages to this alignment were limited compared to the potential issues associated with damage from flooding and hydraulic concerns. In addition, the existing river wall is in a dilapidated condition for much of its length and is set below the flood plain. Because fill is required for pipeline protection and because the pipe is in the flood plain and its velocity zone, it was determined that the risk associated with potential pipe damage from flooding exceeded the benefits of this routing. In addition, the poor condition of the river wall will, over time, subject the shoreline to erosion and put the pipeline at further risk.


View of existing river wall – looking south

Perimeter Routing: The perimeter routing followed a path from the OF-217 Diversion Structure to the west, along an alignment that was parallel to Tidewater Street. The pipeline would extend towards Taft Street, and then continue to the north along the western boundary of the Tidewater site. National Grid extended caution regarding the proximity of the work to Tidewater Street because of the utility congestion within Tidewater Street and the unknown condition of an aging 16-inch diameter, cast iron, high pressure gas main that also runs parallel, and north of Tidewater Street. National Grid has provided additional information about the gas main as the design has progressed. National Grid has indicated that the gas main has been leak tested and its condition is such that there is no plan for replacement of the main. National Grid has provided protocol and rules for utility construction in the vicinity of their infrastructure and the information is being incorporated into the deign documents. The alignment has been proposed with the rules and protocol in full consideration. The most limiting rule relative to separation from the cast iron main is that in which defines that the gas utility needs to be replaced if construction is proposed within 10 feet.

The recommended alignment is the perimeter routing and it has been presented to National Grid and the City's developer for their review. The developer indicated that the alignment was improved and has been working with the information. Information pertaining to the perimeter routing is presented below.

Connection to the existing OF-217 CSO pipe will be made downstream of the junction manhole where the CSO pipe from Merry Street joins the CSO pipe on Tidewater Street. A new Relocation Structure and 48-inch diameter pipe will be installed to redirect all flow towards the north to the new OF-217 Diversion Structure. The consolidation conduit will exit to the west, with the new OF-217 CSO pipe exiting the same structure downstream of the weir to the north west towards the new outfall location.

The first 210-foot stretch of consolidation conduit downstream of the diversion structure ranges in depth between 10 and 20-feet. Open-cut construction is recommended due to anticipated subsurface obstacles, which are discussed in Section 4.1.2 below. The remainder of the consolidation conduit on the property ranges in depth between 20 and 35-feet. Microtunneling methods are recommended for this construction due to the depth of the pipe and to limit exposure to the contaminants present in the soil and groundwater.

4.1.2 Construction Considerations

The selected consolidation conduit alignment will involve installation by microtunneling methods and open-cut construction. Below is a summary of the following construction considerations:

- Site and Subsurface Conditions
- Excavation Support and Dewatering
- Utility Relocation and Coordination
- Shaft and working space
- Traffic flow and access for vehicles and pedestrians
- Regulations

Site and Subsurface Conditions

Mixed ground conditions are anticipated with the tunnel zone alignment in the Tidewater property. Beginning at MH-217-6, bedrock is anticipated and consists of strong, slightly weathered, purple Sandstone. Proceeding up-station, the subsurface conditions within the tunnel horizon transition to a full face of soil in the area of MH217-7. Alluvium Deposits overlying Glacial Deposits are expected within the tunnel horizon. The Alluvium is expected to consist of medium stiff dark gray clayey silt. The Glacial Deposits are anticipated to consist of very dense, coarse to fine gravel with varying amounts of sand and silt.

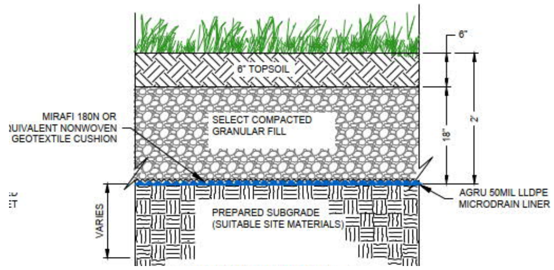
Heading up-station from MH217-7, the subsurface conditions within the tunnel horizon are expected to consist of Alluvium Deposits overlying Glacial Deposits or a full face of Fill. The Fill consists of dense brown sand with varying amounts of gravel and silt and contains fragments of brick.

Groundwater levels are anticipated to be above the tunnel crown.

Depending on the timing of construction relative to National Grid's remediation contract, the construction may require disruption of a Tidewater cap system. Pipe installation on the Tidewater property will require construction through foundations for abandoned buildings and tank structures, as well as the potential for encountering subsurface demolition debris.

Tidewater Cap System: The Tidewater property is to receive a cap system as part of their Sitewide Remedy Design. The cap system will consist of a combined barrier layer and drainage media system constructed with linear low-density polyethylene (LLDPE) liner. The system is overlain with geotextile followed by 24-inches of drainage and surface material. The cap system also includes a network of underdrains. Cap areas impacted and disrupted by the consolidation conduit construction will include:

- 18-inches compacted gravel / 6-inches topsoil (Dense grade or crushed stone)
- 19.5-inches dense grade / 4.5-inches hot mix asphalt
- Underdrain system



Typical Cap Detail
Source: Sitewide Remedy Design – National Grid

The cap may be disrupted at microtunnel drive shafts and exit pits and at sections requiring open-cut construction:

- Drive Shaft Locations (1)
- Exit Pit (1)
- OF-217 Diversion Structure,
- Consolidation Conduit (300 linear feet) and associated manholes / OF-217 Relocation Structure
- OF-217 Outfall Pipe (470 linear feet) and associated manholes
- Tie-in manhole and manholes associated with consolidation conduit

It is anticipated that the areas to be disrupted will be initially stripped of its cover soil followed by the liner system being cut out and removed to the extents required to complete the work. Following the pipeline construction, the cap system will need to be disrupted further to provide a clean-cut interface and connection point to repair the liner. The repair will be completed by a certified installer in accordance with the manufacturer's requirements. Provisions will be made within the contract for repair of the cap liner system as a result of the project construction activities.

Existing Foundations: The foundations and features of former gas and power plant structures, buildings, concrete and brick foundations, tanks, piping, etc. are anticipated to be encountered for portions of the alignment. Provisions will be made within the contract for the management and disposal of these materials as necessary.

At the transition from microtunnel to open-cut construction, the depth of construction will range between 10 and 20-feet. These depths carry through the 300-feet section of pipeline between the microtunnel/open-cut interface and the tie-in point with the existing CSO pipe to the west. It is anticipated that foundations for the former Meter Room and Relief Holder No. 4 will be encountered during this stretch, as well as any potential subsurface debris related thereto. Open-cut construction is recommended for this relatively short stretch of pipeline to allow effective management of any obstructions encountered and the relatively shallow depth of excavation.

Management of Contaminated Soil and Groundwater: At the request of National Grid, no environmental investigations were conducted on the site as part of this project. Although environmental testing was not completed, evidence of contamination was observed during the geotechnical subsurface investigation completed for the project. Oil sheen was noted on some of the split spoon samples along with elevated PID readings.

Based on review of investigations previously completed by National Grid, historic releases at the Site include spills, overflows and other releases of oils, tars and process residuals. Below grade releases to the river associated with MGP residuals in the forms of sheen outbreaks have been witnessed in the past. Releases resulted from activities such as equipment maintenance and leakage from above and below grade equipment, vessels, and tanks. Process residuals and their associated contaminants include:

- Coal tar: PAHs
- Lighter oils: benzene, toluene, ethylbenzene, and xylenes,
- Raw condensate and purifying waters: cyanide, metals, sulfur, ammonias, phenols, and tars.

The area where construction is anticipated is referred to in documents as the North Fill Area (NFA) and Former Gas Plant Area (FGPA). Review of data in the vicinity of the work indicates that soil and groundwater contamination can be expected. Surface soil contamination exists with elevated readings above RIDEM direct exposure criteria (Commercial/Industrial) for PAH's, TPH, Arsenic, and lead. Groundwater contamination also exists with concentrations of VOCs including Toluene, Xylene, Styrene, trimethylbenzene, and Naphthalene and SVOCs including Naphthalene, Acenaphthene, and fluorene.

Excavation Support and Dewatering

Performance specifications for the excavation support system to accommodate construction of MH217-6 and MH217-7 will provide guidance and supporting documentation to provide the contractor sufficient information to design circular concrete working shafts that provide sufficient support and limit the intrusion of ground and provide an effective groundwater cutoff with the bedrock surface. Depending on the rock quality at the base, permeation grouting may be required to create a plug to cut-off water inflows. No inflows will be permitted into these shafts considering the ground is contaminated. MH217-6 and MH217-7 will serve as launching pits for the deep MTBM drives necessary to complete the trenchless reaches. The circular concrete working shafts will be designed by the contractor in accordance with ACI 318. The circular shafts resists lateral loads through ring compression and could therefore be designed as unreinforced without internal bracing.

Performance specifications will provide the contractor earth pressures based on soil parameters from the GDSR. This will be used to design the excavation support system for strength. Lateral loads to be considered in the design include earth, groundwater and construction surcharge based on a vertical surface load of 600-psf. The design should also consider temperature effects where applicable.

Excavation support to accommodate construction of the 42-inch diameter RCP outfall and the sections of the 48-inch diameter RCP consolidation conduit that is identified to be constructed with open-cut construction methods, as well as manholes MH217-8 and MH217-10 to MH217-11, will also be provided by the contractor. To evaluate clearances and construction costs, it has been assumed for the purposes of this report that excavation support will consist of steel soldier piles and timber lagging. The excavation support system should be designed and installed in accordance with the methods described in Section 3.6

Trench box for earth support may be considered when excavations for outfall and consolation conduits are 10-feet in depth or less, however, with the man-made obstructions expected below grade, this may be prohibitive.

Utility Relocation and Coordination

Approximately 300-feet of the existing OF-217 pipe system resides beneath an active substation on the Tidewater Property. The CSO pipe, which is the property of the City of Pawtucket, has recently undergone structural repair for a collapse section located immediately upstream of the discharge. Because of its existing location being beneath the secured electrical Substation, combined with its age and deteriorating condition, the NBC and National Grid mutually agreed that the CSO flow be redirected.

The new outfall will be positioned approximately 450-feet to the north of the existing location. Improvements to the river wall on the eastern perimeter of the National Grid site is part of the Sitewide Remedial Plan, and the river wall in the vicinity of the new outfall involves construction of a steel, sheet pile, bulkhead wall with a rip rap revetment on the river side. The new OF-217 will require a penetration in the Sheet pile wall

The new OF-217 design will include the horizontal and vertical location of the pipe, and a penetration detail through the steel sheeting. To reduce the potential for river water to enter the tunnel during flood conditions, a flap gate is being incorporated into the design. The flap gate is to be installed with thin the Diversion Structure.

It is anticipated that the cap will be constructed before the NBC's OF-217 contract begins. The existing OF-217 outfall will remain in service until completion of the consolidation conduit project.

Shaft and Working Space

Shaft to launch the microtunneling machine, jack the pipe and receive the machine are located where there is adequate working space on the surface to accommodate support equipment close to the jacking shaft and for staging and material laydown. Typical microtunneling support surface area requirement to accommodate the following:

Operator control room	Generator and backup power supply	Lubrication system
Shaft crane	Slurry separation system	Temporary muck storage
Pipe storage	Crew change trailer	Field office
Material and parts storage		

The jacking shaft will be of adequate size to accommodate the earth support system, the jacking system required for the 48-inch diameter pipe to be installed, thrust reaction block, slurry system piping valves and pumps, shaft emergency access and egress, ventilation and sufficient workspace for bottom shaft personnel. Receiving shafts will be sized to provide adequate space and clearance for lifting equipment to retrieve the microtunnel boring machine. Shafts will be located to avoid overhead and subsurface utilities and minimize traffic and community impact. Poles and overhead wires associated with area street lighting will likely require temporary relocation to accommodate construction.

The staging area associated with the microtunnel operation will be established on the Tidewater property and is confined to areas identified by the temporary construction and permanent easements.

Traffic flow and access for vehicles and pedestrians

It is anticipated that the Tidewater facility will be used for contractor staging and for passage of construction vehicles. Traffic management plans will be developed with the goal of limiting impact to local traffic, residents and businesses as well cyclists and pedestrians.

Regulations

The design for microtunneling and shaft construction will identify and meet the applicable federal, state and local regulations and identify the need for environmental documentation, and permits, local regulations for discharges and handling of materials, erosion control measures and noise limitation.

Special project and site-specific considerations will be identified which may include limited work hours, restricted access, haul routes and disposal sites, dust control, disposal of slurry, spoils and groundwater.

4.2 Tidewater to Taft Street

The OF-217 consolidation conduit continues from the Tidewater property and extends to a point south of the Division Street Bridge on Taft Street. The limit of the project is the termination of consolidation conduit to be constructed under Contract IIIA-4.

The 48-inch diameter consolidation conduit is approximately 796-feet long, located between Sta. 0+00 and Sta. 7+96(MH217-6) as presented on the 60% Design Drawings, is designed to convey a peak flow of approximately 39 MGD, and has a minimum slope of 0.0018 ft/ft. The consolidation conduit runs south to north, approximately parallel to Taft Street and a portion of the alignment is within the Town Landing Property, Parcel 54-827, owned by the City of Pawtucket. Much of the Parcel is currently undeveloped, with a boat ramp and park area at its northern end and a small community garden located at the south west corner of the property.

As previously noted, the City of Pawtucket's Town Landing property is part of a planned development project, and the alignment of the consolidation conduit is based on coordination with the developer and their interest in limiting restrictions to the development parcel. The proposed alignment considers the new development and, to the extent practical, the alignment has been shifted to the west towards Taft Street. The alignment also takes into consideration minimum separation clearances with an existing 16-inch cast iron gas main, as required by National Grid. Construction of the proposed consolidation conduit will require temporary disruptions to the sidewalk the access drive for the boat ramp and park area. The community garden will also be temporarily disrupted during construction. The consolidation conduit will connect to the IIIA-4 consolidation conduit and flow to DS-213.

4.2.1 Construction Considerations

The alignment between Station 1+26 and 7+96 is proposed to be constructed with microtunneling methods. The tunneling will progress from the south to the north with a drive shaft located in one of two locations:

- South west corner of Town Landing property
- North west corner of Tidewater property

The two potential locations are adjacent to each other. The sole benefit to maintaining the location on the Tidewater property is that the Community garden will remain undisturbed during construction and if the property remains undeveloped clearing can be avoided on the Town Landing Parcel. The benefits to locating the shaft on the City property include:

- Disruption of the National Grid cap for construction of the shaft is eliminated
- Avoid National Grid construction and soil management requirements

The location at the south west corner of Town Landing property is selected for the 60% design. The drive shaft will be approximately 20-feet in diameter and will be about 40 feet in depth. Approximately 15-feet of rock removal is anticipated.

The exit shaft will be located within Taft Street between a 16-inch gas main and a 12-inch storm drain. The pit will favor the drain and will require rerouting of the drain around the pit. The exit pit construction will also require disruption of the sidewalk, access drive to the boat ramp, and temporary relocation of poles and overhead wires associated with street lighting. The exit pit will be approximately 10-feet by 12-feet.

The vertical alignment for the consolidation conduit ranges in depth between 16-feet and almost 40-feet with the exit shaft at approximately 16-feet, and 35-feet at the drive shaft.

Subsurface Conditions

Subsurface conditions within the tunnel horizon along Taft Street from MH217-5 to MH217-6 are anticipated to be in mixed ground conditions. Beginning at MH-217-5, Glacial Deposits are expected. Heading up-station, Glacial Deposits overlying Bedrock are expected to transition to a full face of bedrock expected in the vicinity of the Taft Street Community Gardens to MH217-6. The Glacial Deposits are anticipated to consist of very dense, coarse to fine gravel with varying amounts of sand and silt. The bedrock is anticipated to consists of strong, greenish gray, slightly to moderately weathered Siltstone or Sandstone.

Groundwater levels are anticipated to be above the tunnel crown.

Excavation Support and Dewatering

Excavation support to accommodate construction of MH217-5, will be the responsibility of the contractor. To evaluate clearances and construction costs, it has been assumed for the purposes of this report that excavation support will consist of steel soldier piles and timber lagging. The excavation support system should be designed and installed in accordance with the methods described in Section 3.6.

5.0 STRUCTURES

5.1 OF-217 RELOCATION STRUCTURE

Connection to the existing OF-217 outfall pipe will be made in-line between the junction manhole where the CSO pipe from Merry Street joins the CSO pipe on Tidewater Street and the down stream manhole on Tidewater Street . A new structure and 48-inch pipe will be installed to redirect all flow to the north to the new OF-217 Diversion Structure and new OF-217 outfall location. The relocation of OF-217 is discussed in Section 4.

5.1.1 STRUCTURE DESCRIPTION

The OF-217 Relocation Structure, identified as MH-217-8 on the plans, is a pre-cast concrete structure . The structure will be constructed in-line with the existing outfall pipe. The 48-inch diameter discharge pipe conveys flow to the north east towards the new OF-217 Diversion Structure

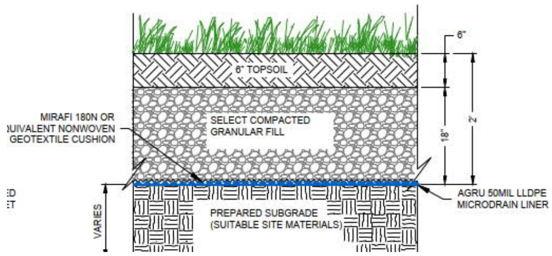
The structure is a box type configuration with overall plan dimensions of 8-feet by 8-feet and is approximately 11-feet deep.

The construction will require disruption of a cap system, and relocation of utilities. The manhole is in paved area of the site.

5.1.2 Construction Considerations

Cap System: The Tidewater property is to receive a cap system as part of their Sitewide Remedy Design. The cap system will consist of a combined barrier layer and drainage media system constructed with linear low-density polyethylene (LLDPE) liner. The system is overlain with geotextile followed by 24-inches of drainage and surface material. The cap system also includes a network of underdrains. Cap areas impacted and disrupted by the structure construction will include:

- 19.5-inches dense grade / 4.5-inches hot mix asphalt



Typical Cap Detail
Source: Sitewide Remedy Design – National Grid

It is anticipated that the areas to be disrupted will be initially stripped and the liner system will be cut out and removed to the extents required to complete the work. Following the pipeline construction, the cap system will be further disrupted to provide a clean cut and connection point to repair the liner. The repair will be completed by a certified installer in accordance with the manufacturer's requirements.

Utility Relocation: Site utility information has been provided by National Grid. Based on review of the available information, relocation of a water main will be required for the installation of the new manhole.

Flow Management: The goal of the flow management scheme is to continue to manage flow through existing pipes and facilities until the new OF-217 outfall is established and complete, at which time short system interruptions need to occur with careful planning and a clear understanding of the weather conditions. Flow management includes construction sequencing, employed construction methods, and temporary dams and pipe connections. It is understood that this contract will be completed in advance of downstream tunnel improvements. The intent is to provide a temporary plug within the consolidation conduit and continue to allow CSO discharges to the new OF-217 location until downstream improvements are complete. The downstream improvements include the tunnel, pump stations, drop shafts, and associated appurtenances required for operation of the CSO control system.

Flow management will be critical in the construction of the Relocation Structure. The pre-cast structure will be installed in-line with the existing combined sewer outfall pipe, and should be constructed after the new OF-217 outfall and associated structures are complete.

Proposed sequence of construction for OF-217 Relocation Structure is as follows:

- Secure the site
- Cut back existing cap system
- Construct new/relocated OF-217 outfall
- Construct new OF-217 consolidation conduit and diversion structure complete including testing
- Install plug in OF-217 Consolidation conduit within OF-217 Diversion Structure
- Install invert in new precast structure and pipe stubs.
- Relocate utilities

- Install excavation support and dewatering systems for OF-217 Relocation Structure
- Excavate to expose existing outfall pipe
- Review weather conditions and schedule construction for a dry period and/or manage existing flow if necessary.
- Manage existing flow (if any)
- Provide support for the existing pipe and cut out existing pipe section to accommodate new structure
- Connect existing CSO pipe and new OF-217 outfall to new structure
- Install permanent plug / bulkhead within existing OF-217 outfall pipe, within new structure.
- Backfill around structure

5.1.3 Subsurface Conditions

The Relocation Structure (MH217-8) will require excavation of soil and possibly bedrock. Approximately 10-feet of Fill is expected to be encountered. Bedrock may be encountered at the planned invert of the structure. The Fill consists of dense fine sand with some gravel and trace silt. Bedrock consists of strong, grey conglomerate Sandstone. Possible boulders or weathered bedrock are expected at the interface between the fill and the top of rock surface. The groundwater level is anticipated to be about 5-feet below the existing ground surface.

5.1.4 Excavation Support and Dewatering

Excavation support to accommodate construction of MH-217-8 will be the responsibility of the contractor. To evaluate clearances and construction costs, it has been assumed for the purposes of this report that excavation support will consist of steel soldier piles and timber lagging. . The excavation support system should be designed and installed in accordance with the methods described in Section 3.6

Trench box for earth support may be considered when excavations for outfall and consolation conduits are 10-feet in depth or less, however, with the man-made obstructions expected below grade, this may be prohibitive.

5.1.5 Structural

MH 217-8 will be of pre-cast construction in accordance with ACI-350 for strength and durability considering moderate exposure to sulfate containing solutions, both on the interior and exterior, and freeze-thaw where applicable. Pre-cast manufacturer shall be directed to design the structure considering the following loads: earth, groundwater, surcharge, earthquake and AASHTO HL-93 truck loading.

Minimum 28-day compressive strength for concrete design will be 4,500 psi.

MH-217-8 will also be designed to resist uplift either solely based on self-weight of the permanent structure and overburden on the roof, or alternatively by a combination of self-weight of the permanent structure and engaging adjacent overburden by employing an extended base of 8-inches or more. Skin friction from adjacent earth will not be permitted in participating in the resistance to uplift. A minimum factor-of-safety of 1.15 shall be achieved to demonstrate adequate uplift resistance when considering the design groundwater elevation.

5.2 OF-217 Diversion Structure

Located downstream of the tie-in structure, the OF-217 Diversion Structure serves to divert wet weather CSO flow from OF-217 to the downstream facilities and ultimately to the Tunnel via DS-213. OF-217 Diversion Structure is located approximately 95-feet northwest of the Relocation Structure, off the paved surface and west of the existing substation.

5.2.1 Structure Description

The diversion structure will be constructed of pre-cast concrete with new pipe entering and exiting the structure. A new 48-inch RCP influent sewer will enter the south side of the structure, the 48-inch diameter consolidation conduit will exit the structure to the northwest and the new 42-inch diameter CSO pipe will flow to the new outfall location north and east of the diversion structure. A weir wall shall be constructed within the structure to direct flow to the 48-inch diameter consolidation conduit.

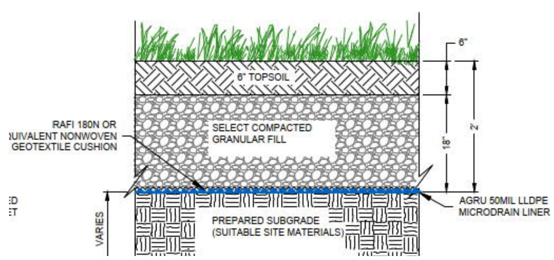
Flow that overtops the diversion weir will discharge to the new outfall location. Relief of the consolidation conduit is necessary to avoid surcharge and flooding when the tunnel is full and the gate at DS-213 closes. When the gate to the tunnel is closed the system will surcharge until it overflows the top of the weir. The weir elevation within the diversion structure is below the FEMA 100-year flood elevation of 13.8'. When the Seekonk River elevation is above the 100-year flood plain elevation, river flow will travel up the new OF-217 outfall pipe, overtop the weir at the diversion structure, and be conveyed to the tunnel by the consolidation conduit unless restricted. The flap gate over the weir at the diversion structure restricts this potential flow pattern. To limit the ability of flood waters to enter the into the system, a flap gate above the weir is incorporated into the design.

The structure has a rectangular shape and overall plan dimensions of 15-feet by 10-feet. The depth of the structure is 12-feet.

5.2.2 Construction Considerations

The construction will require disruption of a cap system,. The strucuture is in an unpaved area of the site.

Cap System: The Tidewater property is to receive a cap system as part of their Sitewide Remedy Design. The cap system will consist of a combined barrier layer and drainage media system constructed with linear low-density polyethylene (LLDPE) liner. The system is overlain with geotextile followed by 24-inches of drainage and surface material. The cap system also includes a network of underdrains. Cap areas impacted and disrupted by the structure construction will include:



Typical Cap Detail
Source: Sitewide Remedy Design – National Grid

- 18-inches compacted gravel / 6-inches topsoil (Dense grade or crushed stone)

It is anticipated that the areas to be disrupted will be initially stripped and the liner system will be cut out and removed to the extents required to complete the work. Following the pipeline construction, the cap system will be further disrupted to provide a clean cut and connection point to repair the liner. The repair will be completed by a certified installer in accordance with the manufacturer's requirements.

Flow Management

The goal of the flow management scheme is to continue to manage flow through existing pipes and facilities until much of the construction is complete, at which time short system interruptions need to occur with careful planning and a clear understanding of the weather conditions. Flow management includes construction sequencing, employed construction methods, and temporary dams and pipe connections. The flow management considerations presented assume that the downstream tunnel improvements will not be complete. The downstream improvements include the tunnel, pump stations, drop shafts, and associated appurtenances required for operation of the CSO control system.

It is anticipated that the consolidation conduit and associated diversions structures will be installed from the downstream end and proceed upstream, with the lower elevation sections completed first (i.e. the section south toward the bridges).

Since existing flow will be managed through the existing OF-217 outfall during construction of the OF-217 Diversion Structure, no flow management at the diversion structure is required. Flow management will be critical in the construction of the Relocation Structure. The pre-cast OF-217 Relocation Structure will be installed in-line with the existing outfall pipe, and the outfall will be maintained in service until the structures and connecting consolidation conduit and new outfall pipes are complete.

Proposed sequence of construction for OF-217 Diversion Structure is as follows:

- Secure the site
- Cut back existing cap system
- Construct new/relocated OF-217 outfall
- Construct new OF-217 consolidation conduit with Microtunneling methods
- Install excavation support and dewatering systems for open cut construction
- Complete installation of consolidation conduit including testing
- Excavate and install Precast diversion structure
- Relocate utilities for construction of OF-217 Relocation /tie-in Structure and connecting piping
- Install connecting consolidation conduit and new outfall pipe to new diversion structure
- Construct invert in the diversion structure and weir
- Install plug in the consolidation conduit at the diversion structure
- Construct piping towards OF-217 Relocation Structure
- Backfill around structure

5.2.3 Subsurface Conditions

The DS-217 structure will require excavation of soil and possibly bedrock. Approximately 10-feet of Fill is expected to be encountered. Bedrock may be encountered at the planned invert of the structure. The Fill consists of dense fine sand with some gravel and trace silt. Bedrock consists of strong, grey conglomerate Sandstone. Possible boulders or weathered bedrock are expected at the interface between the fill and the top of rock surface. The groundwater level is anticipated to be about 5-feet below the existing ground surface.

5.2.4 Excavation Support and Dewatering

Excavation support to accommodate construction of the diversion structure will be the responsibility of the contractor. To evaluate clearances and construction costs, it has been assumed for the purposes of this report that excavation support will consist of steel soldier piles and timber lagging., The excavation support system should be designed and installed in accordance with the methods described in Section 3.6

5.2.5 Structural

The diversion structure will be precast concrete structure designed in accordance with ACI-350 for strength and durability considering moderate exposure to sulfate containing solutions, both on the interior and exterior, and freeze-thaw where applicable. The precast manufacturer will be directed to consider the following loads as part of the design: earth, groundwater, surcharge, earthquake and AASHTO HL-93 truck loading.

Minimum 28-day compressive strength for concrete design will be 4,500 psi.

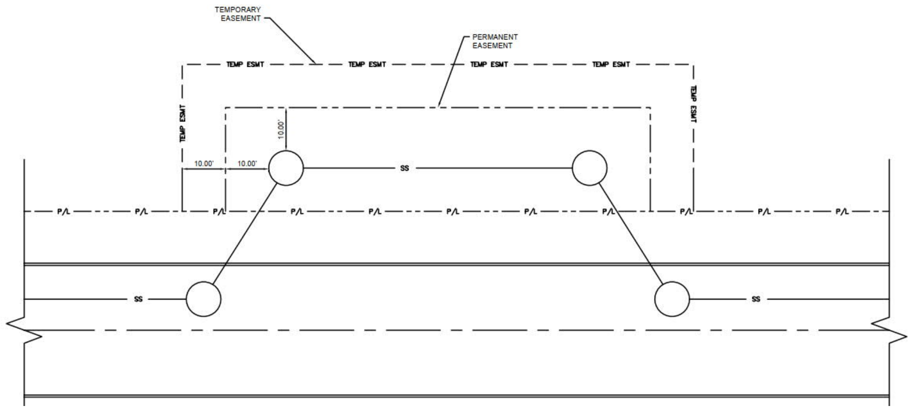
The structure will also be designed to resist uplift either solely based on self-weight of the permanent structure and overburden on the roof, or alternatively by a combination of self-weight of the permanent structure and engaging adjacent overburden by employing an extended base of 8-inches or more. Skin friction from adjacent earth will not be permitted in participating in the resistance to uplift. A minimum factor-of-safety of 1.15 will be required to demonstrate adequate uplift resistance when considering the design groundwater elevation.

5.2.6 Level Instrumentation

Level instrumentation for the OF-217 Diversion Structure consists of a non-contact radar transmitter like the VEGAPLUS 66 shall be bracket mounted from the top of the diversion structure. A high-level float switch shall be suspended from a bracket mounted to the top of the diversion structure. The level instrumentation and transmission of output signals from the devices back to the SCADA Control Panel PLC I/O modules at the Gate and Screening Structure are part of a separate NBC Contract.

6.0 Easements

The proposed improvements were positioned, to the extent practical, within the public rights-of-way. However there are locations where the alignment extends onto private property to avoid existing infrastructure that would be costly to relocate, or the relocation of that utility would in-turn need to extend onto private property. Permanent and temporary easements will be required in locations where the contractor's activities are required to extend onto private property for the construction of the improvements. Permanent easements will be required where permanent works extend onto private property. Measured by the square foot, the easement will cover the area occupied by the infrastructure as well as an agreed upon off-set area that will be utilized for future maintenance or access. Temporary easements generally cover areas of private property that will likely be disturbed by contractor activity during the construction of the permanent works. Easement plans for the project are provided in Appendix 5. A schematic of a general easement scenario is provided below.



It is noted that staging and equipment storage areas, required by the contractor, are not addressed here. It is assumed these areas will be arranged by the Contractor independently and they will form a separate Agreement with the property owner.

6.1 City of Pawtucket

Permanent and temporary construction easement areas will be required on City property. The selected consolidation conduit alignment extends on City property for approximately 400 linear feet. The alignment was dictated by the desire to construct microtunnel shafts off the roadway to limit disturbances and traffic disruptions along Taft Street and the Blackstone Academy Charter School at the intersection of Tidewater Street and Taft Street. It is noted that MH-217-6, a microtunnel shaft location, initially planned for the Tidewater property was shifted to the north of the Tidewater property to limit cap disturbance and accommodate future Tidewater development. Development of the easement plans is pending. It is our understanding that further subdivision of the parcels may occur.

Table 6-1: City of Pawtucket Easement

Parcel	Property Owner	Temporary Easement Area (SF)	Permanent Easement Area (SF)
54//827	City of Pawtucket	Pending (*)	Pending (*)

6.2 National Grid

Permanent and temporary construction easement areas will be required on the Tidewater Property. NBC infrastructure included on the Tidewater Property includes manholes, microtunnel shafts, OF-217 diversion structure, CSO pipe for OF-217 and consolidation conduit. Development of the easement plans is pending. It is our understanding that further subdivision of the parcels is pending Agreement between National Grid and the developer.

Table 6-2: National Grid Easement

Parcel	Property Owner	Temporary Easement Area (SF)	Permanent Easement Area (SF)
54//826	Narragansett Electric Co	Pending	Pending
65//662	Narragansett Electric Co	Pending	Pending

7.0 Environmental Conditions

Performed In conjunction with the subsurface investigation work, BETA conducted an Environmental Investigation program with the Project area. The purpose of the Environmental Investigation program was to identify areas and potential areas of soil and/or groundwater contamination that may be encountered during construction activities. The program sought to identify potential contamination through research of historical information and databases, site reconnaissance, and soil and groundwater sampling and analysis.

The Environmental Investigation was performed in accordance with the "NBC Phase III CSO Program Consolidation Conduits Phase IIIA-4 and IIIA-5, Subsurface Investigation Work Plan", by McMillen Jacobs Associates, revised July 1, 2019. A summary of findings is presented in the "NBC Phase III Consolidation Conduits IIIA-4 and IIIA-5, Environmental Technical Memorandum," by BETA Group, Inc., dated March 30, 2020. The following summarizes the environmental conditions in the project area, conclusions, and recommendations.

Historic research identified several properties along the proposed project route with known releases and the potential to impact the property. The project crosses two of these, Town Landing and Tidewater, both of which are active remediation sites with the Rhode Island Department of Environmental Management (RIDEM).

BETA reviewed a "Site Investigation Report/Targeted Brownfields Assessment" prepared by Fuss & O'Neill for the Town Landing property. This report included laboratory data from four soil borings near the proposed layout on the Town Landing property. The data indicated concentrations of lead and polynuclear aromatic hydrocarbons (PAHs) in soil above RIDEM's standards.

Tidewater is the site of a former manufactured gas plant (MGP). The proposed project area is known to have soil and groundwater contamination associated with its former use and are listed as a "State Site" under RIDEM's Remediation Regulations (RIDEM Case No. 95-022). The former MGP operated from the 1880s until 1954 and coal was used as the principal fuel to produce coal gas. In the later years of operation (1954 until the late 1960s), the MGP produced gas using oil and propane. BETA reviewed a January 2011 "Site Investigation Data Report" prepared by GZA GeoEnvironmental, Inc. (GZA) for the Tidewater property. This report included laboratory data from six soil borings near the proposed layout on the Tidewater property. The data indicated concentrations of arsenic, lead, PAHs, volatile organic compounds (VOCs), cyanide, total petroleum hydrocarbons (TPH), and polychlorinated biphenyls (PCBs) in soil.

In August and September 2019 and February 2020, BETA oversaw the advancement of eight (8) soil borings with installation of monitoring wells in four of these borings on the Tidewater property. At the request of National Grid, no environmental sampling was conducted as part of this project.

Based on the investigatory activities conducted in support of the NBC Phase III CSO Consolidation Conduits IIIA-5 project, BETA makes the following conclusions:

- Review of reports for the Town Landing property indicate the presence of lead and PAHs in soil
- Although soil and groundwater sampling was not allowed on the Tidewater property, review of GZA's report for the site indicate the presence of lead, arsenic, TPH, cyanide, PCBs, and SVOCs in soil near the proposed work areas above RIDEM's Residential Direct Exposure Criteria (RDEC) and, in some cases, above RIDEM's Industrial/Commercial Direct Exposure Criteria (ICDED). The concentrations of lead (up to 19,000 milligrams per kilogram) could result in some soil being classified as hazardous waste. Soil and groundwater management requirements on the Tidewater Property will be dictated by National Grid.

BETA makes the following recommendations for the project:

- Contractors will need to develop Health and Safety Plans and Soil Management Plans that address contaminants identified at the Town Landing and Tidewater properties.
- Soil management at Tidewater will consist of excavation of impacted soil, stockpiling at locations designated by National Grid, backfilling with excavated material, and restoration of the cap system to National Grid's standards. Disposal of excess soil at Tidewater will be coordinated with the requirements of National Grid.
- Soil management outside of the Tidewater area will consist of excavation of impacted soil, stockpiling at locations to be determined, backfilling with excavated soil to the extent possible, and backfilling with documented clean fill if needed. After stockpiling of the soil, sampling of the soil for disposal facility parameters will be required. Disposal of soil will be at approved facilities based on the results of stockpile sampling.
- Groundwater dewatering will require treatment prior to discharge to the NBC system. The contractor will be required to design a treatment system to meet NBC's Buckling Point Wastewater Treatment Facility (BPWWTF) local limits. Treatment will likely include settling tanks, bag filtration, and carbon treatment. Effluent sampling will include twelve metals, VOCs, SVOCs, TPH, total suspended solids, and pH.

The Environmental Technical Memorandum is provided as Appendix 6.

8.0 Risk Management

As is the case with every project, risk is an ever present and inherent part of the design and construction industry. To determine how risk may affect a project, risks must be identified, then evaluated for their likelihood of a particular risk event occurring and the anticipated impact to the project cost and project schedule should said event take place. A risk management strategy and associated approach must be identified for each risk and the residual risk likelihood and impacts to cost and schedule, post-risk management, must be assessed.

BETA has identified several risks to the project and cataloged them in a Risk Register. The Risk Register categorizes risks into a few different categories, specifically Safety, Planning & Permitting, Procurement, Design, Construction, Environmental, Stakeholder Engagement, Financial, Land Acquisition/Easements/Right of Entry, and Operations & Maintenance. The likelihood of each risk is assessed, ranging from “Rare” (1% chance of occurring) to “Probable” (70% chance of occurring) and assigned a corresponding likelihood score ranging from 1 to 5, with 1 being the least likely to occur of occurrence and 5 being the most likely to occur. Cost and schedule impacts associated with risk event are assessed, ranging from “Very Low” (<$100k for cost, <15 days for schedule) to” Very High” (>$2.5M for cost, >90 days for schedule). Cost and schedule are each assigned a corresponding score based on the identified impact ranging from 1 to 100, with 1 representing the lowest impact to cost or schedule and 100 representing the highest impact.

The Cost Risk Level and Schedule Risk Level are calculated for each risk based on the risk’s likelihood score and cost and schedule scores.

Cost Risk Level = Likelihood Score x Cost Score

Schedule Risk Level = Likelihood Score x Schedule Score

The Cost Risk Level and Schedule Risk Level are used to evaluate the risks across all the various risk categories to identify which risks pose the highest threat to the project.

For each risk, a strategy is identified as to how the risk would be managed if such an event occurred, as well as an approach defined to better clarify some of the mechanisms of risk transfer and proposed measures for risk mitigation. The risk strategies employed for this project include:

- Transfer – Transferring a risk involves assigning the risk to another party usually through contractual terms or through insuring against a particular risk or threat.
- Avoid – Avoiding a risk event involves not performing the activity for which the risk affects or advancing an alternative that eliminates the risk.
- Mitigate – Mitigating a risk involves specifying measures to reduce the likelihood and/or consequence of a risk occurrence.
- Accept – Accepting the consequences and associated impacts should a risk event occur.

The risk status is also identified. Many of the risks are simply identified as potential risks. Other risks have already occurred on the project. They are active and currently being mitigated, accepted, transferred, or avoided. Risks that did not occur over the life of the project are identified as “Expired”. Risks that have occurred and the strategy is complete are considered closed. Currently, many risks have simply been identified with a risk strategy to be implemented later. However, some identified risks have occurred, and the risk management strategies actively implemented.

Ideally, the implementation of a risk management strategy will reduce the risk level from its pre-managed identified risk levels, either by reducing the likelihood that the risk event will occur or by reducing the cost and/or schedule impact to the project. However, most risks will have a residual risk component after risk management strategies are implemented. Likelihood of occurrence, cost impacts, and schedule impacts for each risk are reevaluated after chosen risk strategies are implemented and scored in the same manner as when the risks were initially identified. Corresponding Cost Risk Levels and Schedule Risk Levels are calculated in the same manner as when the risks were initially identified. Based on the resulting Levels, one can again compare risks across the various risk categories to identify which risks pose the highest threat to the project and may require further investigation.

Currently, forty-one (41) risks have been identified and included in the risk register. Nine of these risks are confirmed as "Active".

The highest risks with respect to cost impacts (post-mitigation) are presented below:

Risk	Status	Cost Risk Level	Risk Mgmt. Strategy
Existing outfall OF-217 must be relocated due to National Grid construction plans	Active	250	Accept
Presence of bedrock identified	Active	250	Accept
Microtunneling – Obstruction	Identified	240	Accept
Contamination migration during groundwater management at Tidewater site	Identified	300	Mitigate

Three of the four high cost level risks have been accepted, which accounts for the elevated risk levels post-mitigation. Contamination migration remains a high cost-level risk due to the high overall cost, even the risk likelihood has decreased. This risk is continuing to be evaluated to reduce the likelihood of occurrence further. Additionally, BETA recommended additional soil borings / rock cores to better identify the bedrock profile. The NBC has elected not to pursue the additional investigation as part of the 60% design stage, thereby eliminating the potential for risk reduction in this area at this time.

The highest risks with respect to schedule impacts (post-mitigation) are presented below:

Risk	Status	Schedule Risk Level	Risk Mgmt. Strategy
Existing outfall OF-217 must be relocated due to National Grid construction plans	Active	400	Accept
Relocation of OF-217 (consolidation conduit) due to development	Active	250	Accept
CRMC approvals delayed	Identified	240	Mitigate

RIDEM approvals delayed	Identified	240	Mitigate
Existing utility information is inaccurate.	Active	240	Mitigate
Presence of bedrock identified	Active	250	Accept
Additional requirements imposed by Tidewater for site investigations	Active	250	Accept
Stakeholder-requested scope changes	Active	400	Accept
City of Pawtucket changes Development Plans	Active	320	Accept
Complications in acquiring easement on Tidewater site	Identified	300	Mitigate
Complications in acquiring easement on Town Landing site	Identified	240	Mitigate

Six of the eleven high schedule level risks have been accepted, which accounts for the elevated risk levels post-mitigation. Delays in permitting agency approval and complications with land acquisition pose the highest risk to the schedule for non-active risks. Mitigation measures to be employed for these risks include early identification of property targets and coordination with property owners as well as advance coordination with permitting agencies.

The Risk Register and associated basis documentation is provided as Appendix 7.

9.0 Traffic Management

Maintenance of pedestrian, bicycle and vehicular traffic around the work zones and construction activities is critical to the public safety with respect to the Phase III CSO Contract IIIA-5 project. BETA has prepared a site-specific traffic management plan with associated Temporary Traffic Control (TTC) Plans for the section of the project west of the Blackstone River extending between Main Street and Tidewater Street along Taft Street/Roosevelt Avenue. The traffic management strategies and TTC plans are based on currently proposed construction locations and activities. Pedestrian and bicycle traffic management shall consist of sidewalk and bicycle route closures with detours and diversions to allow access along the routes and to abutting properties. Vehicular traffic management shall consist of lane shifts, lane and shoulder closures, and temporary road closures and associated detours. Typical traffic control details in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) will be implemented and have been included in the documents. Vehicular

The proposed work will impact vehicular traffic along Taft Street that includes lane shifts, lane and shoulder closures, and roadway closures. It is anticipated based upon trench and construction zone requirements that at a minimum one 11-foot travel lane could be maintained for either one-way or alternating one-way traffic as necessary.

Should a temporary road closure be required to facilitate construction, BETA has developed separate detour plans for two segments along the westerly side of the Blackstone River including Taft Street (TTC Plan 1) and Roosevelt Avenue (TTC Plan 2). The vehicle traffic detour is based on closure by segment along Taft Street. Detour Plan 1 consist of closure to through traffic along the section of Taft Street between Spencer Street and Jenks Way with the detour route via Pleasant Street. It is anticipated that daily access to abutting properties will be impacted during such times and as a result, a provision is included to ensure the Contractor's responsibility of notifying abutters 48 hours in advance of the start of any work that may require temporary daily interference with or closure of site access.

Preliminary detour plans and typical temporary traffic control plans in accordance with the MUTCD, latest edition, have been prepared and are included in the 30% design drawings.

9.1 Pedestrians

Sidewalks are provided on both sides of Taft Street within the construction zone limits. Consistent with the preliminary design outlined in the Technical Memo, it is anticipated that sidewalks will be closed to pedestrians daily as needed in short segments along Taft Street requiring detours. Sidewalk on the west side of the street shall remain open at all times along Taft Street. Typical Sidewalk Detour and Diversion details are provided in the current submission and will be implemented by the contractor on a day-by-day basis dependent upon construction activities. Sidewalk closures requiring crossings will be provided at an existing marked crosswalk. The proposed plan includes closure of the Taft Street east side sidewalk in the vicinity of the Boat ramp and near the community garden. Pedestrians will be provided accessible routes in accordance with provided contract specifications that are compliant with the American with Disabilities Act (ADA) guidelines.

9.2 Bicyclist

Taft Street/Roosevelt Avenue within the project area provides for an on-street bike route as part of a shared vehicular/bicycle lane. South of I-95 extending south to Tower Street, the bike route is separate dedicated bike lanes in each direction.

Consistent with the preliminary design, during construction where separate bike lanes are temporarily closed due to narrowing in the construction zone, but vehicle travel lanes are maintained, bicycles will be permitted to operate in a "shared lane" with vehicles through the work area similar to existing conditions north of I-95. In addition, if a bicycle detour is required as a result of roadway closure, bicycles will be directed to use the vehicle detour and operate as a vehicle through the detour route. Applicable MUTCD details with signage for direction of bicycle users will be provided in the TTC plans.

10.0 Opinion of Probable Construction Cost and Schedule

10.1 Opinion of Probable Construction Cost

An Opinion of Probable Construction Costs (OPCC) has been prepared for the preliminary design. The OPCC is a Class 3 Conceptual Cost Estimate prepared in accordance with the Association for the Advancement of Cost Engineering (AACE) International Recommended Practice 18R-97. The OPCC is provided as Appendix 8.

The Engineers' Opinion of Probable Capital Costs for infrastructure are initially developed as part of the planning process. As the project progresses, it is critical that these costs are updated and refined at each stage of the planning and design process to accurately reflect items that may impact them. Items that could impact cost include, but are not limited to:

- Changes in bidding climate and tariffs.

- Design changes resulting from planned property development.
- Owner-driven decisions and changes.

The 60% Design level OPCC includes a ___% construction contingency to cover undeveloped parts of the project and bidding variability. Cost elements that are known to require further development include the cost for management of soils on the Tidewater and Town Landing properties. During final design, a reduced contingency will be carried, as more design details will be addressed. The final design contingency is primarily for variability in the bidding climate, project changes before bidding, and change orders due to unforeseen conditions.

Elements of the work that will impact the price of the work, and that are difficult to define, are associated with working on the Tidewater property and include:

- Sharing the site with multiple contractors due to the overlapping of construction schedules associated with the National Grids remediation project and the construction of the new stadium.
- Health and Safety Measures to be enforced due to the presence of contamination, i.e. minimum training standards, working in advanced levels of PPE, and air monitoring with low action levels
- Potential construction stoppages associated with uncovering unknown pipes, special soil management, air monitoring, and dust monitoring,
- Construction with a mix of microtunneling and open cut may result in higher open cut construction costs than typical construction estimates. Constructing through cap of tidewater site will also drive up construction cost.

10.2 Opinion of Probable Construction Schedule

The construction schedule will be influenced by the planned Stadium Development and National Grid construction, and coordination with the two entities is ongoing. The schedule presents the work such that the work on the Tidewater site is completed first. The schedule is presented with little overlap of construction activities, but it is anticipated that further coordination will result in establishment of milestone dates to be incorporated into the contract. The dates will likely require that the contractor schedule different portions of the work to occur coincident with each other to limit the time that the IIIA-5 contractor is occupying the site. In addition to limiting time on site, expediting and overlapping construction activities may also allow for reuse of soil on site. National Grid is currently developing that window of opportunity, and if excess soils are available before National Grid completes capping of their site, the excess soil may be used as grading material. Both the NBC and National Grid will benefit from this coordination, as NBC will realize a cost benefit and National Grid has indicated that they would like to limit the amount of soil disposed off-site.

Refer to Appendix 9 for the Opinion of Probable Construction Schedule. Dates current;y incorporated into the schedule include:

- Bidding: August 2021
- Notice To Proceed: December 2021
- Construction Start: March 2022

11.0 REFERENCES

Stantec

"Phase III CSO Program, Conceptual Design for Consolidation Conduits and Regulator Modifications, Technical Memorandum, January 25, 2019"

Tidewater Property

"Site Investigation Data Report, Former Tidewater MGP and Power Plant, Pawtucket, Rhode Island, RIDEM Case No. 95-022, Prepared for RIDEM, OWR, Providence Rhode Island, Prepared by: GZA GeoEnvironmental, Inc., On Behalf of National Grid, Waltham MA, Date: January 2011."

"Former Tidewater Facility, Pawtucket, Rhode Island, Sitewide Remedy Design, Permit Set, August 2019, Prepared by: GZA GeoEnvironmental, Inc.,

APPENDIX 1
DRAWING LIST

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IIIA-5: List of Drawings

GENERAL SHEETS

G-1	Location and Vicinity Map
G-2	List of Drawings
G-3	Symbols
G-4	Abbreviations

GEOTECHNICAL SHEETS

B-1	Instrumentation Plan Sta 0+00 – 8+00
B-2	Instrumentation Plan Sta 8+00 – 16+00
B-3	Instrumentation Plan Sta 16+00 – 17+66, Sta 0+00 – 4+48
B-4	Instrumentation Details
B-5	Instrumentation Schedules
B-6	Minimum Design Criteria for Excavation Support
B-7	Geotechnical Notes For Analysis and Design
B-8	Secant Pile Shaft Reference Design

CIVIL SHEETS

GC-1	Notes
GC-2	Symbols
GC-3	Legend & Notes
C-1	Staging Plan – Tidewater Site
C-2	OF-217 Consolidation Conduit Plan and Profile I: STA 0+00 – 4+00
C-3	OF-217 Consolidation Conduit Plan and Profile II: STA 4+00 – 8+00
C-4	OF-217 Consolidation Conduit Plan and Profile III: STA 8+00 – 12+00
C-5	OF-217 Consolidation Conduit Plan and Profile IV: STA 12+00 – 16+00
C-6	OF-217 Consolidation Conduit Plan and Profile V: STA 16+00 – 18+88
C-7	OF-217 Outfall Plan and Profile VI: STA 0+00 – 4+47
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T-2	Traffic Management Plan - Details

INSTRUMENTATION SHEETS

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S-2	OF-217 Diversion Structure Plan and Sections
S-3	OF-217 Revetment Plan and Section

ELECTRICAL SHEETS

GE-1	Notes & Symbols
GE-2	Abbreviations
E-1	One Line Diagram, Control Block Wiring Diagram, and Panel Schedule
E-2	Site Plan, Ductbank Sections, and OF-217 Diversion Structure Plan
E-3	Details

APPENDIX 2

SPECIFICATION LIST

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NARRAGANSETT BAY COMMISSION
CSO PHASE IIIA-5
OF-217 CONSOLIDATION CONDUIT
CONTRACT NO. 308.05C

TABLE OF CONTENTS

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APPENDIX 3

GEOTECHNICAL DATA REPORT

(Unchanged from 30%)

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APPENDIX 4
CALCULATIONS

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Consolidation Conduit Capacity
Contract IIIA-4 and IIIA-5
NBC - Pawtucket RI

Purpose:
Purpose of computation is to determine minimum slope and confirm pipe sizes for Consolidation Conduit

Source: " Phase III CSO Program: Conceptual Design for Consolidation Conduits and Regulator Modifications - Technical Memorandum January 25, 2019
Table ES-5, Pager 21 of 32 and RFI #10 RFI 10 Superceded by CFD and ICM Model dated 11-12-2020

Design Criteria:

Maximum Velocity: < 10 ft/sec
>8 ft/sec requires evaluation to determine if special design considerations are required
Capacity: Manage 2 year peak hourly flow without surcharging

Design Flow IIIA-4	Of 210, 211, 213, 214	179.78	cfs	Revised / Superceded	140.79	CFS
2-year Peak Hourly Flow		116.20	MGD	CFD Model & ICM Model Results	91	MGD

Determine minimum Slope and Pipe Size for OF-210 and 211 Consolidation Conduit
Q=63.2 MGD (RFI 10) Revised / Superceded CFD Model & ICM Model Results 11/12/2020 52.3 MGD
OF-210,211

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>63.2 MGD)	48		12.56	0.013	1	1	**0.0225**	0.15	17.19	215.94	96,912	139.55
Maximum Slope	48		12.56	0.013	1	1	**0.0162**	0.1272792	14.59	183.23	82,232	118.41
Maximum Slope	48		12.56	0.013	1	1	**0.0075**	0.0866025	9.93	124.67	55,952	80.57

Determine minimum Slope and Pipe Size for Down Stream of OF-213 Consolidation Conduit
Q=83.2 MGD (RFI 10) Revised / Superceded CFD Model & ICM Model Results 11/12/2020 64 MGD
OF-210,211, 213

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>83.2 MGD)	54		15.90	0.013	1.125	1.0816872	**0.0043**	0.0655744	8.13	129.23	58,000	83.52
Maximum Slope (V<8 ft/sec)												
Maximum Slope (V<10 ft/sec)	54		15.90	0.013	1.125	1.0816872	**0.0065**	0.0806226	10.00	158.89	71,310	102.69

Determine minimum Slope and Pipe Size for Down Stream of OF-214 Consolidation Conduit

Q=116 (MGD) RFI 10 - Superceded CFD Model & ICM Model Results 11/12/2020 91 MGD
OF-210,211, 213, 214

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>116 MGD)	60		19.63	0.013	1.25	1.1603972	**0.0048**	0.069282	9.21	180.83	81,158	116.87

Determine minimum Slope and Pipe Size for Down Stream of OF-217 Consolidation Conduit
Q=39 (MGD) CFD Model & ICM Model Results 11/12/2020 36.3 MGD
OF-217

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>39 MGD)	48		12.56	0.013	1	1	**0.0018**	0.0424264	4.86	61.08	27,411	39.47
Maximum Slope (V<8 ft/sec)	48		12.56	0.013	1	1	**0.0048**	0.069282	7.94	99.74	44,762	64.46
Maximum Slope (V<10 ft/sec)	48		12.56	0.013	1	1	**0.0075**	0.0866025	9.93	124.67	55,952	80.57

Determine minimum Slope and Pipe Size for Down Stream of Junction Chamber
Q=155.2 (MGD) CFD Model & ICM Model Results 11/12/2020 91+36.3 127.3 MGD
OF-210,211, 213, 214,217

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>155.2 MGD)	72		28.26	0.013	1.5	1.3103707	**0.0025**	0.05	7.51	212.22	95,243	137.15
Maximum Slope (V<10 ft/sec)	72		28.26	0.013	1.5	1.3103707	**0.0044**	0.0663325	9.96	281.54	126,354	181.95

Determine minimum Slope and Pipe Size for Approach Channel
Q=155.2 (MGD) CFD Model & ICM Model Results 11/12/2020 91+36.3 127.3 MGD
OF-210,211, 213, 214,217

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope (Q>155.2 MGD)	6	6	36.00	0.013	1.5	1.3103707	**0.0014**	0.0374166	5.62	202.30	90,794	130.74
Maximum Slope (V<10 ft/sec)	6	6	36.00	0.013	1.5	1.3103707	**0.0044**	0.0663325	9.96	358.65	160,960	231.78

Determine Maximum Slope for OF-217 Outfall Pipe

Existing pipe = 42"
Existing slope = 0.18%

Design Limit: V<10 ft/sec

Manning Eq'n (solve for "v"):	**v=(1.49/n)*(rH^(2/3)(s)^(1/2)**											
	Pipe Size		Area (ft^2)	n	rH	rH^(2/3)	**s**	s^(1/2)	v (ft/sec)	q (cfs)	q (gpm)	q (MGD)
Minimum Slope	42		9.62	0.013	0.875	0.914826	**0.0018**	0.042426	4.45	42.78	19,199	27.65
Maximum Slope (V<8 ft/sec)	42		9.62	0.013	0.875	0.914826	**0.0048**	0.069282	7.26	69.86	31,352	45.15
Maximum Slope (V<10 ft/sec)	42		9.62	0.013	0.875	0.914826	**0.008**	0.089443	9.38	90.18	40,475	58.28

Technical Memorandum

To:	William Skerpan, Jr. BETA Group, Inc.	Project:	NBC Phase III CSO Program OF-217 Consolidation Conduit IIIA5
From:	Tennyson M. Muindi, PE McMillen Jacobs Associates	cc:	File
Prepared by:	Norman A. Joyal, PE Hui Lu McMillen Jacobs Associates	Job No.:	5980
Date:	December 23, 2020		
Subject:	Pipe Jack Design Calculations for Trenchless Segments OF-217 Consolidation Conduit IIIA-5 (60% Design)		

1.0 Introduction

This memorandum presents the results of McMillen Jacobs Associates (McMillen Jacobs) design calculations for the proposed trenchless installation segments of the consolidation conduit planned for the Narraganset Bay Commission (NBC) OF-217 Consolidation Conduit Contract IIIA-5 (the Project). This Project is part of the overall NBC Phase III CSO Program located in Rhode Island, which began in 2016 and is focused primarily on the Bucklin Point Service Area (BPSA) in the communities of Pawtucket and Central Falls.

This Project includes the design and construction of a consolidation conduit, a diversion structure, manholes, and other ancillary facilities necessary to convey flow from outfall OF-217 to the future Pawtucket Tunnel via Drop Shaft 213 (DS-213) and connecting adit set to be constructed under separate contract.

The following calculations are included in this memorandum:

- Calculations for anticipated jacking forces
- Calculations demonstrating that the recommended conduit pipe can sustain the maximum anticipated jacking force

This work was performed as part of McMillen Jacobs trenchless design evaluations for BETA Group, Inc. (BETA), the Project Design Consultant. McMillen Jacobs is providing geotechnical and structural engineering services under contract with BETA.

2.0 Trenchless Segments

The consolidation conduit is planned to be a 48-inch nominal inside diameter reinforced concrete pipe (RCP) constructed using a combination of trenchless methods and open cut methods. The design evaluations presented herein are for the trenchless segments. Segments (reaches) requiring trenchless installation are summarized below in Table 1. Microtunneling was evaluated and considered as the technically feasible trenchless method.

Table 1 Summary of Trenchless Reaches

Pipe Reach	Location	Approximate Length (ft)	Approximate Depth Range to Invert (ft)
MH217-5 to MH217-6	Sta. 1+27 to 7+97	670	17 to 36
MH217-6 to MH217-7	Sta. 7+97 to 12+57	460	25 to 36
MH217-7 to Sta. 16+65	Sta. 12+57 to 16+65	408	25

A brief description of the anticipated ground conditions along each trenchless reach is provided below.

2.1 MH217-5 and MH217-6

The consolidation conduit between MH217-5 and MH217-6 is located along Taft Street from just south of the Division Street Bridge to just south of the Community Gardens. Existing ground surface ranges from approximately El. ±12 to El. ±38 with a depth to invert ranging from about 17 to 36 feet.

Subsurface conditions within the tunnel horizon are anticipated to be mixed ground conditions. Beginning at MH-217-5, Glacial Deposits are expected. Heading up-station, Glacial Deposits overlying bedrock are expected to transition to a full face of bedrock in the vicinity of the Community Gardens to MH217-6. Groundwater levels are anticipated to be above the tunnel crown. This reach will be constructed last.

2.2 MH217-6 and MH217-7

The consolidation conduit between MH217-6 and MH217-7 is located along Taft Street from just south of the Community Gardens to the intersection of Taft Street and Tidewater Street. Heading up-station, existing ground surface ranges from approximately El. ±40 to El. ±25, with a depth to invert of ranging from about 25 to 36 feet.

Heading up-station from MH217-6, the subsurface conditions within the tunnel horizon transition from bedrock to a full face of soil in the area of MH217-7. Bedrock transitioning to Alluvial Deposits overlying Glacial Deposits are expected within the tunnel horizon. Groundwater levels are anticipated to be above the tunnel crown. This reach will be constructed second.

2.3 MH217-7 to Sta. 16+65

The consolidation conduit between MH217-7 and Sta. 16+65 is located within the Tidewater Site. Heading up-station, existing ground surface ranges from approximately El. ±27 to El. ±23 with a depth to invert at about 25 feet.

Heading up-station from MH217-7, the subsurface conditions within the tunnel horizon are expected to consist of Alluvial and Glacial Deposits transitioning to a full face of Fill. Groundwater levels are anticipated to be above the tunnel crown. In addition, contaminated ground as well as remnant foundations are anticipated along this reach. This reach will be constructed first.

3.0 Pipe Jacking Force Calculations

The available jacking capacity must be high enough to overcome resistance resulting from pressure at the face of the tunnel and the frictional resistance that develops along the sides of the pipe. The jacking forces incurred during microtunneling are a function of the ground conditions as well as the contractor's means and methods in terms of the proper use of engineered excavation fluids and lubrication. Our calculations assume that microtunneling will be performed by a qualified contractor utilizing means and methods in general conformance with guidelines presented in ASCE 36-15, Standard Design and Construction Guidelines for Microtunneling as it pertains to the use of fluids and lubrication.

The calculations are performed for the three reaches (from MH217-5 to MH217-6, from MH217-6 to MH217-7, and from MH217-7 to Sta. 16+65) based on methodologies presented by Thompson (1993), Bennett & Cording (2000), Najafi (2004), and Staheli, et al (2011). These four different methodologies were used to demonstrate the variability of results given by the different methods. Based on the anticipated ground conditions and length of trenchless reach, the alignment from MH217-5 to MH217-6, which is the longest reach, resulted in the highest anticipated jacking forces. Typically, the active earth pressure at the face is used in the total jacking force calculations. Calculating the face pressure component of the jacking forces based on active pressure could underestimate the face pressure needed to fracture the bedrock anticipated. Therefore, passive pressure was used at the face for the reach from MH217-5 to MH217-6 and the reach from MH217-6 to MH217-7 considering the expected bedrock at the face at some locations The reason for using the passive pressure for the total jacking force is to account for the jacking force needed to impart point loading on the tooling to efficiently mine the rock. For the reach from MH217-7 to Sta. 16+65, the full face is anticipated to be completely in soil formations, and the active pressure component has been used to estimate the face pressure component of the jacking force.

Our calculations for the anticipated jacking forces are included in Section 6.0 (Attachment A.) A plot of the jacking force per distance along the alignment resulting from each of the methodologies is included. No one theory stands out over another in estimating jacking forces. Therefore, we have included an additional calculation for the average maximum jacking force assuming a lubricated and non-lubricated pipe. The average maximum jacking force was used for comparison to the allowable concrete pipe capacity which is synonymous with maximum allowable jacking force.

4.0 Pipe Design

As indicate above, the consolidation conduit is planned as a 48-inch nominal diameter RCP. The pipe will be constructed through areas of known ground contamination and will be fully lined after installation to prevent any groundwater infiltration into the pipe. BETA is responsible for design of the final liner and the joint gaskets. McMillen Jacobs has been tasked with recommending a pipe wall thickness and concrete strength suitable for installation by microtunnel methods. We assume that the pipe will be manufactured to the dimensional tolerances for diameter, roundness, end squareness, straightness, and joint length in accordance with ASCE 36-15.

The earth load includes external pressure resulting from the ground and groundwater loads above the pipe and were calculated using the existing ground surface and tunnel elevations noted above for the three trenchless reaches. An initial concrete strength and wall thickness was assumed based on the pipe classes specified in ASTM C72, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe. An allowable pipe capacity was determined and compared to the average maximum jacking force.

An iterative process was performed until the wall thickness was determined that produced an allowable pipe capacity that exceeded the average maximum jacking force using a factor of safety 3.

5.0 Results and Recommendations

The results of the pipe design calculations indicate that the estimated average maximum jacking force is approximately 500 tons assuming lubrication is used for the most critical reach from MH217-5 to MH217-6. Based on this anticipated jacking load, we recommend a 6,000 psi concrete strength pipe with a minimum 6-inch wall thickness specified to Class V, Wall C in accordance ASTM C76. For the two shorter drives, our calculations indicate that a concrete pipe with 4-inch thick walls would be adequate. However, that would result in a smaller outside diameter than the 6-inch wall pipe thus requiring a smaller microtunnel machine for two of the three drives. This is generally not practical, especially for the relatively short drives, thus our recommendation is to use the thicker walled pipe for all three drives as depicted in the calculations.

6.0 Attachment A

6.1 MH 217-5 and MH 217-6

McMILLEN JA ENGINEERING PLLC			
PROJECT	NBC Consolidation Conduit IIIA-5		
SUBJECT	Microtunnel Jacking Force Calculations Station 1+27 to 7+97, 670 Foot Drive Shaft Wall to Shaft Wall	DATE	12/15/2020
BY	HL	CHECKED	NAJ
PROJECT NO.	5980.0		

(1) PIPE PROPERTIES

ENGLISH UNITS

(1.1) CASING DIMENSIONS AND DRIVE LENGTH

D (in):	60.00	outside diameter of pipe
L_{PIPE} (ft):	10.00	length of pipe segment
A (ft^2):	19.6	cross-sectional area of pipe/MTBM face
L (ft):	670	total length of trenchless drive
t (in)	6.00	thickness of pipe wall
ID (in)	48.00	inside diameter of pipe (minimum clear diameter)
A (ft^2):	7.07	cross sectional area of pipe
P (ft2/ft)	15.71	Pipe perimeter area

(1.2) SOIL PROPERTIES

H (ft):	38.0	height of soil above pipe invert (measured at downstream end of alignment)
g_S (pcf):	135	unit weight of soil
ϕ (deg):	34	friction angle of soil (assumed residual angle = 30 degrees)
C_a:	1.50	arching factor (for Bennett & Cording, from Ref [1])
μ:	0.51	pipe-soil residual interface friction coefficient (for Staheli et al, from Ref [2])
R (psi):	1.10	circumferential frictional resistance (for Najafi, from Ref [3])

(1.3) GROUNDWATER PROPERTIES

H_w (ft):	28.0	height of water surface to invert of pipe (measured at downstream end of alignment)
g_w (pcf):	62.4	unit weight of water

(2) FACE PRESSURE (USING RANKINE THEORY):

$$F_f = (K_a \sigma'_v + g_w H_w)(A_{face})\left(\frac{1\ ton}{2{,}000\ lb}\right)$$

$$\sigma'_v = g_s(H - H_w) + (g_s - g_w)H_w$$

$$K_p = tan^2\left(45 + \frac{\varphi}{2}\right) \qquad K_a = tan^2\left(45 - \frac{\varphi}{2}\right)$$

Upper Bound Passive Pressure:

	where:	
F_f (tons):	**51**	maximum face component of jacking force at full passive pressure
K_p :	3.54	passive pressure coefficient (calculates upper bound theoretical face pressure for conservatism)
σ'_v (psf):	3,694	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	135	unit weight of soil
g_w (pcf):	62.4	unit weight of water
H (ft):	38.0	height of soil above pipe
H_w (ft):	23.0	height of water surface above top of pipe

Lower Bound Active Pressure:

	where:	
F_f (tons):	**9**	minimum face component of jacking force at active pressure (for lower bound comparison)
K_a :	0.28	active pressure coefficient (calculates lower bound theoretical face pressure)
σ'_v (psf):	3,695	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	135	unit weight of soil
g_w (pcf):	62.4	unit weight of water
H (ft):	38.0	height of soil above pipe
H_w (ft):	23.0	height of water surface above top of pipe

NOTE: The passive face pressure was used to calculate the total jacking force in the different approaches for conservatism and to account for face pressure necessary to excavate the bedrock.

(3) JACKING FORCE USING BENNETT AND CORDING (2000):

(3.1) SKIN FRICTION

(3.1.1) Non-Lubricated

$$F_r = C_a D_p \gamma' \tan(C_f \varphi_r) A_p L \left(\frac{1ton}{2{,}000lbs}\right)$$ From Ref [1]

where:

F_r (tons):	**1,654**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.157**	normalized friction force
C_a:	1.5	arching factor
D_p (ft):	5.00	pipe outside diameter
γ' (pcf):	73	effective soil unit weight
C_f:	1.0	friction reduction factor (assumed to be 1.0 for non-lubricated bore)
ϕ_r (deg):	30.0	residual friction angle (assumed)
A_p (ft^2):	15.7	unit surface area of the pipe
L (ft):	670	length of bore

(3.1.2) Lubricated

If lubrication is used, assume C_f equals 0.5 and F_r is reduced as shown below

F_r (tons):	**768**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.07**	normalized friction force

(3.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + F_r$$

(3.2.1) Non-Lubricated

JF (tons):	**1,705**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.162**	normalized jacking force
F_f (tons):	51	face component of jacking force
F_r (tons):	1,654	frictional component, **non-lubricated**

(3.2.2) Lubricated

JF (tons):	**819**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.078**	normalized jacking force
F_f (tons):	51	face component of jacking force
F_r (tons):	768	frictional component, **lubricated**

(4) JACKING FORCE USING STAHELI et al. (2011):

(4.1) FRICTION LOAD

(4.1.1) Non-Lubricated

$$JF_{frict} = \mu_{int} \frac{g_s\, r \cos\left(45+\frac{\varphi_r}{2}\right)}{\tan \varphi_r} \pi\, D\, L \left(\frac{1\ ton}{2{,}000\ lb}\right)$$ From Ref [2]

where:

JF_{frict} (tons):	**784**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.075**	Normalized friction force
μ_{int}:	0.51	pipe-soil residual interface friction coefficient (from Table 1 of Ref [2])
g_S (pcf):	135	unit weight of soil
r (ft):	2.50	pipe radius
ϕ_r (deg):	30	residual friction angle of the soil (assumed)
D (ft):	5.00	outside diameter of pipe
L (ft):	670	total length of trenchless drive

(4.1.2) Lubricated

If lubrication is used, assume JF_{frict} is reduced by 50%

JF_{frict} (tons):	**392**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.037**	Normalized jacking friction force

(4.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + JF_{frict}$$

(4.2.1) Non-Lubricated

JF (tons):	**836**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.079**	
F_f (tons):	51	face component of jacking force
JF_f (tons):	784	frictional component, **non-lubricated**

(4.2.2) Lubricated

JF (tons):	**443**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.042**	
F_f (tons):	51	face component of jacking force
JF_f (tons):	392	frictional component, **lubricated**

(5) JACKING FORCE USING NAJAFI (2004), EMPIRICAL APPROACH:

(5.1) FRICTION LOAD

$$FR = R \cdot S \cdot L \left(\frac{12in}{1ft}\right)\left(\frac{1ton}{2{,}000lb}\right)$$

From Ref [3]

where:

FR (tons):	**834**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.079**	normalized friction force
R (psi):	1.10	circumferential frictional resistance
S (in):	188.5	perimeter of pipe cross section
L (ft):	670	length of trenchless drive

Note: Values calculated using Najafi approach are empirical. The case histories used to determine the value of R reportedly includes both lubricated and non-lubricated drives. Therefore, it is not possible to distinguish between lubricated and non-lubricated values of skin friction using this approach. Refer to Reference [3] for additional discussion.

(5.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

JF (tons):	**885**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.084**	normalized jacking force
F_f (tons):	51	face component of jacking force
FR (tons):	834	frictional component of jacking force (at distance *L* from launching shaft)

(6) JACKING FORCE USING THOMPSON (1993), ASSUMING BORE STABLE BORE:

(6.1) FRICTION LOAD

(6.1.1) Non-Lubricated

$$P_p = \left(\frac{W_p \tan \delta_p}{\cos \zeta}\right) L$$

From Ref [4]

where:

P_P (tons):	**362**	frictional component of jacking force (at distance *L* from launching shaft)
W_P (lb/ft):	1,060	weight per unit length of pipe
ζ (deg):	60	offset of reaction from vertical
$\tan\delta_P$:	0.51	coefficient of friction between pipe and rock
L (ft):	670	length of trenchless drive

(6.1.2) Lubricated

If lubrication is used, assume P_p is reduced by 50%

P_P (tons):	**181**	frictional component of jacking force (at distance *L* from launching shaft)

(6.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

(6.2.1) Non-Lubricated

JF (tons):	**414**	maximum anticipated jacking load
F_f (tons):	51	face component of jacking force
P_P (tons):	362	frictional component, **non-lubricated**

(6.2.2) Lubricated

JF (tons):	**232**	maximum anticipated jacking load
F_f (tons):	51	face component of jacking force
P_P (tons):	181	frictional component, **lubricated**

(7) SUMMARY OF ESTIMATED JACKING FORCES VS MAXIMUM ALLOWABLE FORCES

MAXIMUM ALLOWABLE JACKING FORCE

P (ton):	**1,018**	Maximum Allowable Jacking Force on RCP pipe
f'_c (psi):	6,000.0	design concrete strength
A (in^2):	1,017.9	cross sectional area of casing
FS:	3.0	Factor of Safety
JFave-nl	984.8	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **non-lubricated condition**
JFave-l	498.2	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **lubricated condition**

(1) Non-lubricated

NG	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-nl)

(2) Lubricated

OK	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-l)

(8) SUMMARY:

The pipe jacking force estimation has been performed at the 670-ft-long tunnel reach from MH217-5 to MH217-6 of the NBC Phase III CSO Program OF-217 Consolidation Conduit. Based on the analyses, we recommend that the tunnel annular space be lubricated to reduce the estimated jacking force.

The analyses presents jacking force calculations associated with approaches presented by Thompson (1993), Bennett & Cording (2000), Najafi (2004) and Staheli, et al (2011). These different theories demonstrate the variability of results and the upper and lower bound results. For purposes of our evaluations, we have assumed an average of these theories represents a reasonalbe estimation of the anticipated jacking forces.

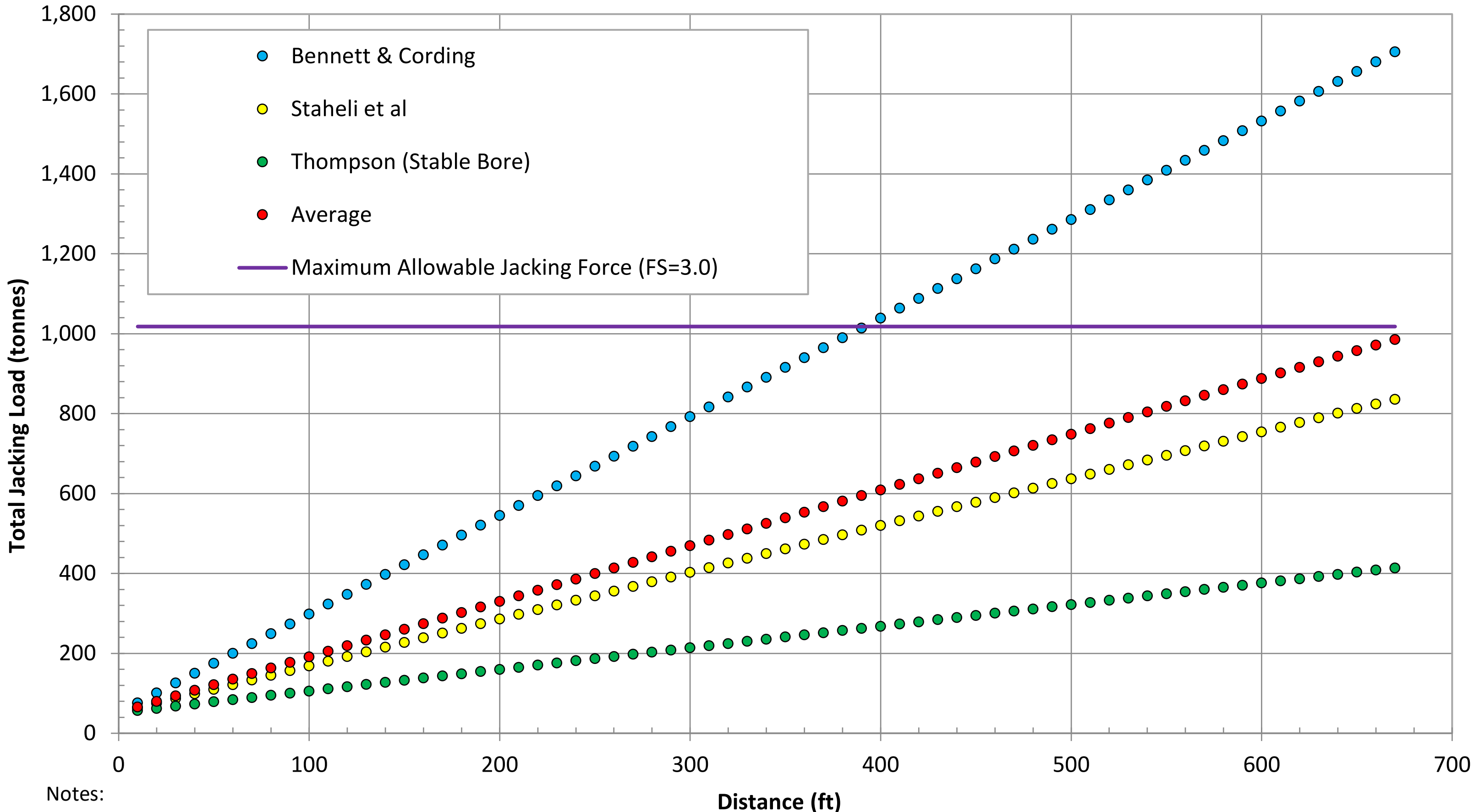
For the non-lubricated tunnel with a similar pipe strength of 6000 psi, the estimated average jacking force is around 990 tons, and a minimum 6-inch thick RCP pipe wall with the allowable jacking force of 1018 tons has to be designed to meet the required factor of safety of 3.0.

For lubricated tunnel conditions assuming a concrete pipe strength of 6000 psi, the estimated average jacking force of 500 tons does not exceed the allowable jacking force for a 6-inch thick RCP pipe.

Based on the results of our evaluations, we recommend a Class V, Wall C concrete pipe with 6-inch thick walls for jacking. We also recommend lubrication of the tunnel during the pipe jacking process to reduce the jacking load, especiallly considering the adverse geology in the microtunnel alignments.

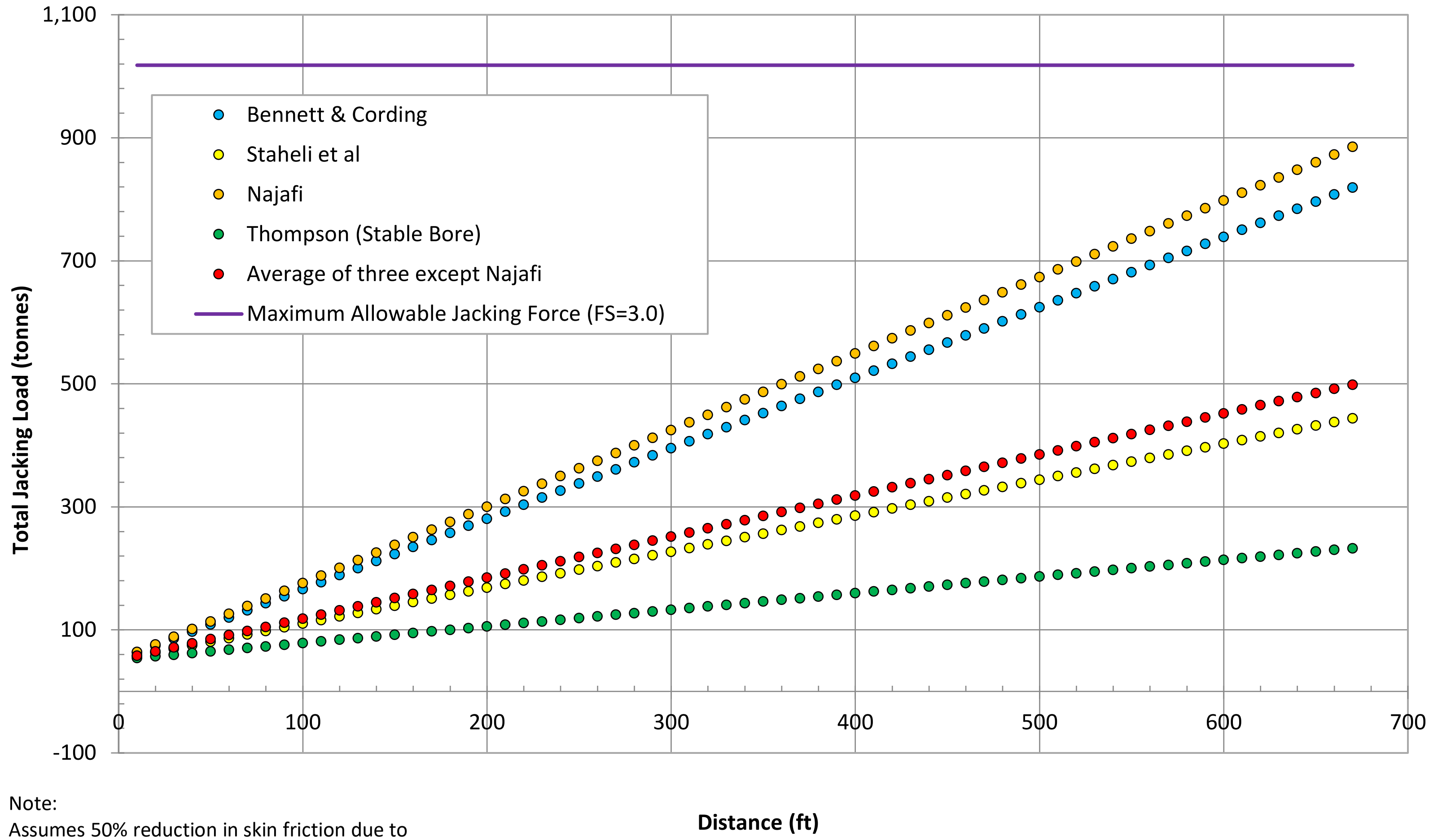
(9) REFERENCES:

[1]	Bennett and Cording, “Jacking Loads & Ground Deformations Associated with Microtunneling”, Proceedings of North American Society for Trenchless Technology International No Dig Conference 2000, Anaheim, California, April 9 -12, 2000.
[2]	Staheli, Wetter, and Davidson, 2011. Quantifying the Effects of Lubrication on Jacking Forces, Proceedings of North American Society for Trenchless Technology International No Dig Conference 2011, Paper A-2-02, Washington D.C., March 27 - 31, 2011.
[3]	Najafi, "Trenchless Technology: Pipeline and Utility Design, Construction, and Renewal", McGraw-Hill, 2004.
[4]	Thompson, "Pipejacking and Microtunneling", McGraw-Hill, 1993.
[5]	Staheli, K., Frost, D. and Iscimen, M., "Studies of Interface Friction Between Jacking Pipe Materials and Frictional Soils and the Impact on Jacking Forces", Proceedings of the North American Society for Trenchless Technology, No-Dig Conference, Nashville TN, March 26-28, 2006.
[6]	Plan and Profile Drawings, C-1 through C-6, 60% Design Phase, prepared by BETA, Inc. dated April 2020
[7]	Geotechnical Data Report, NBC Phase iii SCO Program Consolidation Conduits IIIA-4 and IIIA-5, prepared by McMillen Jacobs Associates, dated June 2020.
[8]	ASTM C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, 2015



Notes:
(1) Assumes 50% reduction in skin friction due to lubrication

Figure A1 - Total Jacking Load with Distance - NON-LUBRICATED (MH217-5 and MH217-6)



Note:
Assumes 50% reduction in skin friction due to lubrication

Figure A2 - Total Jacking Load with Distance - LUBRICATED (MH217-5 and MH217-6)

6.2 MH 217-6 and MH 217-7

McMILLEN JA ENGINEERING PLLC			
PROJECT	NBC Consolidation Conduit IIIA-5		
SUBJECT	Microtunnel Jacking Force Calculations Station 7+97 to 12+57, 460 Foot Drive Shaft Wall to Shaft Wall	DATE	12/15/2020
BY HL	CHECKED NAJ	PROJECT NO.	5980.0

(1) PIPE PROPERTIES

ENGLISH UNITS

(1.1) CASING DIMENSIONS AND DRIVE LENGTH

D (in):	60.00	outside diameter of pipe
L_{PIPE} (ft):	10.00	length of pipe segment
A (ft^2):	19.6	cross-sectional area of pipe/MTBM face
L (ft):	460	total length of trenchless drive
t (in)	6.00	thickness of pipe wall
ID (in)	48.00	inside diameter of pipe (minimum clear diameter)
A (ft^2):	7.07	cross sectional area of pipe
P (ft2/ft)	15.71	Pipe perimeter area

(1.2) SOIL PROPERTIES

H (ft):	33.0	height of soil above pipe invert (measured at downstream end of alignment)
g_S (pcf):	135	unit weight of soil
ϕ (deg):	34	friction angle of soil (assumed residual angle = 30 degrees)
C_a:	1.50	arching factor (for Bennett & Cording, from Ref [1])
μ:	0.51	pipe-soil residual interface friction coefficient (for Staheli et al, from Ref [2])
R (psi):	1.10	circumferential frictional resistance (for Najafi, from Ref [3])

(1.3) GROUNDWATER PROPERTIES

H_w (ft):	23.0	height of water surface to invert of pipe (measured at downstream end of alignment)
g_w (pcf):	62.4	unit weight of water

(2) FACE PRESSURE (USING RANKINE THEORY):

$$F_f = (K_a\sigma'_v + g_w H_w)(A_{face})\left(\frac{1\ ton}{2{,}000\ lb}\right)$$

$$\sigma'_v = g_s(H - H_w) + (g_s - g_w)H_w$$

$$K_p = tan^2\left(45 + \frac{\varphi}{2}\right) \qquad K_a = tan^2\left(45 - \frac{\varphi}{2}\right)$$

Upper Bound Passive Pressure:

	where:	
F_f (tons):	**46**	maximum face component of jacking force at full passive pressure
K_p :	3.54	passive pressure coefficient (calculates upper bound theoretical face pressure for conservatism)
σ'_v (psf):	3,331	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	135	unit weight of soil
g_W (pcf):	62.4	unit weight of water
H (ft):	33.0	height of soil above pipe
H_w (ft):	18.0	height of water surface above top of pipe

Lower Bound Active Pressure:

	where:	
F_f (tons):	**7**	minimum face component of jacking force at active pressure (for lower bound comparison)
K_a :	0.28	active pressure coefficient (calculates lower bound theoretical face pressure)
σ'_v (psf):	3,332	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	135	unit weight of soil
g_W (pcf):	62.4	unit weight of water
H (ft):	33.0	height of soil above pipe
H_w (ft):	18.0	height of water surface above top of pipe

NOTE: The passive face pressure was used to calculate the total jacking force in the different approaches for conservatism and to account for face pressure necessary to excavate the bedrock.

(3) JACKING FORCE USING BENNETT AND CORDING (2000):

(3.1) SKIN FRICTION

(3.1.1) Non-Lubricated

$$F_r = C_a D_p \gamma' \tan\left(C_f \varphi_r\right) A_p L \left(\frac{1ton}{2{,}000lbs}\right)$$

From Ref [1]

where:

F_r (tons):	**1,135**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.157**	normalized friction force
C_a:	1.5	arching factor
D_p (ft):	5.00	pipe outside diameter
γ' (pcf):	73	effective soil unit weight
C_f:	1.0	friction reduction factor (assumed to be 1.0 for non-lubricated bore)
ϕ_r (deg):	30.0	residual friction angle (assumed)
A_p (ft^2):	15.7	unit surface area of the pipe
L (ft):	460	length of bore

(3.1.2) Lubricated

If lubrication is used, assume C_f equals 0.5 and F_r is reduced as shown below

F_r (tons):	**527**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.07**	normalized friction force

(3.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + F_r$$

(3.2.1) Non-Lubricated

JF (tons):	**1,181**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.163**	normalized jacking force
F_f (tons):	46	face component of jacking force
F_r (tons):	1,135	frictional component, **non-lubricated**

(3.2.2) Lubricated

JF (tons):	**573**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.079**	normalized jacking force
F_f (tons):	46	face component of jacking force
F_r (tons):	527	frictional component, **lubricated**

(4) JACKING FORCE USING STAHELI et al. (2011):

(4.1) FRICTION LOAD

(4.1.1) Non-Lubricated

$$JF_{frict} = \mu_{int} \frac{g_S\, r \cos\left(45+\frac{\varphi_r}{2}\right)}{\tan \varphi_r} \pi\, D\, L \left(\frac{1\ ton}{2{,}000\ lb}\right)$$ From Ref [2]

where:

JF_{frict} (tons):	**539**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.075**	Normalized friction force
μ_{int}:	0.51	pipe-soil residual interface friction coefficient (from Table 1 of Ref [2])
g_S (pcf):	135	unit weight of soil
r (ft):	2.50	pipe radius
ϕ_r (deg):	30	residual friction angle of the soil (assumed)
D (ft):	5.00	outside diameter of pipe
L (ft):	460	total length of trenchless drive

(4.1.2) Lubricated

If lubrication is used, assume JF_{frict} is reduced by 50%

JF_{frict} (tons):	**269**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.037**	Normalized jacking friction force

(4.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + JF_{frict}$$

(4.2.1) Non-Lubricated

JF (tons):	**584**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.081**	
F_f (tons):	46	face component of jacking force
JF_f (tons):	539	frictional component, **non-lubricated**

(4.2.2) Lubricated

JF (tons):	**315**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.044**	
F_f (tons):	46	face component of jacking force
JF_f (tons):	269	frictional component, **lubricated**

(5) JACKING FORCE USING NAJAFI (2004), EMPIRICAL APPROACH:

(5.1) FRICTION LOAD

$$FR = R \cdot S \cdot L\left(\frac{12in}{1ft}\right)\left(\frac{1ton}{2{,}000lb}\right)$$

From Ref [3]

where:

FR (tons):	**572**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.079**	normalized friction force
R (psi):	1.10	circumferential frictional resistance
S (in):	188.5	perimeter of pipe cross section
L (ft):	460	length of trenchless drive

Note: Values calculated using Najafi approach are empirical. The case histories used to determine the value of R reportedly includes both lubricated and non-lubricated drives. Therefore, it is not possible to distinguish between lubricated and non-lubricated values of skin friction using this approach. Refer to Reference [3] for additional discussion.

(5.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

JF (tons):	**618**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.086**	normalized jacking force
F_f (tons):	46	face component of jacking force
FR (tons):	572	frictional component of jacking force (at distance *L* from launching shaft)

(6) JACKING FORCE USING THOMPSON (1993), ASSUMING BORE STABLE BORE:

(6.1) FRICTION LOAD

(6.1.1) Non-Lubricated

$$P_p = \left(\frac{W_p \tan \delta_p}{\cos \zeta}\right) L$$

From Ref [4]

where:

P_P (tons):	**249**	frictional component of jacking force (at distance *L* from launching shaft)
W_P (lb/ft):	1,060	weight per unit length of pipe
ζ (deg):	60	offset of reaction from vertical
$\tan\delta_P$:	0.51	coefficient of friction between pipe and rock
L (ft):	460	length of trenchless drive

(6.1.2) Lubricated

If lubrication is used, assume P_p is reduced by 50%

P_P (tons):	**124**	frictional component of jacking force (at distance *L* from launching shaft)

(6.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

(6.2.1) Non-Lubricated

JF (tons):	**294**	maximum anticipated jacking load
F_f (tons):	46	face component of jacking force
P_P (tons):	249	frictional component, **non-lubricated**

(6.2.2) Lubricated

JF (tons):	**170**	maximum anticipated jacking load
F_f (tons):	46	face component of jacking force
P_P (tons):	124	frictional component, **lubricated**

(7) SUMMARY OF ESTIMATED JACKING FORCE VS MAXIMUM ALLOWABLE FORCES

MAXIMUM ALLOWABLE JACKING FORCE

P (ton):	**1,018**	Maximum Allowable Jacking Force on RCP pipe
f'_c (psi):	6,000.0	design concrete strength
A (in^2):	1,017.9	cross sectional area of casing
FS:	3.0	Factor of Safety
JFave-nl	686.5	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **non-lubricated condition**
JFave-l	352.5	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **lubricated condition**

(1) Non-lubricated

NG	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-nl)

(2) Lubricated

OK	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-l)

(8) SUMMARY:

The pipe jacking force estimation has been performed at the 460-ft-long tunnel reach from MH217-6 to MH217-7 of the NBC Phase III CSO Program OF-217 Consolidation Conduit. Based on the analyses, we recommend that the tunnel annular space be lubricated to reduce the estimated jacking force.

The analyses presents jacking force calculations associated with approaches presented by Thompson (1993), Bennett & Cording (2000), Najafi (2004) and Staheli, et al (2011). These different theories demonstrate the variability of results and the upper and lower bound results. For purposes of our evaluations, we have assumed an average of these theories represents a reasonalbe estimation of the anticipated jacking forces.

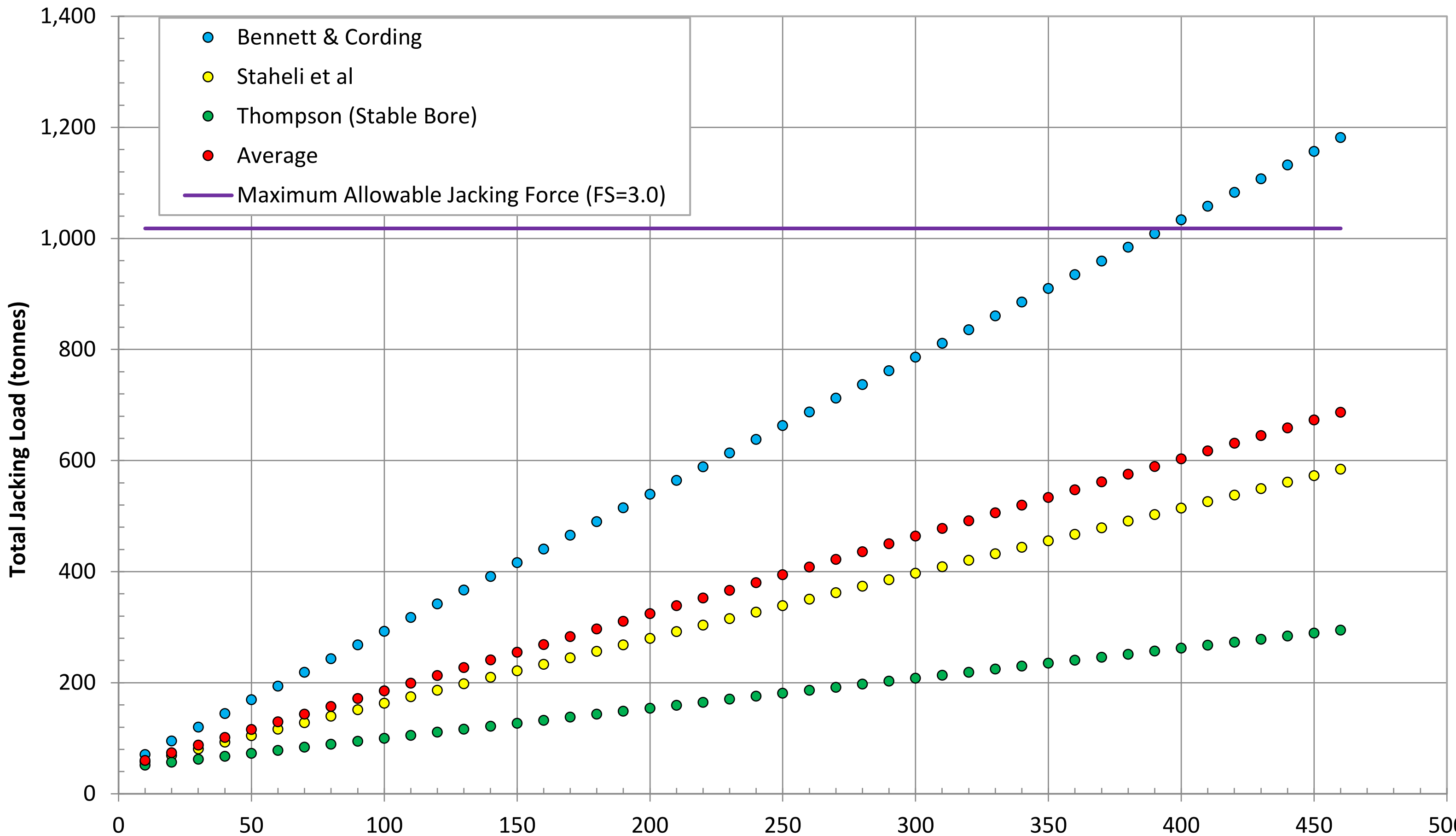
For the non-lubricated tunnel with a similar pipe strength of 6000 psi, the estimated average jacking force is around 570 tons, and a pipe wall with a minimum thickness of 4.0 inches is required to satisfy a factor of safety of 3.0. If a 6-inch thick RCP pipe is used, the estimated average jacking force for the non-lubricated tunnel is around 690 tons, within the allowable capacity of RCP pipe of 1018 tons.

For lubricated tunnel conditions assuming a concrete pipe strength of 6000 psi, the estimated average jacking force of 290 tons does not exceed the allowable jacking force for a 4-inch thick RCP pipe. If a 6-inch thick RCP pipe is used, the estimated average jacking force for the non-lubricated tunnel is around 350 tons, within the allowable capacity of RCP pipe of 1018 tons.

Based on the results of our jacking force evaluations on the three reaches (MH 217-5 to MH 217-6, MH 217-6 to MH 217-7, and MH 217-7 to STA 16+65), we recommend a Class V, Wall C concrete pipe with 6-inch thick walls for jacking even though 4-inch thick walls would work. We also recommend lubrication of the tunnel during the pipe jacking process to reduce the jacking load, especiallly considering the adverse geology in the microtunnel alignments.

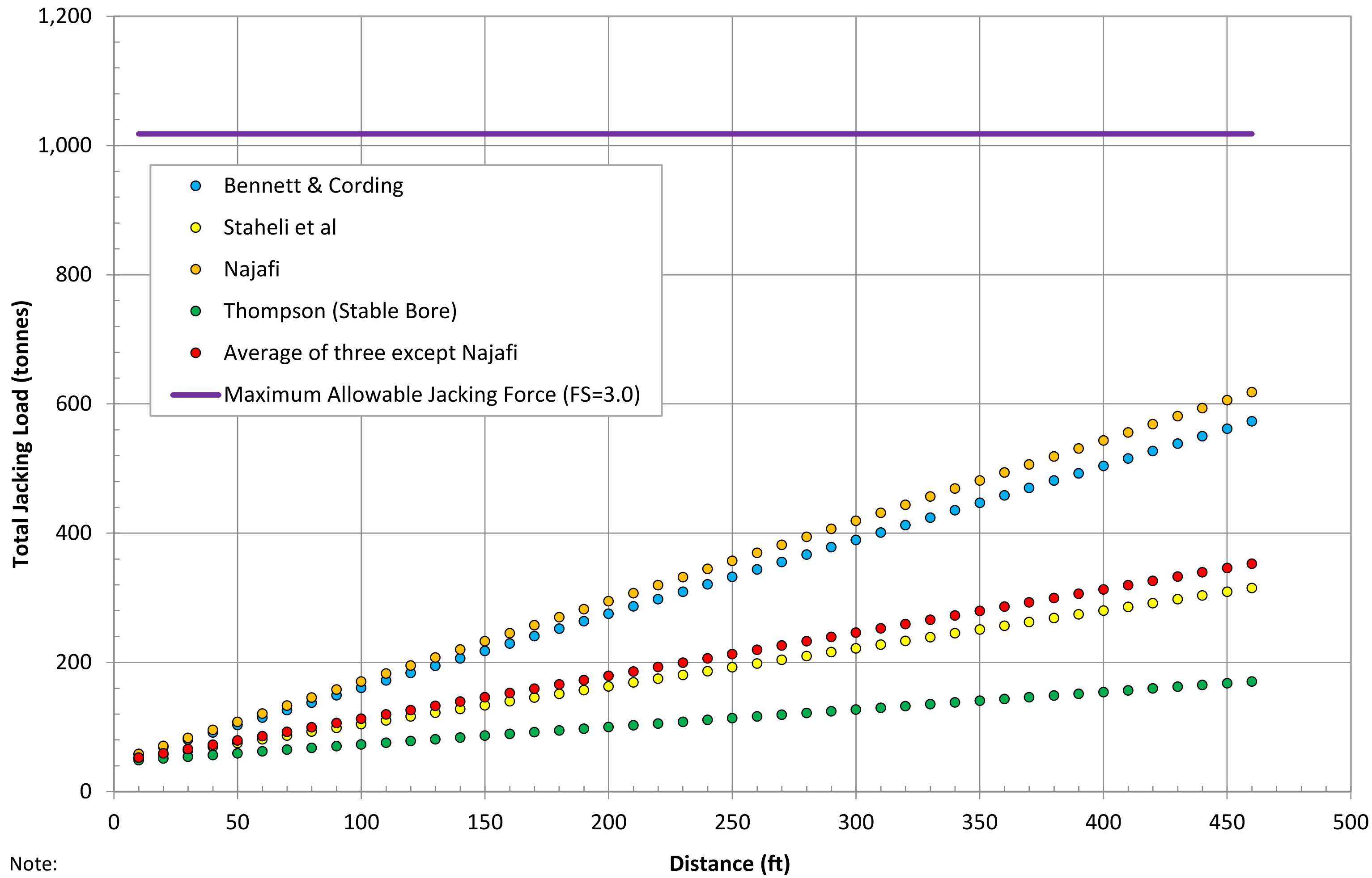
(9) REFERENCES:

[1]	Bennett and Cording, “Jacking Loads & Ground Deformations Associated with Microtunneling”, Proceedings of North American Society for Trenchless Technology International No Dig Conference 2000, Anaheim, California, April 9 -12, 2000.
[2]	Staheli, Wetter, and Davidson, 2011. Quantifying the Effects of Lubrication on Jacking Forces, Proceedings of North American Society for Trenchless Technology International No Dig Conference 2011, Paper A-2-02, Washington D.C., March 27 - 31, 2011.
[3]	Najafi, "Trenchless Technology: Pipeline and Utility Design, Construction, and Renewal", McGraw-Hill, 2004.
[4]	Thompson, "Pipejacking and Microtunneling", McGraw-Hill, 1993.
[5]	Staheli, K., Frost, D. and Iscimen, M., "Studies of Interface Friction Between Jacking Pipe Materials and Frictional Soils and the Impact on Jacking Forces", Proceedings of the North American Society for Trenchless Technology, No-Dig Conference, Nashville TN, March 26-28, 2006.
[6]	Plan and Profile Drawings, C-1 through C-6, 60% Design Phase, prepared by BETA, Inc. dated April 2020
[7]	Geotechnical Data Report, NBC Phase iii SCO Program Consolidation Conduits IIIA-4 and IIIA-5, prepared by McMillen Jacobs Associates, dated June 2020.
[8]	ASTM C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, 2015



Notes:
(1) Assumes 50% reduction in skin friction due to lubrication

Figure A3 - Total Jacking Load with Distance - NON-LUBRICATED (MH217-6 and MH217-7)



Note:
Assumes 50% reduction in skin friction due to lubrication

Figure A4 - Total Jacking Load with Distance - LUBRICATED (MH217-6 and MH217-7)

6.3 MH217-7 to Sta. 16+65

McMILLEN JA ENGINEERING PLLC			
PROJECT	NBC Consolidation Conduit IIIA-5		
SUBJECT	Station 12+57 to 16+65, 408 Foot Drive Shaft Wall to Shaft Wall	DATE	12/15/2020
BY	HL	CHECKED	NAJ
PROJECT NO.	5980.0		

(1) PIPE PROPERTIES

ENGLISH UNITS

(1.1) CASING DIMENSIONS AND DRIVE LENGTH

D (in):	60.00	outside diameter of pipe
L_{PIPE} (ft):	10.00	length of pipe segment
A (ft^2):	19.6	cross-sectional area of pipe/MTBM face
L (ft):	408	total length of trenchless drive
t (in)	6.00	thickness of pipe wall
ID (in)	48.00	inside diameter of pipe (minimum clear diameter)
A (ft^2):	7.07	cross sectional area of pipe
P (ft2/ft)	15.71	Pipe perimeter area

(1.2) SOIL PROPERTIES

H (ft):	22.0	height of soil above pipe invert (measured at downstream end of alignment)
g_S (pcf):	130	unit weight of soil
ϕ (deg):	34	friction angle of soil (assumed residual angle = 30 degrees)
C_a:	1.50	arching factor (for Bennett & Cording, from Ref [1])
µ:	0.51	pipe-soil residual interface friction coefficient (for Staheli et al, from Ref [2])
R (psi):	0.70	circumferential frictional resistance (for Najafi, from Ref [3])

(1.3) GROUNDWATER PROPERTIES

H_w (ft):	12.0	height of water surface to invert of pipe (measured at downstream end of alignment)
g_w (pcf):	62.4	unit weight of water

(2) FACE PRESSURE (USING RANKINE THEORY):

$$F_f = (K_a \sigma'_v + g_w H_w)(A_{face})\left(\frac{1\ ton}{2{,}000\ lb}\right)$$

$$\sigma'_v = g_s(H - H_w) + (g_s - g_w)H_w$$

$$K_p = tan^2\left(45 + \frac{\varphi}{2}\right) \qquad K_a = tan^2\left(45 - \frac{\varphi}{2}\right)$$

Upper Bound Passive Pressure:

	where:	
F_f (tons):	**32**	maximum face component of jacking force at full passive pressure
K_p :	3.54	passive pressure coefficient (calculates upper bound theoretical face pressure for conservatism)
σ'_v (psf):	2,423	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	130	unit weight of soil
g_w (pcf):	62.4	unit weight of water
H (ft):	22.0	height of soil above pipe
H_w (ft):	7.0	height of water surface above top of pipe

Lower Bound Active Pressure:

	where:	
F_f (tons):	**4**	minimum face component of jacking force at active pressure (for lower bound comparison)
K_a :	0.28	active pressure coefficient (calculates lower bound theoretical face pressure)
σ'_v (psf):	2,423	vertical effective stress at tunnel crown
A_{face} (ft^2):	7.1	cross sectional area of pipe
ϕ (deg):	34	friction angle of soil
g_S (pcf):	130	unit weight of soil
g_w (pcf):	62.4	unit weight of water
H (ft):	22.0	height of soil above pipe
H_w (ft):	7.0	height of water surface above top of pipe

NOTE: The active face pressure was used to calculate the total jacking force in the different approaches. Rock is not anticipated in this reach therefore the active pressure component was used to calcualte the total jacking force.

(3) JACKING FORCE USING BENNETT AND CORDING (2000):

(3.1) SKIN FRICTION

(3.1.1) Non-Lubricated

$$F_r = C_a D_p \gamma' \tan(C_f \varphi_r) A_p L \left(\frac{1ton}{2{,}000lbs}\right)$$ From Ref [1]

where:

F_r (tons):	**938**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.146**	normalized friction force
C_a:	1.5	arching factor
D_p (ft):	5.00	pipe outside diameter
γ' (pcf):	68	effective soil unit weight
C_f:	1.0	friction reduction factor (assumed to be 1.0 for non-lubricated bore)
ϕ_r (deg):	30.0	residual friction angle (assumed)
A_p (ft^2):	15.7	unit surface area of the pipe
L (ft):	408	length of bore

(3.1.2) Lubricated

If lubrication is used, assume C_f equals 0.5 and F_r is reduced as shown below

F_r (tons):	**435**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.07**	normalized friction force

(3.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + F_r$$

(3.2.1) Non-Lubricated

JF (tons):	**942**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.147**	normalized jacking force
F_f (tons):	4	face component of jacking force
F_r (tons):	938	frictional component, **non-lubricated**

(3.2.2) Lubricated

JF (tons):	**439**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.069**	normalized jacking force
F_f (tons):	4	face component of jacking force
F_r (tons):	435	frictional component, **lubricated**

(4) JACKING FORCE USING STAHELI et al. (2011):

(4.1) FRICTION LOAD

(4.1.1) Non-Lubricated

$$JF_{frict} = \mu_{int} \frac{g_s\, r \cos\left(45+\frac{\varphi_r}{2}\right)}{\tan \varphi_r} \pi\, D\, L \left(\frac{1\ ton}{2{,}000\ lb}\right)$$ From Ref [2]

where:

JF_{frict} (tons):	**460**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.072**	Normalized friction force
μ_{int} :	0.51	pipe-soil residual interface friction coefficient (from Table 1 of Ref [2])
g_S (pcf):	130	unit weight of soil
r (ft):	2.50	pipe radius
ϕ_r (deg):	30	residual friction angle of the soil (assumed)
D (ft):	5.00	outside diameter of pipe
L (ft):	408	total length of trenchless drive

(4.1.2) Lubricated

If lubrication is used, assume JF_{frict} is reduced by 50%

JF_{frict} (tons):	**230**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.036**	Normalized jacking friction force

(4.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + JF_{frict}$$

(4.2.1) Non-Lubricated

JF (tons):	**464**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.072**	
F_f (tons):	4	face component of jacking force
JF_f (tons):	460	frictional component, **non-lubricated**

(4.2.2) Lubricated

JF (tons):	**234**	maximum anticipated jacking load
NJF_{frict} (tons/ft2)	**0.037**	
F_f (tons):	4	face component of jacking force
JF_f (tons):	230	frictional component, **lubricated**

(5) JACKING FORCE USING NAJAFI (2004), EMPIRICAL APPROACH:

(5.1) FRICTION LOAD

$$FR = R \cdot S \cdot L \left(\frac{12in}{1ft}\right)\left(\frac{1ton}{2{,}000lb}\right)$$

From Ref [3]

where:

FR (tons):	**323**	frictional component of jacking force (at distance *L* from launching shaft)
NJF_{frict} (tons/ft^2):	**0.050**	normalized friction force
R (psi):	0.70	circumferential frictional resistance
S (in):	188.5	perimeter of pipe cross section
L (ft):	408	length of trenchless drive

Note: Values calculated using Najafi approach are empirical. The case histories used to determine the value of R reportedly includes both lubricated and non-lubricated drives. Therefore, it is not possible to distinguish between lubricated and non-lubricated values of skin friction using this approach. Refer to Reference [3] for additional discussion.

(5.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

JF (tons):	**327**	maximum anticipated jacking load
NJF_{frict} (tons/ft^2):	**0.051**	normalized jacking force
F_f (tons):	4	face component of jacking force
FR (tons):	323	frictional component of jacking force (at distance *L* from launching shaft)

(6) JACKING FORCE USING THOMPSON (1993), ASSUMING BORE STABLE BORE:

(6.1) FRICTION LOAD

(6.1.1) Non-Lubricated

$$P_p = \left(\frac{W_p \tan \delta_p}{\cos \zeta}\right) L$$

From Ref [4]

where:

P_P (tons):	**221**	frictional component of jacking force (at distance *L* from launching shaft)
W_P (lb/ft):	1,060	weight per unit length of pipe
ζ (deg):	60	offset of reaction from vertical
$\tan\delta_P$:	0.51	coefficient of friction between pipe and rock
L (ft):	408	length of trenchless drive

(6.1.2) Lubricated

If lubrication is used, assume P_p is reduced by 50%

P_P (tons):	**110**	frictional component of jacking force (at distance *L* from launching shaft)

(6.2) MAXIMUM ANTICIPATED JACKING LOAD

$$JF = F_f + FR$$

(6.2.1) Non-Lubricated

JF (tons):	**225**	maximum anticipated jacking load
F_f (tons):	4	face component of jacking force
P_P (tons):	221	frictional component, **non-lubricated**

(6.2.2) Lubricated

JF (tons):	**114**	maximum anticipated jacking load
F_f (tons):	4	face component of jacking force
P_P (tons):	110	frictional component, **lubricated**

(7) SUMMARY OF ESTIMATED JACKING FORCE VS MAXIMUM ALLOWABLE FORCES

MAXIMUM ALLOWABLE JACKING FORCE

P (ton):	**1,018**	Maximum Allowable Jacking Force on RCP pipe
f'_c (psi):	6,000.0	design concrete strength
A (in^2):	1,017.9	cross sectional area of casing
FS:	3.0	Factor of Safety
JFave-nl	543.4	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **non-lubricated condition**
JFave-l	262.5	Average estimated jacking forces of Bennett & Cording (2000), Staheli et al (2011) and Thompon (Stable Bore) (1993) for **lubricated condition**

(1) Non-lubricated

OK	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-nl)

(2) Lubricated

OK	Check P > JF (Bennett &Cording 2000)
OK	Check P > JF (Staheli et al 2011)
OK	Check P > JF (Najafi 2004)
OK	Check P > JF (Thompson (Stable Bore) 1993)
OK	Check P > JF (Average JFave-l)

(8) SUMMARY:

The pipe jacking force estimation has been performed at the 408-ft-long tunnel reach from MH217-7 to STA 16+65 of the NBC Phase III CSO Program OF-217 Consolidation Conduit. Based on the analyses, we recommend that the tunnel annular space be lubricated to reduce the estimated jacking force.

The analyses presents jacking force calculations associated with approaches presented by Thompson (1993), Bennett & Cording (2000), Najafi (2004) and Staheli, et al (2011). These different theories demonstrate the variability of results and the upper and lower bound results. For purposes of our evaluations, we have assumed an average of these theories represents a reasonalbe estimation of the anticipated jacking forces.

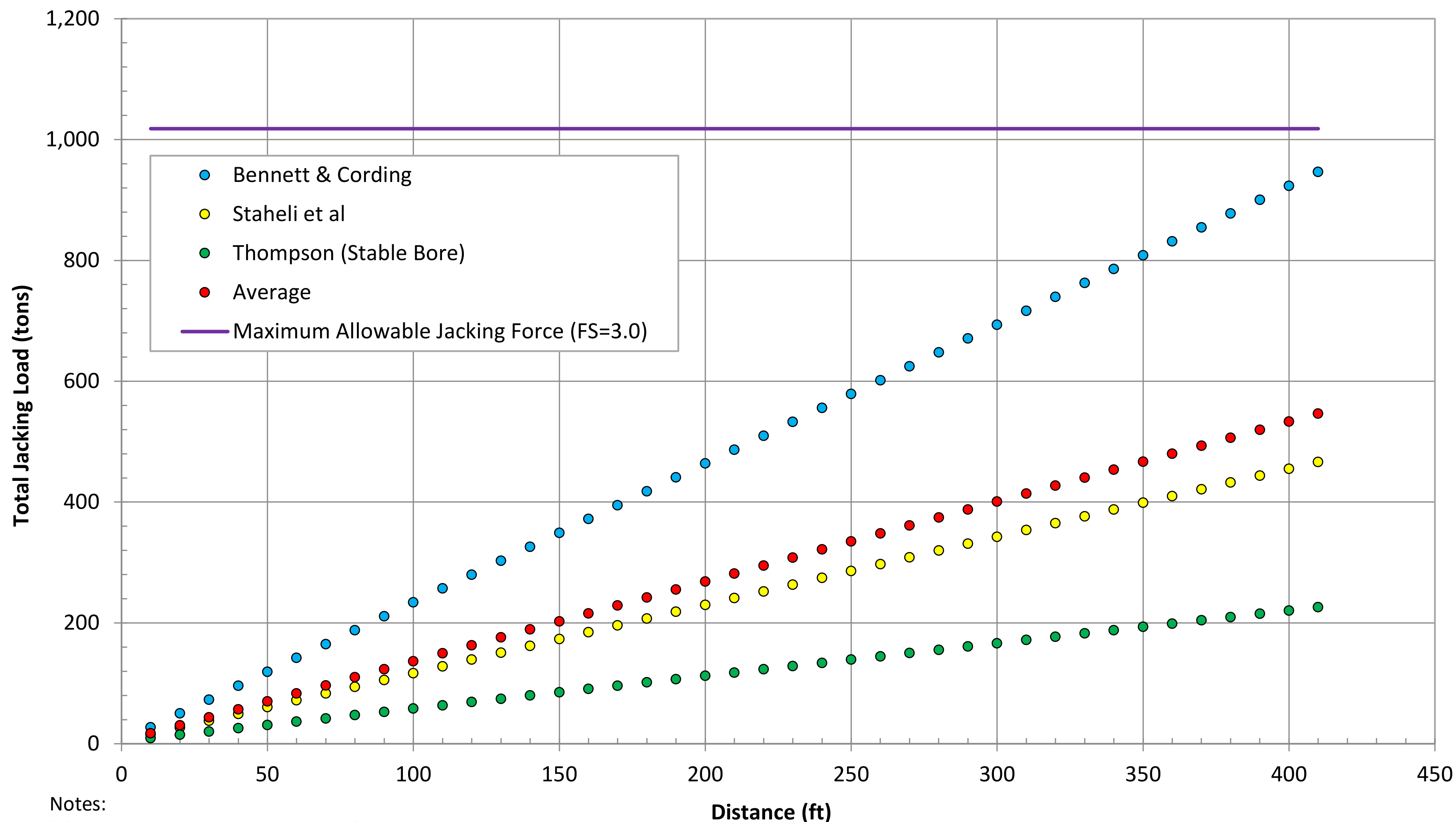
For the non-lubricated tunnel with a similar pipe strength of 6000 psi, the estimated average jacking force is around 460 tons, and a pipe wall with a minimum thickness of 4.0 inches is required to satisfy a factor of safety of 3.0. If a 6-inch thick RCP pipe is used, the estimated average jacking force for the non-lubricated tunnel is around 550 tons, within the allowable capacity of RCP pipe of 1018 tons.

For lubricated tunnel conditions assuming a concrete pipe strength of 6000 psi, the estimated average jacking force of 220 tons does not exceed the allowable jacking force for a 4-inch thick RCP pipe. If a 6-inch thick RCP pipe is used, the estimated average jacking force for the lubricated tunnel is around 260 tons, within the allowable capacity of RCP pipe of 1018 tons.

Based on the results of our jacking force evaluations on the three reaches (MH 217-5 to MH 217-6, MH 217-6 to MH 217-7, and MH 217-7 to STA 16+65), we recommend a Class V, Wall C concrete pipe with 6-inch thick walls for jacking even though 4-inch thick walls would work. We also recommend lubrication of the tunnel during the pipe jacking process to reduce the jacking load, especiallly considering the adverse geology in the microtunnel alignments.

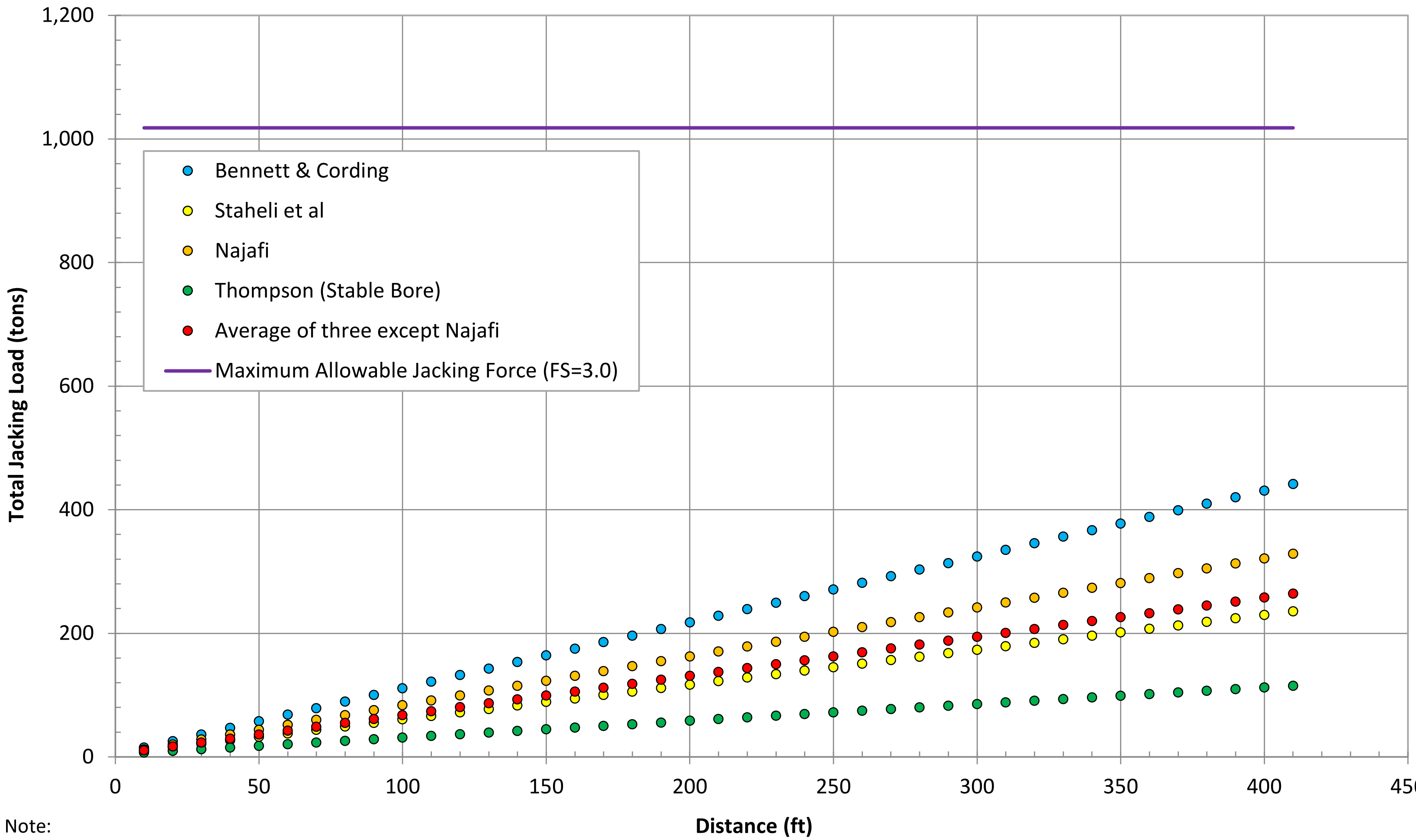
(9) REFERENCES:

[1]	Bennett and Cording, "Jacking Loads & Ground Deformations Associated with Microtunneling", Proceedings of North American Society for Trenchless Technology International No Dig Conference 2000, Anaheim, California, April 9 -12, 2000.
[2]	Staheli, Wetter, and Davidson, 2011. Quantifying the Effects of Lubrication on Jacking Forces, Proceedings of North American Society for Trenchless Technology International No Dig Conference 2011, Paper A-2-02, Washington D.C., March 27 - 31, 2011.
[3]	Najafi, "Trenchless Technology: Pipeline and Utility Design, Construction, and Renewal", McGraw-Hill, 2004.
[4]	Thompson, "Pipejacking and Microtunneling", McGraw-Hill, 1993.
[5]	Staheli, K., Frost, D. and Iscimen, M., "Studies of Interface Friction Between Jacking Pipe Materials and Frictional Soils and the Impact on Jacking Forces", Proceedings of the North American Society for Trenchless Technology, No-Dig Conference, Nashville TN, March 26-28, 2006.
[6]	Plan and Profile Drawings, C-1 through C-6, 60% Design Phase, prepared by BETA, Inc. dated April 2020
[7]	Geotechnical Data Report, NBC Phase iii SCO Program Consolidation Conduits IIIA-4 and IIIA-5, prepared by McMillen Jacobs Associates, dated June 2020.
[8]	ASTM C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, 2015



Notes:
(1) Assumes 50% reduction in skin friction due to

Figure A5 - Total Jacking Load with Distance - NON-LUBRICATED (MH217-7 to Sta. 16+65)



Note:
Assumes 50% reduction in skin friction due to lubrication

Figure A6 - Total Jacking Load with Distance - LUBRICATED (MH217-7 to Sta. 16+65)

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APPENDIX 5

EASEMENT DRAWINGS

(PENDING)

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APPENDIX 6

ENVIRONMENTAL TECHNICAL MEMO

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APPENDIX 7

RISK REGISTER

Phase IIIA CSO Program

Project Risk Register (Contracts IIIA-5)

Updated: 12/22/2020

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No.	Risk	RISK ASSESSMENT: Likelihood	Cost	Schedule	Consequence: Likelihood Score	Cost Score	Schedule Score	Cost Risk Level	Schedule Risk Level	RISK MANAGEMENT: Risk Management Strategy	Approach	Status	Risk Owner	Residual Risk: Likelihood	Cost	Schedule	Consequence: Likelihood Score	Cost Score	Schedule Score	Cost Risk Level	Schedule Risk Level
	Safety																				
1S	Contractor non-compliance with H&S Plan (IIIA-5)	Likely - 50%	Low 100K - 500K	Very Low <15	4	10	1	40	4	Transfer	Contractor solely responsible for H&S of his employees.	Identified	Contractor	Likely - 50%	Low 100K - 500K	Very Low <15	4	10	1	40	4
2S	Worker Fatality	Rare - 1%	Very High > 2.5M	Medium 30-60	1	100	50	100	50	Transfer	Contractor solely responsible for H&S of his employees.	Identified	Contractor	Rare - 1%	Very High > 2.5M	Medium 30-60	1	100	50	100	50
3S	Worker Lost Time	Possible - 30%	Low 100K - 500K	Very Low <15	3	10	1	30	3	Transfer	Contractor solely responsible for H&S of his employees.	Identified	Contractor	Possible - 30%	Low 100K - 500K	Very Low <15	3	10	1	30	3
4S	School Bus / Schoolchildren accident near Charter School due to construction activities	Possible - 30%	High 1.0M-2.5M	Low 15-30	3	80	10	240	30	Mitigate	Contract Documents to confine Contractor staging and work limits off Taft Street right-of-way and require work limits to be fenced and locked.	Identified	Contractor	Rare - 1%	High 1.0M-2.5M	Low 15-30	1	80	10	80	10
5S	Pedestrian accident due to construction activities	Probable - 70%	High 1.0M-2.5M	Low 15-30	5	80	10	400	50	Transfer	Contractor responsible for managing work zone and pedestrian safety through providing appropriate signage and properly securing work zone.	Identified	Contractor	Unlikely - 10%	High 1.0M-2.5M	Low 15-30	2	80	10	160	20
	Planning & Permitting																				
1PP	Existing outfall OF-217 must be relocated due to National Grid construction plans.	Probable - 70%	Medium 500K - 1.0M	High 60-90	5	50	80	250	400	Accept	Outfall relocation accepted by NBC. Included in design and construction contract. Cost and schedule impacts identified and accepted.	Active	NBC	Probable - 70%	Medium 500K - 1.0M	High 60-90	5	50	80	250	400
2PP	Relocation of OF-217 (consolidation conduit) due to development	Probable - 70%	Low 100K - 500K	Medium 30-60	5	10	50	50	250	Accept	NBC has accepted redesign of the alignment to support proposed development.	Active	NBC	Probable - 70%	Low 100K - 500K	Medium 30-60	5	10	50	50	250
3PP	CRMC approvals delayed	Possible - 30%	Very Low <100K	High 60-90	3	1	80	3	240	Mitigate	PM/CM to proactively coordinate with agency early in design process.	Identified	PM/CM	Possible - 30%	Very Low <100K	High 60-90	3	1	80	3	240
4PP	RIDEM approvals delayed	Possible - 30%	Very Low <100K	High 60-90	3	1	80	3	240	Mitigate	PM/CM to proactively coordinate with agency early in design process.	Identified	PM/CM	Possible - 30%	Very Low <100K	High 60-90	3	1	80	3	240
5PP	RIHPHC approval delayed	Possible - 30%	Very Low <100K	High 60-90	3	1	80	3	240	Mitigate	PM/CM to proactively coordinate with agency early in design process. No historic sites of concern to RIHPHC.	Identified	PM/CM	Rare - 1%	Very Low <100K	Low 15-30	1	1	10	1	10
	Procurement																				
1P	Contract execution delayed due to contractor bonding	Unlikely - 10%	High 1.0M-2.5M	Medium 30-60	2	80	50	160	100	Accept	Contract terms and bonding requirements to be identified in the Bid Advertisement / Information for Bidders	Identified	PM/CM	Unlikely - 10%	High 1.0M-2.5M	Medium 30-60	2	80	50	160	100
2P	Bids exceed project cost estimate	Possible - 30%	High 1.0M-2.5M	Medium 30-60	3	80	50	240	150	Mitigate	Conduct OPCC at all project design stages.	Identified	Designer	Unlikely - 10%	Medium 500K - 1.0M	Medium 30-60	2	50	50	100	100
3P	Lack of contractor interest	Possible - 30%	High 1.0M-2.5M	High 60-90	3	80	80	240	240	Mitigate	Pre-advertise project in trade periodicals for specialty subcontractors to generate interest prior to bidding.	Identified	PM/CM	Unlikely - 10%	High 1.0M-2.5M	High 60-90	2	80	80	160	160
	Design																				
1D	Mapping provided by PM/CM is insufficient for design	Probable - 70%	Very Low <100K	Medium 30-60	5	1	50	5	250	Mitigate	Review mapping when available to determine if product is sufficient for design purposes. Supplement withadditional survey information as needed.	Active	Designer	Unlikely - 10%	Low 100K - 500K	Medium 30-60	2	10	50	20	100
2D	Existing utility information is inaccurate	Likely - 50%	High 1.0M-2.5M	High 60-90	4	80	80	320	320	Mitigate	Conduct SUE investigation (vacuum excavation). Additional coordination with utilities.	Active	Designer	Possible - 30%	Medium 500K - 1.0M	High 60-90	3	50	80	150	240
3D	Presence of bedrock identified	Probable - 70%	Medium 500K - 1.0M	Medium 30-60	5	50	50	250	250	Accept	BETA recommended that additional borings be performed to better identify bedrock profile for Contractor's information. NBC elected not to authorize additional borings.	Active	NBC	Probable - 70%	Medium 500K - 1.0M	Medium 30-60	5	50	50	250	250
4D	Additional requirements imposed by Tidewater for site investigations	Probable - 70%	Very Low <100K	Medium 30-60	5	1	50	5	250	Accept	Coordinate with NGrid to identify requirements before mobilizing to the site for investigations.	Active	Designer	Probable - 70%	Very Low <100K	Medium 30-60	5	1	50	5	250
5D	Stakeholder-requested scope changes	Probable - 70%	Low 100K - 500K	High 60-90	5	10	80	50	400	Accept	Coordinate with NBC and PM/CM on a routine basis to ensure expectations are clear and identify and incorporate any changes early in the design process, where possible.	Active	NBC	Probable - 70%	Low 100K - 500K	High 60-90	5	10	80	50	400
6D	No provisions for NBC project elements made during Tidewater capping project construction	Likely - 50%	Medium 500K - 1.0M	Medium 30-60	4	50	50	200	200	Mitigate	Coordinate with NGrid to coordinate NBC design features that will affect completed NGrid capping work so NGrid can make provisions to limit impacts to cap. NGrid is advancing construction. Opportunities to reuse soil as part of the NGrid project are lessened due to respective construction schedules.	Active	NBC	Possible - 30%	Medium 500K - 1.0M	Low 15-30	3	50	10	150	30
	Construction																				
1C	Microtunneling - Selected boring tools are ineffective, premature wearing	Unlikely - 10%	Medium 500K - 1.0M	High 60-90	2	50	80	100	160	Transfer	Contractor responsible for selecting boring tools to complete the work. Contractor responsible for interpreting subsurface data provided in the Geotechnical Data Report (GDR) to select the most appropriate boring tools.	Identified	Contractor	Unlikely - 10%	Very Low <100K	High 60-90	2	1	80	2	160
2C	Microtunneling - Equipment failure	Possible - 30%	High 1.0M-2.5M	Medium 30-60	3	80	50	240	150	Transfer	Contractor responsible for providing and maintaining equipment in good working order. No compensation will be provided due to Contractor's equipment failure.	Identified	Contractor	Unlikely - 10%	Very Low <100K	Medium 30-60	2	1	50	2	100
3C	Microtunneling - Obstruction	Possible - 30%	High 1.0M-2.5M	Medium 30-60	3	80	50	240	150	Accept	Provide allowance item in Contractor for construction of a recovery pit.	Identified	NBC	Possible - 30%	High 1.0M-2.5M	Medium 30-60	3	80	50	240	150
4C	Insufficient Support-of-Excavation (SOE) at structures	Unlikely - 10%	Medium 500K - 1.0M	Low 15-30	2	50	10	100	20	Transfer	Contractor responsible for designing Support-of-Excavation	Identified	Contractor	Unlikely - 10%	Very Low <100K	Low 15-30	2	1	10	2	20
4C2	Difficulty installing circular MTBM shafts due to obstructions	Possible - 30%	Medium 500K - 1.0M	Medium 30-60	3	50	50	150	150	Accept	Contractor responsible for designing SOE. Potential mitigation for pre-trenching may be cost-prohibitive as compared with accepting risk.	Identified	Contractor	Possible - 30%	Medium 500K - 1.0M	Medium 30-60	3	50	50	150	150
5C	Insufficient dewatering at structures	Possible - 30%	Low 100K - 500K	Low 15-30	3	10	10	30	30	Transfer	Contractor responsible for designing dewatering systems	Identified	Contractor	Possible - 30%	Very Low <100K	Low 15-30	3	1	10	3	30
5C2	Watertight MTBM shafts cannot be achieved	Possible - 30%	Low 100K - 500K	Low 15-30	3	10	10	30	30	Transfer	Contractor responsible for designing dewatering systems and SOE. Mitigation measures may include additional cost of handling, treatment, and disposal of additional groundwater or injection grouting (the latter likely the higher cost alternative).	Identified	Contractor	Possible - 30%	Low 100K - 500K	Low 15-30	3	10	10	30	30
6C	Insufficient dewatering for utility trenching operation	Possible - 30%	Low 100K - 500K	Low 15-30	3	10	10	30	30	Transfer	Contractor responsible for designing dewatering systems	Identified	Contractor	Possible - 30%	Very Low <100K	Low 15-30	3	1	10	3	30
7C	Improper management of Existing Outfalls / Flow during construction	Possible - 30%	High 1.0M-2.5M	Low 15-30	3	80	10	240	30	Transfer	Contract Documents to require Contractor submit an existing flow management plan	Identified	Contractor	Possible - 30%	Very Low <100K	Low 15-30	3	1	10	3	30
	Environmental																				
1E	Tidewater - Contamination migration during GW management	Probable - 70%	Very High > 2.5M	Medium 30-60	5	100	50	500	250	Mitigate	Groundwater cut-off within excavations; Clay dams along sewer pipes	Identified	Contractor	Possible - 30%	Very High > 2.5M	Medium 30-60	3	100	50	300	150
2E	Contamination encountered within the project area, outside of Tidewater Site	Possible - 30%	Medium 500K - 1.0M	Low 15-30	3	50	10	150	30	Mitigate	Conduct soil borings and analyze samples taken outside the Tidewater site for presence of contaminants	Identified	Designer	Possible - 30%	Medium 500K - 1.0M	Low 15-30	3	50	10	150	30
	Stakeholder Engagement																				
1SE	Charter School files complaint due to construction activities	Probable - 70%	Very Low <100K	Low 15-30	5	1	10	5	50	Mitigate	Contractor to construct and maintain screening measures to provide visual and audible barrier between the construction activities and the school.	Identified	Contractor	Likely - 50%	Very Low <100K	Low 15-30	4	1	10	4	40
2SE	City of Pawtucket changes Development Plans	Likely - 50%	Low 100K - 500K	High 60-90	4	10	80	40	320	Accept	Coordinate with developer to extent possible	Active	Designer	Likely - 50%	Low 100K - 500K	High 60-90	4	10	80	40	320
3SE	National Grid Changes construction Phasing	Unlikely - 10%	Very Low <100K	Very Low <15	2	1	1	2	2	Accept	Coordinate with NGrid / GZA to identify appropriate cap restoration measures to be incorporated into NBC documents	Identified	Designer	Unlikely - 10%	Very Low <100K	Very Low <15	2	1	1	2	2
4SE	Resident / business claims of property damage due to construction vibrations	Possible - 30%	Medium 500K - 1.0M	Very Low <15	3	50	1	150	3	Transfer	Contractor to conduct pre-construction site survey and maintain builder's risk insurance	Identified	Contractor	Possible - 30%	Very Low <100K	Very Low <15	3	1	1	3	3
5SE	Vehicular access to private property / access to private parking lots	Likely - 50%	Very Low <100K	Very Low <15	4	1	1	4	4	Avoid	Proposed alignment and trenchless construction technique will minimize Contractor's surface footprint.	Identified	Contractor	Unlikely - 10%	Very Low <100K	Very Low <15	2	1	1	2	2
	Financial																				
1F	OPCC exceeds project budget	Possible - 30%	Medium 500K - 1.0M	Medium 30-60	3	50	50	150	150	Mitigate	Prepare OPCC at various project design milestones and course-correct / value-engineer solutions as needed.	Identified	Designer	Possible - 30%	Low 100K - 500K	Low 15-30	3	10	10	30	30
2F	Reduction in SRF funding availability	Unlikely - 10%	Medium 500K - 1.0M	High 60-90	2	50	80	100	160	Accept	No action taken.	Identified	NBC	Unlikely - 10%	Medium 500K - 1.0M	High 60-90	2	50	80	100	160
	Land Acquisition/Easements/ROE																				
1LA	Complications in acquiring easement on Tidewater site	Possible - 30%	Medium 500K - 1.0M	Very High >90	3	50	100	150	300	Mitigate		Identified	NBC	Possible - 30%	Medium 500K - 1.0M	Very High >90	3	50	100	150	300

3LA	Complications in acquiring easement on Town Landing site	Possible - 30%	Low 100K - 500K	High 60-90	3	10	80	30	240	Mitigate		Identified	NBC	Possible - 30%	Low 100K - 500K	High 60-90	3	10	80	30	240
	Operations & Maintenance																				
1OM	Floatables from Diversion Structure cannot be removed	Likely - 50%	Low 100K - 500K	Very Low <15	4	10	1	40	4	Mitigate	Design shall incorporate access directly above floatables screen at diversion structure to allow NBC O&M personnel to vacuum floatables from structure.	Identified	Designer	Rare - 1%	Low 100K - 500K	Very Low <15	1	10	1	10	1
2OM	River water level higher than diversion structure weir, enters consolidation conduit	Probable - 70%	High 1.0M-2.5M	Very Low <15	5	80	1	400	5	Mitigate	Add tide gate structure on outfall pipe, at or downstream of diversion structure weir	Identified	Designer	Rare - 1%	High 1.0M-2.5M	Very Low <15	1	80	1	80	1

Risk Likelihood Rating

Likelihood	Probability	Score
Probable - 70%	70%	5
Likely - 50%	50%	4
Possible - 30%	30%	3
Unlikely - 10%	10%	2
Rare - 1%	1%	1

Cost Consequence Rating

Severity	Consequence	
	Cost ($)	Score
Very High > 2.5M	>2.5M	100
High 1.0M-2.5M	1.0M-2.5M	80
Medium 500K - 1.0M	500K-1.0M	50
Low 100K - 500K	100K-500K	10
Very Low <100K	<100K	1

Schedule Consequence Rating

Severity	Consequence	
	Cal. Day Delay	Score
Very High >90	>90	100
High 60-90	60-90	80
Medium 30-60	30-60	50
Low 15-30	15-30	10
Very Low <15	<15	1

Risk Matrix

Likelihood (Score)	Very Low (1)	Low (10)	Medium (50)	High (80)	Very High (100)
Probable (5)	5	50	250	400	500
Likely (4)	4	40	200	320	400
Possible (3)	3	30	150	240	300
Unlikely (2)	2	20	100	160	200
Rare (1)	1	10	50	80	100

Risk Strategy

Strategy	Description
Transfer	Assign risk to others or insure risk
Avoid	Do not perform activity
Mitigate	Specify measures to reduce likelihood and/or consequence
Accept	Willing to accept consequences

Risk Management Strategy

Status	Description
Active	Risk has occurred and strategy being implemented
Identified	Identified but not yet implementated or occurred
Expired	Risk did not occur, has expired and implementation not needed
Closed	Risk occurred and strategy is complete

Risk Owner

PM/CM
Designer
Contractor
NBC

NBC Phase III CSO Program
Contract IIIA-5 - Basis of Risk Register
Updated: 12/22/2020

Risk ID	Risk Title	Basis of Likelihood Impact	Basis of Cost Impact	Basis of Schedule Impact	Strategy	Basis of Approach	Basis of Residual Likelihood Impact	Basis of Residual Cost Impact	Basis of Residual Schedule Impact
	Safety								
1S	Contractor non-compliance with H&S Plan	Given non-traditional restrictions associated with working on Tidewater site, it is likely that a non-compliance event from workers will occur.	OSHA fine and contractor shutdown for period of time until compliance achieved.	If OSHA fine only, no schedule impact. If contractor shut down for non-compliance, contractor self-incentivized to achieve compliance.	Transfer	Contractor solely responsible for Health & Safety of his employees.	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile
2S	Worker Fatality	On-the-job worker fatality is a rare occurrence in the modern construction industry.	Significant OSHA fine, work shutdown, legal fees associated with wrongful death lawsuit, possible settlement costs, etc.	OSHA project shutdown during investigation	Transfer	Contractor solely responsible for Health & Safety of his employees.	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile
3S	Worker Lost Time	Worker accidents are possible in the modern construction industry.	Medical bills, workman compensation claims, lost productivity	Limited time lost	Transfer	Contractor solely responsible for Health & Safety of his employees.	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile	Risk Transferred - No current reduction in risk profile
4S	School Bus / Schoolchildren accident near Charter School due to construction activities	Proximity of construction activities to charter school, construction hours coincide with school hours and arrival / dismissal times	Repair costs (equipment), medical costs, legal costs, public relation response costs	Lost productivity; management of public relations situation	Mitigate	Contractor responsible for managing work zone. Alignment and work limits located off Taft Street right-of-way, limiting potential for school bus incidents. Require screening and security measures (fencing, gates for privacy, noise, etc.) between work zone and Taft Street right-of-way in vicinity of school.	Opportunity for bus accident due to	No change from pre-strategy assumptions	No change from pre-strategy assumptions
5S	Pedestrian accident due to construction activities	Proximity of construction activities to pedestrian ways; ability of pedestrians to travel through work zone	Repair costs (equipment), medical costs, legal costs, public relation response costs	Lost productivity; management of public relations situation	Mitigate	Contractor responsible for managing work zone. Alignment and work limits located off Taft Street right-of-way. Require screening and security measures (fencing, gates for privacy, noise, etc.) between work zone and Taft Street right-of-way. Pedestrian management plans to be included in Contract Documents to designate proposed pedestrian travel ways in areas where normal pedestrian access is impacted by construction activities.	Risk Transferred - No current reduction in risk profile	No change from pre-strategy assumptions	No change from pre-strategy assumptions
	Planning & Permitting								
1PP	Existing outfall OF-217 must be relocated due to National Grid construction plans.	Existing outfall identified to be relocated.	Cost impact includes additional survey and design efforts and additional construction activities to be incorporated into project.	Schedule impact includes additional survey and design efforts and additional construction activity.	Accept	Outfall relocation accepted by NBC. Included in design and construction contract. Cost and schedule impacts identified and accepted.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2PP	Relocation of OF-217 (consolidation conduit) due to development	OF-217 consolidation conduit relocated from conceptual design based on development proposal at Tidewater / Town Landing.	Cost impact includes additional survey, geotechnical investigation, and design efforts and additional coordination with developer.	Schedul impact includes additional survey, geotechnical investigation, and redesign efforts.	Accept	NBC has accepted redesign of the alignment to support proposed development.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
3PP	CRMC approvals delayed	Profile / scale of CSO Phase III program; agency permitting history	Limited to additional permitting rework time and effort	Critical path schedule. Bidding and procurement will be delayed if permit approvals delayed.	Mitigate	Early coordination with CRMC to present design and permit intent should allow for agency requiement incorporation into permitting and contract documents.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
4PP	RIDEM approvals delayed	Profile / scale of CSO Phase III program; agency permitting history	Limited to additional permitting rework time and effort	Critical path schedule. Bidding and procurement will be delayed if permit approvals delayed.	Mitigate	Early coordination with RIDEM to present design and permit intent should allow for agency requiement incorporation into permitting and contract documents.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
5PP	RIHPHC approval delayed	Profile / scale of CSO Phase III program; agency permitting history	Limited to additional permitting rework time and effort	Critical path schedule. Bidding and procurement will be delayed if permit approvals delayed.	Mitigate	Early coordination with RIHPHC to present design and permit intent should allow for agency requiement incorporation into permitting and contract documents.	No historic sites of concern identified. Permitting process should be relatively straightforward.	No change from pre-strategy assumptions	Risk of schedule impact reduced based on confirmation of no historic sites of concern.
	Procurement								
1P	Contract execution delayed due to contractor bonding	Apparent low bid contractor to be disqualified due to inability to secure required bonds.	Cost assumes apparent low bid contractor cannot secure bonding and another contractor must be selected.	Schedule impact associated with abandoning contracting process with initial contractor and initiating contracting process to another contractor.	Accept	None	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2P	Bids exceed project cost estimate	Competitive marketplace	Cost associated with bid prices above estimates.	Tied to cost - On low end of cost, schedule impacts are minimal if within contingencies. On high end of cost, schedule impacts associated with readvertisement of project.	Mitigate	Conduct OPCC at all project design stages.	Risk decreased due to monitoring of anticipated project costs.	Residual cost impacts associated with specialty construction costs.	No change from pre-strategy assumptions
3P	Lack of contractor interest	Similar construction contracts competing for the same specialty contractors advertised at approximately the same time.	Cost impacts associated with elevated bid prices due to decreased competition.	Schedule impact assumes all bids rejected and project re-advertised.	Mitigate	Pre-advertise project in trade periodicals for specialty subcontractors to generate interest prior to bidding.	Advance advertisement and tactical program scheduling will gnerate interest and help ensure competitive bidding for each project.	No change from pre-strategy assumptions	No change from pre-strategy assumptions
	Design								
1D	Mapping provided by PM/CM is insufficient for design	PM/CM stated that mapping provided would likely not be sufficient for design purposes.	Cost associated with additional survey information to be obtained.	Schedule impacts associated with obtaining proposal and procurement of additional survey and aditional survey information.	Mitigate	Review mapping when available to determine if product is sufficient for design purposes. Supplement withadditional survey information as needed.	Assumes sufficient survey information will be obtained by the Designer (with additional costs covered via Change Order).	No change from pre-strategy assumptions. Pre-strategy assumptions include costs to mitigate.	No change from pre-strategy assumptions. Pre-strategy assumptions include schedule impacts associated with mitigation.
2D	Existing utility information is inaccurate	Large number of utilities in the area; NGrid has stated that the utility locations presented on the Tidewater Site are schematic.	Cost associated with damaged utilities due to inaccurate information, cost associated with additional investigation (potholing)	Schedule impacts associated with additional investgation and downtime associated with utility strikes resulting from inaccurate information.	Mitigate	Conduct SUE investigation (vacuum excavation). Additional coordination with utilities.	Assumes utility strikes based on inaccurate information may still occur, despite best efforts to property identify all utilities	Cost associated with damaged utilities due to inaccurate information.	Schedule impacts associated with implementing additional investgation and downtime associated with potential utility strikes resulting from inaccurate information.
3D	Presence of bedrock identified	Existing borings identify bedrock.	Increased cost associated with management / removal of rock in lieu of soil	Production differential of microtunneling in rock vs. soil	Accept	BETA recommended that additional borings be performed to better identify bedrock profile for Contractor's information. NBC elected not to authorize additional borings.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
4D	Additional requirements imposed by Tidewater for site investigations	Controlled site. Additional requirements for working on site are probable.	Cost impacts associated with implementing additional requirements.	Schedule impact associated with implementing additional requirements and notification requirements.	Accept	Coordinate with NGrid to identify requirements before mobilizing to the site for investigations.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
5D	Stakeholder-requested scope changes	The NBC has requested scope changes.	Cost associated with additional design and investgation efforts. Costs associated with re-design will increase as design progresses.	Schedule impacts associated re-design efforts and obtaining supplemental information through remobilization of subconsultants.	Accept	Coordinate with NBC and PM/CM on a routine basis to ensure expectations are clear and identify and incorporate any changes early in the design process, where possible.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions

NBC Phase III CSO Program
Contract IIIA-5 - Basis of Risk Register
Updated: 12/22/2020

Risk ID	Risk Title	Basis of Likelihood Impact	Basis of Cost Impact	Basis of Schedule Impact	Strategy	Basis of Approach	Basis of Residual Likelihood Impact	Basis of Residual Cost Impact	Basis of Residual Schedule Impact
6D	No provisions for NBC project elements made during Tidewater capping project construction	Tidewater capping project is scheduled to be constructed before Contract IIIA-5, so potential to disturb constructed cap exists.	Cost include repairs to cap disturbances and disposal of hazardous soil not previously managed by National Grid.	Schedule impacts associated with repairing cap disturbances and managing hazardous material.	Mitigate	Coordinate with NGrid to coordinate NBC design features that will affect completed NGrid capping work so NGrid can make provisions to limit impacts to cap. NGrid is advancing construction. Opportunities to reuse soil as part of the NGrid project are lessened due to respective construction schedules.	Residual risk likelihood possible due to potential miscommunications between NBC / NGrid and/or alignment modifications after NGrid construction commences.	Cost risk reduced if coodination measures implemented. Factors in clean corriors for open cut construction and gaps in geomembrane cap to accommodate structures.	Schedule impact reduced by coordinated provisions.
	Construction								
1C	Microtunneling - Selected boring tools are ineffective, premature wearing	Assumes subsurface conditions consistent with those presented in the GDR. Based on accurate information, improper tool selection from qualified microtunneling contractors is unlikely.	Cost associated with contractor's labor and equipment downtime, lost productivity	Schedule impacts associated with removing ineffective tools from the site, re-evaluation of subsurface conditions, and mobilization of more-effective boring solutions.	Transfer	Contractor responsible for selecting boring tools	No change from pre-strategy assumptions	Contractor bears cost of improper tool selection. Cost risk transferred.	No change from pre-strategy assumptions
2C	Microtunneling - Equipment failure	Mechanical failure of specialized equipment is possible.	Cost associated with contractor's labor and equipment downtime, lost productivity due to mechanical failure of TBM, excavation of recovery pit to retrieve TBM	Schedule impacts associated with construction of recovery pit to retrieve TBM, lost productivity	Transfer	Contractor responsible for providing and maintaining equipment in good working order. No compensation will be provided due to Contractor's equipment failure.	Contractor will test equipment prior to commencing microtunneling operations	Contractor bears cost of equipment failure. Cost risk transferred.	No change from pre-strategy assumptions
3C	Microtunneling - Obstruction	Obstructions associated with microtunneling are an inherent risk to the technique, elevated due to filled nature of the Tidewater site.	Cost associated with contractor's labor and equipment downtime, lost productivity due to obstruction, excavation of recovery pit to retrieve TBM	Schedule impacts associated with construction of recovery pit to retrieve TBM, lost productivity	Accept	Make provisions in Contract to allow for construction of a recovery pit due to obstruction.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
4C	Insufficient Support-of-Excavation (SOE) at structures	SOE required at all structures based on depth of excavation.	Cost associated with contractor's labor and equipment downtime, SOE re-design costs, SOE repairs	Schedule impacts associated with SOE failure	Transfer	Contractor responsible for SOE design and construction.	No change from pre-strategy assumptions	Contractor bears cost of SOE failure and cure. Cost risk transferred.	No change from pre-strategy assumptions
4C2	Difficulty installing circular MTBM shafts due to obstructions	Filled nature of the site at the proposed shaft locations introduces associated with drilled SOE features.	Cost associated with potential redesign of SOE system, increased dewatering costs, and/or obstruction removal.	Schedule impacts associated with redesign of SOE and/or removal of obstruction.	Transfer	Contractor responsible for designing SOE. Potential mitigation for pre-trenching may be cost-prohibitive as compared with accepting risk.	No change from pre-strategy assumptions	Contractor bears cost of SOE failure and cure. Cost risk transferred.	No change from pre-strategy assumptions
5C	Insufficient dewatering at structures	Dewatering and/or groundwater cutoff / management required at all structures based on groundwater data obtained and provided.	Cost associated with contractor's labor and equipment downtime, implementation of additional dewatering measures (wells, pumps, etc.), additional groundwater treatment measures	Schedule impacts associated with curing dewatering system failure (drilling additional wells, mobilizing additional equipment)	Transfer	Contractor responsible for dewatering design and implementation.	No change from pre-strategy assumptions	Contractor bears cost to cure dewatering operations. Cost risk transferred.	No change from pre-strategy assumptions
5C2	Watertight MTBM shafts cannot be achieved	Bottom of SOE located within the water table. Dependent upon good groundwater cutoff at bedrock surface.	Cost associated with additional dewatering handling, treatment, and discharge and/or grouting at rock interface to minimize infiltration.	Schedule impacts associated with additional measures taken.	Transfer	Contractor responsible for SOE and dewatering design.	No change from pre-strategy assumptions	Contractor bears cost of SOE failure / additional dewatering. Cost risk transferred.	No change from pre-strategy assumptions
6C	Insufficient dewatering for utility trenching operation	Dewatering and/or groundwater cutoff / management required at most utility trenching locations based on groundwater data obtained and provided.	Cost associated with contractor's labor and equipment downtime, implementation of additional dewatering measures (wells, pumps, etc.), additional groundwater treatment measures	Schedule impacts associated with curing dewatering system failure (drilling additional wells, mobilizing additional equipment)	Transfer	Contractor responsible for dewatering design and implementation.	No change from pre-strategy assumptions	Contractor bears cost to cure dewatering operations. Cost risk transferred.	No change from pre-strategy assumptions
7C	Improper management of Existing Outfalls / Flow during construction	Existing outfall flow must be managed during construction. Some existing infrastructure will be out of service during the construction process.	Fines and penalties associated with mismanagement of existing outfall flow.	Limited schedule impact associated with implementing cure measures.	Transfer	Contract Documents to require Contractor submit an existing flow management plan	No change from pre-strategy assumptions	Contractor bears cost to cure mismanaged outfall operations and associated penalties. Cost risk transferred.	No change from pre-strategy assumptions
	Environmental								
1E	Tidewater - Contamination migration during GW management	Known presence of contaminated groundwater on site in conjunction with construction activities within groundwater table. Utility installation providing preferential pathway for groundwater migration.	Remediation of downstream properties; testing; property value reduction; regulatory fines; enhanced environmental monitoring	Project delays while groundwater management issues addressed	Mitigate	Eliminate groundwater migration at structures with SOE measures to ensure full groundwater cutoff (i.e. secant pile construction). Install benotnite clay dams along sewer pipe alignment to minimize groundwater migration through pipe bedding (where sewer pipes are bedded with stone).	Measures implemented to mitigate groundwater migration effectively reduce the likelihood of occurrence.	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2E	Contamination encountered within the project area, outside of Tidewater Site	Project site (outside of Tidewater) located in an urban fill area, where encountering low level contamination is a possibility.	Costs include special handling / disposal of soil, possible groundwater treatment	Minimal project delays associated with disposal facility administration.	Mitigate	Conduct soil borings and analyze samples taken outside the Tidewater site for presence of contaminants	Soil samples will not reduce the likelihood of encountering contamination, but will identify if risk is elevated (if contamination is encountered in sampling program.)	No change from pre-strategy assumptions	No change from pre-strategy assumptions
	Stakeholder Engagement								
1SE	Charter School files complaint due to construction activities	Construction activities will generate dust and noise in close proximity to the school. Construction hours coincide with schooltime hours.	Public relations response costs;	Possible temporary shutdown until acceptable mitigation measures can be implemented.	Mitigate	Visual and noise-mitigating barrier between construction activity and school minimize risk of disruption	Stakeholder history with activities on Tidewater site makes complaint from school likley, regardless of activity and mitigation measures employed.	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2SE	City of Pawtucket changes Development Plans	At start of project, no development plans at NGrid Tidewater Site. Development plans at Town Landing site in preliminary stages with no recognized financial backing. After project commenced, new soccer stadium development proposed for both sites.	Re-design costs; cost of additional unanticipated coordination; potential rework due to changes in development.	Redesign of proposed consolidation conduit facilities; Coordination with developer; Uncertainty of developer's design due to the early stage of development	Accept	Developer plans are very preliminary. DC to coordinate with developer to the extent possible to minimize potential impacts to designed improvements from anticipated development.	No change from pre-strategy assumptions	No change from pre-strategy assumptions. Cost impacts will become greater if changes are required to accommodate development later in the design process.	No change from pre-strategy assumptions. Schedule impacts will become greater if changes are required to accommodate development later in the design process.

NBC Phase III CSO Program
Contract IIIA-5 - Basis of Risk Register
Updated: 12/22/2020

Risk ID	Risk Title	Basis of Likelihood Impact	Basis of Cost Impact	Basis of Schedule Impact	Strategy	Basis of Approach	Basis of Residual Likelihood Impact	Basis of Residual Cost Impact	Basis of Residual Schedule Impact
3SE	National Grid Changes construction Phasing	NGrid's plan for capping the site is nearing construction. Changes to construction phasing are unlikely at this point.	Minimal costs. Project team accepts that capping project will precede NBC project and cap restoration efforts will be rquired as part of the NBC project.	Minimal schedule impact. Project team accepts that capping project will precede NBC project and cap restoration efforts will be rquired as part of the NBC project.	Accept	Coordinate with NGrid / GZA to identifiy appropriate cap restoration measures to be incorporated into NBC documents.	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
4SE	Resident / business claims of property damage due to construction vibrations	Property damage caused by construction operations are possible.	Costs associated with damage assessment, repairs, relocation of stakeholders (if necessary)	Minimal schedule impact. Assumes mitigation / restoration measures performed during active construction.	Transfer	Contractor to conduct pre-construction site survey and maintain builder's risk insurance	No change from pre-strategy assumptions	Contractor (or Contractor's insurance carrier) bears costs associated with assessment / repair of property damage. Cost risk transferred.	No change from pre-strategy assumptions
5SE	Vehicular access to private property / access to private parking lots	Utility construction within travelled right-of-ways generally impact access to abutting properties at some point during construction.	Limited cost implications associated with public outreach. Potential costs associated with temporary access provisions.	Limited schedule impact associated with potential temporary access provisions.	Avoid	Proposed alignment sites a portion of the work zone outside the travelled right-of-way. Alignment within right-of-way proposed to be installed by trenchless construction techniques, limiting surface disturbance to access locations.	See "Basis of Approach"	Limited cost implications associated with public outreach, if necessary.	No change from pre-strategy assumptions
	Financial								
1F	OPCC exceeds project budget	Estimated project costs may exceed project budget with larger contingencies at earlier design stages. Risk likelihood may be reduced as design progresses.	Cost associated with value engineering design to work within project budget.	Schedule impact associated with value engineering activities.	Mitigate	Prepare OPCC at various project design milestones and course-correct / value-engineer solutions as needed.	Some elements may not be able to be value engineered out for a successful project. Discuss accepting minor exceedences at lated design stages, if necessary.	Review of OPCC at regular design intervals will reduce cost impact risk.	Review of OPCC at regular design intervals will reduce schedule impact risk.
2F	Reduction in SRF funding availability	Project identified on CWSRF CY2020 Project Proiority List	Cost associated with applying for and securing funding from alternative source; Potential for inferior borrowing terms	Procurement impacts associated with securing project funding from alternative source	Accept	None	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
	Land Acquisition / Easements								
1LA	Complications in acquiring easement on Tidewater site	All parties appear to accept that NBC will require an easement. NBC maintains eminent domain powers, if necessary.	Cost associated with redesigning an alternate alignment to get off Tidewater site with all infrastructure.	Schedule impacts associated with redesigning an alternate alignment to get off Tidewater site.	Mitigate	NBC, PM/CM, and Designer coordinating with NGrid on required alignment	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2LA	Complications in acquiring Masonic Temple site	Initial response receptive from property owners; NBC always has option to take portion of property by eminent domain	Cost associated with identifying an alternate site for the GSS and Drop Shaft DS-213. Additional design costs associated with system reconfiguration.	Schedule impacts associated with identifying, securing, re-design and vetting activities (geotechnical, environmental, etc.) associated with a new GSS site.	Mitigate	NBC and PM/CM coordinating with Masonic Temple property owners. Curent plan is to purchase entire property, set for closing on June 30, 2020.	Purchase of the property appears likely given that a closing date is set.	No change from pre-strategy assumptions	No change from pre-strategy assumptions
3LA	Complications in acquiring easement on Town Landing site	All parties appear to accept that NBC will require an easement. NBC maintains eminent domain powers, if necessary. Could more easily relocate off Town Landing parcel than Tidewater parcel.	Cost associated with redesigning an alternate alignment to get off Town Landing site with all infrastructure.	Schedule impacts associated with redesigning an alternate alignment to get off Town Landing site.	Mitigate	NBC, PM/CM, and Designer coordinating with City of Pawtucket on required alignment	No change from pre-strategy assumptions	No change from pre-strategy assumptions	No change from pre-strategy assumptions
	Operations & Maintenance								
1OM	Floatables from Diversion Structure cannot be removed	Floatables will accumulate in diversion structure, eventually requiring increased maintenance at GSS or overtopping screen and discharging to outfall.	Increased maintenance recurrence at GSS and fines/penalties associated with floatables discharging to river.	No identifiable schedule impact.	Mitigate	Design shall incorporate access directly above floatables screen at diversion structure to allow NBC O&M personnel to vacuum floatables from structure.	With proper access to floatables screen, likelihood of floatables discharging over screen will be rare.	No change from pre-strategy assumptions	No change from pre-strategy assumptions
2OM	River water level higher than diversion structure weir, enters consolidation conduit	Flood stage elevation of river near OF-217 is higher than proposed weir elevation at diversion structure, allowing river water into consolidation conduit during flood events.	Fines and penalties associated with overflows caused partly by Seekonk River taking capacity within the consolidation conduit.	No identifiable schedule impact.	Mitigate	Provide measure to keep river water out of consolidation conduit.	Only situation where river water can enter the consolidation conduit is due to a malfunction of the tide gate during a flood event.	No change from pre-strategy assumptions	No change from pre-strategy assumptions

APPENDIX 8

OPINION OF PROBABLE CONSTRUCTION COST

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BETA GROUP INC.

PHASE III COMBINED SEWER OVERFLOW PROGRAM – OF-217 (IIIA-5) CONSOLIDATION CONDUIT CONTRACT NO. 308.05C

60% ESTIMATE – REV02

DECEMBER 23, 2020

CITY POINT PARTNERS LLC
11 Elkins Street, Suite 470
Boston, MA 02127

617 315 7832 main

www.citypointpartners.com

SUMMARY

City Point Partners has performed a cost estimate analysis of the Phase III Combined Sewer Overflow Program – OF-217 Consolidation Conduit (IIIA-5), Contract No. 308.05C, based on plans and specifications dated December, 2020 as well communications with team members from BETA and McMillen Jacobs. The pricing was based on current labor rates, material pricing from database from Sage estimating software, and other reference databases like RIDOT Weighted Average Unit Prices.

Contract IIIA-5 OF-217 Consolidation Conduit includes construction of precast OF-217 Diversion Structures, precast Reconnection Structure, and precast manhole structures. It includes approximately 1540 linear feet of Microtunneling operation, 350 linear feet of 48” RCP, 450 linear feet of 42” RCP and 55 linear feet of 12” RCP in open trench.

The total assessment of the Contract IIIA-5 has been calculated for an estimated value of **$15,250,833.**

Assumptions:

Contract IIIA-5:

Support of Excavation: Secant Piles will be used as SOE for MH-217-6 and MH-217-7. Shafts for MH-217-6 & 7 are assumed to be 20’ in diameter. Soldier Pile and Lagging will be used for the rest of the structures and open trenches for piping.

Dewatering: Assumed 5 wells monitored and capped @ 100GPM for open trenching and 2 wells each for MH-217-5 and 2 sump holes 20’ deep each for MH-217-6 & 7.

Trenchless Construction: IIIA-5 includes approximately 1540 LF of 48” RCP Microtunneling operation. Assumed productivity of 30 lf/day and mobilization of $300,000 /job

Open Trenching: Assumed 12” of bedding, 36” cover for all piping and soldier pile & lagging for excavation greater than 12’ depths and trench boxes for excavations less than 12’ depths.

Assumed 2 acres of clearing and grubbing.

Temporary Services, Trailers, Erosion Control, Final Cleaning, Site Security, Contractor Health & Safety etc. included in General Requirements.

The construction start date is assumed to be January 17, 2022 and end date as April 12, 2023. Based on these assumptions, the escalation is calculated at **6.85%**.

Markups:

Overhead & Profit	12%
Contingency	20%
Escalation to Mid-Point	4% Annually

Additional References:
The following sources were used in preparation of this estimate in addition to plans and specifications issued by Beta:

Stantec

- "Phase III CSO Program, Conceptual Design for Consolidation Conduits and Regulator Modifications - Technical Memorandum, January 25, 2019" for the Narragansett Bay Commission, prepared by Stantec

RIDOT

- "RI Department of Transportation, Plans, Profiles and Sections of Proposed Bridge Replacement, Pawtucket Bridge No. 550, I-95 Over the Seekonk River, Volume 3 Bridge Plans, RI Contract No. 2010-CB-004, FA Project Nos. BRO-0550(003), IM-0550(004), IMG-0550(005), Length =0.9 miles, Commonwealth Engineers and Consultants, Inc. Providence RI, April 2010"
- "RI Department of Public Works, Division of Roads and Bridges, Plan, Profile and Sections of Proposed State Highway, Division St. Project, Contract Three, RIFA Project NO. I-01(11) Length 0723 Miles, Contract Number 5753, April 1957"
- "Construction Stage Soil Management Plan for the Pawtucket River Bridge #550 Replacement and Improvements, For Commonwealth Engineers and Consultants, Inc., DEM Case #2009-13, August 2009" by Wright Pierce
- Site investigation Report of the Phase II and III ESA Work Associated with Pawtucket Bridge #550 Replacement and Improvements for Commonwealth Engineers and Consultants, Inc., DEM Case #2009-13, Volume 1 and Volume 2, August 2009" by Wright Pierce
- Remedial Action Work Plan for the Pawtucket Bridge #550 Replacement and Improvements for Commonwealth Engineers and Consultants, Inc., DEM Case #2009-13, October 2009, Revised December 2009" by Wright Pierce

City of Pawtucket

City of Pawtucket, Seekonk/Blackstone River Wall Repair Project, June 10, 2011, Prepared for: City of Pawtucket, Prepared by: Fuss and O'Neill Inc.

Tidewater Property

- "Site Investigation Data Report, Former Tidewater MGP and Power Plant, Pawtucket, Rhode Island, RIDEM Case No. 95-022, Prepared for RIDEM, OWR, Providence Rhode Island, Prepared by: GZA GeoEnvironmental, Inc., On Behalf of National Grid, Waltham MA, Date: January 2011."

- "Former Tidewater Facility, Pawtucket, Rhode Island, Sitewide Remedy Design, Permit Set, August 2019, Prepared by: GZA GeoEnvironmental, Inc., Estimate submitted by

Vashisht Reddy – Project Controls Specialist
Jim Stetson – VP Project Controls
City Point Partners

CITY POINT PARTNERS

Location	CSI Div	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Grand Total Unit Price	Grand Total
CONSOLIDATION CONDUIT															
12" RCP Open Cut															
	31	**EARTHWORK**													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket, includes trench box	455.00 cy	21.48 /cy	83.36 /mh	9,772			83.70 /mh	4,906		32.26 /cy	14,678	42.58 /cy	19,375
		Backfill, trench, air tamped compaction, add	58.00 ecy	15.44 /ecy	77.22 /mh	896			8.91 /mh	207		19.01 /ecy	1,102	25.09 /ecy	1,455
		Fill by borrow and utility bedding, for pipe and conduit, crushed or screened bank run gravel, excludes compaction	31.00 lcy	14.12 /lcy	88.26 /mh	438	17.18 /lcy	533	39.05 /mh	65		33.38 /lcy	1,035	44.06 /lcy	1,366
		Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	31.00 ecy	7.64 /ecy	85.89 /mh	237			3.98 /mh	11		7.99 /ecy	248	10.54 /ecy	327
		31 EARTHWORK				**11,342**		**533**		**5,188**			**17,063**		**22,523**
	33	**UTILITIES**													
		Reinforced concrete pipe (RCP) with gaskets, 12" diameter	164.00 lf	17.35 /lf	79.30 /mh	2,845	37.50 /lf	6,150	124.23 /mh	637		58.73 /lf	9,632	77.52 /lf	12,714
		33 UTILITIES				**2,845**		**6,150**		**637**			**9,632**		**12,714**
		12" RCP Open Cut	**164.00 LF**	**86.51 /LF**		**14,187**		**6,683**		**5,825**		**162.77 /LF**	**26,695**	**214.86 /LF**	**35,237**
42" RCP Open Cut															
	31	**EARTHWORK**													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket, includes trench box	355.00 cy	21.48 /cy	83.36 /mh	7,625			83.70 /mh	3,828		32.26 /cy	11,452	42.58 /cy	15,117
		Backfill, trench, air tamped compaction, add	160.00 ecy	15.44 /ecy	77.22 /mh	2,471			8.91 /mh	570		19.01 /ecy	3,041	25.09 /ecy	4,014
		Fill by borrow and utility bedding, for pipe and conduit, crushed or screened bank run gravel, excludes compaction	85.00 lcy	14.12 /lcy	88.26 /mh	1,200	17.18 /lcy	1,460	39.05 /mh	177		33.38 /lcy	2,838	44.06 /lcy	3,746
		Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	85.00 ecy	7.64 /ecy	85.89 /mh	649			3.98 /mh	30		7.99 /ecy	679	10.54 /ecy	896
		31 EARTHWORK				**11,945**		**1,460**		**4,605**			**18,010**		**23,773**
	33	**UTILITIES**													
		Reinforced concrete pipe (RCP) with gaskets, 42" diameter	450.00 lf	61.30 /lf	79.30 /mh	27,585	132.00 /lf	59,400	124.23 /mh	6,988		208.83 /lf	93,973	275.65 /lf	124,044
		33 UTILITIES				**27,585**		**59,400**		**6,988**			**93,973**		**124,044**
		42" RCP Open Cut	**450.00 LF**	**87.84 /LF**		**39,530**		**60,860**		**11,593**		**248.85 /LF**	**111,983**	**328.48 /LF**	**147,817**
48" RCP Open Cut															
	31	**EARTHWORK**													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket	275.00 cy	14.82 /cy	83.36 /mh	4,075			83.70 /mh	2,046		22.26 /cy	6,121	29.38 /cy	8,080
		Backfill, trench, air tamped compaction, add	50.00 ecy	15.44 /ecy	77.22 /mh	772			8.91 /mh	178		19.01 /ecy	950	25.09 /ecy	1,255
		Fill by borrow and utility bedding, for pipe and conduit, crushed or screened bank run gravel, excludes compaction	65.00 lcy	14.12 /lcy	88.26 /mh	918	17.18 /lcy	1,117	39.05 /mh	135		33.38 /lcy	2,170	44.06 /lcy	2,864
		Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	65.00 ecy	7.64 /ecy	85.89 /mh	496			3.98 /mh	23		7.99 /ecy	519	10.54 /ecy	685
		Soldier Pile & Lagging - TEMP. SOE	2,960.00 sf	36.03 /sf	79.00 /mh	106,645	6.46 /sf	19,136	6.87 /mh	7,419		45.00 /sf	133,200	59.40 /sf	175,824
		31 EARTHWORK				**112,907**		**20,253**		**9,801**			**142,961**		**188,708**
	33	**UTILITIES**													
		Reinforced concrete pipe (RCP) with gaskets, 48" diameter	350.00 lf	69.39 /lf	79.30 /mh	24,286	150.00 /lf	52,500	124.23 /mh	5,435		234.92 /lf	82,221	310.09 /lf	108,531
		33 UTILITIES				**24,286**		**52,500**		**5,435**			**82,221**		**108,531**
		48" RCP Open Cut	**350.00 LF**	**391.98 /LF**		**137,193**		**72,753**		**15,236**		**643.38 /LF**	**225,182**	**849.26 /LF**	**297,240**
Open Trench Dewater															
	31	**EARTHWORK**													
		Open Trench Dewatering Treatment	1.00 LS								307,153	307,153.33 /LS	307,153	405,442.38 /LS	405,442
		Rent 8" diam wellpoint discharge pipe	200.00 day						0.40 /day	80		0.40 /day	80	0.53 /day	106
		Rent wellpoint header pipe, 4" diameter, flow to 150 GPM	2,600.00 day						0.40 /day	1,040		0.40 /day	1,040	0.53 /day	1,373
		Rent wellpoint 25' long w/fittings & riser pipe 1-1/2" or 2" suction	840.00 day						3.20 /day	2,688		3.20 /day	2,688	4.22 /day	3,548
		Rent wellpoint pump, diesel, 20 HP, 4" suction	840.00 day						178.35 /day	149,814		178.35 /day	149,814	235.42 /day	197,754
		Wells, for dewatering, with steel casing, 10' to 20' deep, 2' diameter, average	130.00 vlf	18.78 /vlf	76.68 /mh	2,441	43.00 /vlf	5,590	39.05 /mh	414		64.97 /vlf	8,446	85.76 /vlf	11,148
		Wellpoints, single stage system, 0.75 labor hours per L.F., installation and removal, minimum	2,600.00 hdr	56.53 /hdr	75.61 /mh	146,979						56.53 /hdr	146,979	74.62 /hdr	194,013
		Wellpoints, pump operation, 4 @ 6 hour shifts, per 24 hour day	85.00 day	1,986.27 /day	78.83 /mh	168,833						1,986.27 /day	168,833	2,621.87 /day	222,859
		31 EARTHWORK				**318,254**		**5,590**		**154,036**	**307,153**		**785,033**		**1,036,244**
		Open Trench Dewater	**1.00 LS**	**318,253.60 /LS**		**318,254**		**5,590**		**154,036**	**307,153**	**785,033.32 /LS**	**785,033**	**1,036,243.97 /LS**	**1,036,244**
		CONSOLIDATION CONDUIT				**509,164**		**145,886**		**186,690**	**307,153**		**1,148,893**		**1,516,538**
GENERAL REQUIREMENTS															
Bonds, Insurance & P															
	01	**GENERAL CONDITIONS**													
		Bonds, Insurance & Permits	1.00 LS								100,000	100,000.00 /LS	100,000	132,000.00 /LS	132,000
		01 GENERAL CONDITIONS									**100,000**		**100,000**		**132,000**
		Bonds, Insurance & P									**100,000**		**100,000**		**132,000**
Erosion Control															
	01	**GENERAL CONDITIONS**													
		Erosion Control	1.00 LS								100,000	100,000.00 /LS	100,000	132,000.00 /LS	132,000
		01 GENERAL CONDITIONS									**100,000**		**100,000**		**132,000**
		Erosion Control									**100,000**		**100,000**		**132,000**
Final Cleaning															
	01	**GENERAL CONDITIONS**													
		Final Cleaning	1.00 LS								50,000	50,000.00 /LS	50,000	66,000.00 /LS	66,000
		01 GENERAL CONDITIONS									**50,000**		**50,000**		**66,000**
		Final Cleaning									**50,000**		**50,000**		**66,000**
Mobilization															
	01	**GENERAL CONDITIONS**													
		Mobilization	1.00 LS								180,000	180,000.00 /LS	180,000	237,600.00 /LS	237,600
		01 GENERAL CONDITIONS									**180,000**		**180,000**		**237,600**
		Mobilization									**180,000**		**180,000**		**237,600**
OSHA Training															
	01	**GENERAL CONDITIONS**													
		OSHA Training	1.00 LS								20,000	20,000.00 /LS	20,000	26,400.00 /LS	26,400
		01 GENERAL CONDITIONS									**20,000**		**20,000**		**26,400**
		OSHA Training									**20,000**		**20,000**		**26,400**
PPE															
	01	**GENERAL CONDITIONS**													
		Respirator mask only, full face, silicon	20.00 ea				287.00 /ea	5,740				287.00 /ea	5,740	378.84 /ea	7,577
		Respirator cartridges, dust or asbestos, 2 req'd per mask	20.00 ea				4.76 /ea	95				4.76 /ea	95	6.28 /ea	126
		Self contained breathing apparatus with full face piece, 60 minute	20.00 ea				3,000.00 /ea	60,000				3,000.00 /ea	60,000	3,960.00 /ea	79,200
		Encapsulating suits, limited use, level B	20.00 ea				405.00 /ea	8,100				405.00 /ea	8,100	534.60 /ea	10,692
		Over boots, Neoprene	20.00 pr				31.00 /pr	620				31.00 /pr	620	40.92 /pr	818
		Gloves, Neoprene coated	20.00 pr				41.50 /pr	830				41.50 /pr	830	54.78 /pr	1,096
		01 GENERAL CONDITIONS						**75,385**					**75,385**		**99,508**
		PPE						**75,385**					**75,385**		**99,508**
Safety Plan															

Location	CSI Div	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Grand Total Unit Price	Grand Total
	01	GENERAL CONDITIONS													
		Health and Safety Plan	1.00 LS								25,000	25,000.00 /LS	25,000	33,000.00 /LS	33,000
		01 GENERAL CONDITIONS									25,000		25,000		33,000
		Safety Plan									25,000		25,000		33,000
Supervision/GC Staff															
	01	GENERAL CONDITIONS													
		Field Personnel, clerk, average - 50% of Project Duration	36.00 weel	485.00 /weel	485.00 /weel	17,460						485.00 /weel	17,460	640.20 /weel	23,047
		Field engineer, average - 50% of Project Duration	36.00 weel	1,500.00 /weel	1,500.00 /weel	54,000						1,500.00 /weel	54,000	1,980.00 /weel	71,280
		Full Time Site Safety Representative	72.00 weel	3,000.00 /weel	3,000.00 /weel	216,000						3,000.00 /weel	216,000	3,960.00 /weel	285,120
		Field Personnel, general purpose laborer, average	72.00 weel	1,600.00 /weel	1,600.00 /weel	115,200						1,600.00 /weel	115,200	2,112.00 /weel	152,064
		Full Time Flagger	72.00 weel	1,850.00 /weel	1,850.00 /weel	133,200						1,850.00 /weel	133,200	2,442.00 /weel	175,824
		Field Personnel, project manager, average - 30% of Project Duration	21.60 weel	2,450.00 /weel	2,450.00 /weel	52,920						2,450.00 /weel	52,920	3,234.00 /weel	69,854
		Field Personnel, superintendent, average - 70% of Project Duration	50.40 weel	2,275.00 /weel	2,275.00 /weel	114,660						2,275.00 /weel	114,660	3,003.00 /weel	151,351
		Scheduling, computer-update	20.00 ea								29,000	1,450.00 /ea	29,000	1,914.00 /ea	38,280
		01 GENERAL CONDITIONS				703,440					29,000		732,440		966,821
		Supervision/GC Staff				703,440					29,000		732,440		966,821
Temp Traffic Control															
	01	GENERAL CONDITIONS													
		Detour sign, reflective aluminum, MUTCD, 30" x 15", post mounted	2.00 ea	45.99 /ea	114.97 /mh	92	3.99 /ea	8				49.98 /ea	100	65.97 /ea	132
		Detour sign, reflective aluminum, MUTCD, 24" x 12", post mounted	2.00 ea	45.99 /ea	114.97 /mh	92	2.56 /ea	5				48.55 /ea	97	64.08 /ea	128
		Detour sign, reflective aluminum, MUTCD, 30" x 24", post mounted	8.00 ea	45.99 /ea	114.97 /mh	368	6.39 /ea	51				52.38 /ea	419	69.14 /ea	553
		Detour sign, reflective aluminum, MUTCD, 21" x 15", post mounted	2.00 ea	45.99 /ea	114.97 /mh	92	2.80 /ea	6				48.79 /ea	98	64.40 /ea	129
		Detour sign, reflective aluminum, MUTCD, 24" x 24", post mounted	1.00 ea	45.99 /ea	114.97 /mh	46	5.11 /ea	5				51.10 /ea	51	67.45 /ea	67
		Detour sign, reflective aluminum, MUTCD, 36" x 36", post mounted	4.00 ea	45.99 /ea	114.97 /mh	184	11.50 /ea	46				57.49 /ea	230	75.88 /ea	304
		Detour sign, reflective aluminum, MUTCD, 48" x 30", post mounted	1.00 ea	45.99 /ea	114.97 /mh	46	12.78 /ea	13				58.77 /ea	59	77.58 /ea	78
		Detour sign, reflective aluminum, MUTCD, 60" x 30", post mounted	2.00 ea	45.99 /ea	114.97 /mh	92	15.97 /ea	32				61.96 /ea	124	81.78 /ea	164
		Detour sign, reflective aluminum, MUTCD, 30" x 12", post mounted	23.00 ea	45.99 /ea	114.97 /mh	1,058	3.19 /ea	73				49.18 /ea	1,131	64.91 /ea	1,493
		01 GENERAL CONDITIONS				2,069		239					2,308		3,047
		Temp Traffic Control				2,069		239					2,308		3,047
Temp. Facilities/Uti															
	01	GENERAL CONDITIONS													
		Temporary Heat, per week, 12 hours per day, incl. fuel and operation	2,600.00 c fl	13.64 /c fl	85.27 /mh	35,472	100.00 /msf					13.64 /c fl	35,472	18.01 /c fl	46,823
		Office Trailer, furnished, buy, 50' x 10', excl. hookups	2.00 ea	2,273.87 /ea	85.27 /mh	4,548	29,300.00 /ea	58,600				31,573.87 /ea	63,148	41,677.50 /ea	83,355
		Office Trailer, delivery, add per mile	150.00 mile				12.00 /mile	1,800				12.00 /mile	1,800	15.84 /mile	2,376
		Storage Boxes, rent per month, 20' x 8'	12.00 ea				84.50 /ea	1,014				84.50 /ea	1,014	111.54 /ea	1,338
		Field Office Expense, office equipment rental, average	18.00 mo				205.00 /mo	3,690				205.00 /mo	3,690	270.60 /mo	4,871
		Field Office Expense, office supplies, average	18.00 mo				82.00 /mo	1,476				82.00 /mo	1,476	108.24 /mo	1,948
		Field Office Expense, telephone bill; avg. bill/month, incl. long dist.	18.00 mo				86.00 /mo	1,548				86.00 /mo	1,548	113.52 /mo	2,043
		Field Office Expense, field office lights & HVAC	18.00 mo				161.00 /mo	2,898				161.00 /mo	2,898	212.52 /mo	3,825
		Rent toilet portable chemical	540.00 day						14.25 /day	7,695		14.25 /day	7,695	18.81 /day	10,157
		Barricades, traffic cones, PVC, 28" high	500.00 ea				17.75 /ea	8,875				17.75 /ea	8,875	23.43 /ea	11,715
		Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, over 1000'	2,000.00 lf	4.03 /lf	75.61 /mh	8,065	3.19 /lf	6,380				7.22 /lf	14,445	9.53 /lf	19,067
		Project Signs, sign, high intensity reflectorized, buy, excl. posts	100.00 ea				25.00 /ea	2,500				25.00 /ea	2,500	33.00 /ea	3,300
		Rubbish handling, dumpster, 20 C.Y., 8 ton capacity, weekly rental, includes one dump per week, cost to be added to demolition cost.	72.00 week				565.00 /wee	40,680				565.00 /wee	40,680	745.80 /wee	53,698
		01 GENERAL CONDITIONS				48,085		129,461		7,695			185,241		244,518
		Temp. Facilities/Uti				48,085		129,461		7,695			185,241		244,518
Testing/Inspection															
	01	GENERAL CONDITIONS													
		Testing and Inspection (Inludes Weekly VOC Testing)	1.00 LS								338,000	338,000.00 /LS	338,000	446,160.00 /LS	446,160
		01 GENERAL CONDITIONS									338,000		338,000		446,160
		Testing/Inspection									338,000		338,000		446,160
		GENERAL REQUIREMENTS				**753,594**		**205,085**		**7,695**	**842,000**		**1,808,374**		**2,387,054**
MANAGEMENT OF EXCESS SOILS															
Soil Disposal															
	31	EARTHWORK													
		Tidewater Property Soil Disposal, Contaminated	1,425.00 CY	217.12 /CY	72.70 /mh	309,398			38.99 /mh	331,852		450.00 /CY	641,250	594.00 /CY	846,450
		City Streets Soil Disposal	660.00 CY	53.07 /CY	72.70 /mh	35,029			38.99 /mh	37,571		110.00 /CY	72,600	145.20 /CY	95,832
		Town Landing Property Soil Disposal, Contaminated	530.00 CY	217.12 /CY	72.70 /mh	115,074			38.99 /mh	123,426		450.00 /CY	238,500	594.00 /CY	314,820
		31 EARTHWORK				459,502				492,848			952,350		1,257,102
		Soil Disposal				459,502				492,848			952,350		1,257,102
		MANAGEMENT OF EXCESS SOILS				**459,502**				**492,848**			**952,350**		**1,257,102**
MICROTUNNELING															
Launch&Receive Pits															
	31	EARTHWORK													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket MH 217-6	460.00 cy	14.82 /cy	83.36 /mh	6,817			83.70 /mh	3,422		22.26 /cy	10,240	29.38 /cy	13,516
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket MH 217-7	330.00 cy	14.82 /cy	83.36 /mh	4,891			83.70 /mh	2,455		22.26 /cy	7,346	29.38 /cy	9,696
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket - RECEIVING PIT STA 16+67	186.00 cy	14.82 /cy	83.36 /mh	2,756			83.70 /mh	1,384		22.26 /cy	4,140	29.38 /cy	5,465
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket MH 217-5	40.00 cy	14.82 /cy	83.36 /mh	593			83.70 /mh	298		22.26 /cy	890	29.38 /cy	1,175
		Backfill, trench, air tamped compaction, add - RECEIVING PIT STA 16+67	186.00 ecy	15.44 /ecy	77.22 /mh	2,873			8.91 /mh	663		19.01 /ecy	3,535	25.09 /ecy	4,667
		Soldier Pile & Lagging - TEMP. SOE STA 16+67	1,400.00 sf	36.03 /sf	79.00 /mh	50,440	6.46 /sf	9,051	6.87 /mh	3,509		45.00 /sf	63,000	59.40 /sf	83,160
		Soldier Pile & Lagging - TEMP. SOE MH 217-5	630.00 sf	36.03 /sf	79.00 /mh	22,698	6.46 /sf	4,073	6.87 /mh	1,579		45.00 /sf	28,350	59.40 /sf	37,422
		Mobilization for secant pile construction - MH 217-7	1.00 LS	5,913.95 /LS	88.03 /mh	5,914			80.36 /mh	44,086		49,999.96 /LS	50,000	65,999.95 /LS	66,000
		Mobilizationfor secant pile construction - MH 217-6	1.00 LS	5,913.95 /LS	88.03 /mh	5,914			80.36 /mh	44,086		49,999.96 /LS	50,000	65,999.94 /LS	66,000
		Secant Pile, Construction - MH 217-7	1,600.00 vlf	194.76 /vlf	82.41 /mh	311,618	15.31 /vlf	24,493	83.72 /mh	143,889		300.00 /vlf	480,000	396.00 /vlf	633,600
		Secant Pile, Construction - MH 217-6	1,600.00 vlf	194.76 /vlf	82.41 /mh	311,618	15.31 /vlf	24,493	83.72 /mh	143,889		300.00 /vlf	480,000	396.00 /vlf	633,600
		31 EARTHWORK				726,131		62,110		389,261			1,177,501		1,554,302
		Launch&Receive Pits				726,131		62,110		389,261			1,177,501		1,554,302
Microtunneling															
	33	UTILITIES													
		Microtunneling,microtunneling slurry method,average 30'per day, 48"outside diameter	1,540.00 lf								3,850,000	2,500.00 /lf	3,850,000	3,300.00 /lf	5,082,000
		Geopolymer Concrete Liner	1,200.00 lf								480,000	400.00 /lf	480,000	528.00 /lf	633,600
		Microtunneling, rent microtunneling machine, average month's lease	1.71 mo								205,200	120,000.00 /mo	205,200	158,400.00 /mo	270,864
		Microtunneling, microtunneling operating technician	50.00 day								31,500	630.00 /day	31,500	831.60 /day	41,580
		Microtunneling, mobilization and demobilization	1.00 job								300,000	300,000.00 /job	300,000	396,000.00 /job	396,000
		Reinforced concrete pipe (RCP) with gaskets, 48" diameter	1,540.00 lf		/mh		150.00 /lf	231,000	/mh			150.00 /lf	231,000	198.00 /lf	304,920
		33 UTILITIES						231,000			4,866,700		5,097,700		6,728,964

Location	CSI Div	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Grand Total Unit Price	Grand Total
		Microtunneling						231,000			4,866,700		5,097,700		6,728,964
		MICROTUNNELING	**1,540.00 LF**	**471.51 /LF**		**726,131**		**293,110**		**389,261**	**4,866,700**	**4,074.81 /LF**	**6,275,201**	**5,378.74 /LF**	**8,283,266**
SITE															
Access Road															
	32	EXTERIOR IMPROVEMENTS													
		Processed Gravel, 12"deep	3,611.00 sy	2.40 /sy	92.93 /mh	8,666	20.78 /sy	75,038	93.94 /mh	6,571		25.00 /sy	90,275	33.00 /sy	119,163
		32 EXTERIOR IMPROVEMENTS				8,666		75,038		6,571			90,275		119,163
	33	UTILITIES													
		Geotextile Fabric	3,611.00 sy	0.50 /sy	1,209.76 /cd	1,820	1.50 /sy	5,417				2.00 /sy	7,237	2.65 /sy	9,552
		33 UTILITIES				1,820		5,417					7,237		9,552
		Access Road				10,486		80,455		6,571			97,512		128,715
Clear & Grub															
	31	EARTHWORK													
		Clearing & grubbing (Assume 2 Acres)	2.00 acre	3,721.30 /acre	77.53 /mh	7,443			82.47 /mh	7,917		7,679.71 /acre	15,359	10,137.22 /acre	20,274
		31 EARTHWORK				7,443				7,917			15,359		20,274
		Clear & Grub				7,443				7,917			15,359		20,274
Demo Tank Holder #4															
	02	SITEWORK & DEMOLITION													
		Cutout demolition, concrete, slab on grade, bar reinforced, to 24" thick, Tank Holder #4	1,500.00 sf	25.08 /sf	76.28 /mh	37,615			5.85 /mh	2,885		27.00 /sf	40,500	35.64 /sf	53,460
		Demolition, concrete, walls, bar reinforced, 6-12 C.F	1,650.00 cf	13.93 /cf	76.28 /mh	22,987			5.85 /mh	1,763		15.00 /cf	24,750	19.80 /cf	32,670
		Rubbish handling, dumpster, 40 C.Y., 13 ton capacity, weekly rental, includes one dump per week	1.00 week				775.00 /wee	775				775.00 /wee	775	1,023.00 /wee	1,023
		Rubbish handling, 100' haul, load, haul to chute and dumping into chute	61.11 cy	73.32 /cy	75.61 /mh	4,481						73.32 /cy	4,481	96.78 /cy	5,914
		Rubbish handling, loading & trucking, chute loaded, including 2 mile haul	61.11 cy	53.84 /cy	75.72 /mh	3,290			67.85 /mh	737		65.90 /cy	4,027	86.99 /cy	5,316
		02 SITEWORK & DEMOLITION				68,373		775		5,385			74,533		98,383
		Demo Tank Holder #4				68,373		775		5,385			74,533		98,383
Demo Tank Holder #8															
	02	SITEWORK & DEMOLITION													
		Cutout demolition, concrete, slab on grade, bar reinforced, to 24" thick (Portion of Tank Holder #8 Demo'ed for MH 217-7)	1,500.00 sf	25.08 /sf	76.28 /mh	37,615			5.85 /mh	2,885		27.00 /sf	40,500	35.64 /sf	53,460
		02 SITEWORK & DEMOLITION				37,615				2,885			40,500		53,460
		Demo Tank Holder #8				37,615				2,885			40,500		53,460
Ductbank A-A															
	02	SITEWORK & DEMOLITION													
		Cycle hlng(,load,travel,unload dump&retrn) time per cycle,excvtd borrow,loose cubic yards,15 min ld/wt/,16.5 truck,cycle 20 miles,35 mph,loadng eqpmnt	7.50 lcy	4.34 /lcy	80.85 /mh	33			38.08 /mh	31		8.43 /lcy	63	11.13 /lcy	83
		02 SITEWORK & DEMOLITION				33				31			63		83
	03	CONCRETE													
		C.I.P. concrete forms, footing, continuous wall, plywood, 4 use, includes erecting, bracing, stripping and cleaning	1,260.00 sfca	7.70 /sfca	116.68 /mh	9,700	2.11 /sfca	2,652				9.80 /sfca	12,352	12.94 /sfca	16,305
		Structural concrete,ready mix,normal weight,4000 psi,includes local aggregate,sand,portland cement and water,excludes all additives and treatments	30.00 cy				113.15 /cy	3,395				113.15 /cy	3,395	149.36 /cy	4,481
		Structural concrete, placing, grade beam, direct chute, includes vibrating, excludes material	30.00 cy	39.02 /cy	121.94 /mh	1,171			3.20 /mh	10		39.36 /cy	1,181	51.96 /cy	1,559
		03 CONCRETE				10,870		6,047		10			16,928		22,344
	31	EARTHWORK													
		Base spacer, plastic duct, type DB, 6" diameter, installed by direct burial in duct bank	35.00 ea	2.80 /ea	111.82 /mh	98	4.44 /ea	155	/mh			7.24 /ea	253	9.55 /ea	334
		Disposal, soil disposal charges, in-state, excl. haul	7.50 CY				/CY					46.24 /CY	347	61.04 /CY	458
		Reinforcing Steel #4 A615, grade 60, incl labor for accessories - Rebar Ductbank Cage	1,500.00 lb	0.78 /lb	101.71 /mh	1,162	0.51 /lb	765	/mh			1.29 /lb	1,927	1.70 /lb	2,544
		Excavating, trench or continuous footing, common earth, 3/4 C.Y. excavator, 6' to 10' deep, excludes sheeting or dewatering	15.00 bcy	6.78 /bcy	95.28 /mh	102			83.70 /mh	45		9.75 /bcy	146	12.87 /bcy	193
		Backfill and compact, by hand, 6" layers, air rammer/tamper	7.50 ecy	18.23 /ecy	86.59 /mh	137			6.74 /mh	11		19.65 /ecy	147	25.93 /ecy	195
		31 EARTHWORK				1,499		920		55			2,821		3,724
		Ductbank A-A				12,402		6,967		96			19,812		26,152
Ductbank B-B															
	02	SITEWORK & DEMOLITION													
		Cycle hlng(,load,travel,unload dump&retrn) time per cycle,excvtd borrow,loose cubic yards,15 min ld/wt/,16.5 truck,cycle 20 miles,35 mph,loadng eqpmnt	2.20 lcy	4.34 /lcy	80.85 /mh	10			38.08 /mh	9		8.43 /lcy	19	11.13 /lcy	24
		02 SITEWORK & DEMOLITION				10				9			19		24
	03	CONCRETE													
		C.I.P. concrete forms, footing, continuous wall, plywood, 4 use, includes erecting, bracing, stripping and cleaning	880.00 sfca	7.70 /sfca	116.68 /mh	6,774	2.11 /sfca	1,852				9.80 /sfca	8,627	12.94 /sfca	11,387
		Structural concrete,ready mix,normal weight,4000 psi,includes local aggregate,sand,portland cement and water,excludes all additives and treatments	4.30 cy				113.15 /cy	487				113.15 /cy	487	149.36 /cy	642
		Structural concrete, placing, grade beam, direct chute, includes vibrating, excludes material	4.30 cy	39.02 /cy	121.94 /mh	168			3.20 /mh	1		39.36 /cy	169	51.96 /cy	223
		03 CONCRETE				6,942		2,339		1			9,283		12,253
	31	EARTHWORK													
		Disposal, soil disposal charges, in-state, excl. haul	2.20 CY				/CY					46.24 /CY	102	61.04 /CY	134
		Reinforcing Steel #4 A615, grade 60, incl labor for accessories - Rebar Ductbank Cage	500.00 lb	0.78 /lb	101.71 /mh	387	0.51 /lb	255	/mh			1.29 /lb	642	1.70 /lb	848
		Base spacer, plastic duct, type DB, 6" diameter, installed by direct burial in duct bank	10.00 ea	2.80 /ea	111.82 /mh	28	4.44 /ea	44	/mh			7.24 /ea	72	9.55 /ea	96
		Excavating, trench or continuous footing, common earth, 3/4 C.Y. excavator, 6' to 10' deep, excludes sheeting or dewatering	4.40 bcy	6.78 /bcy	95.28 /mh	30			83.70 /mh	13		9.75 /bcy	43	12.87 /bcy	57
		Backfill and compact, by hand, 6" layers, air rammer/tamper	2.20 ecy	18.23 /ecy	86.59 /mh	40			6.74 /mh	3		19.65 /ecy	43	25.93 /ecy	57
		31 EARTHWORK				485		299		16			903		1,192
		Ductbank B-B				7,437		2,638		27			10,204		13,469
Pavement Markings															
	32	EXTERIOR IMPROVEMENTS													
		Painted pavement markings, thermoplastic, white or yellow	2,000.00 sf	4.59 /sf	75.73 /mh	9,180	0.57 /sf	1,140	30.91 /mh	3,746		7.03 /sf	14,067	9.28 /sf	18,568
		32 EXTERIOR IMPROVEMENTS				9,180		1,140		3,746			14,067		18,568
		Pavement Markings				9,180		1,140		3,746			14,067		18,568
Paving															
	32	EXTERIOR IMPROVEMENTS													
		Base Course, Gravel, 12"deep	700.00 sy	1.57 /sy	92.93 /mh	1,095	13.55 /sy	9,485	93.94 /mh	831		16.30 /sy	11,411	21.52 /sy	15,062
		Asphalt Emulsion	200.00 gal	0.25 /gal	91.58 /mh	49	4.50 /gal	900	50.19 /mh	27		4.88 /gal	976	6.44 /gal	1,288
		Bitumious Binder Course, 6" thick	200.00 sy	3.18 /sy	88.47 /mh	635	21.21 /sy	4,241	112.19 /mh	220		25.48 /sy	5,096	33.63 /sy	6,727
		Bituminous Concrete Surface Course, 2" thick	1,000.00 sy	1.12 /sy	89.69 /mh	1,115	5.90 /sy	5,900	91.38 /mh	378		7.39 /sy	7,393	9.76 /sy	9,759
		Micromilling	1,000.00 sy	1.03 /sy	89.69 /mh	1,025	5.43 /sy	5,427	91.38 /mh	348		6.80 /sy	6,800	8.98 /sy	8,976
		32 EXTERIOR IMPROVEMENTS				3,920		25,953		1,803			31,676		41,812
		Paving				3,920		25,953		1,803			31,676		41,812
Replace Gas Valve															
	33	UTILITIES													
		Replacement of Gas Valve (Gas Company Quote)	1.00 LS								85,300	85,300.00 /LS	85,300	112,596.00 /LS	112,596
		33 UTILITIES									85,300		85,300		112,596
		Replace Gas Valve									85,300		85,300		112,596
Sidewalks															
	32	EXTERIOR IMPROVEMENTS													
		Sidewalks, driveways, and patios, sidewalk, concrete, cast-in-place with 6 x 6 - W1.4 x W1.4 mesh, broomed finish, 3000 psi, 4" thick, excludes base	800.00 sf	4.02 /sf	100.47 /mh	3,215	2.01 /sf	1,608				6.03 /sf	4,823	7.96 /sf	6,366

Location	CSI Div	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Grand Total Unit Price	Grand Total
		32 EXTERIOR IMPROVEMENTS				3,215		1,608					4,823		6,366
		Sidewalks				3,215		1,608					4,823		6,366
Temp. Relocate OHW															
	33	UTILITIES													
		Temporary Relocation of Overhead Wires	1.00 LS								25,000	25,000.00 /LS	25,000	33,000.00 /LS	33,000
		33 UTILITIES									25,000		25,000		33,000
		Temp. Relocate OHW									25,000		25,000		33,000
Waterline Relocation															
	33	UTILITIES													
		Waterline Relocation (Assume 100FT)	100.00 lf		/mh		150.00 /lf	15,000	/mh			150.00 /lf	15,000	198.00 /lf	19,800
		33 UTILITIES						15,000					15,000		19,800
		Waterline Relocation						15,000					15,000		19,800
		SITE				160,071		134,537		28,430	110,300		433,785		572,597
STRUCTURES															
Diversion Structure															
	04	STONE & MASONRY													
		Brick Invert	40.00 sf	30.86 /sf	83.58 /mh	1,234	9.14 /sf	366				40.00 /sf	1,600	52.80 /sf	2,112
		04 STONE & MASONRY				1,234		366					1,600		2,112
	05	METALS													
		Fiberglass reinforced polymer, #4 bar (Assumed 6" Spacing) - Bar Rack	26.00 lf	20.00 /lf	86.78 /mh	520	10.00 /lf	260				30.00 /lf	780	39.60 /lf	1,030
		05 METALS				520		260					780		1,030
	26	ELECTRICAL													
		Wire, copper, stranded, 600 volt, #3, type THW, in raceway	1.20 clf	135.17 /clf	84.48 /mh	162	105.00 /clf	126				240.17 /clf	288	317.02 /clf	380
		Building grounding system, average cost per sf	150.00 sf	1.57 /sf	84.48 /mh	236	0.93 /sf	139				2.50 /sf	375	3.30 /sf	495
		Smart metering, In panel, three phase, 277/480 volt, 400 amp	1.00 ea	144.10 /ea	84.48 /mh	144	880.00 /ea	880				1,024.10 /ea	1,024	1,351.81 /ea	1,352
		Panelboard, 120/208 V, 100 amp	1.00 ea	1,161.60 /ea	84.48 /mh	1,162	1,738.55 /ea	1,739				2,900.15 /ea	2,900	3,828.20 /ea	3,828
		Concrete Encased Conduits, PVC, 4 @ 4" diameter, includes excavation, backfill and cast in place concrete	35.00 lf	68.33 /lf	1,351.68 /cd	2,392	31.67 /lf	1,108				100.00 /lf	3,500	132.00 /lf	4,620
		26 ELECTRICAL				4,095		3,992					8,087		10,675
	31	EARTHWORK													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket	90.00 cy	14.82 /cy	83.36 /mh	1,334			83.70 /mh	670		22.26 /cy	2,003	29.38 /cy	2,644
		Backfill, trench, air tamped compaction	10.00 ecy	15.44 /ecy	77.22 /mh	154			8.91 /mh	36		19.01 /ecy	190	25.09 /ecy	251
		Soldier Pile & Lagging	2,444.00 sf	36.03 /sf	79.00 /mh	88,054	6.46 /sf	15,800	6.87 /mh	6,126		45.00 /sf	109,980	59.40 /sf	145,174
		31 EARTHWORK				89,542		15,800		6,831			112,173		148,069
	33	UTILITIES													
		Flap Gate	1.00 LS								10,000	10,000.00 /LS	10,000	13,200.00 /LS	13,200
		Diversion Structure, Precast Unit (Approx. 2500CF)	1.00 ea	29,999.96 /ea	79.30 /mh	30,000	242,000.00 /ea	242,000	234.00 /mh	3,120		275,119.96 /ea	275,120	363,158.34 /ea	363,158
		Electric Handholes	2.00 ea	2,211.40 /ea	110.57 /mh	4,423	3,000.00 /ea	6,000	32.38 /mh	185		5,303.90 /ea	10,608	7,001.15 /ea	14,002
		33 UTILITIES				34,423		248,000		3,305	10,000		295,728		390,361
		Diversion Structure	1.00 EA	129,814.50 /EA		129,814		268,418		10,136	10,000	418,368.66 /EA	418,369	552,246.63 /EA	552,247
MH 217-10															
	31	EARTHWORK													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket MH 217-10	22.22 cy	14.82 /cy	83.36 /mh	329			83.70 /mh	165		22.26 /cy	495	29.38 /cy	653
		Backfill, trench, air tamped compaction, add MH 217-10	5.40 ecy	15.44 /ecy	77.22 /mh	83			8.91 /mh	19		19.01 /ecy	103	25.09 /ecy	136
		31 EARTHWORK				413				185			597		788
	33	UTILITIES													
		Base slab; form, resteel and concrete to 8" thick, avg cost per CY	1.23 cy	243.51 /cy	84.08 /mh	300	217.00 /cy	268	3.20 /mh	1		461.18 /cy	569	608.74 /cy	751
		Utilty area drains,catch basins manhls catch basins manhls frames and covers,cast iron,heavy traffc,36"dm,1150lb, excluds footing,excavtn,and backfill MH 217-10	1.00 ea	613.46 /ea	76.68 /mh	613	875.00 /ea	875	39.05 /mh	104		1,592.59 /ea	1,593	2,102.22 /ea	2,102
		Storm Drainage Manholes, Frames, and Covers, concrete, precast, 8' I.D., excludes base, excavation, backfill, frame and cover MH 217-10	10.00 vlf	306.73 /vlf	76.68 /mh	3,067	515.00 /vlf	5,150	39.05 /mh	391		860.78 /vlf	8,608	1,136.23 /vlf	11,362
		33 UTILITIES				3,981		6,293		495			10,769		14,215
		MH 217-10	1.00 EA	4,393.78 /EA		4,394		6,293		680		11,366.37 /EA	11,366	15,003.61 /EA	15,004
MH 217-4															
	31	EARTHWORK													
		Rent 8" diam wellpoint discharge pipe - MH 217-4 DEWATERING	150.00 day						0.40 /day	60		0.40 /day	60	0.53 /day	79
		Rent wellpoint header pipe, 4" diameter, flow to 100 GPM - MH 217-4 DEWATERING	1,000.00 day						0.40 /day	400		0.40 /day	400	0.53 /day	528
		Rent wellpoint 25" long w/fittings & riser pipe 1-1/2" or 2" suction - MH 217-4 DEWATERING	50.00 day						3.20 /day	160		3.20 /day	160	4.22 /day	211
		Rent wellpoint pump, diesel, 20 HP, 4" suction - MH 217-4 DEWATERING	125.00 day						178.35 /day	22,294		178.35 /day	22,294	235.42 /day	29,428
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket MH 217-4	40.00 cy	14.82 /cy	83.36 /mh	593			83.70 /mh	298		22.26 /cy	890	29.38 /cy	1,175
		Wells, for dewatering, with steel casing, 10' to 20' deep, 2' diameter, average - MH 217-4 DEWATERING	40.00 vlf	18.78 /vlf	76.68 /mh	751	43.00 /vlf	1,720	39.05 /mh	128		64.97 /vlf	2,599	85.76 /vlf	3,430
		Wellpoints, single stage system, 0.75 labor hours per L.F., installation and removal, minimum - MH 217-4 DEWATERING	1,000.00 hdr	56.53 /hdr	75.61 /mh	56,531						56.53 /hdr	56,531	74.62 /hdr	74,620
		Wellpoints, pump operation, 4 @ 6 hour shifts, per 24 hour day - MH 217-4 DEWATERING	12.50 day	1,986.27 /day	78.83 /mh	24,828						1,986.27 /day	24,828	2,621.87 /day	32,773
		Backfill, trench, air tamped compaction, add MH 217-4	10.71 ecy	15.44 /ecy	77.22 /mh	165			8.91 /mh	38		19.01 /ecy	204	25.09 /ecy	269
		31 EARTHWORK				82,868		1,720		23,377			107,965		142,514
	33	UTILITIES													
		Base slab; form, resteel and concrete to 8" thick, avg cost per CY	1.23 cy	243.51 /cy	84.08 /mh	300	217.00 /cy	268	3.20 /mh	1		461.18 /cy	569	608.75 /cy	751
		Utilty area drains,catch basins manhls catch basins manhls frames and covers,cast iron,heavy traffc,36"dm,1150lb, excluds footing,excavtn,and backfill MH 217-5	1.00 ea	613.46 /ea	76.68 /mh	613	875.00 /ea	875	39.05 /mh	104		1,592.59 /ea	1,593	2,102.22 /ea	2,102
		Storm Drainage Manholes, Frames, and Covers, concrete, precast, 8' I.D., excludes base, excavation, backfill, frame and cover MH 217-5	10.00 vlf	306.73 /vlf	76.68 /mh	3,067	515.00 /vlf	5,150	39.05 /mh	391		860.78 /vlf	8,608	1,136.23 /vlf	11,362
		33 UTILITIES				3,981		6,293		495			10,769		14,215
		MH 217-4	1.00 EA	86,849.35 /EA		86,849		8,013		23,872		118,734.39 /EA	118,734	156,729.39 /EA	156,729
MH 217-5															
	31	EARTHWORK													
		Rent 8" diam wellpoint discharge pipe - MH 217-5 DEWATERING	150.00 day						0.40 /day	60		0.40 /day	60	0.53 /day	79
		Rent wellpoint header pipe, 4" diameter, flow to 100 GPM - MH 217-5 DEWATERING	1,000.00 day						0.40 /day	400		0.40 /day	400	0.53 /day	528
		Rent wellpoint 25" long w/fittings & riser pipe 1-1/2" or 2" suction - MH 217-5 DEWATERING	50.00 day						3.20 /day	160		3.20 /day	160	4.22 /day	211
		Rent wellpoint pump, diesel, 20 HP, 4" suction - MH 217-5 DEWATERING	125.00 day						178.35 /day	22,294		178.35 /day	22,294	235.42 /day	29,428
		Wells, for dewatering, with steel casing, 10' to 20' deep, 2' diameter, average - MH 217-5 DEWATERING	40.00 vlf	18.78 /vlf	76.68 /mh	751	43.00 /vlf	1,720	39.05 /mh	128		64.97 /vlf	2,599	85.76 /vlf	3,430
		Wellpoints, single stage system, 0.75 labor hours per L.F., installation and removal, minimum - MH 217-5 DEWATERING	1,000.00 hdr	56.53 /hdr	75.61 /mh	56,531						56.53 /hdr	56,531	74.62 /hdr	74,620
		Wellpoints, pump operation, 4 @ 6 hour shifts, per 24 hour day - MH 217-5 DEWATERING	12.50 day	1,986.27 /day	78.83 /mh	24,828						1,986.27 /day	24,828	2,621.87 /day	32,773
		Backfill, trench, air tamped compaction, add MH 217-5	10.71 ecy	15.44 /ecy	77.22 /mh	165			8.91 /mh	38		19.01 /ecy	204	25.09 /ecy	269
		31 EARTHWORK				82,276		1,720		23,079			107,075		141,339
	33	UTILITIES													
		Base slab; form, resteel and concrete to 8" thick, avg cost per CY	1.23 cy	243.51 /cy	84.08 /mh	300	217.00 /cy	268	3.20 /mh	1		461.18 /cy	569	608.75 /cy	751
		Utilty area drains,catch basins manhls catch basins manhls frames and covers,cast iron,heavy traffc,36"dm,1150lb, excluds footing,excavtn,and backfill MH 217-5	1.00 ea	613.46 /ea	76.68 /mh	613	875.00 /ea	875	39.05 /mh	104		1,592.59 /ea	1,593	2,102.22 /ea	2,102
		Storm Drainage Manholes, Frames, and Covers, concrete, precast, 8' I.D., excludes base, excavation, backfill, frame and cover MH 217-5	10.00 vlf	306.73 /vlf	76.68 /mh	3,067	515.00 /vlf	5,150	39.05 /mh	391		860.78 /vlf	8,608	1,136.23 /vlf	11,362
		33 UTILITIES				3,981		6,293		495			10,769		14,215
		MH 217-5	1.00 EA	86,256.56 /EA		86,257		8,013		23,575		117,844.00 /EA	117,844	155,554.08 /EA	155,554
MH 217-6															

CITY POINT PARTNERS

Location	CSI Div	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Grand Total Unit Price	Grand Total
	31	EARTHWORK													
		Dewatering, pumping, 8 hr., attended 2 hours per day, 2" diaphragm pump used for 8 hours, includes 20 l.f. suction hose and 100 l.f. of discharge hose - 4 Sumps	72.00 day	249.97 /day	83.32 /mh	17,998			2.40 /mh	1,381		269.15 /day	19,379	355.28 /day	25,580
		Dewatering, sump hole construction, pit with gravel collar, corrugated, 12" gravel collar, 18" corr. pipe, 16 ga, includes excavation and gravel pit - 4 Sumps	40.00 lf	36.81 /lf	76.68 /mh	1,472	32.00 /lf	1,280	39.05 /mh	250		75.06 /lf	3,002	99.07 /lf	3,963
		Backfill, trench, air tamped compaction, add MH 217-6	115.00 ecy	15.44 /ecy	77.22 /mh	1,776			8.91 /mh	410		19.01 /ecy	2,186	25.09 /ecy	2,885
		31 EARTHWORK				21,246		1,280		2,041			24,567		32,429
	33	UTILITIES													
		Base slab; form, resteel and concrete to 8" thick, avg cost per CY	1.23 cy	243.51 /cy	84.08 /mh	300	217.00 /cy	268	3.20 /mh	1		461.18 /cy	569	608.75 /cy	751
		Utilty area drains,catch basins manhls catch basins manhls frames and covers,cast iron,heavy traffc,36"dm,1150lb, excluds footing,excavtn,and backfill	1.00 ea	613.46 /ea	76.68 /mh	613	875.00 /ea	875	39.05 /mh	104		1,592.59 /ea	1,593	2,102.22 /ea	2,102
		Storm Drainage Manholes, Frames, and Covers, concrete, precast, 8' I.D., excludes base, excavation, backfill, frame and cover MH 217-6	29.00 vlf	230.05 /vlf	76.68 /mh	6,671	515.00 /vlf	14,935	39.05 /mh	1,132		784.10 /vlf	22,739	1,035.01 /vlf	30,015
		33 UTILITIES				7,585		16,078		1,237			24,900		32,868
		MH 217-6	1.00 EA	28,831.27 /EA		28,831		17,358		3,278		49,467.21 /EA	49,467	65,296.72 /EA	65,297
MH 217-7															
	31	EARTHWORK													
		Dewatering, pumping, 8 hr., attended 2 hours per day, 2" diaphragm pump used for 8 hours, includes 20 l.f. suction hose and 100 l.f. of discharge hose - 4 Sumps	72.00 day	249.97 /day	83.32 /mh	17,998			2.40 /mh	1,381		269.15 /day	19,379	355.28 /day	25,580
		Dewatering, sump hole construction, pit with gravel collar, corrugated, 12" gravel collar, 18" corr. pipe, 16 ga, includes excavation and gravel pit - 4 Sumps	40.00 lf	36.81 /lf	76.68 /mh	1,472	32.00 /lf	1,280	39.05 /mh	250		75.06 /lf	3,002	99.07 /lf	3,963
		Backfill, trench, air tamped compaction, add MH 217-7	92.60 ecy	15.44 /ecy	77.22 /mh	1,430			8.91 /mh	330		19.01 /ecy	1,760	25.09 /ecy	2,323
		31 EARTHWORK				20,900		1,280		1,961			24,141		31,867
	33	UTILITIES													
		Base slab; form, resteel and concrete to 8" thick, avg cost per CY	1.23 cy	243.51 /cy	84.08 /mh	300	217.00 /cy	268	3.20 /mh	1		461.18 /cy	569	608.74 /cy	751
		Utilty area drains,catch basins manhls catch basins manhls frames and covers,cast iron,heavy traffc,36"dm,1150lb, excluds footing,excavtn,and backfill MH 217-7	1.00 ea	613.46 /ea	76.68 /mh	613	875.00 /ea	875	39.05 /mh	104		1,592.59 /ea	1,593	2,102.22 /ea	2,102
		Storm Drainage Manholes, Frames, and Covers, concrete, precast, 8' I.D., excludes base, excavation, backfill, frame and cover MH 217-7	18.00 vlf	306.73 /vlf	76.68 /mh	5,521	515.00 /vlf	9,270	39.05 /mh	703		860.78 /vlf	15,494	1,136.23 /vlf	20,452
		33 UTILITIES				6,435		10,413		808			17,655		23,305
		MH 217-7	1.00 EA	27,335.08 /EA		27,335		11,693		2,769		41,796.65 /EA	41,797	55,171.58 /EA	55,172
Reconnection Str.															
	03	CONCRETE													
		Concrete, ready mix, regular weight, 4000 psi - Below Brick	7.50 cy				128.00 /cy	960				128.00 /cy	960	168.96 /cy	1,267
		03 CONCRETE						960					960		1,267
	04	STONE & MASONRY													
		Brick Invert	25.00 sf	30.86 /sf	83.58 /mh	772	9.14 /sf	228				40.00 /sf	1,000	52.80 /sf	1,320
		04 STONE & MASONRY				772		228					1,000		1,320
	31	EARTHWORK													
		Excavate pit, common earth, hyd backhoe, 3/4 CY bucket	70.00 cy	14.82 /cy	83.36 /mh	1,037			83.70 /mh	521		22.26 /cy	1,558	29.38 /cy	2,057
		Backfill, trench, air tamped compaction	18.00 ecy	15.44 /ecy	77.22 /mh	278			8.91 /mh	64		19.01 /ecy	342	25.09 /ecy	452
		Soldier Pile & Lagging	600.00 sf	36.03 /sf	79.00 /mh	21,617	6.46 /sf	3,879	6.87 /mh	1,504		45.00 /sf	27,000	59.40 /sf	35,640
		31 EARTHWORK				22,933		3,879		2,089			28,900		38,148
	33	UTILITIES													
		Reconnection Structure, Precast, (Approx. 1500CF)	1.00 ea	22,499.99 /ea	79.30 /mh	22,500	121,000.00 /ea	121,000	234.00 /mh	3,120		146,619.99 /ea	146,620	193,538.39 /ea	193,538
		33 UTILITIES				22,500		121,000		3,120			146,620		193,538
		Reconnection Str.	1.00 EA	46,204.09 /EA		46,204		126,067		5,209		177,480.32 /EA	177,480	234,274.02 /EA	234,274
		STRUCTURES				409,685		445,854		69,519	10,000		935,058		1,234,276
		SUBTOTAL DIRECT COST											11,553,661		
		OVERHEAD & PROFIT	12%										1,386,439		
		DESIGN CONTINGENCY	20%										2,310,732		
		GRAND TOTAL											15,250,833		
		RECOMMENDED ESCALATION	6.85%												

APPENDIX 9
OPINION OF PROBABLE CONSTRUCTION SCHEDULE

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Schedule 60% CTD Submittal

Phase III Combined Sewer Overflow Program

IIIA-5 OF-217 Consolidation Conduit

Data Date: July 31, 2021 (Advertise Date)

Prepared for

The Narragansett Bay Commission

Prepared by

CITY POINT PARTNERS
A WBE/DBE Firm

December 22, 2020

Table of Contents

I. CTD SUMMARY

The 60% CTD schedule begins with an Advertisement Date of July 31, 2021 as the initial data date and projects an NTP date of December 03, 2021. The Substantial Completion of contract IIIA-5 is calculated at 495 calendar days to April 12, 2023 and with a total of 556 calendar days from NTP to Contractor Field Completion on June 12, 2023.

The CTD schedule was developed using Primavera P6 Version R16.2 software.

The following milestones are included in the CTD schedule:

Milestones No.	Phase III Combined Sewer Overflow Program, Pawtucket, RI - IIIA-5 CTD Activity Name	Current Submission 60% CTD	
		Dates	Durations from NTP
ADV	Advertise Date	31-Jul-21	N/A
BDO	Bid Opening	29-Aug-21	N/A
NTP	Issue Contractor NTP	03-Dec-21	N/A
Milestones			
SC IIIA-5	Substantial Completion Contract IIIA-5	12-Apr-23	495
CFC	Contractor Field Completion	12-Jun-23	556

II. PURPOSE

The schedule and the narrative are developed for the sole use of Narragansett Bay Commission (NBC) and should not be shared with the contractor. The CTD is prepared using Critical Path Method (CPM) scheduling techniques to estimate the duration for the construction portion of the project and is generated to demonstrate that there is at least one reasonable/buildable plan to finish the project within the time frame specified. This CTD considers most critical constructability aspects as part of this planning effort, however, not all constructability aspects have been drafted/commented upon as part of this CTD. This CTD schedule is based on the 60% design and is intended to provide a baseline comparison of what is a reasonable and achievable duration for the construction of the project.

III. PROJECT DESCRIPTION

Contract IIIA-5, the OF-217 consolidation conduit, includes construction of precast OF-217 diversion structures, manhole over the existing OF-217 and additional precast manhole structures. It includes approximately 1540 linear feet of microtunneling operation, 350 linear feet of 48” RCP, 42” RCP and 12” RCP installed in open trench.

IV. REFERENCES

The 60% CTD was developed using information contained in the following documents:

- 60% Plans - PHASE III COMBINED SEWER OVERFLOW PROGRAM OF-217 CONSOLIDATION CONDUIT CONTRACT NO. 308.05C 60% DESIGN December 2020
- 60% Cost Estimate – PHASE IIIA-5 CSO Program - 60% Estimate - 12-17-2020 (Developed by City Point Partners as part of this submission)

V. METHODOLOGY

Beta Group, Inc. has engaged City Point Partners LLC to develop a 60% contractors time determination (CTD) schedule for this project. After reviewing the reference information for the project and the Narragansett Bay Commission requirements, the scope of work was identified and analyzed. The 60% cost estimate was used as the starting point for the schedule to maintain traceability between the two documents. The project scope was further broken down into a work breakdown structure (WBS) of work categories and elements, and further detailed into a discrete set of items of work (activities). The duration of each activity was calculated based on the quantity take offs, estimated hours and productivity, previous historical data, as well as equipment efficiencies and crew compositions. After defining the activities which represent the scope of the project, logical relationships between the activities were created to reflect the sequencing in which the work will be performed. The schedule was then calculated based on the activity durations, and the sequence of the activities. The application of the resources over time was evaluated based on the number of activities worked during the construction of each phase, and restrictions based on assumptions of availability of labor and equipment.

Two standard calendars have been used in the development of the schedule:

1. Cal01-7d/8hr/NoHol(ms) - Those activities which are milestones, administrative or long-range tracking such as submittals, are using a 7-day, 8-hour work calendar with no holidays.

2. Cal02-5d/8hr/10hol - The primary calendar is a 5-day, 8-hour work calendar with 10 federal holidays for all work activities.
3. Cal02-5d/8hr/10hol Winter Shutdown- The primary calendar is a 5-day, 8-hour work calendar with 10 federal holidays and winter restriction from December 15 to March 31 for weather sensitive work activities.

VI. CRITICAL PATH

For this CTD, a project's critical path is the longest continuous path of activities through the project. The critical path determines the completion date of the project. A delay of any of the activities on the critical path will delay the completion date of the project.

To provide an understanding of the critical path, a written description is below. The full schedule and critical path reports are attached with the narrative.

The project's critical path begins with the preconstruction activities including the advertising date followed by the Bid Opening, Issue Notice of Award, Notice to Proceed followed by the submittals.

Contract IIIA-5 on critical path starts contractor mobilization followed by the initial sitework activities for traffic control, erosion control, installation of dewatering system, clearing and grubbing and utility protection. Microtunneling from MH 217-7 to Station 16+67 is next on critical path followed by the activities for microtunneling from MH 217-7 to MH 217-6, microtunneling from MH 217-6 to MH 217-5. The final activities on critical path include repairing of cap system, installation of topsoil, installation of final paving and removal of safety signing and equipment leading to Substantial Completion of Contract IIIA-5.

The milestone Substantial Completion is next followed by the NBC/RIDOT punch list inspection, punch list, project documentation and closeout and contractor demobilization leading to the Contractor Field Completion milestone.

VII. ASSUMPTIONS

Schedule Sequencing Assumptions

The project is subdivided into the following work structure:

- Milestones and Bid Phase
- Preconstruction for Permits Submittals and Long Lead Items
- Construction of IIIA-5
- Closeout Activities

Work under IIIA-5:

The work begins with mobilization of the contractor followed by clearing and grubbing, installation temporary traffic controls and safety signing, erosion control, test pits and utility protection.

The consolidation conduit will be installed in the following sequence:

1. Microtunneling from MH 217-7 as driving pit to Station 16+67 as receiving pit.
2. Microtunneling from MH 217-7 as driving pit to MH 217-6 as receiving pit. MH 217-7 will be installed after the microtunneling operation is complete in this stage.
3. Microtunneling from MH 217-6 as driving pit to MH 217-5 as receiving pit. MH 217-5 will be installed after the microtunneling operation is complete in this stage.
4. Open trench from STA 16+67 to Diversion Structure 217.
5. Open trench from Diversion Structure 217 to outfall.
6. Open trench from diversion structure 217 to MH 217-10 followed by the installation of MH 217-10 and Diversion Structure 217.
7. Open trench from diversion structure 217 to MH 217-8 followed by the installation of MH 217-8.
8. Open trench from MH 217-5 to MH 217-4 followed by the installation of MH 217-4.

Final activities under IIIA-5 include repairing cap system, installation of topsoil and removal of temporary safety signage.

Activity Assumptions

The following assumptions for durations were made for microtunneling activities. The following tasks are consolidated into activities that are included in the schedule.

Driving Pit Activities

Mobilize Drive Shaft Equipment (7 Days)

- Microtunnel Machine
- Hydraulic Jacking Equipment
- Operation and Power Distribution Cabins
- Slurry pumping and separation equipment
- Lubrication Equipment
- Cranes
- Generators

Assemble and Prep Drive Shaft Equipment (12 Days)

- Set Cranes
- Set and Test Generators
- Microtunnel Machine
- Hydraulic Jacking Equipment
- Operation and Power Distribution Cabins
- Slurry pumping and separation equipment
- Lubrication Equipment

Construct and Setup Drive Shaft Operations

- Concrete Base Slab Poured
- Thrust Wall and Entrance Portal poured and cured
- Install Jacking Rig and MTBM
- Setup Microtunnel/Pipe Jack System
- Test MTBM/Pipe jacking System

Reception Shaft Activities

Mobilize and Prep Reception Shaft Equipment (1 Days)

- Set Cranes

Construct and Setup Drive Shaft Operations (Varies by Location)

- Concrete Base Slab Poured and cured
- Form and Pour Exit Portal and Sealing Gaskets
- Install Receiving Rig

VIII. RISKS

The following are concerns that can have an impact on the anticipated construction schedule:

1. Activities for utilities to be performed by other utility companies with their force account personnel are not included in the 60% CTD schedule. If there is utility work identified in the future, there will be substantial increase in the overall project duration.
2. The preparation and review and approval of submittals are critical to the beginning of the project. Any delay to submittals will delay the start of construction. There are multiple agencies involved in the project, including NBC and RIDOT coordination which will need to be closely coordinated.
3. Time of Year (TOY) restrictions are not anticipated to impact construction. Any slowdown of construction due to winter weather conditions will impact the completion of the project. Currently this schedule continues with work which may require winter shutdown periods.

IX. RESOURCES

Activities in the schedule that require specialty equipment required for construction will need to be planned for and scheduled in advance to avoid any impact to the schedule, especially microtunneling and headhouse and other structure equipment and associated electrical work. The activities on the critical path require diligence in all aspects of the construction sequencing to ensure timely delivery. The availability of equipment and labor resources and materials for microtunneling and pipe jacking must be monitored carefully prior to the installation of consolidation conduit.

X. COST

The schedule is not cost, or resource loaded. The current available cost and quantity estimates were utilized to derive the activity and schedule duration. Refer to the current cost estimate for quantities and project value.

XI. LIMITATIONS OF OPERATIONS

HOLIDAY WORK RESTRICTIONS FOR CALENDAR YEAR 2021

The schedule has incorporated the federal holiday restrictions as outlined below into the calendars for the CTD schedule as per the special provisions of the work as described below.

Below are the holiday work restrictions for the Calendar Year 2021. Assuming for CTD schedule that subsequent years are applied in the same fashion.

New Year’s Day (Federal Holiday)
Friday, January 1, 2021

Martin Luther King's Birthday (Federal Holiday)
Monday, January 18, 2021

President's Day (Federal Holiday)
Monday, February 15, 2021

Memorial Day (Federal Holiday)
Monday, May 31, 2021

Independence Day (Federal Holiday)
Sunday, July 4, 2021

Labor Day (Federal Holiday)
Monday, September 6, 2021

Columbus Day (Federal Holiday)
Monday, October 11, 2021

Veterans' Day (Federal Holiday)
Thursday, November 11, 2021

Thanksgiving Day (Federal Holiday)
Thursday, November 25, 2021

Christmas Day (Federal Holiday)
Friday, December 25, 2021

XII. TRAFFIC CONTROL

Taft Street traffic is diverted to Pleasant Street during construction. This does not have any impact on the schedule.

XIII. ATTACHMENTS

a. **Full Detailed Schedule Report**

b. **Critical Path Report**

c. **Electronic File – NBCPhaseIIISewer IIIA-5 60%CTD.XER**

Prepared by,

Apoorva Paruchuri
Lead Project Controls Specialist

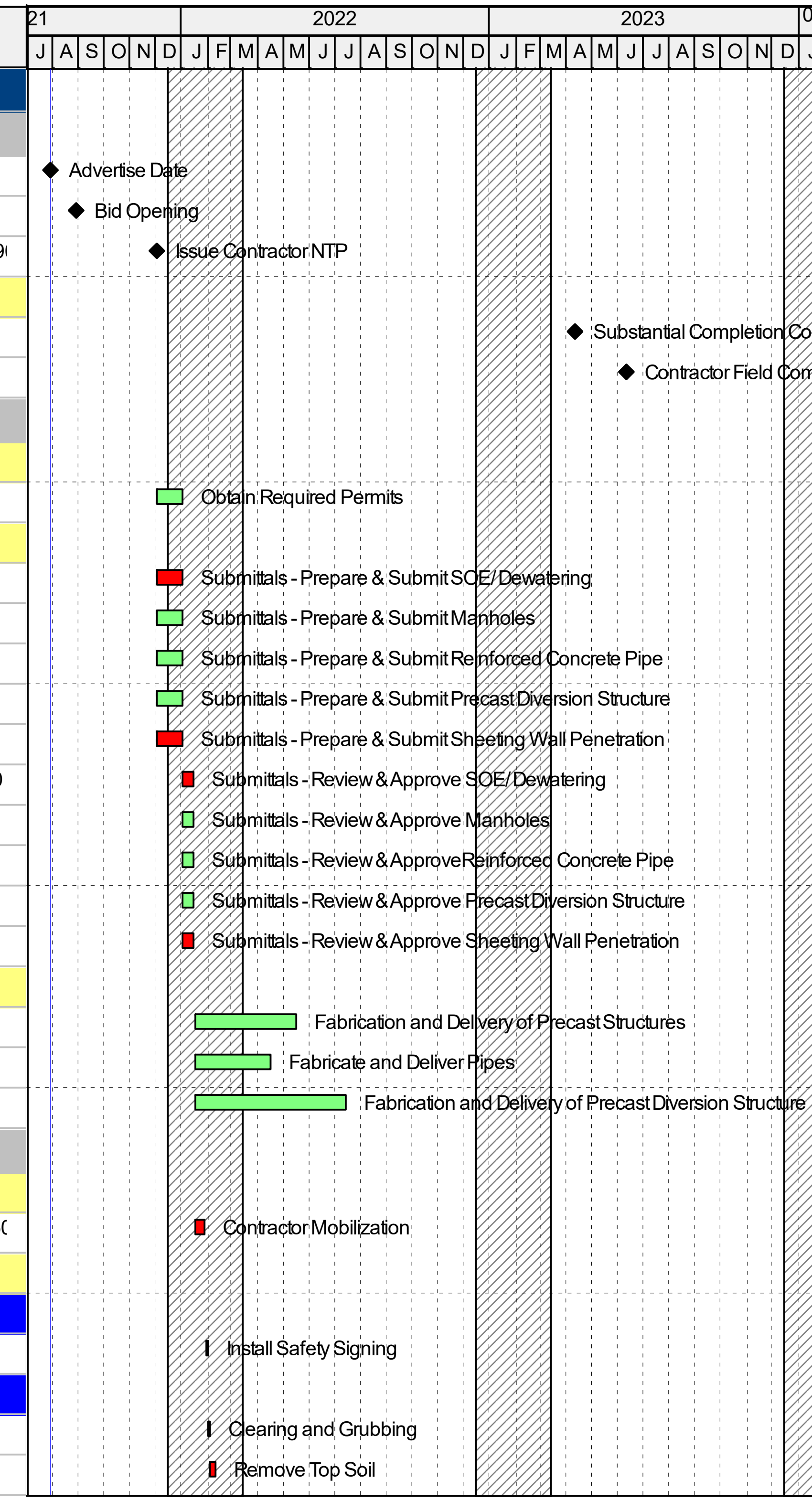
Vashisht Reddy
Project Controls Specialist

Jim Stetson
VP Project Controls
City Point Partners LLC

Project Name: RI NBC Abatement IIIA-5 60% CTD

Phase III Combined Sewer Overflow Program, Pawtucket, RI
60% CTD - All Activities

Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
RI NBC Abatement IIIA-5 60% CTD			467	0	31-Jul-21	12-Jun-23		
Milestones		Cal01-7d/8Hr/No Hol (ms)	682	0	31-Jul-21	12-Jun-23		
ADV	Advertise Date	Cal01-7d/8Hr/No Hol (ms)	0	0	31-Jul-21			BDO
BDO	Bid Opening	Cal01-7d/8Hr/No Hol (ms)	0	0		29-Aug-21	ADV	NTP
NTP	Issue Contractor NTP	Cal01-7d/8Hr/No Hol (ms)	0	0	03-Dec-21		BDO	P1830, P1600, P1870, P189
Milestones		Cal01-7d/8Hr/No Hol (ms)	61	0	12-Apr-23	12-Jun-23		
SC IIIA-5	Substantial Completion Contract IIIA-5	Cal01-7d/8Hr/No Hol (ms)	0	0		12-Apr-23	A6060	C330, C380, C350
CFC	Contractor Field Completion	Cal01-7d/8Hr/No Hol (ms)	0	0		12-Jun-23	C360, C330, C380, C3	
Preconstruction		Cal01-7d/8Hr/No Hol (ms)	225	213	03-Dec-21	15-Jul-22		
Permits		Cal01-7d/8Hr/No Hol (ms)	30	15	03-Dec-21	01-Jan-22		
P1600	Obtain Required Permits	Cal01-7d/8Hr/No Hol (ms)	30	15	03-Dec-21	01-Jan-22	NTP	C070
Submittals		Cal01-7d/8Hr/No Hol (ms)	45	273	03-Dec-21	16-Jan-22		
P1830	Submittals - Prepare & Submit SOE/ Dewatering	Cal01-7d/8Hr/No Hol (ms)	30	0	03-Dec-21	01-Jan-22	NTP	P1840
P1870	Submittals - Prepare & Submit Manholes	Cal01-7d/8Hr/No Hol (ms)	30	273	03-Dec-21	01-Jan-22	NTP	P1880
P1890	Submittals - Prepare & Submit Reinforced Concrete Pipe	Cal01-7d/8Hr/No Hol (ms)	30	8	03-Dec-21	01-Jan-22	NTP	P1900
P1910	Submittals - Prepare & Submit Precast Diversion Structure	Cal01-7d/8Hr/No Hol (ms)	30	11	03-Dec-21	01-Jan-22	NTP	P1920
P1930	Submittals - Prepare & Submit Sheeting Wall Penetration	Cal01-7d/8Hr/No Hol (ms)	30	0	03-Dec-21	01-Jan-22	NTP	P1940
P1840	Submittals - Review & Approve SOE/ Dewatering	Cal01-7d/8Hr/No Hol (ms)	15	0	02-Jan-22	16-Jan-22	P1830	C070, P1850, P1860, A1760
P1880	Submittals - Review & Approve Manholes	Cal01-7d/8Hr/No Hol (ms)	15	273	02-Jan-22	16-Jan-22	P1870	P1850
P1900	Submittals - Review & Approve Reinforced Concrete Pipe	Cal01-7d/8Hr/No Hol (ms)	15	8	02-Jan-22	16-Jan-22	P1890	P1860
P1920	Submittals - Review & Approve Precast Diversion Structure	Cal01-7d/8Hr/No Hol (ms)	15	11	02-Jan-22	16-Jan-22	P1910	P1950
P1940	Submittals - Review & Approve Sheeting Wall Penetration	Cal01-7d/8Hr/No Hol (ms)	15	0	02-Jan-22	16-Jan-22	P1930	C070
Long Lead Items		Cal01-7d/8Hr/No Hol (ms)	180	213	17-Jan-22	15-Jul-22		
P1850	Fabrication and Delivery of Precast Structures	Cal01-7d/8Hr/No Hol (ms)	120	273	17-Jan-22	16-May-22	P1840, P1880	A5960, A6020
P1860	Fabricate and Deliver Pipes	Cal01-7d/8Hr/No Hol (ms)	90	8	17-Jan-22	16-Apr-22	P1840, P1900	A5400, A5800, A4980
P1950	Fabrication and Delivery of Precast Diversion Structure	Cal01-7d/8Hr/No Hol (ms)	180	11	17-Jan-22	15-Jul-22	P1920	A5260
Contract IIIA-5			312	0	17-Jan-22	12-Apr-23		
Mobilization		Cal02-5d/8Hr/10hol	10	0	17-Jan-22	28-Jan-22		
C070	Contractor Mobilization	Cal02-5d/8Hr/10hol	10	0	17-Jan-22	28-Jan-22	P1840, P1600, P1940	A1030, A1760, A1000, A105
Initial Sitework		Cal02-5d/8Hr/10hol	28	0	31-Jan-22	10-Mar-22		
Construction Road Signing & Barriers		Cal02-5d/8Hr/10hol	2	0	31-Jan-22	01-Feb-22		
A1760	Install Safety Signing	Cal02-5d/8Hr/10hol	2	0	31-Jan-22	01-Feb-22	C070, P1840	A1000
Clearing & Grubbing		Cal02-5d/8Hr/10hol	7	0	02-Feb-22	10-Feb-22		
A1000	Clearing and Grubbing	Cal02-5d/8Hr/10hol	2	0	02-Feb-22	03-Feb-22	C070, A1760	A1030, A1040, A1010
A1010	Remove Top Soil	Cal02-5d/8Hr/10hol	5	0	04-Feb-22	10-Feb-22	A1000	A1030



Actual Work
Remaining Work
Critical Remaining Work
Milestone

User = aparuchuri, Filter = TASK filter: All Activities
Data Date = 31-Jul-21, Run Date = 22-Dec-20, 15:54
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Date	Revision	Checked	Approved

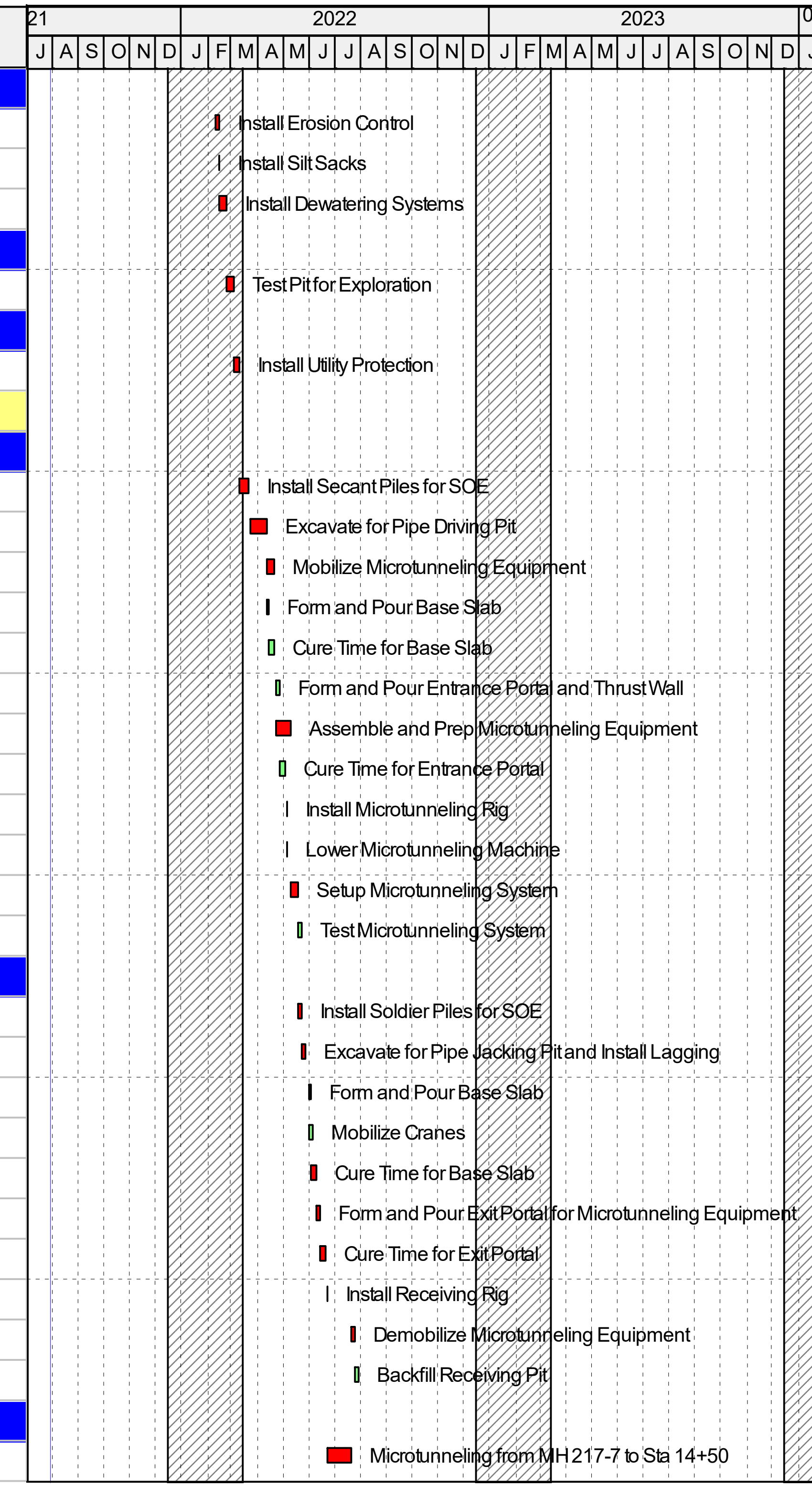
Prepared by CPP

CITY POINT PARTNERS

Project Name: RI NBC Abatement IIIA-5 60% CTD

Phase III Combined Sewer Overflow Program, Pawtucket, RI
60% CTD - All Activities

Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
Erosion Control		Cal02-5d/8Hr/10hol	7	0	11-Feb-22	22-Feb-22		
A1030	Install Erosion Control	Cal02-5d/8Hr/10hol	2	0	11-Feb-22	14-Feb-22	C070,A1000,A1010	A1040,A6880
A1040	Install Silt Sacks	Cal02-5d/8Hr/10hol	1	4	15-Feb-22	15-Feb-22	A1000,A1030	A1050
A6880	Install Dewatering Systems	Cal02-5d/8Hr/10hol	5	0	15-Feb-22	22-Feb-22	A1030	A6600,A1050,A4980
Testing and Test Pits		Cal02-5d/8Hr/10hol	7	0	23-Feb-22	03-Mar-22		
A1050	Test Pit for Exploration	Cal02-5d/8Hr/10hol	7	0	23-Feb-22	03-Mar-22	C070,A1040,A6880	A1060
Utilities		Cal02-5d/8Hr/10hol	5	0	04-Mar-22	10-Mar-22		
A1060	Install Utility Protection	Cal02-5d/8Hr/10hol	5	0	04-Mar-22	10-Mar-22	A1050	A6600,A5360,A6150
Microtunneling MH 217-7 to Sta 16+67			98	149	11-Mar-22	29-Jul-22		
Driving Pit @ MH 217-7			51	21	11-Mar-22	23-May-22		
A6600	Install Secant Piles for SOE	Cal02-5d/8Hr/10hol	8	0	11-Mar-22	22-Mar-22	A1060,A6880	A6610
A6610	Excavate for Pipe Driving Pit	Cal02-5d/8Hr/10hol	14	0	23-Mar-22	11-Apr-22	A6600	A6620,A6540,A4980
A6540	Mobilize Microtunneling Equipment	Cal02-5d/8Hr/10hol	7	0	12-Apr-22	21-Apr-22	A6610	A6560,A6550
A6620	Form and Pour Base Slab	Cal02-5d/8Hr/10hol	3	1	12-Apr-22	14-Apr-22	A6610	A6630
A6630	Cure Time for Base Slab	Cal01-7d/8Hr/No Hol (ms)	7	3	15-Apr-22	21-Apr-22	A6620	A6210
A6210	Form and Pour Entrance Portal and Thrust Wall	Cal02-5d/8Hr/10hol	4	1	22-Apr-22	27-Apr-22	A6630	A6220
A6550	Assemble and Prep Microtunneling Equipment	Cal02-5d/8Hr/10hol	12	0	22-Apr-22	09-May-22	A6540	A6580
A6220	Cure Time for Entrance Portal	Cal01-7d/8Hr/No Hol (ms)	7	1	28-Apr-22	04-May-22	A6210	A6560
A6560	Install Microtunneling Rig	Cal02-5d/8Hr/10hol	1	1	05-May-22	05-May-22	A6540,A6220	A6570
A6570	Lower Microtunneling Machine	Cal02-5d/8Hr/10hol	1	1	06-May-22	06-May-22	A6560	A6580
A6580	Setup Microtunneling System	Cal02-5d/8Hr/10hol	7	0	10-May-22	18-May-22	A6570,A6550	A6590,A5410
A6590	Test Microtunneling System	Cal02-5d/8Hr/10hol	3	21	19-May-22	23-May-22	A6580	A5400
Receiving Pit @ Sta 14+50			50	149	19-May-22	29-Jul-22		
A5410	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	3	0	19-May-22	23-May-22	A6580	A5420
A5420	Excavate for Pipe Jacking Pit and Install Lagging	Cal02-5d/8Hr/10hol	4	0	24-May-22	27-May-22	A5410	A5430,A5620
A5430	Form and Pour Base Slab	Cal02-5d/8Hr/10hol	3	0	31-May-22	02-Jun-22	A5420	A5440
A5620	Mobilize Cranes	Cal02-5d/8Hr/10hol	5	11	31-May-22	06-Jun-22	A5420	A5470
A5440	Cure Time for Base Slab	Cal01-7d/8Hr/No Hol (ms)	7	0	03-Jun-22	09-Jun-22	A5430	A5450
A5450	Form and Pour Exit Portal for Microtunneling Equipment	Cal02-5d/8Hr/10hol	3	0	10-Jun-22	14-Jun-22	A5440	A5460
A5460	Cure Time for Exit Portal	Cal01-7d/8Hr/No Hol (ms)	7	0	15-Jun-22	21-Jun-22	A5450	A5470
A5470	Install Receiving Rig	Cal02-5d/8Hr/10hol	1	0	22-Jun-22	22-Jun-22	A5460,A5620	A5400
A5480	Demobilize Microtunneling Equipment	Cal02-5d/8Hr/10hol	2	0	22-Jul-22	25-Jul-22	A5400	A5490,A5340
A5490	Backfill Receiving Pit	Cal02-5d/8Hr/10hol	4	149	26-Jul-22	29-Jul-22	A5480	A6370
Microtunneling		Cal02-5d/8Hr/10hol	20	0	23-Jun-22	21-Jul-22		
A5400	Microtunneling from MH 217-7 to Sta 14+50	Cal02-5d/8Hr/10hol	20	0	23-Jun-22	21-Jul-22	A5470,P1860,A6590	A5480



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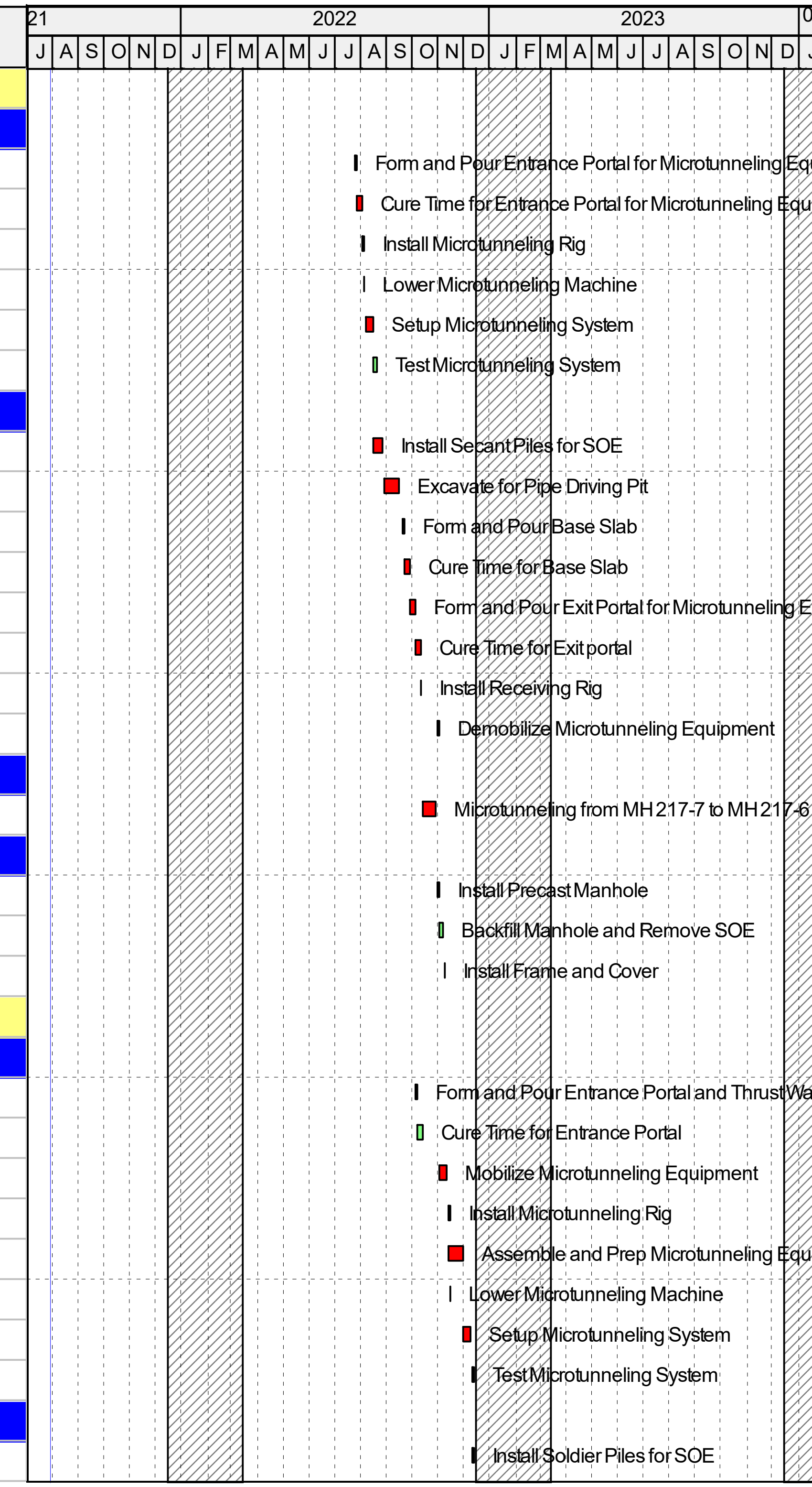
Date	Revision	Checked	Approved

Prepared by CPP

Project Name: RI NBC Abatement IIIA-5 60% CTD	Phase III Combined Sewer Overflow Program, Pawtucket, RI 60% CTD - All Activities

Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
Microtunneling MH 217-7 to MH 217-6			74	65	26-Jul-22	08-Nov-22		
Driving Pit @ MH 217-7			19	36	26-Jul-22	19-Aug-22		
A5340	Form and Pour Entrance Portal for Microtunneling Equipment	Cal02-5d/8Hr/10hol	2	0	26-Jul-22	27-Jul-22	A5480	A5350
A5350	Cure Time for Entrance Portal for Microtunneling Equipment	Cal01-7d/8Hr/No Hol (ms)	7	0	28-Jul-22	03-Aug-22	A5340	A5360
A5360	Install Microtunneling Rig	Cal02-5d/8Hr/10hol	1	0	04-Aug-22	04-Aug-22	A5350,A1060	A5600,A6640
A6640	Lower Microtunneling Machine	Cal02-5d/8Hr/10hol	1	0	05-Aug-22	05-Aug-22	A5360	A6650
A6650	Setup Microtunneling System	Cal02-5d/8Hr/10hol	7	0	08-Aug-22	16-Aug-22	A6640	A6660,A6690
A6660	Test Microtunneling System	Cal02-5d/8Hr/10hol	3	36	17-Aug-22	19-Aug-22	A6650	A5600
Receiving Pit @ MH 217-6			53	0	17-Aug-22	01-Nov-22		
A6690	Install Secant Piles for SOE	Cal02-5d/8Hr/10hol	8	0	17-Aug-22	26-Aug-22	A6650	A6700
A6700	Excavate for Pipe Driving Pit	Cal02-5d/8Hr/10hol	14	0	29-Aug-22	16-Sep-22	A6690	A6670
A6670	Form and Pour Base Slab	Cal02-5d/8Hr/10hol	3	0	19-Sep-22	21-Sep-22	A6700	A6680
A6680	Cure Time for Base Slab	Cal01-7d/8Hr/No Hol (ms)	7	0	22-Sep-22	28-Sep-22	A6670	A5740
A5740	Form and Pour Exit Portal for Microtunneling Equipment	Cal02-5d/8Hr/10hol	4	0	29-Sep-22	04-Oct-22	A6680	A5750,A6150
A5750	Cure Time for Exit portal	Cal01-7d/8Hr/No Hol (ms)	7	0	05-Oct-22	11-Oct-22	A5740	A6500
A6500	Install Receiving Rig	Cal02-5d/8Hr/10hol	1	0	12-Oct-22	12-Oct-22	A5750	A5600
A5680	Demobilize Microtunneling Equipment	Cal02-5d/8Hr/10hol	2	0	31-Oct-22	01-Nov-22	A5600	A6120
Microtunneling		Cal02-5d/8Hr/10hol	12	0	13-Oct-22	28-Oct-22		
A5600	Microtunneling from MH 217-7 to MH 217-6	Cal02-5d/8Hr/10hol	12	0	13-Oct-22	28-Oct-22	A5360,A6660,A6500	A5680,A5990
MH 217-7 Construction		Cal02-5d/8Hr/10hol	7	65	31-Oct-22	08-Nov-22		
A5990	Install Precast Manhole	Cal02-5d/8Hr/10hol	3	65	31-Oct-22	02-Nov-22	A5600	A5970
A5970	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol	3	65	03-Nov-22	07-Nov-22	A5990	A5980
A5980	Install Frame and Cover	Cal02-5d/8Hr/10hol	1	65	08-Nov-22	08-Nov-22	A5970	A6020
Microtunneling MH 217-6 to MH 217-5			103	0	05-Oct-22	06-Mar-23		
Driving Pit @ MH 217-6			48	19	05-Oct-22	14-Dec-22		
A6150	Form and Pour Entrance Portal and Thrust Wall	Cal02-5d/8Hr/10hol	2	30	05-Oct-22	06-Oct-22	A1060,A5740	A6160
A6160	Cure Time for Entrance Portal	Cal01-7d/8Hr/No Hol (ms)	7	46	07-Oct-22	13-Oct-22	A6150	A6170
A6120	Mobilize Microtunneling Equipment	Cal02-5d/8Hr/10hol	7	0	02-Nov-22	10-Nov-22	A5680	A6170,A6140
A6170	Install Microtunneling Rig	Cal02-5d/8Hr/10hol	1	10	14-Nov-22	14-Nov-22	A6160,A6120	A6180
A6140	Assemble and Prep Microtunneling Equipment	Cal02-5d/8Hr/10hol	12	0	14-Nov-22	30-Nov-22	A6120	A6190,A5810
A6180	Lower Microtunneling Machine	Cal02-5d/8Hr/10hol	1	10	15-Nov-22	15-Nov-22	A6170	A6190
A6190	Setup Microtunneling System	Cal02-5d/8Hr/10hol	7	0	01-Dec-22	09-Dec-22	A6180,A6140	A6200,A5870,A5810
A6200	Test Microtunneling System	Cal02-5d/8Hr/10hol	3	19	12-Dec-22	14-Dec-22	A6190	A5800
Receiving Pit @ MH 217-5			49	9	12-Dec-22	21-Feb-23		
A5810	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	3	0	12-Dec-22	14-Dec-22	A6140,A6190	A5820



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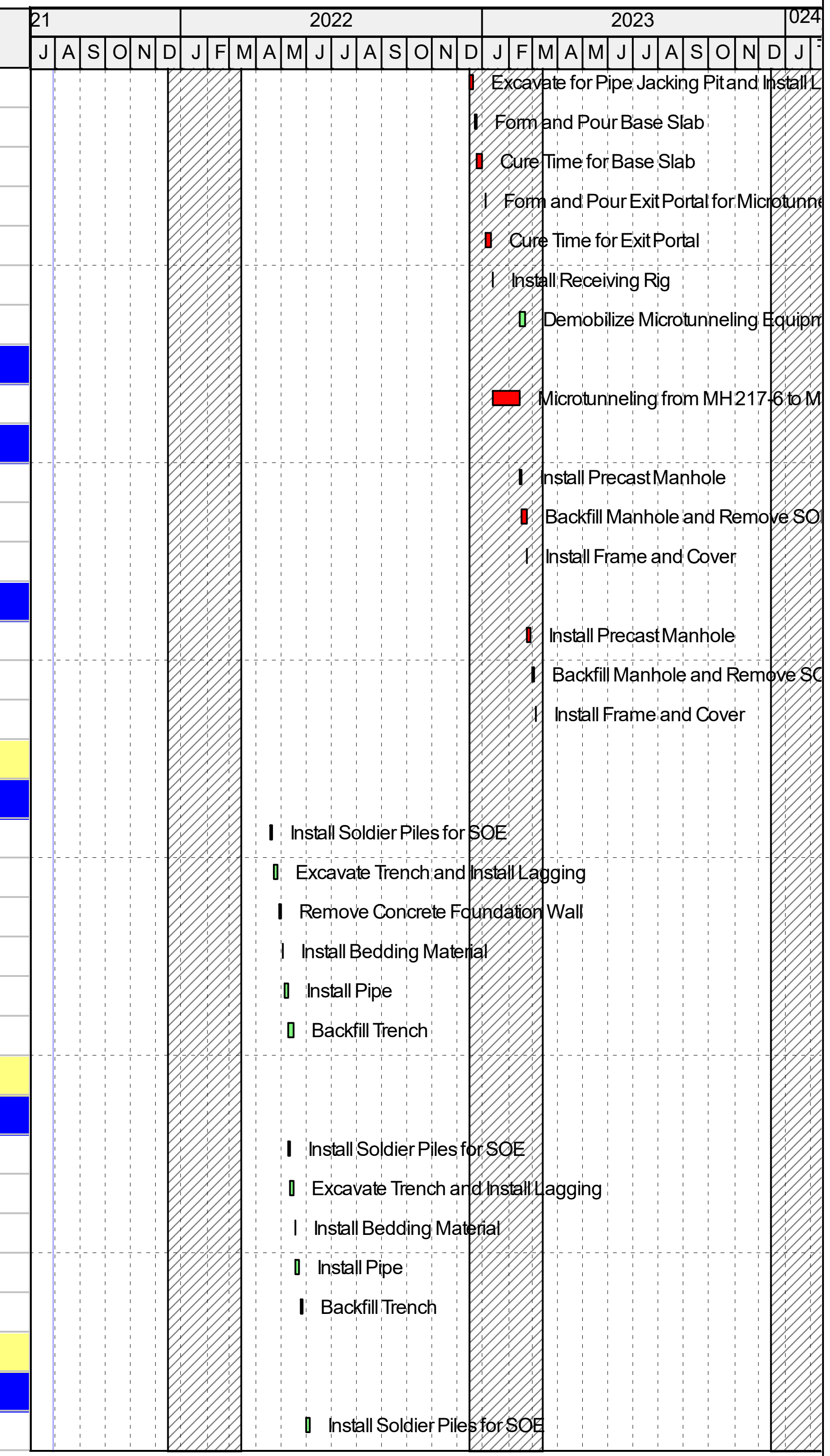
Date	Revision	Checked	Approved

Prepared by CPP

Project Name: RI NBC Abatement IIIA-5 60% CTD

Phase III Combined Sewer Overflow Program, Pawtucket, RI
60% CTD - All Activities

Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
A5820	Excavate for Pipe Jacking Pit and Install Lagging	Cal02-5d/8Hr/10hol	4	0	15-Dec-22	20-Dec-22	A5810	A5830
A5830	Form and Pour Base Slab	Cal02-5d/8Hr/10hol	3	0	21-Dec-22	23-Dec-22	A5820	A5840
A5840	Cure Time for Base Slab	Cal01-7d/8Hr/No Hol (ms)	7	3	24-Dec-22	30-Dec-22	A5830	A5850
A5850	Form and Pour Exit Portal for Microtunneling Equipment	Cal02-5d/8Hr/10hol	2	0	03-Jan-23	04-Jan-23	A5840	A5860
A5860	Cure Time for Exit Portal	Cal01-7d/8Hr/No Hol (ms)	7	0	05-Jan-23	11-Jan-23	A5850	A5870
A5870	Install Receiving Rig	Cal02-5d/8Hr/10hol	1	0	12-Jan-23	12-Jan-23	A5860,A6190	A5800
A5880	Demobilize Microtunneling Equipment	Cal02-5d/8Hr/10hol	5	9	14-Feb-23	21-Feb-23	A5800	A6370
Microtunneling		Cal02-5d/8Hr/10hol	22	0	13-Jan-23	13-Feb-23		
A5800	Microtunneling from MH 217-6 to MH 217-5	Cal02-5d/8Hr/10hol	22	0	13-Jan-23	13-Feb-23	A6200,A5870,P1860	A5880,A6020,A5960
MH 217-5 Construction		Cal02-5d/8Hr/10hol	7	0	14-Feb-23	23-Feb-23		
A6020	Install Precast Manhole	Cal02-5d/8Hr/10hol	3	0	14-Feb-23	16-Feb-23	A5800,P1850,A5980	A6000
A6000	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol	3	0	17-Feb-23	22-Feb-23	A6020	A6010
A6010	Install Frame and Cover	Cal02-5d/8Hr/10hol	1	0	23-Feb-23	23-Feb-23	A6000	A5960
MH 217-6 Construction		Cal02-5d/8Hr/10hol	7	0	24-Feb-23	06-Mar-23		
A5960	Install Precast Manhole	Cal02-5d/8Hr/10hol	3	0	24-Feb-23	28-Feb-23	P1850,A5800,A6010	A5940
A5940	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol	3	0	01-Mar-23	03-Mar-23	A5960	A5950
A5950	Install Frame and Cover	Cal02-5d/8Hr/10hol	1	0	06-Mar-23	06-Mar-23	A5940	A6370
Open Trench from Sta 16+67 to Diversion Structure 217		Cal02-5d/8Hr/10hol	20	13	19-Apr-22	16-May-22		
Pipe Installation		Cal02-5d/8Hr/10hol	20	13	19-Apr-22	16-May-22		
A4980	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	3	4	19-Apr-22	21-Apr-22	A6610,P1860,A6880	A4990,A5260
A4990	Excavate Trench and Install Lagging	Cal02-5d/8Hr/10hol	5	4	22-Apr-22	28-Apr-22	A4980	A5000,A5120
A5120	Remove Concrete Foundation Wall	Cal02-5d/8Hr/10hol	2	4	29-Apr-22	02-May-22	A4990	A5000
A5000	Install Bedding Material	Cal02-5d/8Hr/10hol	2	4	03-May-22	04-May-22	A4990,A5120	A5010
A5010	Install Pipe	Cal02-5d/8Hr/10hol	3	4	05-May-22	09-May-22	A5000	A5020,A5260,A6820
A5020	Backfill Trench	Cal02-5d/8Hr/10hol	5	13	10-May-22	16-May-22	A5010	A6320
Open Trench from Sta Diversion Structure 217 to Outfall		Cal02-5d/8Hr/10hol	14	4	10-May-22	27-May-22		
Pipe Installation		Cal02-5d/8Hr/10hol	14	4	10-May-22	27-May-22		
A6820	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	3	4	10-May-22	12-May-22	A5010	A6830
A6830	Excavate Trench and Install Lagging	Cal02-5d/8Hr/10hol	3	4	13-May-22	17-May-22	A6820	A6840
A6840	Install Bedding Material	Cal02-5d/8Hr/10hol	2	4	18-May-22	19-May-22	A6830	A6850
A6850	Install Pipe	Cal02-5d/8Hr/10hol	3	4	20-May-22	24-May-22	A6840	A6860,A5260
A6860	Backfill Trench	Cal02-5d/8Hr/10hol	3	4	25-May-22	27-May-22	A6850	A6320
Open Trench from Diversion Str 217 to MH 217-10		Cal02-5d/8Hr/10hol	63	4	31-May-22	26-Aug-22		
Pipe Installation		Cal02-5d/8Hr/10hol	36	4	31-May-22	20-Jul-22		
A6320	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	5	4	31-May-22	06-Jun-22	A5020,A6860	A6330



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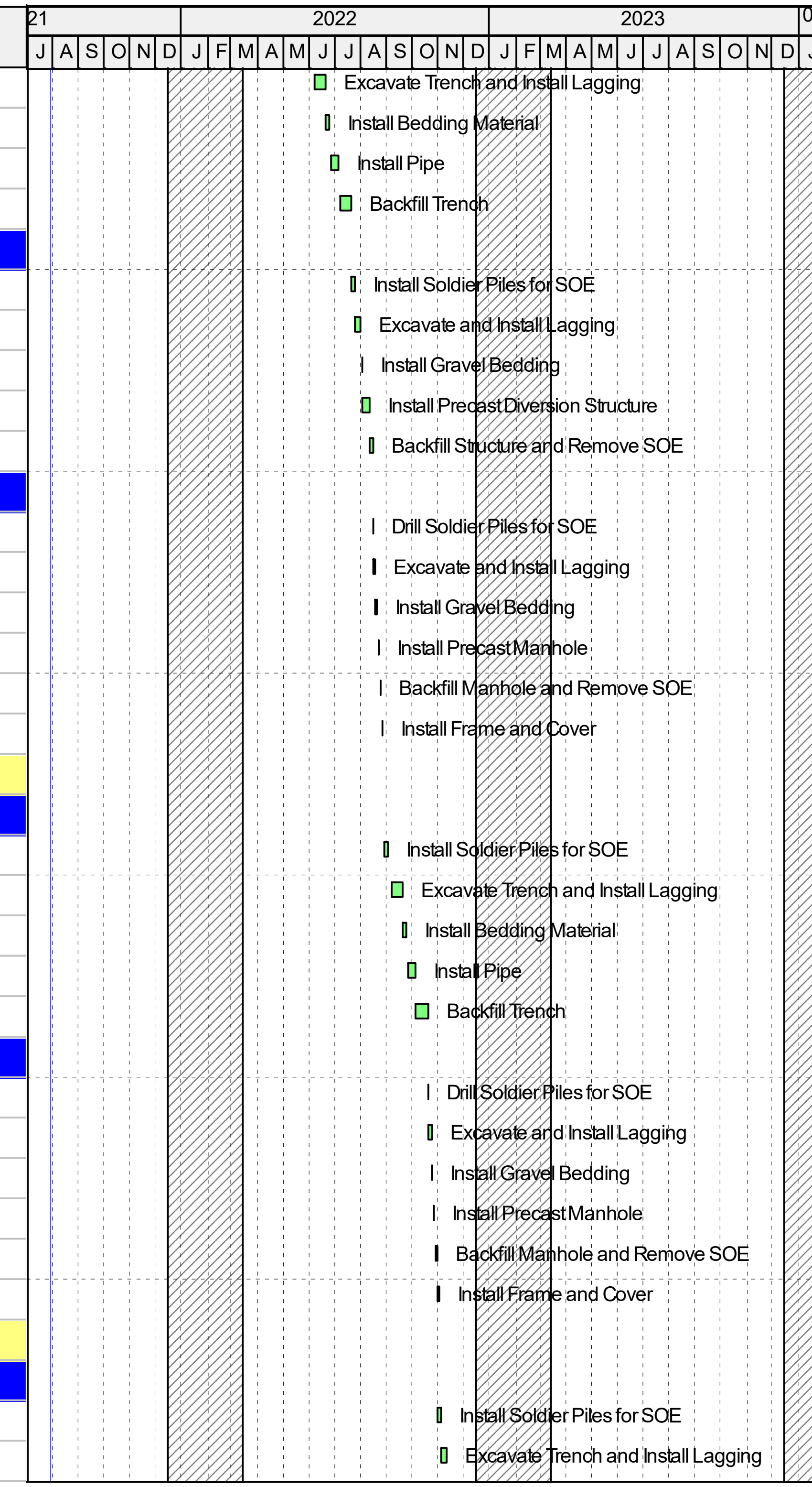
Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
A6330	Excavate Trench and Install Lagging	Cal02-5d/8Hr/10hol	10	4	07-Jun-22	20-Jun-22	A6320	A6340
A6340	Install Bedding Material	Cal02-5d/8Hr/10hol	4	4	21-Jun-22	24-Jun-22	A6330	A6350
A6350	Install Pipe	Cal02-5d/8Hr/10hol	7	4	27-Jun-22	06-Jul-22	A6340	A6360,A6260
A6360	Backfill Trench	Cal02-5d/8Hr/10hol	10	4	07-Jul-22	20-Jul-22	A6350	A6260,A5260
	Diversion Structure 217 Construction	Cal02-5d/8Hr/10hol	18	4	21-Jul-22	15-Aug-22		
A5260	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	3	4	21-Jul-22	25-Jul-22	A4980,A5010,P1950,	A5270
A5270	Excavate and Install Lagging	Cal02-5d/8Hr/10hol	5	4	26-Jul-22	01-Aug-22	A5260	A5280
A5280	Install Gravel Bedding	Cal02-5d/8Hr/10hol	1	4	02-Aug-22	02-Aug-22	A5270	A5200
A5200	Install Precast Diversion Structure	Cal02-5d/8Hr/10hol	7	4	03-Aug-22	11-Aug-22	A5280	A5290
A5290	Backfill Structure and Remove SOE	Cal02-5d/8Hr/10hol	2	4	12-Aug-22	15-Aug-22	A5200	A6260
	MH 217-10 Construction	Cal02-5d/8Hr/10hol	9	4	16-Aug-22	26-Aug-22		
A6260	Drill Soldier Piles for SOE	Cal02-5d/8Hr/10hol	1	4	16-Aug-22	16-Aug-22	A6350,A6360,A5290	A6270
A6270	Excavate and Install Lagging	Cal02-5d/8Hr/10hol	2	4	17-Aug-22	18-Aug-22	A6260	A6280
A6280	Install Gravel Bedding	Cal02-5d/8Hr/10hol	1	4	19-Aug-22	19-Aug-22	A6270	A6310,A5150
A6310	Install Precast Manhole	Cal02-5d/8Hr/10hol	2	4	22-Aug-22	23-Aug-22	A6280	A6290
A6290	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol	2	4	24-Aug-22	25-Aug-22	A6310	A6300
A6300	Install Frame and Cover	Cal02-5d/8Hr/10hol	1	4	26-Aug-22	26-Aug-22	A6290	A5150
	Open Trench from Diversion Str 217 to MH 217-8	Cal02-5d/8Hr/10hol	45	84	29-Aug-22	01-Nov-22		
	Pipe Installation	Cal02-5d/8Hr/10hol	36	4	29-Aug-22	19-Oct-22		
A5150	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol	5	4	29-Aug-22	02-Sep-22	A6300,A6280	A5160
A5160	Excavate Trench and Install Lagging	Cal02-5d/8Hr/10hol	10	4	06-Sep-22	19-Sep-22	A5150	A5170
A5170	Install Bedding Material	Cal02-5d/8Hr/10hol	4	4	20-Sep-22	23-Sep-22	A5160	A5180
A5180	Install Pipe	Cal02-5d/8Hr/10hol	7	4	26-Sep-22	04-Oct-22	A5170	A5190,A4890
A5190	Backfill Trench	Cal02-5d/8Hr/10hol	10	4	05-Oct-22	19-Oct-22	A5180	A4890
	MH 217-8 Construction	Cal02-5d/8Hr/10hol	9	84	20-Oct-22	01-Nov-22		
A4890	Drill Soldier Piles for SOE	Cal02-5d/8Hr/10hol	1	4	20-Oct-22	20-Oct-22	A5180,A5190	A4900
A4900	Excavate and Install Lagging	Cal02-5d/8Hr/10hol	2	4	21-Oct-22	24-Oct-22	A4890	A4910
A4910	Install Gravel Bedding	Cal02-5d/8Hr/10hol	1	4	25-Oct-22	25-Oct-22	A4900	A4940
A4940	Install Precast Manhole	Cal02-5d/8Hr/10hol	2	4	26-Oct-22	27-Oct-22	A4910	A4920
A4920	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol	2	4	28-Oct-22	31-Oct-22	A4940	A4930,A6770,A6910
A4930	Install Frame and Cover	Cal02-5d/8Hr/10hol	1	84	01-Nov-22	01-Nov-22	A4920	A6370
	Open Trench from Diversion Str 217-5 to MH 217-4	Cal02-5d/8Hr/10hol Winter Shutdown	26	4	01-Nov-22	08-Dec-22		
	Pipe Installation	Cal02-5d/8Hr/10hol Winter Shutdown	17	4	01-Nov-22	25-Nov-22		
A6770	Install Soldier Piles for SOE	Cal02-5d/8Hr/10hol Winter Shutdown	3	4	01-Nov-22	03-Nov-22	A4920	A6780
A6780	Excavate Trench and Install Lagging	Cal02-5d/8Hr/10hol Winter Shutdown	5	4	04-Nov-22	10-Nov-22	A6770	A6790



Legend	
	Actual Work
	Remaining Work
	Critical Remaining Work
◆ ◆	Milestone

User = aparuchuri, Filter = TASK filter: All Activities
Data Date = 31-Jul-21, Run Date = 22-Dec-20, 15:54
Project Start = 31-Jul-21 Project Finish = 12-Jun-23

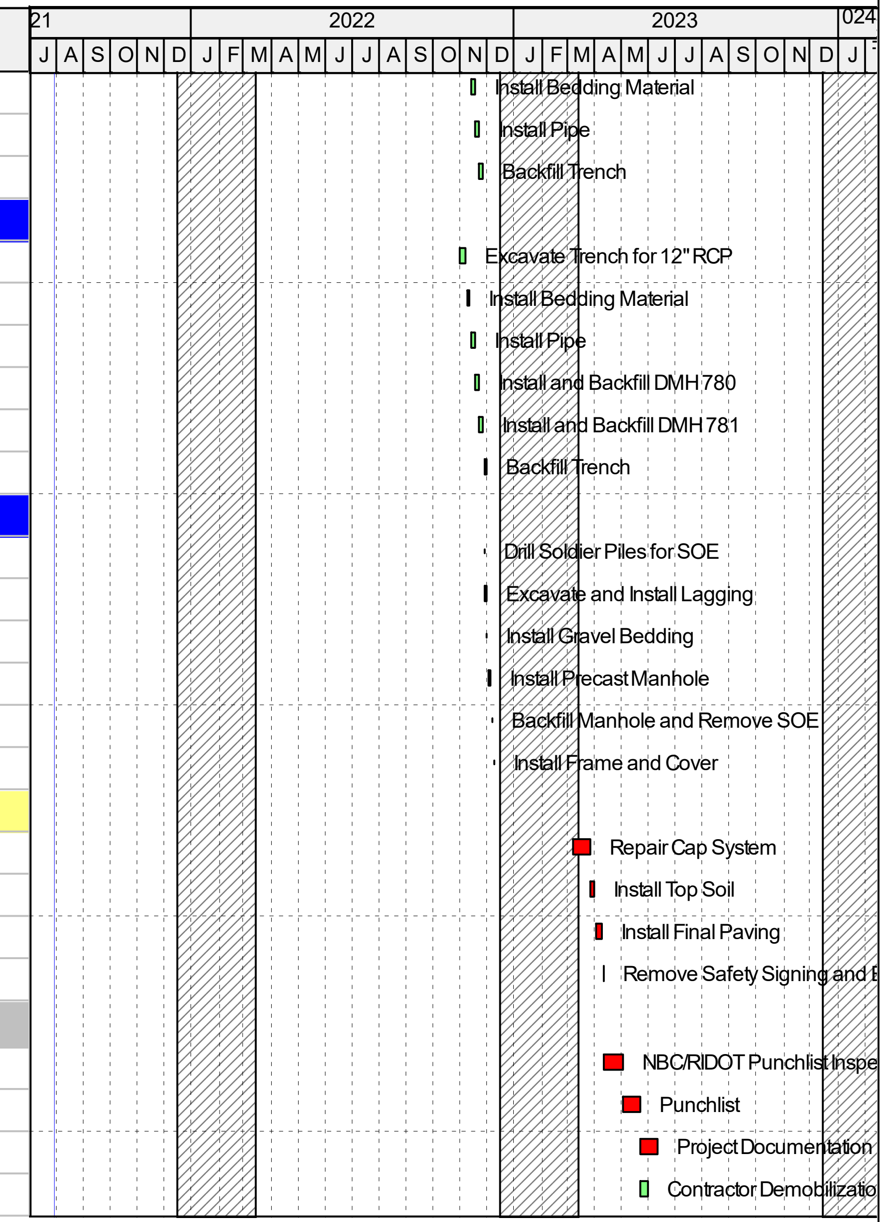
Date	Revision	Checked	Approved

Prepared by CPP

Project Name: RI NBC Abatement IIIA-5 60% CTD

Phase III Combined Sewer Overflow Program, Pawtucket, RI
60% CTD - All Activities

Activity ID	Activity Name	Calendar	OD	Total Float	Start	Finish	Predecessors	Successors
A6790	Install Bedding Material	Cal02-5d/8Hr/10hol Winter Shutdown	3	4	14-Nov-22	16-Nov-22	A6780	A6800
A6800	Install Pipe	Cal02-5d/8Hr/10hol Winter Shutdown	3	4	17-Nov-22	21-Nov-22	A6790	A6810,A6710
A6810	Backfill Trench	Cal02-5d/8Hr/10hol Winter Shutdown	3	4	22-Nov-22	25-Nov-22	A6800	A6710
Pipe Installation from Taft Street CB to MH 781		Cal02-5d/8Hr/10hol Winter Shutdown	19	11	01-Nov-22	29-Nov-22		
A6910	Excavate Trench for 12" RCP	Cal02-5d/8Hr/10hol Winter Shutdown	5	11	01-Nov-22	07-Nov-22	A4920	A6920
A6920	Install Bedding Material	Cal02-5d/8Hr/10hol Winter Shutdown	3	11	08-Nov-22	10-Nov-22	A6910	A6930
A6930	Install Pipe	Cal02-5d/8Hr/10hol Winter Shutdown	3	11	14-Nov-22	16-Nov-22	A6920	A6940,A6950
A6950	Install and Backfill DMH 780	Cal02-5d/8Hr/10hol Winter Shutdown	3	11	17-Nov-22	21-Nov-22	A6930	A6960
A6960	Install and Backfill DMH 781	Cal02-5d/8Hr/10hol Winter Shutdown	3	11	22-Nov-22	25-Nov-22	A6950	A6940
A6940	Backfill Trench	Cal02-5d/8Hr/10hol Winter Shutdown	2	11	28-Nov-22	29-Nov-22	A6930,A6960	A6370
MH 217-4 Construction		Cal02-5d/8Hr/10hol Winter Shutdown	9	4	28-Nov-22	08-Dec-22		
A6710	Drill Soldier Piles for SOE	Cal02-5d/8Hr/10hol Winter Shutdown	1	4	28-Nov-22	28-Nov-22	A6800,A6810	A6720
A6720	Excavate and Install Lagging	Cal02-5d/8Hr/10hol Winter Shutdown	2	4	29-Nov-22	30-Nov-22	A6710	A6730
A6730	Install Gravel Bedding	Cal02-5d/8Hr/10hol Winter Shutdown	1	4	01-Dec-22	01-Dec-22	A6720	A6760
A6760	Install Precast Manhole	Cal02-5d/8Hr/10hol Winter Shutdown	2	4	02-Dec-22	05-Dec-22	A6730	A6740
A6740	Backfill Manhole and Remove SOE	Cal02-5d/8Hr/10hol Winter Shutdown	2	4	06-Dec-22	07-Dec-22	A6760	A6750
A6750	Install Frame and Cover	Cal02-5d/8Hr/10hol Winter Shutdown	1	4	08-Dec-22	08-Dec-22	A6740	A6370
Final Activities		Cal02-5d/8Hr/10hol	27	0	07-Mar-23	12-Apr-23		
A6370	Repair Cap System	Cal02-5d/8Hr/10hol	15	0	07-Mar-23	27-Mar-23	A5490,A4930,A5950,	A6070
A6070	Install Top Soil	Cal02-5d/8Hr/10hol	4	0	28-Mar-23	31-Mar-23	A6370	A6060,A6890
A6890	Install Final Paving	Cal02-5d/8Hr/10hol	6	0	03-Apr-23	10-Apr-23	A6070	A6060
A6060	Remove Safety Signing and Equipment	Cal02-5d/8Hr/10hol	2	0	11-Apr-23	12-Apr-23	A6070,A6890	SC IIIA-5
Close-Out			41	0	12-Apr-23	12-Jun-23		
C350	NBC/RIDOT Punchlist Inspection	Cal04-7d/8Hr/No Hol (ms)	21	0	12-Apr-23	03-May-23	SC IIIA-5	CFC, C380, C330
C330	Punchlist	Cal04-7d/8Hr/No Hol (ms)	20	0	03-May-23	23-May-23	SC IIIA-5, C350	CFC, C380, C360
C360	Project Documentation and Closeout	Cal04-7d/8Hr/No Hol (ms)	20	0	23-May-23	12-Jun-23	C330	CFC
C380	Contractor Demobilization	Cal02-5d/8Hr/10hol	5	8	24-May-23	31-May-23	C330, C350, SC IIIA-5	CFC



Actual Work
Remaining Work
Critical Remaining Work
Milestone

User = aparuchuri, Filter = TASK filter: All Activities
Data Date = 31-Jul-21, Run Date = 22-Dec-20, 15:54
Project Start = 31-Jul-21 Project Finish = 12-Jun-23

Date	Revision	Checked	Approved

Prepared by CPP

CITY POINT PARTNERS

APPENDIX 10
PROGRAM DESIGN CHECKLIST &
QA/QC STATEMENT

60% Design Project Checklist

Project Name: Contract IIIA-5

Project Manager (DC): Chris Cronin, P.E. BETA Group, Inc.

Project Manager (PM/CM): **Date Completed:**

Planning/Design Manager Approval (PM/CM): **Date Approved:**

Chief Engineer/Program PTL Approval (PM/CM): **Date Approved:**

60% Submittal Date: **60% Milestone Date:**

Purpose: The 60% design should generally consist of the proposed alignment and profile, location of all structures, resolution of utility conflicts, property lines, proposed utility relocations, and easements. The intent is for the design to show an essentially complete project to allow a complete PM/CM, NBC, utility, municipal, and permitting review to including contract drawings, project manual, cost estimate, and subsurface investigations. The 60% submittal should include all Division 0 and Division 1 specifications essentially complete with draft versions of all remaining specification sections. The 60% design documents should identify anticipated type and limits of temporary SOE, construction dewatering, present findings of field investigations during previous phase, and prepare documentation to support permit level plans for regulatory submission. OPCC should be consistent with OPCC standards.

This **60% Design Project Checklist** is provided to Project Managers and Design Consultants responsible for project design. Items presented in this checklist are a compilation of industry-standard design criteria, program specific design criteria and general lessons learned from previously constructed projects. This list is not intended to be all inclusive. Project Managers shall review each item listed in this checklist and indicate whether or not the item has been addressed in the 60% submittal or if it is not applicable. For every item not addressed a comment shall be provided. All items not addressed shall be addressed in the 90% Design Checklist.

A completed ***60% Design Project Checklist*** shall be required prior to scheduling a Technical Review Meeting.

Yes	No	N/A	General and Project Management	Comments
☐	☒	☐	1. Have all unresolved items in the 30% checklist been resolved?	Coord. with Nat Grid and Stadium Dev is ongoing
☒	☐	☐	2. Design coordination meetings conducted with City, RIDEM, RIDOT, or other agency?	
☒	☐	☐	3. Have updates to design criteria, 30% design, OPCC update, and revision/updates Basis of Design (if applicable) been prepared?	
☒	☐	☐	4. Were Program, PWSB, and RIDOT standard details used?	
☐	☒	☐	5. List of project stakeholders for future outreach and traffic management been prepared. Contact information included?	
☒	☐	☐	6. Has the project area been re-walked with the 60% plans to look for accuracy and any changes?	
☐	☒	☐	7. Have easement plans been prepared? Legal descriptions and easement filings to be prepared by others.	Coord. with Nat Grid and Stadium Dev is ongoing. Parcels to be subdivided
☒	☐	☐	8. If appropriate, have the plans been distributed for peer review and/or value engineering?	
☐	☐	☒	9. If structure inspections are included, are they complete and has a draft summary report been submitted?	
☒	☐	☐	10. Does the drawing set include a Phase III program standard cover sheet; index sheet; general notes, abbreviations, and legend sheet as appropriate? Does it comply Program CAD Standards?	
☒	☐	☐	11. Does the design documentation include a project specific checklist developed by the DC? Does the design include cross-discipline review?	
☐	☒	☐	12. Has private property restoration been identified and clearly defined including driveway repaving?	Coord. with Nat Grid and Stadium Dev is ongoing
☒	☐	☐	13. Does the submission include Program Standard specification (DIV 0 and 1) and applicable technical specifications? It is noted that some technical specifications may not be fully developed.	
☒	☐	☐	14. Has a 60% QA/QC statement been provided by the DC?	

Yes	No	N/A	Drawing Layouts/ Data Collection/Survey Coordination	Comments
☐	☒	☐	1. Has required clearing and grubbing been shown and limits defined?	Coord. with Nat Grid and Stadium Dev is ongoing
☒	☐	☐	2. Proposed and existing ground elevations shown on plans/profiles?	
☒	☐	☐	3. All new sanitary sewers, drains and major water mains are profiled?	
☒	☐	☐	4. Are large diameter pipes, manholes, catch basins, vaults, electrical ducts, etc. shown to scale, including outside dimensions?	
☐	☒	☐	5. Are final site restoration of all disturbed areas delineated on drawings?	Coord. with Nat Grid and Stadium Dev is ongoing
☒	☐	☐	6. Are paving limits delineated on drawings?	

☒	☐	☐	7. Does drawing set delineate required erosion and sediment control details and notes?	
☒	☐	☐	8. Accuracy of surface features/structures checked via site walks?	
☒	☐	☐	9. Benchmark(s) identified on the site plan and located at a minimum every 500 feet along the route?	
☒	☐	☐	10. All rights-of-way, property lines, and easements shown (source of data noted?	
☒	☐	☐	11. All flood plains, edge of wetlands, buffer zones and setbacks shown?	
☒	☐	☐	12. Have highway and railroad right-of-ways been identified?	
☐	☐	☒	13. If applicable, has a note been added stating that Contractor is required to coordinate with railroad prior to start of work?	
☐	☐	☒	14. Lawn or kept areas, trees and shrubs are shown (size and type)?	
☒	☐	☐	15. All underground utilities and structures, ducts, overhead wires, and service connections shown?	
☒	☐	☐	16. Location of existing houses (plat/lot, ownership name), buildings, fences, walls, signs, poles, mailboxes, and structures shown?	
☒	☐	☐	17. Has the DC team completed a field walk through along the alignment and documented field notes and photos?	

Yes	No	N/A	Utility Coordination	Comments
☒	☐	☐	1. Have duct bank dimensions been verified through test pits and/or confirmation by utilities? Often times they are stacked.	
☒	☐	☐	2. All existing fire hydrants and valve locations shown and verified?	
☒	☐	☐	3. Water mains of any size crossing other utilities are profiled, conflicts resolved?	
☐	☐	☒	4. Have any SUE investigation been conducted? Are the results shown on the drawings?	SUE Test Pits not proposed.
☐	☒	☐	5. Have City/Town records been checked to locate the presence of underdrains?	
☒	☐	☐	6. Have all overhead conflicts been identified during site walks?	Coordination with Nat Grid on- going
☐	☐	☒	7. Have all the dimensions and shape (egg, oval, cradle, etc.) of all large diameter and crossing sewers and drains been verified?	
☒	☐	☐	8. Design coordination meetings conducted with Utilities when needed. Have 60% plans been submitted to utilities (list at bottom of checklist)?	Coordinating with Nat Grid

Yes	No	N/A	Soils/Groundwater/ Erosion Control	Comments
[x]	[ ]	[ ]	1. Supplemental soil borings and monitoring wells complete?	Supplemental borings not authorized
[x]	[ ]	[ ]	2. Where refusal is encountered above final excavation depth, have rock cores been taken and has rock been profiled and characterized? Has geotechnical engineer confirmed adequacy of spacing?	
[x]	[ ]	[ ]	3. Has a draft soils management plan been incorporated into the design drawings and specifications? Have regulated/impacted soils been identified during the environmental investigation?	Soil Management requirements included in Specification
[x]	[ ]	[ ]	4. Does the design include temporary SOE, construction dewatering, construction sequence, and geotechnical instrumentation?	Design responsibility for temporary SUE shifted to Contractor
[x]	[ ]	[ ]	5. Do drawings conform to RIDEM erosion control and sedimentation regulations?	
[x]	[ ]	[ ]	6. Erosion and sediment control devices shown and details included?	
[x]	[ ]	[ ]	7. Have groundwater levels been determined and shown on boring logs?	
[x]	[ ]	[ ]	8. Have water levels been monitored in monitoring wells?	
[x]	[ ]	[ ]	9. Has a draft geotechnical/environmental summary memo been prepared? Did EH&S consultant review?	EH&S Consultant has not reviewed. Coordination for Tidewater Site requirements ongoing
[x]	[ ]	[ ]	10. Has the soil disposal method been defined? Soil pre-characterization may require additional delineation over stockpiling or centralized soil disposal.	Soil Management requirements included in Specification. Coord with National Grid Ongoing for Tidewater
[x]	[ ]	[ ]	11. Have the borings and monitoring wells been shown on the plans and profiles, including supplemental borings and monitoring wells.	

Yes	No	N/A	Permitting	Comments
[ ]	[ ]	[ ]	1. Local and State permit/approval applications prepared (as needed). Submit following the 60% review.	
[ ]	[ ]	[ ]	a. CRMC	
[ ]	[ ]	[x]	b. RIDOT Physical Alternation	
[ ]	[ ]	[ ]	c. RIDEM Order of Approval	
[ ]	[ ]	[ ]	d. RIPDES permit for stormwater	
[ ]	[ ]	[ ]	e. National Grid Gas – encroachment review	

Yes	No	N/A	Roadway and Traffic Management	Comments
☐	☒	☐	1. Have pavement and sub-base thicknesses been clearly identified in the borings including asphalt and concrete?	
☒	☐	☐	2. Has a preliminary concept for maintaining traffic been prepared?	
☐	☒	☐	3. Has anticipated paving schedules been coordinated with City/Town?	
☐	☐	☒	4. Have state highways been identified?	
☐	☐	☒	5. Has a note been added stating that Contractor is required to obtain permits from RIDOT prior to start of work?	

Yes	No	N/A	Water Main Design	Comments
☐	☒	☐	1. Did 30% design drawings identify need for water main relocation to accommodate proposed design elements?	
☒	☐	☐	2. Does the plan identify existing valves and proposed values and number of services impacted by shutdown?	
☐	☒	☐	3. Did design identify need for water by-pass plan?	
☒	☐	☐	4. Are noted water main relocation and/or placement in conformance with PWSB standards?	
☐	☐	☐	5. Does the design report include PWSB design checklist as an attachment?	
☒	☐	☐	6. Are pipe material and valve type identified and consistent with PWSB?	

Yes	No	N/A	Sewer	Comments
☒	☐	☐	1. The manhole diameter is adequate for the number, diameter, and angle of pipes entering and leaving?	
☒	☐	☐	2. A minimum of 10’ horizontal separation is maintained between sewer lines; between sewer lines and water lines; and between sewer lines and storm drainage structures, where possible.	
☐	☐	☒	3. If water and sewer lines cross perpendicular, is joint spacing maximized from the crossing location?	
☒	☐	☐	4. All sewers are labeled with size, grade, length, direction of flow, and type and class of pipes?	
☒	☐	☐	5. All manholes are labeled with rim and invert elevations; coordinates; and/or locations, size and inverts of drop pipes?	
☒	☐	☐	6. Drops of at least 0.1’ included in all manholes to comply with RIDEM criteria?	
☒	☐	☐	7. Verify Minimum slopes meet TR-16 criteria.	
☐	☐	☒	8. Avoid siphons where possible. If required, are pig launching and flushing connections provided in access manholes?	
☒	☐	☐	9. Velocities greater than 10 fps should be avoided, unless special provisions have been made for erosion.	

Yes	No	N/A	Storm Drain Design	Comments
☒	☐	☐	1. Catch basin connector laterals are profiled, where necessary?	
☒	☐	☐	2. The pipe material, size, and slope shown?	
☐	☐	☒	3. Are grates or trash racks at inlets and access barriers (outlet end) shown on exposed ends of all drains 18” or greater?	
☒	☐	☐	4. Have utility conflicts been resolved on catch basin laterals?	
☐	☐	☒	5. Manholes have been designed such that changes in pipe size match crown elevations?	
☒	☐	☐	6. Specific requirements such as hoods, deep sumps, etc. are incorporated.	
☐	☐	☒	7. If building disconnections are included, are they sufficiently detailed?	

Yes	No	N/A	CSO Consolidation Design	Comments
☒	☐	☐	1. Does the hydraulic capacity meet the defined hydraulic criteria based on model results (i.e. peak flow, maximum velocity)?	
☒	☐	☐	2. Does the HGL meet the defined level of service?	
☒	☐	☐	3. All crossings with other utilities are shown and conflicts resolved?	
☐	☐	☒	4. Existing sewer connections to the property shown on drawings.	

Yes	No	N/A	GSI Design	Comments
☐	☐	☒	1. Does the design comply with RIDEM SW Design Manual?	
☐	☐	☒	2. Does maximum capture volume and promote infiltration?	
☐	☐	☒	3. Drainage maps completed with pre- and post-development sub-areas delineated?	
☐	☐	☒	4. Details meet RIDEM standards?	
☐	☐	☒	5. Basis of design identifies capture volume and reduction of volume for 3-month storm.	
☐	☐	☒	6. Design incorporates features to minimize maintenance and use native plantings.	
☐	☐	☒	7. Minimum velocity in a drain is 2 fps.	

Other Specific Issues or Concerns of the PM:

Yes	No	N/A		Comments
☐	☐	☐	1. Direct Manager (PM/CM) recommends proceeding to technical review meeting.	
☐	☐	☐	2. Did the DC submit the necessary inputs to facilitate technical review meeting?	
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		

Yes	No		Date
☐	☐	**1. Design Consultant Authorized to Advance to Next Stage of Design?** **(If DC is Conditionally Authorized to Advance the Design, Attach a Summary of these Conditions to this Checklist)**	

BETA
IMPROVING COMMUNITIES TOGETHER

MEMORANDUM

Date:	December 22, 2020	Job No.:	6412
To:	Chris Feeney, P.E. PM/CM Project Manager		
Cc:			
From:	Chris Cronin, P.E. Lead Design Engineer		
Subject:	QA/QC Statement – 60% Design Submission OF-217 Consolidation Conduit Contract IIIA-5		

The purpose of this Memorandum is to provide a statement documenting the QA/QC process for the submission documents.

QA/QC for the project documents was conducted in accordance with our Project Management Plan.

Technical Reviews

- Design Plans / Opinion of Probable Construction Cost: Nick Corvello (BETA Group, Inc.) Documentation Attached
- Basis of Design Report / Geotechnical Summary Report: Bill Skerpan (BETA Group, Inc.) Documentation Attached
- Specifications / Construction Schedule: Chris Cronin (BETA Group, Inc.) Documentation Attached

Technical Review Committee Meetings

- Bill Skerpan (BETA Group, Inc.)
- Chris Cronin (BETA Group, Inc.)
- Nick Corvello (BETA Group, Inc.)
- Tennyson Muindi (McMillen Jacobs)

Independent Reviews

- Joe D'Alesio (BETA Group, Inc.) Documentation Attached
- Dan Dobbels

Chris Cronin, P.E.

Lead Design Engineer

BETA Group, Inc.

Technical Review Report

BETA Project Number: 6412

Client: Stantec

Project Name: NBC Phase III CSO - Contract IIIA-5

Document to be Reviewed: 60% Design Submission (Specs, CTD Schedule)

Review Originated by: Nick Corvello, P.E.

Assigned Reviewer: Chris Cronin, P.E.

REVIEW CONCLUSIONS: (to be completed by Reviewer)

Comments: Comments included in individual specifications as appropriate - electronic file "Track Changes". Schedule mark-ups on PDF document

Additional Comments Included: ☑ Document Markup and/or ☐ Attached Pages, No. of Pages: ____

REVIEW REPORT:

☑ The Review has been Completed and Comments Provided.

[signature] Date: 12-22-2020

Signature of Reviewer

☑ The Reviewer has verified that review comments have been incorporated or resolved.

[signature] Date: 12-22-2020

Signature of Reviewer

☑ The Review has been completed and all comments not resolved between the reviewer and the originator have been resolved by the Project Manager or Principal in Charge.

[signature] Date: 12-22-2020

Signature of Project Manager or P-I-C

cc: Project Quality Assurance File

BETA Group, Inc.

Technical Review Report

BETA Project Number: 6412

Client: Stantec

Project Name: NBC Phase III CSO - Contract IIIA-5

Document to be Reviewed: 60% Design Submission (Drawings, Cost Estimate)

Review Originated by: Chris Cronin, P.E.

Assigned Reviewer: Nick Corvello, P.E.

REVIEW CONCLUSIONS: (to be completed by Reviewer)

Comments: Comments provided on documents entitled: "IIIA-5 PLAN SET_60%_NJCreview.pdf" (plans) and "OF-217 CONSOLIDATION CONDUIT PHASE IIIA-5 - 60% Estimate - 12-17-2020 DRAFT_NJCreview" (cost estimate)

Additional Comments Included: ☒ Document Markup and/or ☐ Attached Pages, No. of Pages: ____

REVIEW REPORT:

☒ The Review has been Completed and Comments Provided.

[signature] Date: 12/22/2020

Signature of Reviewer

☒ The Reviewer has verified that review comments have been incorporated or resolved.

[signature] Date: 12/28/2020

Signature of Reviewer

● The Review has been completed and all comments not resolved between the reviewer and the originator have been resolved by the Project Manager or Principal in Charge.

[signature] Date: 12/28/20

Signature of Project Manager or P-I-C

cc: Project Quality Assurance File

BETA Group, Inc.

Technical Review Report

BETA Project Number: 6412

Client: Stantec

Project Name: NBC Phase III CSO - Contract IIIA-5

Document to be Reviewed: 60% Design Submission (BODR / GDSR)

Review Originated by: Chris Cronin, P.E.

Assigned Reviewer: Bill Skerpan

REVIEW CONCLUSIONS: (to be completed by Reviewer)

Comments: See attached BODR and GDSR for review comments, including recommended edits.

Additional Comments Included: [X] Document Markup and/or [ ] Attached Pages, No. of Pages: ____

REVIEW REPORT:

[X] The Review has been Completed and Comments Provided.

Signature of Reviewer   Date: 12/17/2020

[X] The Reviewer has verified that review comments have been incorporated or resolved.

Signature of Reviewer   Date: 12/23/2020

● The Review has been completed and all comments not resolved between the reviewer and the originator have been resolved by the Project Manager or Principal in Charge.

Signature of Project Manager or P-I-C   Date: 12/28/20

cc: Project Quality Assurance File

BETA Group, Inc.

INDEPENDENT TECHNICAL REVIEW REPORT

BETA Project Number: 6412

Client: Stantec

Project Name: NBC Phase III CSO - Contract IIIA-5

Document to be Reviewed: 60% Design Submission (Plans / Specs / BODR / GDSR)

Review Originated by: Chris Cronin, P.E.

Assigned Reviewer: Joe D'Alesio, P.E.

REVIEW CONCLUSIONS: (to be completed by Reviewer)

Comments: Comments for IIIA-5 included in 60% BDR and drawings.

Additional Comments Included: ☒ Document Markup and/or ☐ Attached Pages, No. of Pages: ____

REVIEW REPORT:

☒ The Review has been Completed and Comments Provided.

Joseph D'Alesio Date: 12/28/2020

Signature of Reviewer

☐ The Reviewer has verified that review comments have been incorporated or resolved.

________________________ Date: ____________

Signature of Reviewer

☐ The Review has been completed and all comments not resolved between the reviewer and the originator have been resolved by the Project Manager or Principal in Charge.

________________________ Date: ____________

Signature of Project Manager or P-I-C

cc: Project Quality Assurance File