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Weighing the Risks of Installing a Lake Tap with Microtunneling

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ABSTRACT: In the summer of 2009 the City of Mercer Island, WA began construction on the Sewer Lake Line and Pump Station No.4 Replacement Project that would replace a portion of the failing sanitary sewers that surround Mercer Island in Lake Washington. The project's original design included the open cut installation of three sewer lines; a 10-inch ductile iron (DI) force main, a 16-inch DI gravity sewer, and an 8-inch DI gravity sewer. The sewer lines were designed to extend from the pump station approximately 135 feet into the lake, crossing beneath an active 10-inch asbestos cement sewer line. During the construction however, the Contractor requested that they be allowed to install the three sewer lines within a single 60-inch steel casing installed by microtunneling.

The City and its' project consultants, performed a detailed risk analysis in response to the request, comparing the risks of installing the lake tap with microtunneling versus the 35-foot deep open cut construction of the three pipelines that had been specified. This paper discusses how the project team weighed the risks involved with using an alternatively proposed trenchless method of construction, and the contractual issues that were overcome to successfully execute a change order while managing those risks. The paper also presents the details of the construction of the lake tap in Lake Washington, the challenges of modifying the existing design of the pump station to accommodate the microtunneling equipment, and the details of the successful installation of the three sewer lines.

1. INTRODUCTION

In the summer of 2009 the City of Mercer Island, WA began construction on the Sewer Lake Line and Pump Station No.4 Replacement Project that would replace a portion of the failing sanitary sewers that surround Mercer Island in Lake Washington. The project's original design included the open cut installation of three sewer lines; a 10-inch ductile iron (DI) force main, a 16-inch DI gravity sewer, and an 8-inch DI gravity sewer. The sewer lines were designed to extend from the pump station approximately 135 feet into the lake, crossing beneath an active 10-inch asbestos cement sewer line. During the construction however, the Contractor requested that they be allowed to install the three sewer lines within a single 60-inch steel casing installed by microtunneling.

The City and its' project consultants, performed a detailed risk analysis in response to the request, comparing the risks of installing the lake tap with microtunneling versus the 35-foot deep open cut construction of the three pipelines that had been specified. This paper discusses how the project team weighed the risks involved with using an alternatively proposed trenchless method of construction, and the contractual issues that were overcome to successfully execute a change order while managing those risks. The paper also presents the details of the construction of the lake tap in Lake Washington, the challenges of modifying the existing design of the pump station to accommodate the microtunneling equipment, and the details of the successful installation of the three sewer lines. Figure 1 shows the existing lake line system, the new lake line system and the location of the microtunnel.

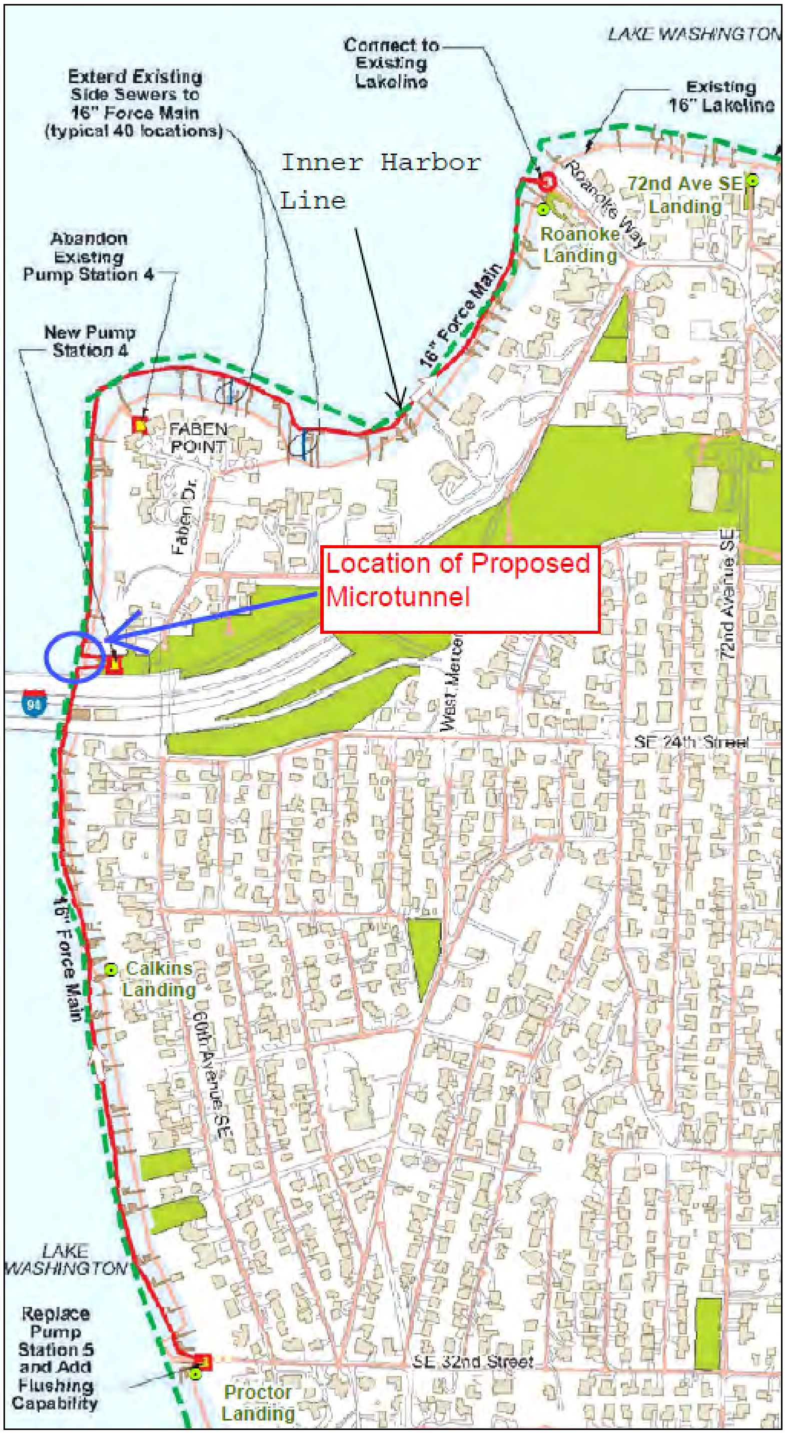

Figure 1. Existing Lake Line, New Lake Line, and Microtunnel Location

2. PROJECT BACKGROUND

The City of Mercer Island, Washington is ringed by a sewer lake line system that collects sewage from lake-front properties and conveys flows from the upland sewer system to a regional conveyance system. This lake line system was originally constructed in mid-1950, with the pipeline being constructed primarily of asbestos cement (AC) pipe. Reach 3 of the lake line system is comprised of two low pressure pump stations and approximately 2 miles of sewer pipeline located just offshore in Lake Washington. The lake line system in this reach had been experiencing advancing pipeline deterioration, capacity deficiencies, and operation and maintenance problems. The deterioration was exhibited in the fragility of the pipe and an increasing occurrence of pipe failures and repairs.

In addition, the Reach 3 system had insufficient capacity to convey peak flows during storm events. The peak flows created by inflow and infiltration (I/I) in the upper reaches of the system greatly exceeded the pump station and pipeline capacities, leading to excessive surcharging in the system and potentially causing sewer backups in shoreline residences and sewage spills to the lake during high-intensity rainfall events.

The City studied a variety of alternatives to replace the lake line system, including an in-lake replacement alignment; a system onshore adjacent to the shoreline; and a system upland away from the lake with grinder pumps to serve shoreline residents. The alternative which was the most acceptable to the community and the most feasible to implement was to install a new lake line system.

The new lake line system consists of two new gravity pipelines (8-inch and 16-inch ductile iron) that convey both upstream basin flows and individual waterfront residence side sewer flows to a new submersible pump station (Pump Station No. 4) located near I-90. Flows are then pumped through a new 10-inch ductile iron force main to the County's pump station. The new lake lines are installed in Lake Washington beyond the Inner Harbor Line in approximately 30 feet of water. Figure 2 shows the configuration of the new Lake Line System.

Construction of the new lake line system was complicated by the following constraints:

- "Fish windows" – work in Lake Washington was allowed only from July 1st to October 15th along most of the shoreline to avoid disturbance to spawning salmon.
- Side sewer service – the existing system had to stay operational to provide sewage collection from the waterfront homes.
- Side sewer transfers – the new lake line gravity and force main and pump station had to be operational before the existing side sewers could be transferred from the old mainline.
- No sewage releases into the Lake – Protecting the fragile AC pipeline to prevent sewage releases was critical.

The construction was bid in June 2007 as one contract for the marine work and the pump station. The new gravity lines and force main run from the new Pump Station No. 4 out into the Lake, and through the existing mainline AC pipe. The design provided for installation of a bypass sewer line from the mainline in the Lake, running up onto shore and around the new pump station and then back into the Lake to reconnect to the mainline. This bypass line kept service in place for the side sewers and allowed the contractor to install the new gravity and force main pipelines by open cut excavation from the new pump station out to the new lake lines. The bids received in July 2007 were 80% over the City's estimate.

The City Council recognized the importance of the project and directed City staff, the CM consultant and the engineer to find ways to reduce project costs.

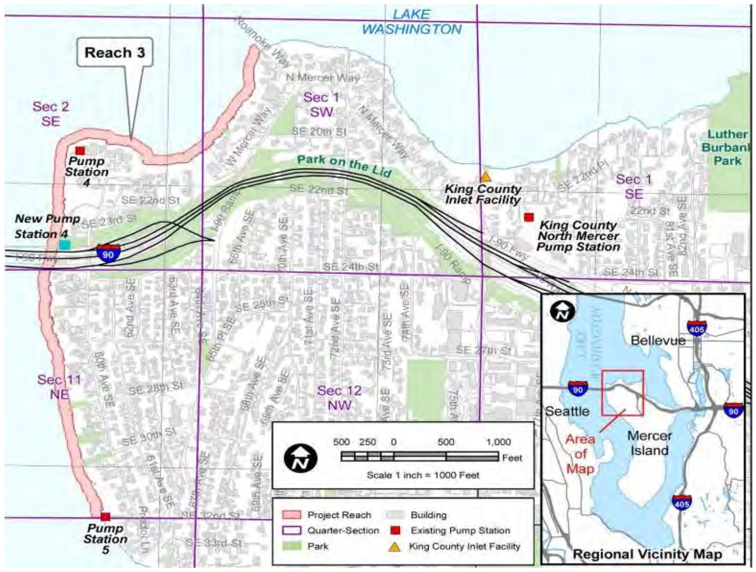

Figure 2. New Lake Line System

3. REPACKAGING THE PROJECT

Based on interviews with the prime contractors, one reason for the high bids was the lack of competitive bidding on the pump station work. Both prime contractors solicited the same subcontractor for the pump station bid. Other concerns were the complex construction sequencing to maintain the existing system until the new lake line and pump station were operational and whether all the marine work could be accomplished in two years with the fish window work restrictions. The project team decided to repackage and rebid the contract allowing contractors to bid on just the marine work, or just the pump station independently, or both the marine work and pump station together.

To allow the pump station work to be contracted separately from the marine work, the contract interfaces and sequencing needed to be simplified. This was accomplished by:

- Establishing an interface point for installation of the new lines from the pump station into the Lake: The pump station contractor would install the new gravity lines and force main from the pump station to the shoreline. The marine contractor would finish the installation into the Lake. This was a schedule milestone for both contractors that supported completing the new gravity lines and force main installation in the first year of construction.

- Eliminating the bypass pipeline around the pump station: The marine contractor would be required to support the existing mainline in place during the open cut installation of the gravity lines and force mains under the existing AC line or remove that portion affected, install a pumped bypass system, and then repair and reactivate the mainline. The contractor was required to keep the mainline operational until the side sewers could be transferred to the new system, during the second year of construction.

- Setting the milestone for having the pump station operational: The pump station contract specified having the pump station ready to take flows by the start of the July fish window in the second year of construction. This allowed the marine contractor to transfer side sewers to the new gravity lines in the second year and based on their production, completing the project in two years.

- Inclusion of a third year fish window in the contract duration: The team worked with permit agencies to provide for a potential third year of marine construction should it be needed.

In repackaging the contract, the project team allocated the risk of maintaining the existing AC mainline section above the new pipelines to the marine contractor and allocated the schedule risk between the pump station and marine work to the City. With the approval of City management and legal counsel, the revised project was rebid in October 2008. Bids came in almost $2 million below the City's revised budget. Based on the bidding, one contract for the marine work was executed at $14.8 million and another contract was executed for the pump station work at $4.3 million.

4. CONTRACTOR MICROTUNNELING PROPOSAL

In early February 2009, the marine contractor presented a proposal to install the gravity lines and force mains by microtunneling into Lake Washington. They saw this as a cost-effective solution to installation of the new lines under the existing AC mainline and less risky than open cut excavation. Their subcontractor had a microtunnel boring machine (MTBM) available that could install a 60-inch steel casing, in which they proposed to install the 8-inch and 16-inch gravity lines, and the 10-inch force main. They would use the pump station wetwell shaft, which was being excavated, as the launch pit and microtunnel directly into Lake Washington. Bulkheads would be installed behind the MTBM to prevent flooding of the casing and allow for grouting the new lines inside the casing. The MTBM, which would be 4 ft below the lake bed, would then be excavated by the barge mounted backhoe and removed. The ends of the new pipelines would be capped until the marine contractor made the connection to the new lines in the Lake. This proposal would be a no-cost change to the contract.

The project team had expressed concerns about the possibility of differing site conditions. The pipeline design was based on open cut excavation, so the geotechnical investigation was adequate for open cut, but not for a microtunnel. The soils consisted largely of glacial till in the proposed microtunnel zone, but there was a potential for boulders and large woody debris. Also concerns about the impacts of the microtunneling on the pump station construction timeline were raised. The marine contractor secured agreement with the pump station contractor that both contractors would take on the geotechnical and schedule risk. The marine contractor indicated if the MTBM was stopped by an obstruction they would complete the pipeline installation by open cut.

A detailed technical and contractual risk analysis was necessary to evaluate whether the City should agree to the contractor's microtunneling proposal. The City enlisted the support of a engineering consulting firm who specializes in microtunneling and other trenchless construction methods. The analysis would have to be done expeditiously, since the contractors wanted approval by May 1st to avoid any impacts to either the pump station or marine pipeline construction. The CM consultant and design team developed a risk analyses while the contractor continued to develop the details of their microtunneling proposal.

5. TECHNICAL RISK ANALYSIS

The City had spent years getting permits to install the new lake lines in Lake Washington, largely due to agency concerns about potential impacts to water quality and marine habitat. The construction was very visible to the waterfront residents of Mercer Island and the hundreds of thousands of commuters taking the I-90 floating bridge into Seattle. An overriding technical and political concern was an accidental discharge of slurry into the Lake. The team identified the following technical risks of the proposed lake tap.

1. Installing a lake tap by microtunneling requires MTBM operator expertise. There were few tunneling operators that had completed this type of tunneling operation. The team had no assurances from the contractor that the personnel proposed by the subcontractor had completed a lake tap.
2. Microtunneling requires the balance of ground water pressures at the face of the machine by means of a slurry pressure. If this slurry broke through the excavation and into the Lake it could cause excessive turbidity, unless contained by a silt curtain or other means.
3. Tunneling into the lake would require a series of bulkheads to be installed inside the tunnel. If a bulkhead failed it could result in flooding of the pump station excavation and potential injury to divers, tunnel operators or pump station workers. The contractor's original proposal did not provide enough detail to evaluate whether their bulkheads would protect the casing and station from flooding and prevent grout release into the Lake during the grouting of the new lines inside the casing.
4. The contractor proposed embedding the tunneled casing pipe in the wall of the new pump station. The potential for differential settlement between the concrete and tunneled pipe, and differential movement

between the casing pipe and the pump station under seismic conditions would need to be investigated. The pipes had been designed with high deflection couplings to account for differential movement between the piping and pump station wall; however the high deflection couplings required in the contract would not function in a similar fashion under the contractor's proposed pipe and casing layout.

5. The MTBM would be day-lighting into the lake and would likely encounter soft lake bottom materials. It was uncertain whether these materials have the strength to support the MTBM.
6. A geotechnical investigation had not been performed to evaluate a tunneling approach. The prevalence of soil conditions or other materials that would inhibit the advancement of the tunnel was uncertain.
7. If the MTBM over excavated the amount of material when it was passing beneath the existing lake line, the possibility of settlement and breakage of the existing line still existed.
8. Divers would be needed to retrieve the MTBM and the tunneling crew might need to enter the casing. A site specific safety plan would be needed from the contractor to address all potential safety issues.
9. The pump station contractor had received approval from the project team to use the sheet pile shoring for the pump station excavation as their outside form for the pump station wall, thus reducing the size of the 50-foot deep excavation. The structural engineers for both the pump station and marine contractor would have to concur that the jacking frame for the MTBM would not damage the pump station sheet pile shoring.

There were potential technical benefits to the microtunneling proposal that were indentified, including:

1. The interface point established in the contract for the pipeline installation was around 20 feet from the pump station. Based on the marine contractor's schedule, they would be installing their shoring for the offshore pipelines at the same time as the pump station contractor was constructing the concrete walls of the pump station. If successful, microtunneling would eliminate the potential for damage to the new concrete construction during shoring installation for the open cut work into the Lake. It would also reduce the risk of damaging the pipelines required to be installed by the pump station contractor between the pump station and the interface of the two contracts.
2. The change would reduce the amount of time required to install the offshore pipelines provided there were no setbacks encountered during the microtunneling operation.
3. The existing lake line would be vulnerable to damage during installation of shoring for the offshore pipelines. A tunneling operation would reduce the risk of damage and potential sewage release into the Lake. Since the condition of the existing mainline could be poor, repairs might be extensive to reactive the line.
4. Excavation quantities and resultant barge traffic for disposal of excavated soils would be substantially reduced. The City had obtained approval for spoils disposal at an approved site in Puget Sound.
5. Disturbance of adjacent properties would be reduced due to decreased shoring installation and excavation quantities.
6. Without open cut excavation, the problematic installation of silt curtains near the shoreline would be resolved and there would be less potential turbidity in the Lake.
7. Contractor had stated that microtunneling would be safer operation than placing divers within a shored open-cut trench; but it was noted that tunneling still required divers to help retrieve the machine from the lake; and there were safety issues associated with tunneling into an open water body.

The project team discussed the technical risks and benefits of the microtunneling proposal and came to the determination that the risks could be managed, based on the willingness of both contractors to make the proposal technically acceptable to the City. The potential benefit of not disturbing the fragile AC mainline and avoiding a sewage release factored significantly in the decision.

6. CONTRACTUAL RISK ANALYSIS

The City was very sensitive to the costs of the project, given the past high bids on the project and the impact to the rate payers to pay for this significant new sewer system. Therefore, reducing the City's exposure to any additional cost risk was a key factor in the analysis of contract risks. The project team identified the following contractual risks:

1. A geotechnical investigation was not performed to evaluate a microtunneling approach. The prevalence of soil conditions or other materials that would inhibit the advancement of the MTBM was uncertain. Could the risk of differing site conditions be completely contractually transferred to the contractors? Could a "no claims" change order be crafted to defend the City against any potential contractor claims?
2. Should the contractor hit an obstruction that damaged the MTBM, it was not clear if the contractor would assume the responsibility for the damage.
3. There were two major schedule interfaces between the pump station and marine pipeline contracts. The first was the installation of the gravity and force main lines from the pump station into the Lake. The second was the operational startup of the pump station. The contractor's initial proposal agreed to relieve the City from all schedule delay risk between the two contractors for the milestone for pipeline installation. However, if the microtunneling was not successful, the subsequent pump station startup milestone could be affected which could push completion of the marine work into a third year. Each contractor would have to be willing to a release of subsequent milestone dates and delay claims that result from the microtunneling operation before the City considered approval of the proposal.
4. Both contractors stated that a decision on acceptance of microtunneling was required by May 1, 2009 so as to not impact their schedules. This put additional pressure on the resources of the City, its attorneys and consultants to work through design review, craft a change order agreement and implement an inspection plan in a very short amount of time. These pieces needed to be in place in late June so that microtunneling could proceed in early July.
5. The City would incur additional costs for the proposal review, change order preparation, and specialty microtunnel inspection support that was not in the project budget.
6. Both contractors were very vested in the microtunneling proposal. Denying them this option, which they were asserting was their "means and methods," could create contention and posturing early in the project.

The potential contractual benefits to the project, if accepted by the contractors, included:

1. The schedule milestone for the pipeline interface would be removed, reducing any schedule delay risk to the City.
2. The schedule milestone for the completion of the pump station or any impacts to the contract completion dates of either contract would be removed.
3. Both Contractors had indicated they would be willing to compensate the City for additional costs for review, approval and inspection of a microtunneling operation, but specific dollar amounts had not been negotiated.
4. The fact that both contractors were vested in their proposal was also a benefit since it could improve negotiation of final proposal details.

In consultation with the City's legal staff and outside legal counsel, the project team suggested the microtunneling proposal could be accepted contractually only if a change order to both contracts could be crafted that would preclude any possibility of claims against the City. The City approved proceeding with change orders to allow the lake tap by microtunneling. The contractor worked with the engineers to address the technical elements of the proposal, which were made in a technical submittal that was referenced in the change order. The major provisions of the change orders to both contracts included:

1. The contractors received no additional monies for the microtunneling and if it failed, agreed to install the pipelines as originally designed.
2. The contractors were fully responsible for the design of the microtunneling.
3. The contractors waived all claims caused by or related to defects in the approved microtunneling proposal.

4. The City assumed no design liability for review of or payment for the microtunneling and the contractor remained liable to the City with applicable law for all damages to the City caused by the contractor's deficient or negligent microtunneling design.

5. The contractors waived their rights to differing site conditions from the pump station to the end of the tunneling (around 135 feet), both Type 1 and Type II, and any obstructions, including wood, debris, rocks, boulders or manmade obstructions.

6. The contractors accepted all risks for any damage to (1) the micro tunneling machine and associated equipment, (2) the shored pump station shaft, and (3) the release of micro tunneling fluids into Lake Washington, and any violation of the existing permits and permitting conditions.

7. The contractors assumed all scheduling risk, including impacts to interface milestones, thus eliminated all the City's schedule risks on both contracts.

The marine contractor agreed to compensate the City $65,000 for its expenses for reviewing the proposal and inspecting the microtunneling.

7. IMPLEMENTATION OF THE MICROTUNNEL LAKE TAP

The contractor's proposed microtunnel is illustrated in Figure 3.

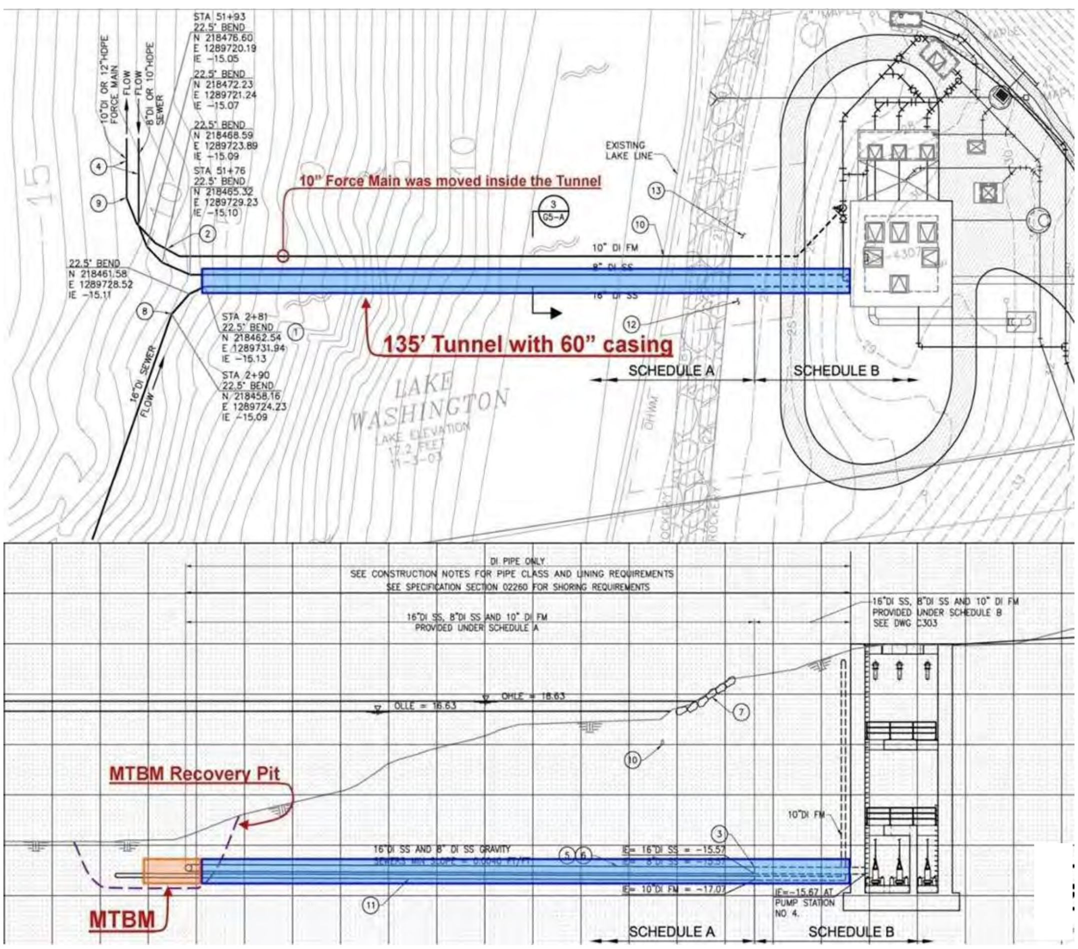

Figure 3. Contractor's Proposed Microtunnel

The project was comprised of a total length of approximately 135 LF from the pump station wetwell shaft out to the point of connection to the in-lake pipes that surround the island in Lake Washington.

The pump station sheet pile shoring was used for the launch shaft. The microtunneling contractor grouted approximately 10-feet outside the shaft to control ground water when launching the MTBM. The contractor also employed a triple gasket, water tight launch seal designed to withstand the full water pressure of the lake.

The microtunneling contractor chose to use a Lovat MTS MTBM (shown in Figure 4) with a nominal diameter of 60-inches and a mixed face cutter head suitable for the sand, gravel and cobbles anticipated in the geology of the bore. A Derrick TBSS-225 solids separation system was used for separating the tunneling spoils from the slurry.

Figure 4. Lovat MTS 200

The tunneling pipe selected by the contractor was 10-foot long sections of 60-inch Permalok with 5/8-inch wall. The lake end of the casing included a double bulkhead. The primary bulkhead was to keep water from entering the casing and the second bulkhead would keep water from entering the MTBM when the divers cut the casing between the two bulkheads. The bulkhead for the casing had stubs for the three product pipes that were installed inside the casing once the tunneling was completed and the MTBM had been removed from the lake.

The jacking frame used for jacking the MTBM forward was an Akkerman MT460 jacking frame, this is a rather compact jacking frame for use in small shafts. The shaft was designed for the size of the wetwell and not for tunneling so the space was limited since the shaft was only about 18.75-feet across.

A bentonite slurry was also employed during the first 100-LF of tunneling. No bentonite slurry was pumped for the last 30-feet of tunneling in order prevent bentonite slurry from getting into the lake.

A pipe brake was employed by the contractor to prevent the force of the groundwater pressure from pushing the pipe back in to the shaft when the jacks were retracted to add another piece of casing.

A flat bottomed reception pit was pre-excavated by the marine prime contractor and bedded with a foot of crushed rock. This pit provide a "landing pad" for the MTBM and simplified the retrieval of the machine under "wet" conditions.

The tunneling began on Saturday, August 29, 2009 and was completed on Wednesday September 9, 2009 for a total of 8 days of tunneling, with no tunneling work occurring during the three day Labor Day holiday. During the course of the 8 days of tunneling only a few minor problems occurred. On the first day the microtunneling contractor had a problem with their power pack, this problem was found to be a error in how the power pack was set up by the contractor. On the third day of tunneling the slurry return pump started smoking and had to be repaired the following day. On the seventh day of tunneling they again had trouble with the slurry return pump and had to replace the pump with the spare pump they had on site. The best day of tunneling production was on the last day of tunneling when the microtunneling contractor installed approximately 35-LF of casing in one day. The layout of the project site is shown in Figure 5.

Figure 5. Overview of Project Site

On the morning following the completion of the tunneling the microtunneling contractor discovered that the shaft had flooded overnight. It was originally feared that the casing had sprung a leak and water had flowed in to the casing and flooded the shaft (Figure 6). However, it was discovered later in the day that the electric utility providing power to the dewatering wells had failed or "tripped" overnight and that the automatic transfer switch that would have started a standby generator had subsequently failed to engage and power was completely disconnected from the pumps. This created some conflicts between the three contractors, but did not involve the City, given the transfer of risk by change order. The shaft was successfully dewatered by the following day. Once the shaft was dewatered the microtunneling contractor was able to remove the jacking frame and some of the other equipment within the shaft. The microtunneling contractor was also able to grout the annular space outside the casing as planned and without incident.

Figure 6. Flooded Shaft

Approximately two weeks later the marine contractor with the assistance of divers and the microtunneling contractor retrieved the MTBM from the bottom of the lake without any difficulties (Figure 7). Once the machine was retrieved the three product pipes were installed, grouted and the required flexible connections at the shaft were made.


Figure 7. Wet Retrieval of MTBM

8. REFERENCES

Jones & Stokes, Final Environmental Impact Statement for the City of Mercer Island Proposed Sewer Lake Line Replacement Project, February 2005.

Tetra Tech, City of Mercer Island Sewer Lake Line and Pump Station No. 4 Replacement Project Contract, 2008, prepared for the City of Mercer Island, 3 volumes.