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Design Challenges for Paradise Whitney Interceptor, Project 669, Las Vegas, Nevada

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1. ABSTRACT

The Paradise Whitney Interceptor (PWI) Project for the Clark County Water Reclamation District will relieve capacity deficiencies for the existing sewer interceptors and provide capacity for the future. The whole PWI project has been divided into three packages. This paper discusses design challenges for the Project 669 Package two (Project) portion of the overall project, the first package to be constructed. Throughout the design, Carollo Engineers (Carollo) and Brierley Associates (Brierley) have worked closely with the design teams for the other two packages to allow seamless contract document presentation for the entire project.

The project consists of 27,138 LF of gravity sewer that ranges in inside diameter from 60- to 72-inches; a 76-inch steel casing pipe required for two of the trenchless crossings. Open cut methods will be utilized for 13,657 LF and trenchless methods will be utilized for eight reaches totaling 13,481 LF.

Brierley was engaged by Carollo early in the design phase due to the anticipated trenchless component of the project. Early involvement allowed beneficial input into the subsurface investigation for the trenchless design. The project encountered numerous design challenges including complicated geology, close proximity to sensitive underground utilities, limited surface access, and other factors forcing trenchless drive lengths of up to 1,500 LF. Some project considerations contributed to an increase in trenchless construction more than 230% (originally about 5,757 LF).

The tunnels for the project will be constructed using microtunneling (MTBM) and earth pressure balance (EPB) methods; ground improvement is required on many of the trenchless drives.

2. INTRODUCTION

In order to relieve existing capacity deficiencies and improve hydraulic operating conditions of the Sunset, Sunset West and Robindale Interceptors, the Clark County Water Reclamation District (District) identified numerous constrictions needing to be addressed to convey the projected wastewater flows out to the year 2044. This project was created as the solution. PWI consists of approximately 71,000 linear ft of 48-, 54-, 60-, 66- and 72-inch diameter sewer interceptor and approximately 1,100 LF of 18-, 21-, 27-, 30-, and 36-inch connection sewers. The PWI project also includes approximately 10,500 ft of 12- and 15-inch diameter relief sewers. The carrier pipe for the project consisted of fiberglass reinforced polymer mortar pipe (FRPMP). The overall project has been divided into three packages; Brierley is involved in the trenchless and open cut portions for package two. During design, Brierley interpreted geologic data, determined feasible construction methods including necessary ground improvement, established baselines in the Geotechnical Baseline Report (GBR), prepared specifications and project drawings and provided an engineer's estimate of probable cost for the trenchless construction.

Several changes occurred throughout the design process including:

1. Carrier pipe and casing pipe diameters were increased.
2. Approximately 7,724 LF of trenchless lengths were added.
3. Drive lengths were extended due to locations where:
   a. Dewatering induced settlements was anticipated.
   b. Lack of access or accessibility to the site was limited.
   c. Materials encountered in the boring logs were not favorable.
   d. Extensive utility relocations were required.
   e. High traffic volume was shown to exist.

The ground conditions, existing utilities, and third party impacts along the alignment presented unique challenges for the design team. This paper presents how the design team dealt with those challenges by providing feasible solutions while managing risk.

3. DESIGN DELIVERABLES

The Geotechnical Data Report (GDR) for the project prepared by Geotechnical & Environmental Services, Inc. (GES) was relied upon by the design team. Due to early involvement in the project, Brierley provided input for the soil boring locations. On the original subsurface exploration plan, borings were taken at shaft locations. Borings were designed to have an average of 500 foot spacing for the open cut areas and 350 foot spacing in the trenchless areas with at least one boring at each end of a trenchless reach. The depths of the borings were 5-to 10-feet below the planned invert for open cut reaches and 10-feet below the planned invert at the trenchless reaches. Due to original designation as open cut reaches, trenchless reaches added later in the design process did not have subsurface investigations at the new shaft locations or at the desired spacing for portions of the alignment converted to trenchless. The location of launching and receiving shafts were reevaluated to account for the added trenchless lengths. The absence of boring information at a shaft location could potentially be a challenge due to the highly interbedded and variable nature of the surrounding soils. At some locations the pipeline profile was deepened to accommodate various adjustments during the design which in turn resulted in a few locations where the zones targeted for laboratory testing was no longer in the tunnel envelope.

Brierley wrote a GBR for the proposed trenchless and open cut portions of the project. The GBR summarized the factual results of the geotechnical investigations, presented an interpretation of the ground behavior, and addressed geotechnical-related construction considerations. The contractual geotechnical baseline conditions were established for use in bidding by the contractor and in administration of the construction contract. Tunnelman's Ground Classification system was used to baseline ground behaviors in the GBR. Because a similar ground classification for trenches did not exist at the time, the Tunnelman's Ground Classification was also utilized for the open cut sections for this project. Since completion of the design phase of this project and due to the apparent need, Brierley has developed a ground classification system for trench, shaft, and slope excavations that can be used for future GBRs.

A risk register was created by Brierley for the trenchless portion of the project during the early phase of design. Risk and mitigation measures were examined for the equipment, ground conditions, third party impacts and contract documents.

Brierley produced design drawings for the trenchless reaches including instrumentation plans and details, casing assembly details and soil preparation for the MTBM/EBP methods. The soil preparation for the MTBM/EBP methods drawings contained grouting schedules, plans and cross sections for areas to be modified by compaction grout and/or jet grout. An engineer's estimate of probable cost for the trenchless portions for the project was also produced. The estimate was based upon an assumed construction approach, an internally developed construction schedule and Clark County prevailing wage rates.

Seven specifications were written by Brierley, which included: Geotechnical Instrumentation and Monitoring, Shaft Excavation Support and Protection, Tunnel Pipe Installation and Backfilling, Contact Grouting, Soil Preparation for Microtunneling using Jet Grouting, Soil Preparation for Microtunneling using Compaction Grouting and Trenchless Construction. Post-qualification forms were also developed to be included in the contract documents for the tunneling contractor, tunneling superintendent and MTBM operator. The design team provided input related to the General Conditions (GC) and Supplemental Conditions.

The District wanted consistency between the contract documents for all three packages for ease of contract administration. Per the District's request, the GBR format and baseline statements, drawing details, specification organization and overall contract language needed to be consistent for all three packages. The three design consultants needed to collaborate in order to produce a seamless contract document presentation. Since this project was the first one going out to bid, our design team needed to efficiently streamline this process.

4. GEOTECHNICAL DESIGN CONDITIONS

The project site has been separated into four zones based on geologic variations noted between the test borings along the alignment. Comparing similarities based on geologic mapping, subsurface profiles and the material properties, the trenchless reaches and open cut sections were broken into regional zones. Each zone was divided further into specific trenchless reaches and open cut sections. A location map for the zones is shown in Figure 1. Table 1 presents a summary of the trenchless reaches and open cut sections.

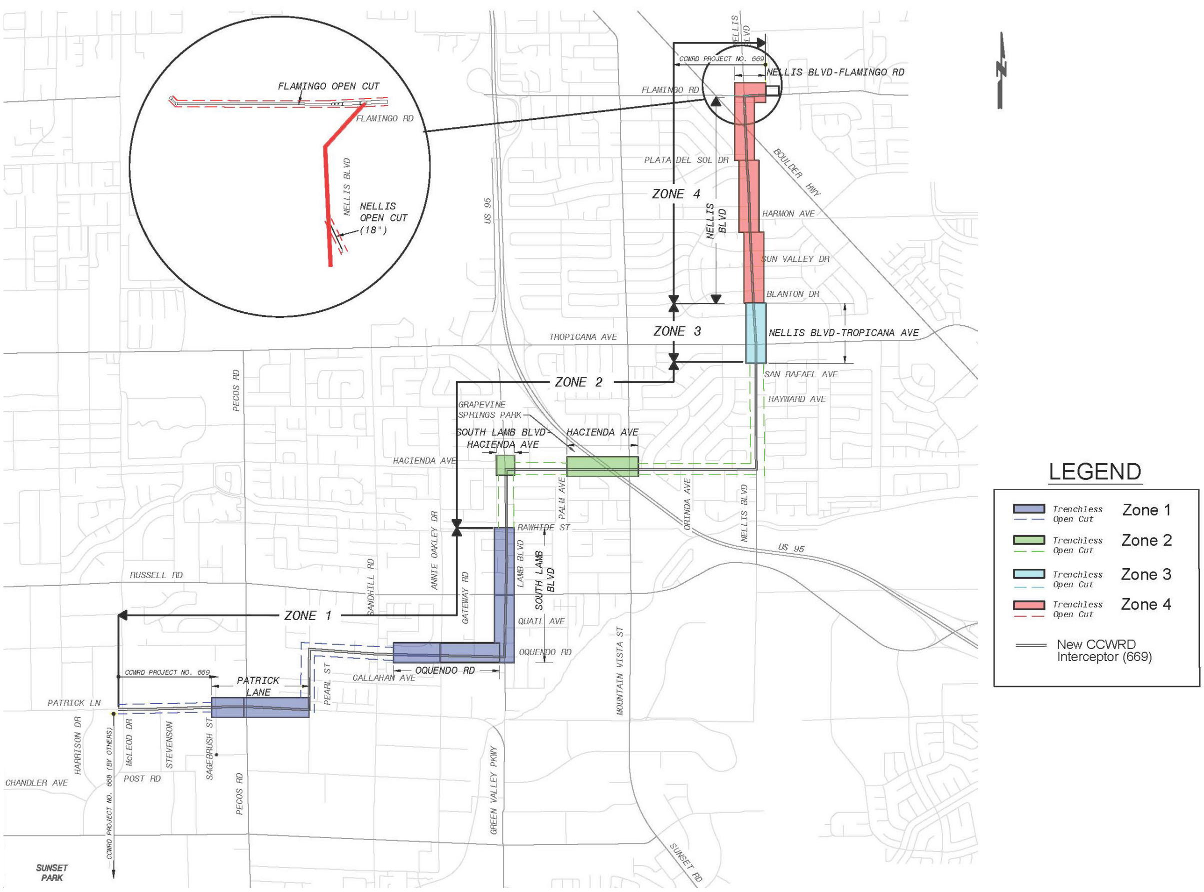

Figure 1. Zone location map.

Table 1. Trenchless and open cut data summary.

Trenchless/Open Cut Sections	Approximate Length (ft)	Carrier Pipe Inside Diameter (inches)	Casing Required	Regional Zone
Open Cut	1,794	60	No	1
Patrick Lane Trenchless	2,032	60	No	1
Open Cut	3,158	60	No	1
Oquendo Road Trenchless	1,755	60	No	1
Open Cut	568	60	No	1
South Lamb Boulevard Trenchless	2,745	60	No	1
Open Cut	1,248	60	No	2
Lamb-Hacienda Trenchless	34	60	Yes	2
Open Cut	1,285	60	No	2
Hacienda Avenue Trenchless	1,388	60	Partial	2
Open Cut	2,593	66	No	2
Open Cut	2,526	66	No	2
Nellis Tropicana Trenchless	1,152	66	No	3
Nellis Boulevard Trenchless	4,255	66, 72	No	4
Nellis-Flamingo Trenchless	120	72	No	4
Nellis Open Cut	65	18	No	4
Flamingo Open Cut	421	30, 48, 84	No	4

The subsurface explorations for the project revealed fill, coarse-grained soil, fine-grained soil and caliche along the project alignment. The fine-grained soil is generally interbedded with the coarse-grained soils. High plasticity clays occur throughout the fine- and coarse-grained material. These clays exhibit varying degrees of collapse/swell potential when wet. During the subsurface investigation, there were no cobbles or boulders observed within the limited diameter of the borings. Therefore, anticipated strength values were based on results from local basalt boulders, which represent the likely source materials for the alluvial deposits in the project area.

Index properties and grain size values were examined and summarized from available laboratory testing for each zone. Data was evaluated for the full-depth profile as well as one diameter above and below the design tunnel profile. Blowcount N-60 values were normalized to account for sampler size and hammer efficiency and plotted by histogram. Summary tables containing the average, high and low for grain size and index values in the alluvium were generated for each trenchless reach and zone. The thinnest and thickest fine- and coarse-grained layer for each trenchless reach and zone was determined. The percent of the excavated volume of fine-grained soil was calculated based on the lengths of each layer. The stickiness of fines was plotted with statistical representation for low, medium and high ranges for each zone. Soil abrasion testing (SAT) was performed on composite samples from each zone due to the required testing weight. SAT values between 0 and 7 are considered low, values between 7 and 22 are characterized as medium and values greater than 22 have high abrasivity.

According to the District's design standards, the excavated soil percentages that can be reused as select backfill was determined. The contractor would have to account for potential shrinkage and bulking, which are defined as the change in volume of the soil from its in-situ condition following excavation, moisture conditioning, placement, and compaction. The contractor needed to provide careful separation and/or processing of the excavated trench soils for reuse purposes. Import and export of fill may be necessary to compensate for shrinkage and bulking due to volume changes once the excavated soil is placed and compacted.

In several locations we anticipate encountering pipe bedding for existing utilities. The pipe bedding is expected to consist of non-cohesive granular materials following Clark County and the Nevada Department of Transportation (NDOT) backfill standards. Although not specifically observed within the test boring logs, obstructions encountered in the fill could pose serious problems to shaft excavation and shoring installation.

Numerous underground and overhead utilities exist along the project alignment. Tunnels and shafts were positioned to avoid conflicts with known buried utilities. A risk assessment with proposed alternatives was examined for the utilities that were in close proximity to the alignment. Ground improvement methods were implemented at several close and/or critical utilities where the alignment could not be modified. Parallel utilities that were a minimum of 12 feet away from the tunnel were monitored. Utility monitoring points were placed on utilities that crossed the pipe alignment. Utilities that were one shaft depth offset in an open cut section next to a trenchless reach required monitoring. Certain utilities not requiring monitoring include most small diameter ductile conduits such as telephone, cable television and electric. Utilities that were monitored include water, sanitary sewer and natural gas line larger than 4-inches in diameter. Additionally, surface survey points were placed 20 feet from every shaft and along the center of each drive. Extensometers were located 20 feet from every launching shaft and to a depth two feet above the crown of the pipe.

4.1 ZONE 1

Zone 1 extends about 12,051 LF where the trenchless reaches along Patrick Lane, Oquendo Road and South Lamb Boulevard had similar parameters particularity regarding the Atterberg Limits, and gradation. They also had very close percentage of clay stickiness along with a similar N-60 distribution shape. The majority of the tunnel excavation will be in fine-grained soil with a clay component.

Potentially collapsible soils are present in areas along the alignment identified by soils with low dry densities. Differential settlement is a major issue associated with collapsible soils. Caution should be used when driving piles for shaft construction in areas where these soils are present to prevent disruption of the sensitive soil bonds. The contractor should propose methods and provide machinery that minimizes vibrations in these locations. Mitigation options, such as ground improvement, may be proposed in areas where vibration-induced settlement may be present.

According to readily available published geologic maps of the area, overburden within the southern portion of the alignment consists mainly of Quaternary-age Sandy Alluvium of Paradise Valley (Map Reference = Qsa) which is described as unconsolidated, well-sorted fine quartz and pebbly sand; locally well cemented calcium carbonate caliche exists in modern washes. The southern portion of the alignment also crosses Sand Dunes (Qd; Holocene) of loose, well-sorted, fine quartz sand and Plio-Pleistocene Silty Sand (QTss; Pliocene) with weakly to prominently thin- to medium- bedded, interbedded silty clay and clayey silt with selenite plates and "sugary" gypsum common throughout.

Generally, there has been a lack of standards and universal testing methods that characterize soil abrasion. In soft ground tunneling, wear can occur due to the interaction between abrasive soils and cutters. Wear may also take place on the excavation chamber and the muck removal system as a result of excavation and handling of the coarse-grained soils. On a slurry tunnel boring machine (TBM) abrasion can have an adverse impact on the slurry discharge components, pipes, and pumps. Particularly on long tunnel drives, severe abrasion can occur due to the extended period of exposure of the discharge components to slurry mixed with excavated soil (Nilsen et al., 2006). Based on laboratory testing the soils in zone 1 resulted in a SAT value of 15, which is considered medium abrasively for the coarse-grained soils.

The subsurface clays associated with both the coarse- and fine-grained soils have the potential to create problems with adhesion or clogging of equipment (Thewes and Burger, 2004), and increased jacking pressures. Clays with a high potential of clogging can impede the removal of spoil from the excavation cutter head of a TBM and create other complications, which can slow or stop tunneling progress. Studies suggest that the stickiness of clay can be correlated based on the consistency index and plastic index of the clay. The consistency index is a function of the natural moisture content, the liquid limit and the plastic index. Laboratory data included in the GDR (GES, 2013) indicates that soils encountered in the project are classified as having "low to high" clogging potential. We estimated in zone 1, the contractor should assume that 11 percent of the excavated clay volume of trenchless reaches would exhibit a high stickiness potential. The contractor was advised to develop plans for managing the clogging potential during construction. Methods available to the contractor may include use of suitable clay dispersants.

Soft ground conditions, identified by low blowcounts (N-60 less than 5) were identified in the soil profile along zone 1. These low blowcount soils may result in poor line and grade performance during MTBM/EBP methods, insufficient bearing capacity, loss of machine steering capability and excess machine settlement causing unwanted dips in jacked pipe. The inconsistent lithology and variable nature of the soils observed in the subsurface borings are anticipated to present challenges; an experienced microtunnel operator and continuous monitoring of line and grade will be important. To reduce some risk associated with potential settlement during tunneling, soil preparation of the trenchless reaches using compaction grouting is required along the Patrick Lane, Oquendo Road, and portions of the South Lamb Boulevard trenchless reaches. Compaction grout is a material blend of fine aggregate, cement and water to achieve a pumpable, viscous grout of a low slump to enable pumping but remain intact after injection. The grout does not penetrate the soil pores, but displaces the subsurface soils by forming a homogeneous grout bulb near the grout pipe tip, densifying the nearby soils. The soil densification is intended to aid in tunnel steering and limit settlement during tunneling.

Due to the potential issues associated with existing utilities within close proximity to the proposed trenchless excavation, soil preparation by jet grouting is required at the Patrick Lane trenchless reach. Jet grouting is the process of injecting cement grout to create a soil-cement mixture in-situ. The cement grout is injected under high pressure and mixed with the soil, while the monitor is rotated and lifted at a slow, smooth, constant speed to achieve a continuous geometry and quality. Due to the significant consequences if existing utilities were to settle or heave, these utilities are to be underpinned by jet grout. The close proximity utilities will also include instrumentation and be monitoring during tunneling operations.

The Patrick Lane trenchless reach has been split into two drives with lengths of approximately 539 and 1,493 feet. Two of the shafts must be watertight due to potential dewatering-induced settlement at those locations, as well as identified groundwater contamination. The third shaft has a limited dewatering duration of 90 days. The most complicated utility for these drives is a 10-inch vitrified clay sanitary sewer pipe located directly above the alignment for about 1,200 LF of the drive, separation between the utility and proposed tunnel crown ranges from about 12 ft at one end to just under 2.5 ft at the other.

Oquendo Road trenchless reach has been split into two drives with lengths of approximately 893 and 876 feet. One shaft for this reach must be watertight due to potential dewatering induced settlement. The remaining two shafts for this reach have a limited dewatering duration of 90 days.

The 60-inch FRPMP South Lamb Boulevard trenchless reach has been split into four drives with lengths ranging from approximately 543 to 750 feet. The trenchless reach will pass beneath a 9-ft by 5-ft reinforced concrete box storm drain and in close proximity to several other utilities. Three of the five shafts along this reach must be watertight due to potential dewatering induced settlement at those locations and one shaft has a limited dewatering duration of 90 days.

4.2 ZONE 2

Zone 2 extends slightly over 9,000 LF. The soils in zone 2 are generally denser, and coarser with a lower percentage of caliche. The soils along the Hacienda-Lamb and Hacienda Avenue trenchless reaches had similar results, particularly the dry densities, moisture contents, plasticity indices, as well as percent sand and fines. Both trenchless reaches had high N-60 values reaching up to 50 blows per 3 inches. The zone 2 sample selected for SAT testing had a value of 19, which is considered as medium abrasivity. Based on our analysis we estimated the soils along the zone 2 trenchless reaches will exhibit high stickiness potential for 30 percent of the excavated clay volume.

Published maps indicate the central portion of the project alignment is underlain by Pediment Deposits of East Las Vegas (Qp; Late Pleistocene and Holocene). The Pediment Deposits are thin pediment and colluvial deposits of silt, sand and gravelly sand with well-cemented calcium carbonate caliche nodules.

Due to the potential issues associated with existing utilities within close proximity to the proposed trenchless excavation, soil preparation by jet grouting was required at the Lamb-Hacienda trenchless reach. At this location 90-inch mortar lined cement pipe (MLCP) force main owned by Southern Nevada Water Authority (SNWA) is located about four feet above the proposed 76-inch casing pipe. The 90-inch MLCP is thought to be approximately 50 years old. As required by SNWA to protect 90-inch Pittman Lateral water line, the Lamb-Hacienda reach must be constructed using trenchless methods, and a steel casing pipe is required. A steel 76-inch casing pipe will house the 60-inch FRPMP carrier pipe for this short 34 ft drive. Dewatering is allowed for both shaft locations; however, one shaft does have a limited dewatering duration of 90 days.

The Hacienda Avenue trenchless reach has been split into two drives with approximate lengths of 1,197 and 190 feet. A steel 76-inch casing pipe is required by NDOT beneath US 95 for the longer drive. Restricted access for a shaft in the local park adjacent to the interstate also dictates the longer drive length. There are no watertight shafts or 90-day dewatering restrictions along this trenchless reach.

4.3 ZONE 3

Zone 3 spans about 1,150 LF and consists of primarily coarse-grained soil and caliche. Relative to the other areas along the alignment, there was an increase in the presence of caliche in zone 3. About half of the zone 3 alignment was mapped in the pediment deposits of east Las Vegas, and the remaining alignment mapped as alluvium. For the trenchless reaches in zone 3, a SAT value of 19 was utilized, which is considered medium abrasivity. We anticipated 17 percent of the excavated clay volume of zone 3 would exhibit a high stickiness potential.

The calcium-carbonate cemented caliche areas can be expected throughout the coarse-grained soils as interbedded layers, lenses, as well as nodules. Caliche nodules are gravel-sized particles classified as coarse-grained soils with respect to material properties and soil behavior. Caliche and poorly-cemented soils were encountered within layers of varying thicknesses throughout the trenchless reaches within this zone. In general the caliche layers encountered were greater than 3 inches and up to 7.5 ft. The thickness of the caliche layers and lenses are expected to vary in lateral extent. The caliche encountered was well-cemented with calcium carbonate and exhibited varying degrees of hardness ranging from medium hard to very hard.

The Nellis-Tropicana reach consists of 66-inch direct jack FRPMP installed in two drives. One of the shafts along this reach must be watertight due to potential dewatering induced settlement.

Due to the potential issues associated with existing utilities within close proximity to the proposed trenchless excavation, soil preparation by jet grouting is required at a 24-inch storm drain. The 24-inch storm drain along Nellis-Tropicana has about 1.5 feet of clearance.

4.4 ZONE 4

Zone 4 spans approximately 4,400 LF and will be constructed by both open cut and trenchless construction of 66-inch and 72-inch FRPMP. The trenchless portion will be installed in five total drives, three of which are 1,000 linear feet or greater. This zone also include open cut sewer connection appurtenances for approximately 65 feet of 18-inch diameter and about 17 feet of 30-inch diameter pipe, 343 feet of 48-inch diameter pipe, and 61 feet of 84-inch diameter pipe.

The northern portion of the project alignment has been mapped predominantly as Holocene-age Alluvium (Qa). The alluvium is generally uncemented and unweathered cobble to small pebble gravel, gravelly sand, sand and silt; locally cemented calcite cement is found in modern washes. The soils along the Nellis Boulevard and Nellis-Flamingo trenchless reaches were determined to have comparable friction angles, moisture content, dry densities, liquid limit, plasticity index, percent silt and high and low N-60 values.

The majority of the excavated volume for the trenchless sections in zone 4 will be fine-grained soil. We estimated 23 percent of the excavated clay volume of zone 4 trenchless reaches will exhibit a high stickiness potential. Laboratory results indicate the soils along the trenchless reaches will have a SAT value of 9 in the coarse-grained soils, which translates to medium abrasivity.

The proposed trenchless excavation will come within 2.5 feet of a water vault along the Nellis Blvd trenchless reach and with less than 2.5 ft of clearance from an 83-inch by 53-inch elliptical storm drain along the Nellis-Flamingo trenchless reach. The trenchless excavation is anticipated to pass through the bedding material below the elliptical pipe for approximately 8 LF. Due to the potential issues associated with existing utilities within close proximity to the proposed trenchless excavation, soil preparation by jet grouting is required at both locations prior to MTBM/EBP excavation to protect the utilities.

Four shafts along Nellis must be watertight due to potential dewatering induced settlement at those locations, and there are no dewatering restrictions along the Nellis-Flamingo reach. One shaft along Nellis was designed as an oversized shaft to house reinforced concrete structural support for an existing perpendicular 66-inch storm drain, which is approximately 1.3 feet above the top of the proposed pipe.

4.5 TRENCHLESS CONSTRUCTION

The number of proposed trenchless sections within the project is the result of pipe depth dictated by grade requirements, dewatering restrictions resulting from dewatering-induced settlement potential, avoidance of conflicts with other subsurface utilities, minimization of surface disruptions and reduced public impacts.

Due to ground conditions, close proximity to existing utilities, and dewatering restrictions along the alignment, MTBM/EPB tunneling are the most favorable option for all of the trenchless reaches. One- and two-pass installations will be used for trenchless installations. Where required, the two-pass installation will include jacking of a larger diameter steel casing with later installation of the FRPMP carrier pipe.

The two types of microtunnel boring machines specified are slurry machines and Earth Pressure Balance Machines. Slurry machines are remotely controlled and provide continuous support of the excavation face through fluid pressure balance, and spoil is removed through a closed loop slurry system. Earth pressure balance machines are manned and develop an adequate soil plug in the screw auger to maintain stabilizing pressure at the tunnel face to counter balance earth and water pressure.

5. LESSONS LEARNED

The geology along the project alignment was determined to be extremely variable with challenging soil conditions ranging from low blowcount and collapsible soils to caliche. The geology along a project alignment can dictate many aspects of project design as well as significantly influence project cost. Typically, the greater the subsurface understanding during design the fewer costly surprises during construction. While Brierley was able to provide input into the subsurface investigation program, including boring location, depth, and laboratory sampling specific to trenchless areas early in the design process, the significant expansion of the trenchless construction on this project was not anticipated and the desired level of subsurface information and testing was not necessarily available for the additional trenchless zones. Although the distribution of subsurface information was less than desired for trenchless design in the additional zones, the information collected for the open cut evaluation was enough to provide an adequate understanding of the subsurface conditions.

Unique ground conditions found along the project alignment include the soft, low blow count soils encountered in zone 1. These soils created concern for a MTBM/EPB to maintain line and grade for this gravity interceptor. A variety of project constraints reduced the number of viable mitigation measures. These limitations along with the wishes of the District prompted Brierley to design a compaction grout cradle in areas of soft soils. To the District, the increase in cost associated with this mitigation measure was not enough to offset the potential risk of settlement of the machine. Additional mitigation measures were also justified in areas where existing utilities were very close to proposed tunneling operations. At these locations, jet grout columns were implemented to limit the influence of tunneling on the adjacent utilities.

Due to the District requested consistency between the contract documents for the overall PWI project, collaboration with other design consultants was critical to provide seamless appearance between the contract documents and drawings for each package. Each design consultant has their own unique styles and preferences, to come together on this task, communication as well as negotiation skills were important.

Incorporating open cut portions of trenchless projects into the GBR is becoming more widely used. Where most tunneling projects use the Tunnelman's Ground Classification system to baseline ground behavior, we discovered the need for a ground behavior system specifically designed for open cut sections. Brierley has proposed such a system titled: "*Ground Classification for Trench, Shaft, and Slope Excavations*" at the 2014 Rocky Mountain Geo-Conference.

6. CONCLUSIONS

Brierley provided engineering design for the Paradise Whitney Interceptor Project, the first of three packages to be constructed. Half of the alignment length will be installed with trenchless construction. The site consists of interbedded and highly variable fine- and coarse-grained soils with areas of low blowcount soils, sticky clays, collapsible soils, dewatering-induced settlement, high groundwater, cemented caliche, and other tricky soils. Additional design challenges included close proximity to sensitive underground utilities, limited surface access, and other factors forcing several trenchless drive lengths of over 1,000 ft. The design team summarized construction methods considered appropriate to ground conditions for each trenchless reach and open cut section. Dewatering induced settlements anticipated along portions of the alignment limit construction alternatives for shafts and tunneling. Watertight shafts and MTBM/EBP methods were the feasible solutions. Ground improvement was necessary for protection of existing utilities and to account for the low blowcount soils. Brierley's proposed "*Ground Classification for Trench, Shaft, and Slope Excavations*" system was developed as a result of this project and is a tool for geotechnical engineers and geologists to communicate using a uniform system for describing and providing baselines for unsupported ground behavior.

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