North American Society for Trenchless Technology (NASTT)
NASTT's 2017 No-Dig Show

Washington, D.C.
April 9-12, 2017

MA-T3-02

Dugway West Interceptor Relief Sewer Project

Creatively Combining Trenchless Techniques to Complete the St. Clair Ave. Relief Sewer

Aaron J. Smith, P.E., CCM, H.R. Gray (A Haskell Company), Akron, Ohio
Anthony S. Vitale, P.E., Northeast Ohio Regional Sewer District, Cleveland, Ohio
Robert J. Auber, CCM, Northeast Ohio Regional Sewer District, Cleveland, Ohio

ABSTRACT: Originally designed as an Open-Cut sewer installation, the westernmost terminus of the St. Clair Ave. Relief Sewer, part of the Northeast Ohio Regional Sewer District's (NEORSD) $58 Million Dugway West Interceptor Relief Sewer (DWIRS) Project, had its share of potential pitfalls. Faced with the prospects of required utility relocations estimated to exceed $2 Million, and several months of traffic hassles resulting from the long-term closure of one of the most congested thoroughfares in Cleveland, OH, the NEORSD elected to explore trenchless alternatives to complete the sewer run. After collaborative discussions with the DWIRS project General Contractor, Walsh-Super Excavators Joint Venture II, a plan was developed to perform the sewer installation via Hand-Mine Tunneling.

The plan for the Hand-Mine Tunnel was comprised of several trenchless technologies including jacked casing, liner plate tunnel, and chemical soil stabilization at the advancing tunnel face. Making the final connection to the existing local sewer would require a blind tie-in to an aging existing brick manhole. Combine these factors with the generally unpredictable nature of trenchless work, and it became evident that this seemingly straightforward tunnel of less than 100 feet in length would be anything but routine. This paper discusses the construction challenges faced during the Hand-Mine Tunneling, sewer installation, and blind tie-in of the westernmost terminus of the St. Clair Ave. Relief Sewer portion of the NEORSD's Dugway West Interceptor Relief Sewer Project.

INTRODUCTION

The Dugway West Interceptor Relief Sewer (DWIRS) is part of a new sanitary sewer system being constructed by the Northeast Ohio Regional Sewer District in the City of Cleveland and the Village of Bratenahl, Ohio. The purpose of this project is to reduce combined sewer overflows (CSOs) in the existing Dugway East Interceptor (DEI) alignment. DWIRS is a major component of the first phase of NEORSD's Project Clean Lake program, a three (3) billion dollar, twenty-five (25) year program with the ultimate goal to ensure 98% of wet weather flows entering the combined sewer system receive treatment, thereby dramatically reducing raw sewage discharges into Lake Erie and adjacent waterways. In addition to DWIRS, the first phase of Project Clean Lake also includes multiple other CSO control projects intended to reduce overall CSO discharges in the NEORSD Easterly Service Area, two of the most notable projects being the Euclid Creek Tunnel and Dugway Storage Tunnel. As part of the Euclid Creek and Dugway Storage Tunnel system, DWIRS provides flow management to decrease the frequency and volume of CSO and flooding in the Dugway Brook West Branch watershed area, which encompasses the Glenville neighborhood of Cleveland. The annual CSO capture for the DWIRS project is approximately 110 million gallons.

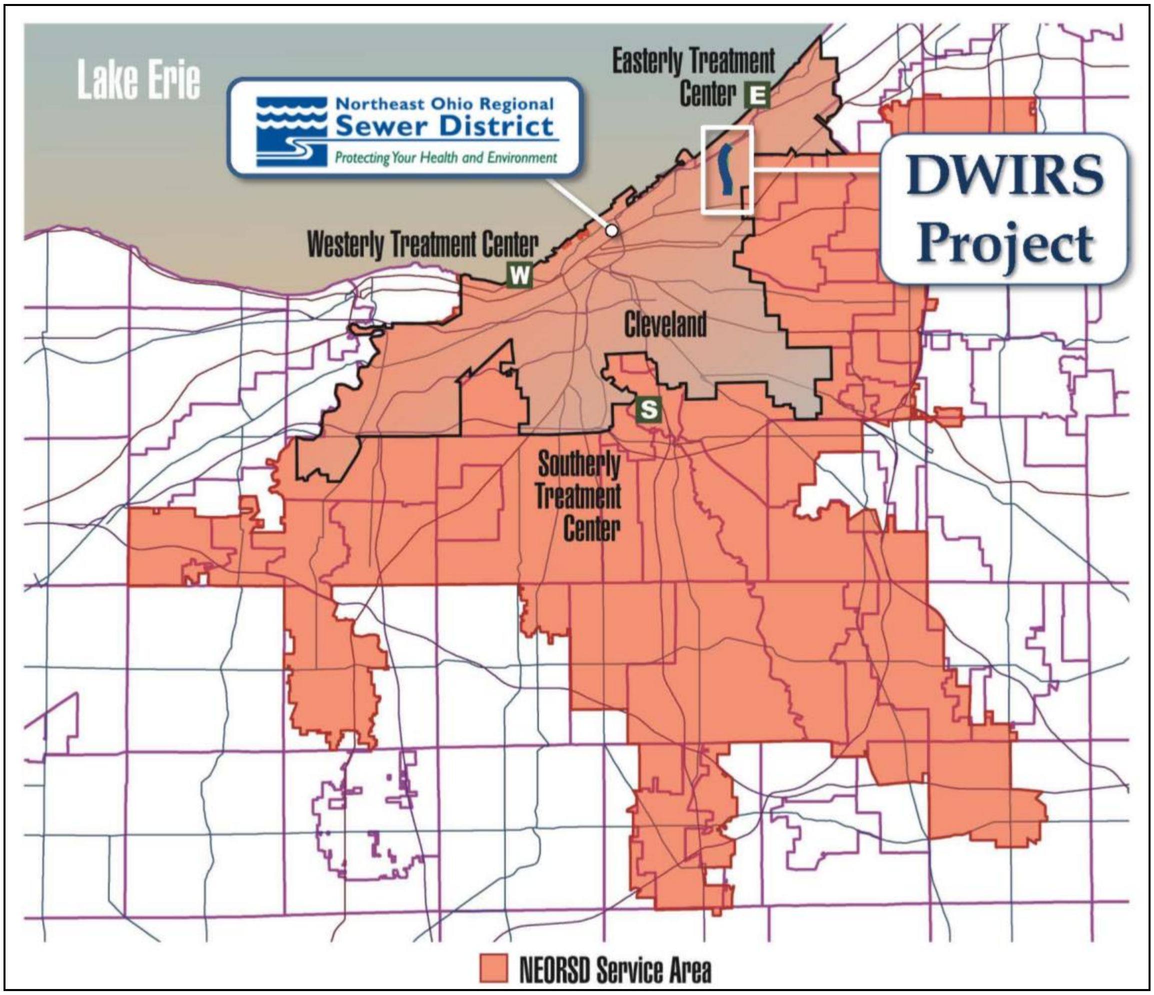

Figure 1. Map showing the general location of the DWIRS project.

The DWIRS project's original design consisted of 6,631 l.f. of 72-inch dia. pipe-in-microtunnel, 3,069 l.f. of 48-inch diameter pipe-in-microtunnel, 2,889 l.f. of open-cut sewer installation ranging from 24-inch to 108-inch in diameter, construction of five (5) cast-in-place concrete flow structures, four (4) cast-in-place concrete connections to or modifications of the existing Dugway West and Dugway East Culverts, installation of seventy-one (71) pre-cast manholes and the abandonment of thirty-nine (39) existing sanitary regulator structures. AECOM Inc., was the lead design consultant for the DWIRS project. On 10/3/13, Walsh/Super Excavators Joint Venture II (WSXJV) was awarded the DWIRS contract by the Northeast Ohio Regional Sewer District (NEORSD) in the amount of $57,479,355.30. Construction commenced in December 2013.

Located in the residential Glenville neighborhood on the east side of Cleveland, OH, the proposed DWIRS sewer alignment was constrained by several factors including but not limited to Right-of-Way boundaries, existing third-party utilities, both overhead and underground, and a varied geotechnical profile that ranged from loose silts and sands to stiff clay and shale. Having extensive past experience in completing projects in complex locations, NEORSD understood as they commenced the DWIRS project that in order to deliver the best-value product, there may be opportunities and/or needs to make adjustments to the original design based on what the field conditions presented. One such opportunity was revealed at the west leg of the DWIRS system, the St. Clair Ave. Relief Sewer. Located on one of Cleveland's most-travelled thoroughfares, St. Clair Ave., the westernmost mainline tie-in from manhole PC-6 to manhole PC-4 was originally proposed to be installed by open-cut methods. However, to install the sewer in this manner, NEORSD was faced with the prospects of required utility relocations estimated to exceed $2 Million, and several months of traffic hassles resulting from the long-term closure of St. Clair Ave. To mitigate these issues, NEORSD elected to explore trenchless alternatives to complete the PC-6 to PC-4 sewer run.

ORIGINAL DESIGN OF THE ST. CLAIR AVE. RELIEF SEWER

The purpose of the proposed St. Clair Ave. Relief Sewer was to intercept local CSOs from St. Clair Ave. and convey them to the mainline DWIRS sewer, from which a majority of the flows will either be conveyed directly to a treatment facility or, in the case of high flows, be conveyed to temporary storage in large diameter tunnels until there is capacity for treatment. The primary existing sewers to be captured along St. Clair were a 24-inch diameter storm water overflow (SWO) sewer at new manhole PC-5 as well as a No. 4 Egg-Shaped sewer (Approximately equivalent to a 34-inch-diameter circular sewer) at new manhole PC-6. Additionally, existing Dugway West Interceptor sewer flows were to be picked up at new manholes PC-2 and PC-3. According to the original design (See Figure 2), these flows were to be conveyed through a series of open-cut sewer runs ranging in diameter from 36 inches to 48 inches, totaling approximately 300 lineal feet and generally running east through manholes PC-6, PC-5, PC-4, PC-3, across Culvert Crossing CX-3 (over Dugway West Culvert), PC-2, finally to PC-1. From PC-1, a 48-inch diameter, 811-foot-long microtunneled sewer would convey flows east to a connection at the mainline DWIRS sewer. Depths of the open-cut runs were approximately 20-feet, while the microtunneled sewer ranged from 20-feet deep to about 33-feet deep (depending on the ground surface topography).

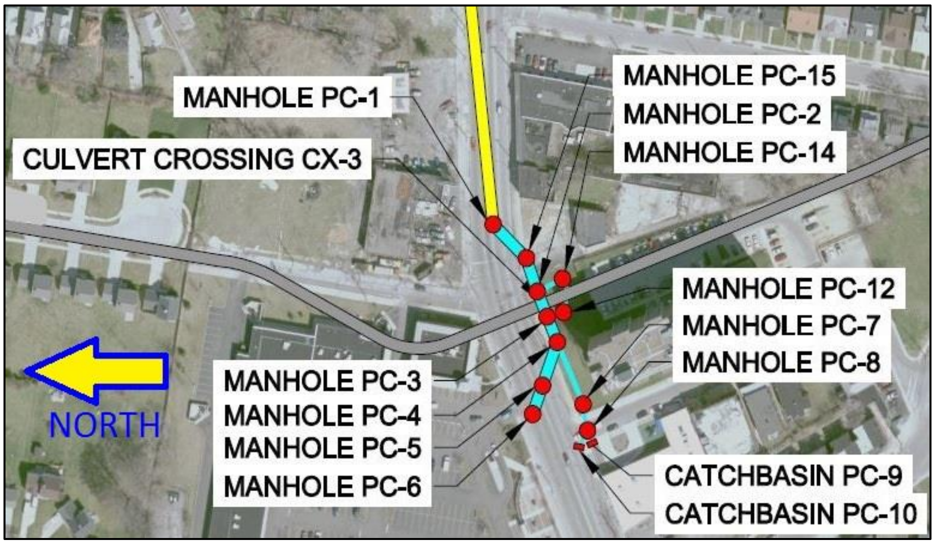

Figure 2. Original design of the St. Clair Ave. Relief Sewer (Yellow = Microtunnel, Teal = Open-Cut).

ANTICIPATED GROUND CONDITIONS AND GEOLOGICAL BASE LINE

The DWIRS Geotechnical Baseline Report showed ground conditions for the PC-6 to PC-4 open-cut sewer run to consist predominately of loose sandy fill. Based on this information, the contract documents specified an undercut to firm glacial till and installation of additional stone backfill for this sewer run. However, the nearest soil boring was immediately adjacent to the western edge of the Dugway West Culvert, over fifty-feet away from the proposed PC-6 to PC-4 alignment. The Dugway West Culvert, constructed in the 1920s, is a culverted stream that generally follows the former streambed. The general geotechnical makeup in the area of the culvert is various fill material on top of an organics-laden streambed layer, below which is a very stiff till layer consisting of hard clayey silt, silty gray clay, and trace sand. Previous project experience had shown the streambed layer to rise diagonally away from the culvert (which generally makes sense considering that this was previously an open stream). Based on the distance of the PC-6 to PC-4 alignment from the Dugway West Culvert (and distance from the nearest soil boring), the Project Team understood the possibility of the stiff till layer being higher than shown in the GBR (See Figure 3). If the till layer was encountered at or above the contract pipe depth, the project could potentially forego the planned undercut.

Other geotechnical considerations included existing obstructions. This area of St. Clair Ave. was known to be a former alignment of the Cleveland City Streetcar Railway. During pre-design exploratory excavations, remnants of these railways, including steel rails and cobbles were encountered. Additionally, the property south of St. Clair was formerly the site of a commercial building, and building remnants were assumed to remain underground. The GBR alerted the contractor to be aware of these obstructions during the bidding process.

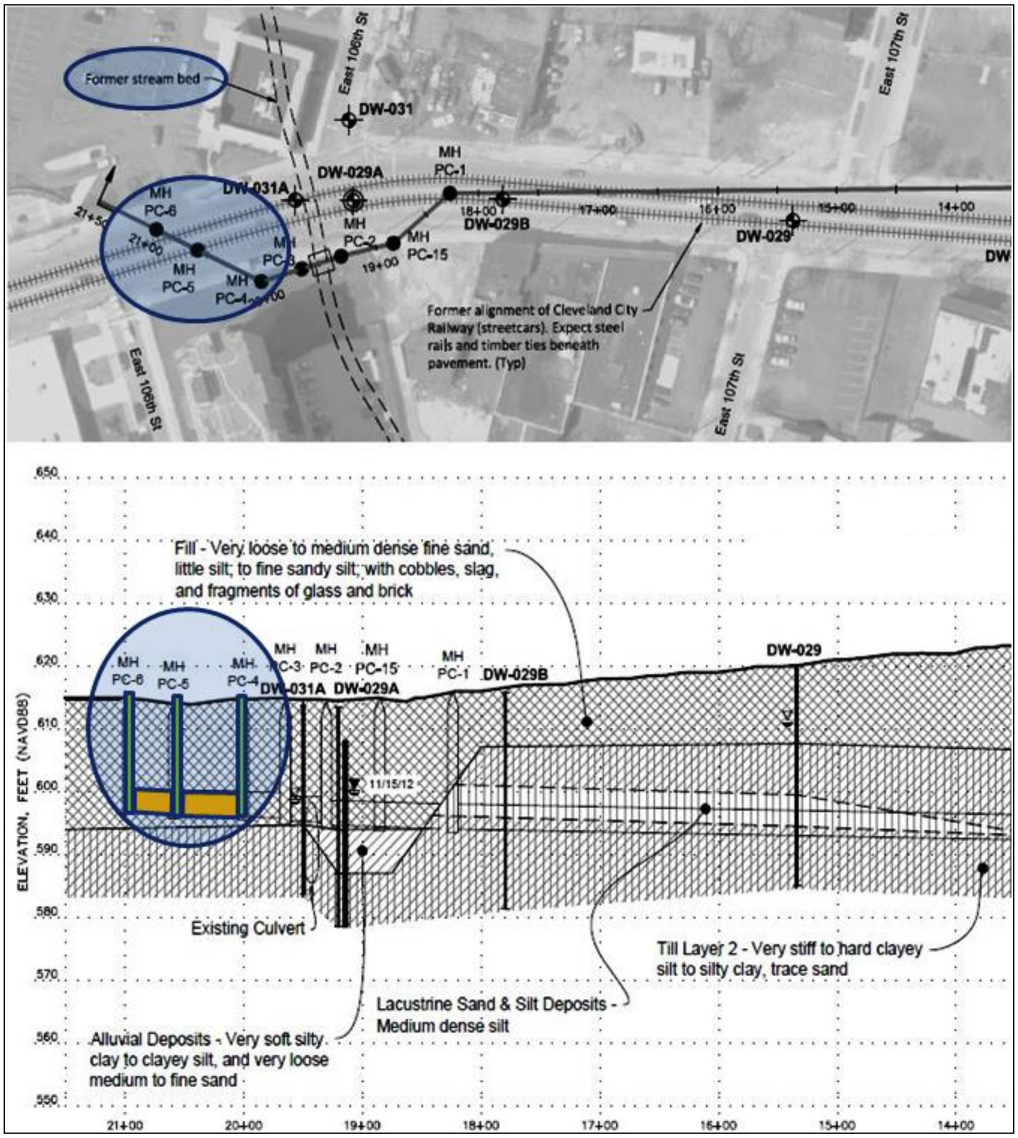

Figure 3. Geotechnical Profile according to DWIRS Geotechnical Baseline Report (GBR)

EXISTING UTILITY CONFLICTS AND OTHER ISSUES WITH ORIGINAL DESIGN

NEORSD recognized going into the DWIRS project that utility relocation, not just along St. Clair Avenue but at several other locations within the project limits would be required to facilitate construction. To account for this, NEORSD included a $2.5 Million Utility Relocation Specific Allowance as part of the DWIRS Project to accommodate utility relocation throughout the project.

Early on in the project WSXJV started conducting bi-weekly utility coordination meetings to coordinate relocations with the major utilities. Initially, project sites and the potential impact of existing utilities would be discussed with representatives of each utility. Potential solutions would be discussed at these meeting but normally each utility would require their Engineering Departments to configure their relocations based on each utilities requirements. Utility companies then provided relocation options accompanied by cost estimates. Early in June of 2014 the cost projections for relocation of just two major utilities, AT&T and Cleveland Electric Illuminating Company (CEI), ran in excess of $2 Million to facilitate construction of the originally-designed St. Clair Ave. open-cut sewer alone. Additionally, and of equal importance, since the relocation would impact CEI's capacity to provide service, CEI would only take their service offline in non-peak seasons (Spring or Fall). This situation was further complicated by the fact that Cleveland had been awarded Republican National Convention and a tremendous amount of infrastructure work was taking place in Cleveland. CEI hinted that their construction docket was full and that this relocation work would most likely slide until the Fall of 2015, resulting in a significant negative impact to the DWIRS project schedule. Once the relocation costs and potential schedule impacts were realized, the DWIRS Project Team began to re-evaluate the original design.

REDESIGN OF THE ST. CLAIR AVE. RELIEF SEWER

To mitigate the mounting potential utility relocation costs associated with the original design of the St. Clair Ave. Relief Sewer leg of the DWIRS Project, the Project Team went back to the drawing board to consider new alignments and construction methods. The eastern (Microtunnel, PC-1, PC-2) portion proved to be a relatively simple redesign. NEORSD acquired an additional easement allowing the proposed 48-inch microtunnel run to the east to be rerouted directly to the PC-2 shaft location which was renamed PC-1 (PC-2 nomenclature was eliminated). By shifting the PC-1 shaft location out of the St. Clair Ave. right-of-way, a portion of the utility relocation could be avoided (See Figure 4). This revised microtunnel alignment was constructed in February, 2015 without the need for major utility relocations. However the PC-6 to PC-4 portion of the sewer further west still needed to be reexamined to mitigate the bulk of the potential utility relocation costs. The alignment of the PC-6 to PC-4 portion of the sewer needed to remain relatively as-designed to capture the existing St. Clair Ave. sewers as intended. If a change was to be made, it would need to be in the construction methods. Therein sat the question: What if this portion of the sewer were installed by trenchless methods instead of open-cut?

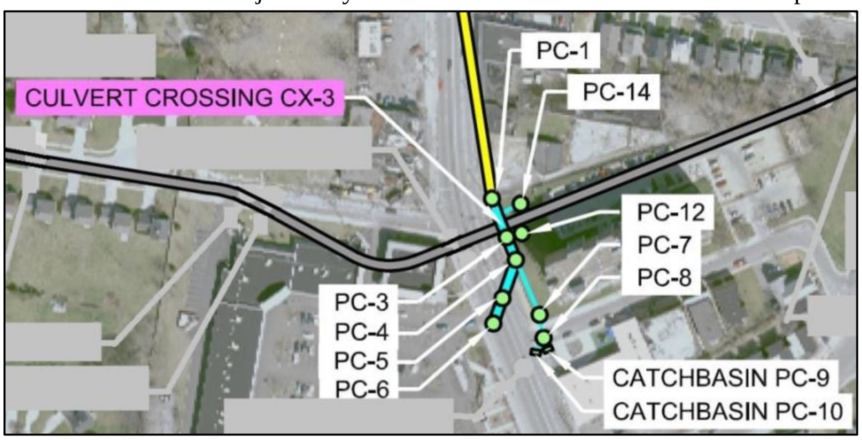

Figure 4. Revised Alignment PC-1 to PC-6.

NEORSD's Project Team explored several trenchless options including microtunneling, jack-and-bore, and hand mine tunneling. Both microtunneling and jack-and-bore would require an exit shaft at the PC-6 location, meaning a large excavation in the middle of St. Clair Ave. (exactly what we were trying to avoid). The option that appeared to be best suited for this application was a hand mine tunnel from the PC-4 location to a blind connection at the existing manhole at the PC-6 location. A minimal excavation would then be required to install manhole PC-5 as a doghouse manhole to pick up flows from the existing 24-inch SWO sewer in a drop connection. This revised methodology would allow for installation of the sewer run while minimizing disturbance to St. Clair Ave. NEORSD's Project Team assembled revised plans and issued a RFP to the Contractor. One key revision included reduction of the pipe run diameter. Instead of the 48-inch-diameter pipe specified in the original design, the Project Team confirmed that a 42-inch HOBAS sewer would achieve the required hydraulic improvements. This reduced pipe diameter would allow for additional clearance during installation. However, the crux of the RFP centered around specifying hand-mine tunnel construction of the sewer run with a blind connection to the existing manhole at the PC-6 location. The physical means and methods of the hand-mining construction were left up to the Contractor to propose.

WSXJV elected to utilize tunneling subcontractor, Turn-Key Tunneling (Turn-Key), based out of Columbus, OH, to address the hand-mine construction. Turn-Key's proposal was intriguing to NEORSD's Project Team because it didn't just employ one trenchless technology, but a hybrid combination of multiple techniques. The tunnel would need to be large enough diameter not only to allow for installation of the 42-inch HOBAS pipe run, but also to execute the blind connection work at PC-6. Turn-Key proposed that the initial portion of the work could be achieved via a jacked casing method. Geotechnical data indicated the existing soil conditions could support this method of construction for the majority of the run. The plan for the jacking operation was to proceed under all of the St. Clair Ave. underground utilities including the existing 24-inch SWO sewer (to be captured by the drop connection at the PC-5 doghouse manhole). The casing was proposed at 108-inch-diameter, allowing for removal of spoils by small machinery and hand-tools. Once the casing was jacked to within five to ten feet of the PC-6 location, Turn-Key planned to proactively stabilize the soil at the mining face by use of chemical fore-grouting. History on the DWIRS Project indicated that soil material near the existing brick sewers was found to be in poor condition after years of service. All parties agreed that the use of chemical grout a wise precaution considering the importance of maintaining the stability of the St. Clair Avenue thoroughfare. Once chemically stabilized, the remainder of the run would be completed by hand-mining and liner plate tunnel installation. To facilitate the structural modifications required to construct the blind connection to the existing brick manhole at the PC-6 location, the liner plate tunnel was proposed to be 120-inch-diameter. The liner plate tunnel was to be installed flush to the southern face of the existing brick manhole PC-6, and the specified reinforced concrete connection would be made to reroute the flow from the No. 4 Brick sewer at PC-6 into the DWIRS system. The 42-inch HOBAS pipe run would then be installed to line and grade, and the pipe-to-tunnel annulus would be grouted.

Turn-Key Tunneling's Hand-Mine Tunnel proposal would be an additional cost to the project. However, when mitigation of additional utility relocation was factored in, a net savings of over $1.4 Million could be realized. That coupled with the reduced impact to the area residents and to the St. Clair Ave. traffic load made this option even more attractive. For these reasons NEORSD directed WSXJV to have Turn-Key proceed with the work accordingly under an additional cost Work Order. The plan was in place, and all that was left was to execute it. But, as is common in underground construction, even the best-laid plans can be subject to unforeseen obstacles below the surface.

HAND-MINE TUNNEL CONSTRUCTION

Excavation of the PC-4 Liner Plate Jacking Shaft commenced late March, 2016. As anticipated, though out of the right-of-way, the utility congested location of this shaft proved to be a challenge. The previously offset fiber-optic communication lines were accommodated and established the northern limits of the shaft. However, the previously offset 8-inch gas line to the south was still within the circular footprint of the shaft and required additional support and protection within the shaft itself.

Obstructions also proved to be an issue during shaft construction (See Figure 5). As shown in the GBR, PC-4 was located in the area where a commercial building was previously situated. Intact brick walls, reinforced concrete, and other similar construction materials were encountered within the first ten feet of depth. Aside from more difficult digging, removal of the obstructions created additional voids that necessitated additional contact/backfill grouting during liner plate installation. Commercial terms surrounding the shaft excavation were resolved at the Project Team level. Final Shaft depth was approximately 22 feet.

Figure 5. Obstructions Encountered During PC-4 Shaft Excavation

Concurrent to shaft excavation was preparation of the casing for the jacking operation. The 108-inch diameter steel jacking casing had a 0.75-inch wall thickness and was supplied in 10-foot lengths. The lead casing was modified to include a system of vertical and horizontal baffles (i.e. sand shelves), portions of which were bolt-connected and removable, to aid in support of the excavated face during advancement of the mining 9. Also included in the modifications were steering fin openings intended to help maintain line and grade during the advancement of the mining. Figure 6 illustrates the modification and completion of the lead casing.

Figure 6. Lead Casing modifications (Upper) and completion (Lower). Note Face Baffles and Steering Fin Slots.

The jacking operation (See Figure 7) was performed using a Bor-It Model 48 ‘Terminator’ boring machine. This machine is capable of producing over 375 tons of normal force. Used primarily as a hydraulic unit, it powered the jacking frame that drove the casing. As the casing was advanced, spoils were removed by hand as well as by use of a mini excavator. Material was then removed from the shaft via an excavator-hoisted muck box.   Once a 10-foot length of casing was completely driven, a new 10-foot length of casing was lowered into position to be welded into the sequence. Each piece of casing pipe was pre-beveled to allow for overlap in the welded joint.

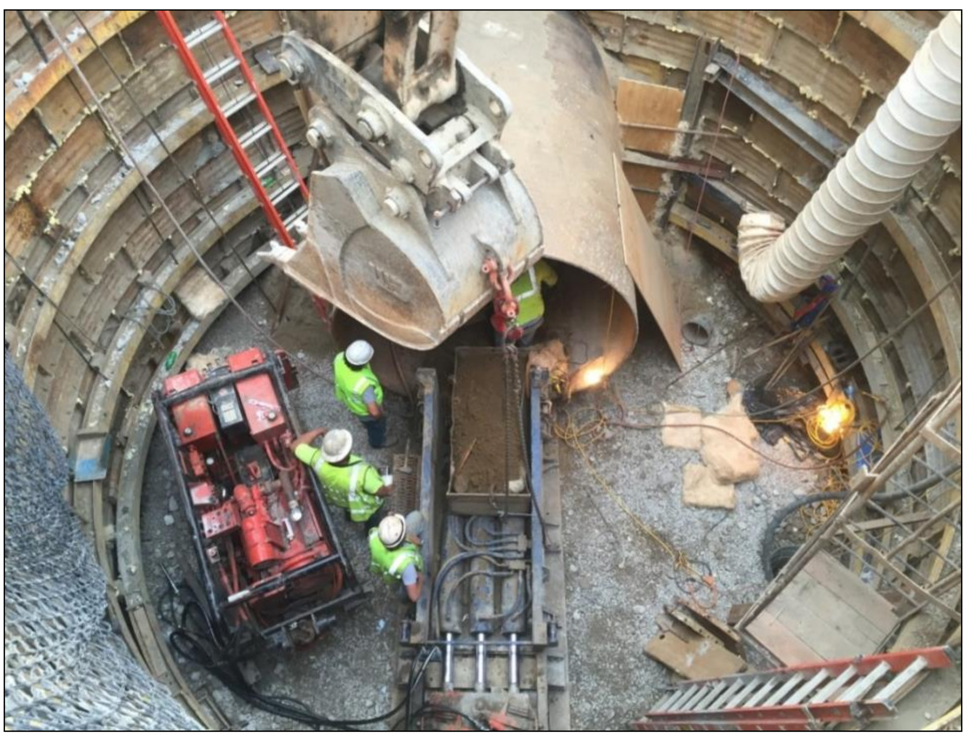

Figure 7. Jacking Operation

The jacking operation commenced April 25, 2016, and was performed on a two 12-hour shift, 24-hour per day basis. This schedule was implemented by Turn-Key to reduce the risk of the casing becoming seized up mid-run due to outside soil pressures. Average production was approximately 7.5 lineal feet (LF) of casing jacked per shift, with a maximum production of 10 LF in a single 12-hour shift. The excavated face revealed soil strata that differed from what was portrayed in the GBR, but coincided with the previously discussed project experience when working around the Dugway West Culvert (See previous section ‘Anticipated Ground Conditions and Geological Baseline’, See also Figure 8). The upper half of the excavated face was sandy fill material. The center of the excavated face was a well-defined organic layer indicative of a streambed formation (incidentally, a number of logs were encountered in this layer during tunnel excavation), below which was stiff gray clay. Again, this was not a surprise to NEORSD’s Project Team as the elevations of these strata were assumed to be higher than shown in the GBR based on the short distance from the Dugway West Culvert to the representative soil boring in comparison to the longer distance to the actual sewer run. For bearing of the casing, this higher-than-anticipated stiff gray clay layer was beneficial as the bearing capacity of the clay was much greater than that of the fill material shown in the GBR.

The Jacking Operation continued as planned, until Shift 2 of April 28, 2016, when at approximate station 0+53 an obstruction was encountered in the upper right (east) quadrant of the excavated face. This obstruction appeared to be an aging brick sewer (See Figure 8). DWIRS Plan/Profile sheets did not show an active sewer at this elevation, so the initial assumption was that this was an abandoned line. However, after investigation, this line was determined to be the existing 24-inch SWO sewer that was to be captured via a drop connection at new manhole PC-5. Based on what was indicated in the DWIRS contract drawings, this was a 24-inch PVC sewer and, the tunnel casing should have had clearance to pass under this sewer. However, this was discovered to actually be an existing brick sewer that had been Cured-In-Place-Pipe (CIPP) lined and the actual elevation of this sewer was several inches lower than shown in the plans. Being an active sewer, its maintenance was critical during the remainder of the tunnel construction until it could be tied into the new PC-5 manhole. After some deliberation, Turn-Key elected to cease jacking operations and commence Liner Plate Tunnel installation at this location, Station 0+53, which was approximately 25-feet sooner than anticipated. As this was a change to the original tunnel proposal, the NEORSD Project Team agreed to an additional adjustment to the original construction change cost for compensation.

Figure 8. Jacked Casing Mining Face – Soil Strata (Left), Brick Sewer Obstruction (Right)

As previously planned, at the casing to liner-plate transition, Turn-Key Tunneling elected to stabilize the surrounding soil by chemical fore-grouting. They contracted T. Luckey and Sons, based out of Harrison, OH (about 25 miles west of Cincinnati, OH), to perform the grouting operations. Utilizing P1210 Flex Grout manufactured by Industrial Support Polymer Network, T. Luckey stabilized an estimated ten to fifteen feet of soil ahead of the excavated face. Turn-Key then resumed tunnel excavation, commencing liner plate installation and supporting the existing 24-inch Brick/CIPP sewer within the excavation with vertical struts.

Tunnel stations 0+53 to 0+70 (approximately thirteen rows of liner plates) were installed at 9-foot-diameter, similar to the jacked casing diameter. Average production was approximately 2.1 LF of liner plate tunnel (equivalent to about 1.5 rows of liner plates) installed per 12-hour shift, with a maximum production of about 4 LF of tunnel installed in a single 12-hour shift.

At station 0+70, Turn-Key remobilized T. Luckey to again chemically stabilize the soil with fore-grouting, this time to the anticipated completion station of the tunnel, approximate station 0+80. Once the soil was chemically stabilized, Turn-Key transitioned from 108-inch diameter liner plate tunnel to 120-inch diameter liner plate tunnel.

Again, this was intended to provide the necessary clearance to install the RFP-specified reinforced concrete connection to the existing brick manhole at PC-6. The rectangular brick manhole was situated diagonally to the tunnel alignment and was initially encountered on the east side of the tunnel at station 0+74. To complete the tunnel closure at the manhole, the west side of the tunnel was installed to approximate station 0+80. The hand-mine tunnel from PC-4 to PC-6 was completed May 17, 2016. (As a side note, it should be noted that based on the successful completion of the PC-4 to PC-6 run, Turn-Key was also contracted to perform an additional short hand-mine tunnel run on the DWIRS Project. To mitigate conflict with an existing City of Cleveland water vault that was in line with the proposed open-cut sewer run from PC-4 to PC-3, Turn-Key utilized the same PC-4 shaft to install a jacked casing hand-mine tunnel from PC-4 to PC-3. This allowed for installation of this portion of the sewer without needing to relocate the City of Cleveland water utility.)

To make the blind connection to the existing brick manhole PC-6, and subsequently capture the No. 4 Brick sewer therein, the south face of the existing brick manhole PC-6 was then completely exposed within the tunnel and concrete was placed around the manhole base to support it in anticipation of making the new connection. Turn-Key then placed the RFP-specified reinforced concrete frame around the proposed opening area in order to support the future connection. Once the connection frame was complete, the south manhole wall was sawcut to provide adequate clearance for installation of the 42-inch HOBAS Pipe connection. The HOBAS Pipe was then installed at the blind connection, laid the full length of the hand-mine tunnel (approximately 80 LF), and blocked into place at line and grade. Interestingly, the design change from 48-inch pipe to 42-inch HOBAS pipe proved to be more beneficial than initially thought. Due to the encountered 24-inch brick sewer, the clearance between that sewer and the 42-inch HOBAS pipe was only 4.5 inches. The originally-specified 48-inch pipe would not have fit.
Once the pipe was secured in place, annulus grouting between tunnel and HOBAS Pipe was performed utilizing a 200 psi cellular grout material, with an approximate total grout take of 190 cubic yards (CY). To complete the PC-6 to PC-4 sewer run, Manhole PC-4 was installed and connected to the previously installed eastern portion of the St. Clair Ave. Relief Sewer, and the newly installed 42-inch HOBAS pipe run from PC-6 to PC-4 was connected at PC-4. Additionally the invert in the existing brick manhole PC-6 was modified to direct flow of the existing No. 4 brick sewer into the newly installed 42-inch HOBAS run. The remaining piece of the puzzle was the installation of the mid-span doghouse manhole, PC-5, which would capture the existing 24-inch CIPP-lined brick sewer encountered during tunneling.

Figure 9. Construction of Manhole PC-6 Blind Connection

DOGHOUSING THE TUNNEL (MANHOLE PC-5 CONSTRUCTION)

Due to the sensitivity of the St. Clair Ave. area (highly traveled, utility laden), the NEORSD Project Team knew the excavation for the PC-5 doghouse manhole would need to be as stable and tight as possible. Therefore they issued a change to WSXJV to contract Turn-Key Tunneling to construct a liner plate shaft to facilitate the installation of PC-5. The shaft was constructed at approximately 13-foot diameter and was excavated to a depth of approximately 20-feet deep to encompass the doghouse connection on the newly installed 42-inch HOBAS Pipe. The careful location and small diameter of this shaft allowed it to be installed in a tight footprint between existing utilities, and the shaft was well supported with contact grouting to maintain stability of the surrounding St. Clair Ave. pavement.

Figure 10. Manhole PC-5 – Doghousing 42-inch HOBAS Pipe and Capturing Existing 24-inch Brick/CIPP Sewer.

Within the PC-5 Shaft footprint, the hand-mine tunnel casing was exposed and removed, as was the annulus grouting material to expose the 42-inch HOBAS pipe. The existing 24-inch CIPP-lined brick sewer was also exposed. The previously installed CIPP lining in this 24-inch SWO sewer proved to be of great benefit to the project. At approximately 0.5-inches thick, this CIPP liner was deemed to be structurally sound, enough so that the drop connection to manhole PC-5 was directly connected to the CIPP liner with a rubber boot connection. For added stability, a concrete collar was poured over this connection as a protective encasement. Once PC-5 was completed the shaft was backfilled and prepared for pavement restoration.

SUMMARY AND CONCLUSION

With all connections tied in, the westernmost terminus of the St. Clair Ave. Relief Sewer, part of the Northeast Ohio Regional Sewer District's $58 Million Dugway West Interceptor Relief Sewer Project was completed. Originally proposed as an open-cut sewer installation, the less than 100-foot-long run from manhole PC-6 to PC-4 could have cost NEORSD over $2 Million in additional required utility relocations. By creatively redesigning this sewer run to combine multiple trenchless techniques, NEORSD was able to realize an estimated tangible cost-savings of approximately $1.4 Million. Additionally, the project schedule was aided as seasonal limitations imposed by utility companies for relocation of their facilities were avoided. Finally, resident disturbance was greatly reduced by minimizing the construction impact to St. Clair Ave., one of the most heavily-traveled streets in Cleveland, OH.

This portion of the Dugway West Interceptor Relief Sewer Project was not without its share of potential pitfalls. The work herein was not immune to the unpredictable nature of underground construction. Unforeseen obstructions and variable soil conditions could have derailed the process. However, by utilizing the expertise of all parties in a collaborative team effort, any issues encountered were resolved quickly and safely, ultimately producing a final product that achieved the hydraulic improvements intended by the original design, while saving costs and reducing negative impact to the area. For those reasons the hand-mine tunneled portion of the St. Clair Ave. Relief Sewer was a great success.

ACKNOWLEDGEMENTS

The authors thank the following individuals who contributed to the development of this paper: Brian Froehlich of Turn-Key Tunneling, Thomas Kral of Walsh/Superexcavators JV II, Kellie Rotunno of Northeast Ohio Regional Sewer District, James Bunsey of Northeast Ohio Regional Sewer District, Doug Lopata of Northeast Ohio Regional Sewer District, Robert Budzilek of AECOM, Glenn Harrah of Terracon Inc., Alex Tomlinson of Terracon Inc., and Laurie Baer of Ozanne Construction Company.