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The City of Redwood City Completes Trenchless Sewer Installation Under Highway 101

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ABSTRACT: The City of Redwood City collects wastewater and transports it to the Silicon Valley Clean Water (SVCW) conveyance system through the Redwood City Pump Station (RWCPS), where the City flows are combined with the SVCW flows for conveyance to the treatment plant. The existing Walnut Street Gravity Sewer Interceptor, which is a 48-inch diameter reinforced concrete pipe (RCP), is the primary connection between the collection system on the west side of Highway 101 and the RWCPS on the east side of the highway. The existing 48-inch Interceptor was enclosed in a 66-inch steel casing under Highway 101. The pipe was not only undersized but also had a reverse grade of 0.7 feet that reduced the pipe capacity and caused operational and maintenance challenges.

The purpose of the Redwood City Walnut Street Interceptor Project was to increase the City's trunk sewer capacity to move raw wastewater under US Highway 101 to the RWCPS. The project included installation of a 60-inch diameter reinforced concrete pipe under Highway 101 using open shield pipe jacking.

1. INTRODUCTION

The purpose of the Redwood City Walnut Street Interceptor Project was to increase the City's trunk sewer capacity to move raw wastewater under US Highway 101 to the Redwood City Pump Station. The service area is mainland Redwood City (excludes Redwood Shores, Pacific Shores and Seaport). Flow also is contributed by the Town of Woodside, and thee San Mateo County-run sewer districts: Fair Oaks, Kensington, Oak Knoll and Emerald Lake Hills. The 2008 Sewer Master Plan reported flow then of PWWF of 38 MGD, but would grow to 41 MGD. PDWF was reported then as 12 MGD but would grow to 15 MGD. This paper will discuss design and construction details, risks, and mitigations related to installation of the new 60-inch diameter reinforced concrete pipe under Highway 101 using open shield pipe jacking including:

- Caltrans permitting
- Existing utility conflicts
- Line and grade control
- Direct jacking sewer pipe without a casing
- Settlement monitoring
- Tunneling through Bay Mud
- Connecting to an active sewage pipe without a shutdown
- Grouting through carrier pipe
- Repairing a 48" diameter RCP pipe

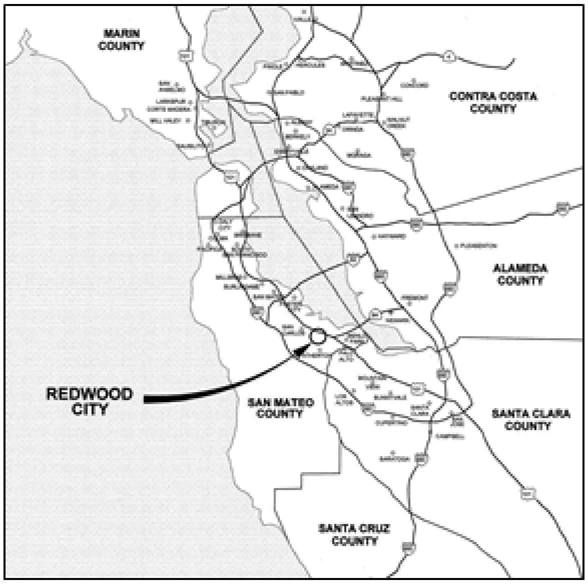

Figure 1: Vicinity Map

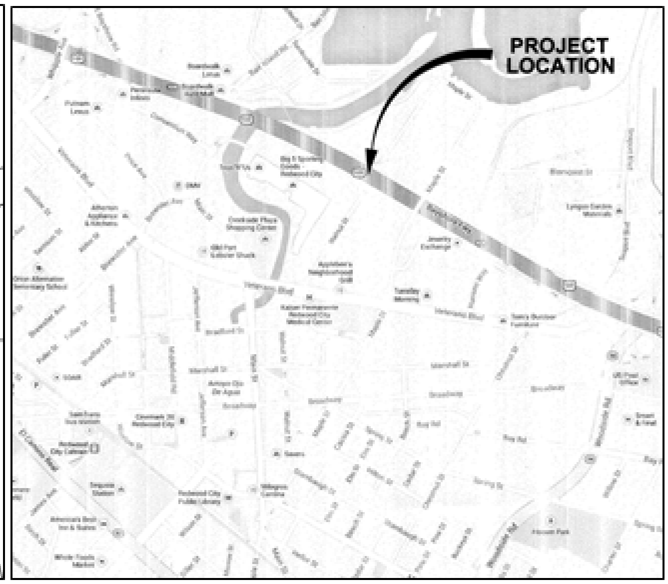

Figure 2: Project Location Map

2. SITE HISTORICAL BACKGROUND

The location for the tunnel has historical documentation going back to the 1800's. The site was originally used as a tannery, and then various industrial and warehouse uses until the Highway was built. By the 1960's it was developed into a marina along Redwood Creek and US Highway 101 was constructed, connecting the cities along the San Francisco Peninsula.

The existing SVCW Force Main and associated Redwood City Pump Station where the pipe discharges was installed in the 1960's with incremental improvements installed since then.

3. GEOTECHNICAL BACKGROUND

The site vicinity was historically tidal flats along the southwestern margin of San Francisco Bay, and the site is located just east of the confluence of Redwood Creek into the bay. Based on the two borings performed for the preliminary design (GeoEngineers, 2010), the subsurface soil beneath US 101 is expected to consist of approximately 7 feet of artificial fill and approximately 8 feet of young bay mud followed by Quaternary-age basin deposits. The artificial fill encountered in the borings, which were located near the ends of Walnut and Maple Streets, comprised gravelly clay, clayey gravel and clayey sand with gravel. The artificial fill used to construct the highway embankment was likely imported, so the soil classification of the fill stratum above the tunnel alignment is unknown. The young bay mud, as encountered, was noted as greenish to bluish black and very dark gray, moist to wet, soft to medium stiff, fat clay. The upper portion of the basin deposits at the elevation of the proposed tunnel alignment was largely comprised of wet, medium stiff to stiff, lean to fat clay with varying amounts of sand. Some thin layers of medium dense, clayey sand were also identified in the upper portion. Coarser-grained basin deposits consisting of poorly-graded to well-graded sand with trace to minor silt were encountered deeper in the subsurface profile. Groundwater within the two GeoEngineers' borings was recorded at depths of 13.5 feet and 8 feet immediately after drilling. Stabilized groundwater levels within nearby borings indicate that the groundwater is higher and is typically as high as 3 to 5 feet below the elevation of Walnut and Maple Streets.

4. SUMMARY OF DESIGN

The project was started by McMillen Jacobs Associates (MJA) and RMC in 2010. The initial project performed the geotechnical investigation, surveying, and conceptual design. The project was then inactive for several years until the City issued a request for qualifications to complete the project in 2013. The Kennedy/Jenks, Staheli Trenchless, and Geotechnical Consultants Inc. team was selected to take the project through final design, provide bidding services, and engineering services during design.

Once design was underway it was determined that the geotechnical report was not complete, delaying the project until the report was completed by MJA (who bought the original geotechnical firm). Geotechnical Consultants Inc. (GTC) performed a thorough review of the site conditions and the preliminary design recommendations. Staheli Trenchless Consultants (STC) then performed the trenchless design, prepared the trenchless specifications and reviewed the trenchless aspects of the project. In addition, STC provided field observation of critical trenchless activities such as initial tunneling operations and tunnel grouting.

The project design consisted of two major elements:

- Trenchless installation of a 60-inch sewer interceptor approximately 375' long.
- Construction of two large diversion structures that can change the pipe that sewerage flows down.

Figure 3 shows the simplified project plan and profile drawing as the project was constructed. As shown below, the trenchless construction extends from the Walnut Street cul de sac to the Maple Steet cul de sac.

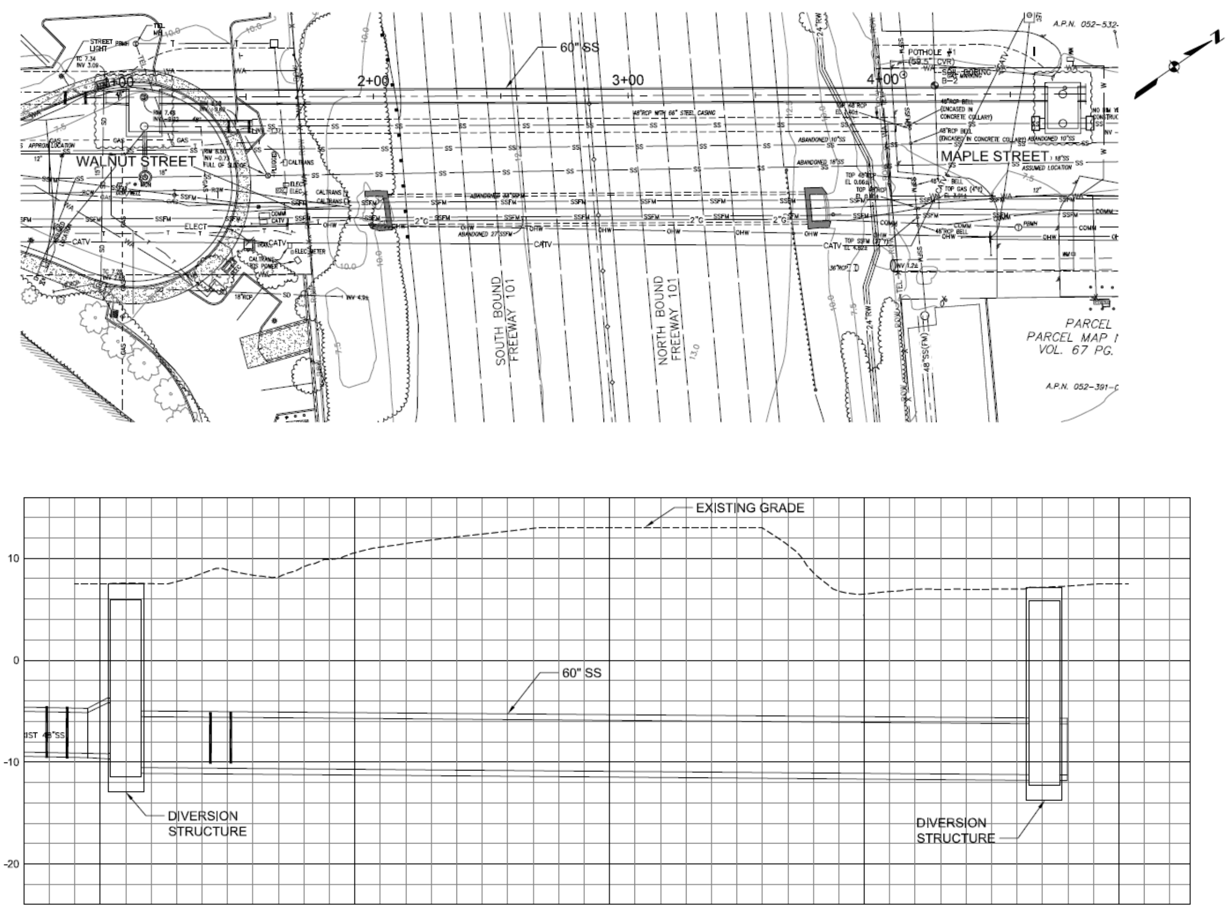

Figure 3: Simplified Plan and Profile of the Walnut Street Interceptor

5. TRENCHLESS DESIGN

The main aspects of the trenchless design were:

- The selection of the tunneling method.
- Designing the pipe to be installed without a casing, including grout ports in carrier pipe, and carrier pipe designed as jacking pipe.
- Evaluation of trenchless methods with local geology (GTC and Staheli), including confirming open shield pipe jacking was feasible in stiff alluvial clays with high groundwater and grade control for avoiding existing utilities. (Used laser guided tunneling machine.)

The project team reviewed the conceptual design report generated by RMC Water and Environmental and Bennett Trenchless Engineers (2011), which identified two feasible methods for the installation of the new interceptor – open shield pipe jacking and microtunneling. Both methods have sufficient accuracy to install the pipeline to the design line and grade. However, there is a significant difference between the two methods in terms of face support. Microtunneling is a closed-face tunneling method which provides positive control of soil and groundwater pressures at the excavation face. In contrast, open shield pipe jacking does not provide face support, leading to potential over-excavation at the tunnel face in unstable or saturated ground.

Despite the anticipated height of the water table in the project area, the lack of face support was not deemed critical to the pipeline installation as the proposed tunnel is located primarily within medium stiff to stiff lean to fat clay with very low permeability (Geotechnical Consultants, 2014). It was anticipated that this material would result in a stable excavation face with groundwater inflow manageable using closable doors at the face and sump pumps in the shaft. Furthermore, the open face would allow for the removal of possible obstructions, should they be encountered beneath US Highway 101. Therefore, the project team agreed with the conceptual design report that while microtunneling was feasible, open-shield pipe jacking was the preferred trenchless construction method for the proposed crossing and would result in a lower overall project cost (RMC & BTE, 2011).

6. DIVERSION STRUCTURE DESIGN

The project included two diversion structures, one at each cul de sac. Figure 4 shows the plan view record drawing of each diversion structure. Each structure was approximately 20’ deep.

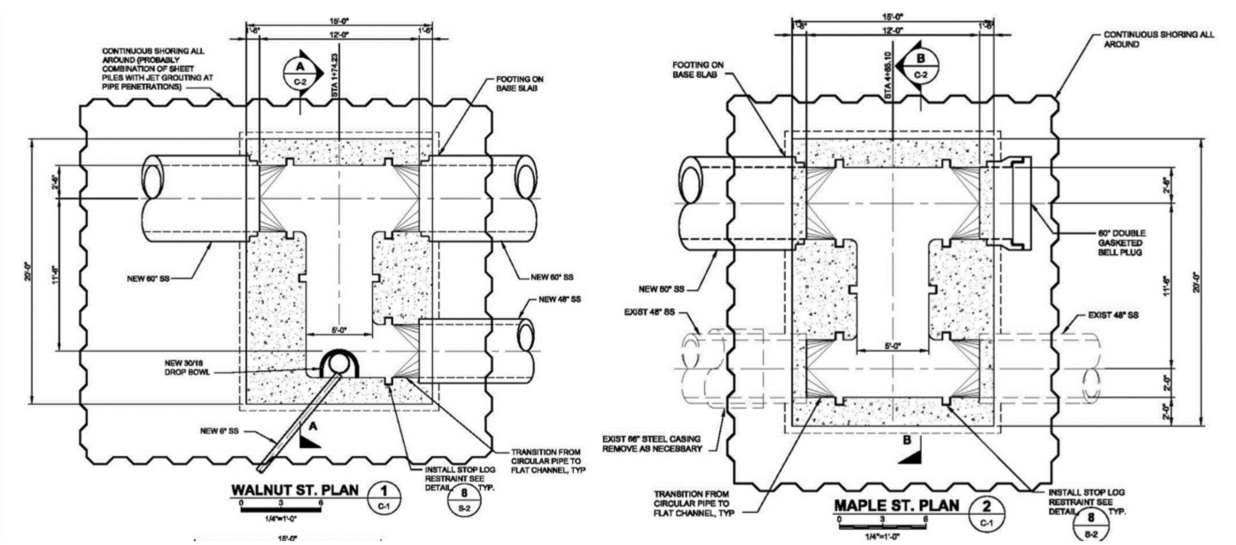

Figure 4: Walnut Street and Maple Street Diversion Structure Record Drawings

The design considerations for the diversion structure design were as follows:

- Local geology of old bay mud and concerns of settlement due to weight resulted in a robust subbase wrapped in geofabric.
- Provide simple robust design with no moving parts, ability to divert flow through either pipe, and perform maintenance on existing 48-inch SS resulted in aluminum stop logs being used to isolate sections of the diversion structure.
- The large size of the structures required relocation of some existing utilities.
- Bypass was necessary and set up during construction, so sewerage could keep flowing. The 48-inch bypass within the Walnut Street Diversion Structure excavation is shown below (green PVC pipe to right of photo).

Figure 5: Sewer bypass in jacking pit (Photo by Kennedy/Jenks)

7. DESIGN CHALLENGES

Caltrans Permitting

The new pipe is routed under Highway 101 which is under Caltrans jurisdiction. Traditionally, water and sewer utility crossings under Caltrans right-of-way Highways require a casing pipe. The encroachment permit was submitted with the near final plans, showing the new 60-inch sewer being installed without a casing pipe. The casing pipe for this project would have been approximately 72- to 84-inches in diameter and would have presented additional challenges due to utility clearance.

The first encroachment permit was accepted by Caltrans with no exceptions. This greatly simplified the project and lessened the concern of utility conflicts due to the tolerances of the alignment.

Existing Utilities

Existing utilities along the alignment presented numerous challenges. This section describes the existing utilities and the challenges encountered while dealing with them.

An existing PG&E gas line located in Walnut Street had a direct interference with the Walnut Street jacking shaft. The gas line was relocated by PG&E without issue.

An existing water service on Maple Street that served the San Mateo County detention center was in direct interference with the receiving shaft and was relocated without issue.

Redwood City installed a new recycled water line before the Walnut Street Interceptor project started, but after the design was completed. The installed pipe was installed on top of an existing 18-inch sanitary sewer that needed a new manhole for a connection. Additionally, the 18-inch sewer in this location was in poor condition. The manhole was moved up the street about 150 feet and the existing 18-inch sanitary sewer was abandoned.

In the cul-de-sac on Walnut Street, Caltrans identified an electrical line and pull box that was in interference with the new 60-inch sanitary sewer as their own. When construction started the project team requested Caltrans relocate these lines. It was then determined that this was an AT&T phone line and there were six, 2-inch conduits in the area where shoring needed to be installed. Fortunately, the Contractor did not hit the unmarked utilities. The project duration was about 8 months and AT&T was unable to relocate the conduits during that time. The solution was to install the shoring wall around the conduits.

The reaction wall and sewer bypass set up on the Walnut Street side of the project was especially challenging. Since the existing 48-inch sewer needed to be bypassed during the project the reaction wall had to be shimmed out from the wall with I beams to function properly.

Figure 6: Reaction Wall on the Walnut Street Side (Photo by Kennedy/Jenks)

The Silicon Valley Clean Water (SVCW) 48-inch force main (FM) parallels US 101 on the Maple Street side of the project. The new 60-inch sanitary sewer pipe was to cross under the force main. Since the existing pipe is very sensitive and prone to leaks when disturbed, great care was taken for this crossing. The clearance was 2 feet from pipe crown to the bottom of the FM. Settlement monitoring was required on this pipe and SVCW installed a steel plate that the TBM would hit if it was off alignment. If a casing pipe for the 60-inch sanitary sewer was used this may have become a direct interference. The force main was the most worrisome of utilities due to the close clearance.

Finally, the alignment paralleled the existing 48-inch RCP sewer line. It is installed in a 60-inch steel casing. There is approximately 5 to 6 feet of clearance from edge to edge. Overall, there was not a great deal of concern about this pipe, since it is parallel and the pipe location was verified to a high degree of accuracy.

Line and Grade

The existing 48-inch pipe was on a reverse slope by 0.7 feet. Reverse slope is such an unusual circumstance that it was surveyed two times to verify the reverse slope. It was assumed that it was installed that way.

The new 60-inch sewer pipe required very tight grade control due to both the ability to convey sewage at the desired minimum velocity, and the need to avoid existing utilities. The completed pipeline was installed within the project tolerances for line and grade. The tunneling equipment used laser guidance to ensure line and grade during tunneling operations.

Direct installation of Sewer Pipe Without Casing

One of the cost and time saving features of this project was the direct installation of the sewer pipe without the use of a casing. Omitting the casing was critical to avoid utility conflicts with the existing 48-inch force main and to save the costs of the steel casing and larger tunneling equipment. The main risk of not using a casing was not being able to obtain a Caltrans encroachment permit for the project which turned out not to be an issue.

Settlement Monitoring

Settlement monitoring was performed along the alignment under the highway. Surface, subsurface, and utility monitoring points were used. No settlement was observed throughout the duration of construction. Tunnel grouting resulted in approximately 6.6 – 7 cubic yards of grout being injected into the ground surrounding the pipe.

8. BIDDING RESULTS AND DETAILS OF BIDDING

The project was originally put out to bid in February of 2016, and the apparent low bidder was considered non-responsive (the apparent low bidder did not fulfill all of the bidding requirements). The second round of bidding resulted in JMB Construction being the apparent low bidder with a bid for $2.7 million. The engineers estimate for the project was $2.5 million, and accounting for escalation the engineer's estimate would have matched the low bidder. The high bid was from Ranger Pipelines at $3.25 million. Please see Table 1 below for bid results. The bid unit cost for tunneling was $1,200 per linear foot of 60-inch RCP installed.

Table 1. Bid Results

	Bid			
	Engineers Estimate ($)	**JMB Construction ($)**	**KJ Woods Construction ($)**	**Ranger Pipelines ($)**
Bid Total	$2,512,604	$2,708,000	$3,138,000	$3,255,000

9. CONSTRUCTION CHALLENGES

The construction started in the summer of 2016 and ended in spring of 2017. The original schedule had the project at substantial completion in December/January of 2016. Due to utility conflicts, rainy weather, slow tunneling, and other issues the project was not substantially complete until the spring of 2017.

Concrete Jacking Pipe

The concrete jacking pipe went through numerous submittals. The Contractor originally submitted traditional bell and spigot ASTM C76 pipe. The material did not meet the specifications for flush bell concrete jacking pipe. After a few rounds of shop drawing submittals and meetings, the Contractor and vendor submitted and supplied flush bell jacking pipe required for the project. Figure 7 and 8 show the as installed pipe and special joint.

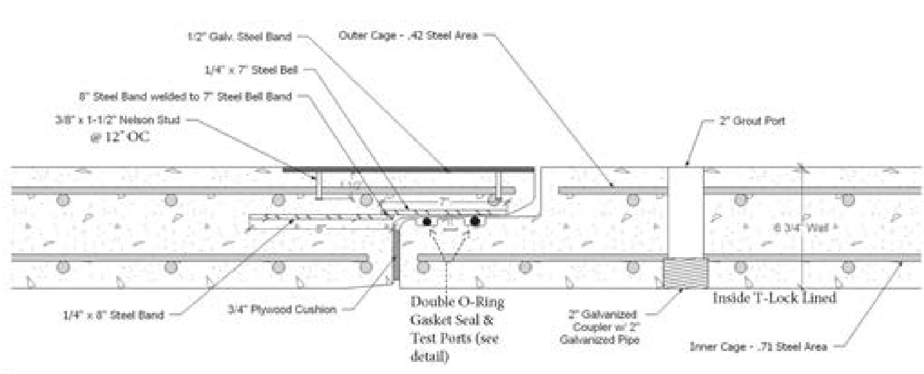

Figure 7: Concrete Jacking Pipe Joint Detail

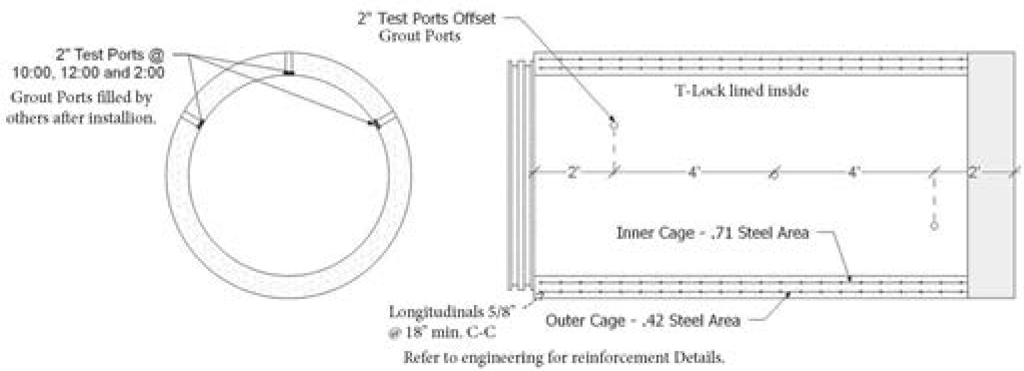

Figure 8 : Concrete Jacking Pipe Detail

Slow Production During Tunneling

The main issue delaying the completion of the project was slow tunneling progress. Figure 9 is a snapshot of a daily tunneling log. The Contractor progressed 6 to 10 feet per day. The tunnel boring machine struggled to move through the stiff clay efficiently.

JACKING FORCES: 60 tons **INSTALLED LENGTH:** 33 ft

RATE OF ADVANCE: 6' in eleven hrs

BENTONITE VOLUME PUMPED: 1200 gal **LOCATION OF PORTS:** At face of tunnel

CASING LINE AND GRADE: 1/2" right. Grade good.

VOLUME OF SPOIL REMOVED: 6 yards

GROUT VOLUME: na **GROUT PRESSURE:** na

Figure 9: Daily Tunneling Log

Sewage Backups

During project construction, Silicon Valley Clean Water was conducting sewer maintenance and testing that resulted in sewer backups through the project several times. This resulted in flooding of the jacking pit with sewage. The flooding occurred because the Contractor had uncovered the old concrete pipe and manholes. The older pipe and manholes had deteriorated gaskets that were unable to prevent the sewage from leaking out at the joints. The Contractor had to pour concrete collars around the existing manholes and pipe joints to prevent the sewage from leaking out into the projects tunneling launching pit.

Tunnel Grouting

The Contractor was able to contact grout the full length of the tunnel without incident. They ended up pumping a total of 6.5 to 7 cubic yards of grout into the grout injection ports located in the pipe. After tunnel grouting, the ports were packed with mortar and the holes in the liner were patched.

Figure 10: Tunnel Grout Port (Photo by Staheli Trenchless)

Field Repairing Existing Concrete Pipe

The contractor had to perform field repairs on existing 48-inch RCP where bypasses were set up. The repair included doweling in rebar and forming and pouring patches on the pipe. The repairs were not previously considered and a timely solution to repairing the pipe had to be figured out and implemented.

10. CONCLUSION

The 60” diameter RCP sewer was successfully installed under Highway 101 with no major issues. The following are a list of lessons learned and recommendations for similar projects.

Pipe Material

The pipe material was a significant issue and slowed down the project. The pipe material design for the concrete jacking pipe was contained exclusively in the in the written specifications. It would have made things clearer if there was a jacking pipe detail included in the drawings. Pointing to a drawing is easier than having to reference a specification section. It is suggested that the pipe material type be very clearly stated, and include pipe and joint details in the project drawings (not just the specifications). It is suggested that the specifications be supplemented with these project drawings and details to minimize Contractor interpretation.

Keep It Simple When It Comes to Tunneling Techniques

While microtunneling was also a feasible alternative for installing the pipe, open shield pipe jacking and guided auger boring was bid while pipe jacking was used for the project. Pipe jacking and auger boring are much less expensive than microtunneling. This saves the owner money to perform other critical infrastructure projects.


Figure 11: Tunnel Machine Exiting the Receiving Pit (Photo by City of Redwood City)

Caltrans Encroachment Permit

Follow Caltran's permit process to the letter and it can be pain free. Caltrans was reluctant to talk about the project until the permit has been started. Extending a permit is easy, the project's permit was issued a year before we started work.

Production Expectations

While some tunneling projects excavate 20-30 feet per day doesn't mean that the next tunneling Contractor will be able to perform to expectations. It is important to include contingency in the schedule to allow for slow production.

Existing Utilities

Existing utilities are extremely important. Conduct utility research, field investigations, physical locates and relocations and include all utility information in the contract drawings. Be familiar with the local municipality's laws regarding franchise utilities and their obligation to relocate. Caltrans likely will not know if they have utilities outside of Caltrans ROW. A small amount of money spent on potholing can save huge amounts of money during construction.

11. REFERENCES

Kennedy/Jenks Consultants, (2018) – NASTT's 2018 No-Dig Show: Redwood City, CA Completes Bay Mud Trechless Crossing of U.S. Highway 101

Geotechnical Consultants Inc., (2014) – Geotechnical Memorandum, Walnut Street Interceptor Replacement

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