GEOTECHNICAL INVESTIGATION

DUNDEE FISH HATCHERY PUMP BACK SYSTEM
DUNDEE, TEXAS

BGE Engineering, Inc.
Dallas, Texas
Report of Geotechnical Investigation
Dundee Fish Hatchery Pump Back System
Dundee, Texas

Submitted herewith is our Report of Geotechnical Investigation for the above referenced project. In brief, the report includes a plan of borings, boring logs, laboratory test results and descriptions of subsurface conditions. Based on the findings, recommendations are set forth for the design and construction of foundations, and earthwork.

Balcones Geotechnical, LLC (Balcones) appreciates the opportunity to provide these geotechnical engineering services to the project team and looks forward to our continued association throughout final design and construction phases.

Sincerely,

Balcones Geotechnical, LLC
TBPE Firm Registration No. F-15624

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John A. Wooley, PE
Principal

Attachments
Distribution:
Dorian French, Erin Magee (BGE Engineering)
File (1)
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INTRODUCTION

The project will include design and construction of a lift station and piping system at the existing Dundee Fish Hatchery in Dundee, Texas. The proposed lift station will consist of a wet well, valve vault, and associated piping, which is part of the pump back system for the fish hatchery. The project site is located at the southern end of the Dundee State Fish Hatchery approximately 850 feet east of the downstream side of the dam impounding Lake Diversion, as shown on the Vicinity Map, Plate 1.

The engineering design services are being provided by BGE Engineering, Inc. Balcones Geotechnical, LLC (Balcones) was retained by BGE Engineering, Inc. to provide geotechnical engineering services.

AUTHORIZATION AND SCOPE

The investigation was authorized by BGE Engineering, Inc. with issuance of Subcontract for Consultant Services dated September 19, 2018. Our work was performed as outlined in our proposal dated August 27, 2018 which was revised from the contract date and scope. Balcones was retained to perform the geotechnical investigation for this project and to provide foundation design recommendations to guide design and construction of the proposed lift station. This report contains all the data developed for that purpose.

The scope of the investigation included 1) drilling of 4 borings to determine subsurface conditions within the wet well structure and for obtaining representative samples for laboratory testing; 2) laboratory testing to determine classification and strength properties of site soils and rock, and 3) preparation of this report to provide foundation design and earthwork recommendations.

Field sampling and laboratory testing were in general accordance with methods, procedures, and practices set forth by the American Society for Testing and Materials, latest version of Annual Book of ASTM Standards, where applicable.
FIELD INVESTIGATION

The field investigation consisted of drilling four (4) borings, designated B-1 through B-4. Boring B-1 was drilled to the 35-ft depth within the proposed wet well footprint. Borings B-2 and B-3 were drilled within the proposed pipe locations, and B-4 was drilled in the proposed paved access drive. Borings B-2 and B-3 were drilled to the 15-ft depth and boring B-4 to the 5-ft depth. Approximate boring locations are shown on the attached Boring Location Plan, Plate 2. A summary of boring information is given in the following table.

<table>
<thead>
<tr>
<th>Boring</th>
<th>Drill Date</th>
<th>Drilled Depth</th>
<th>GPS Coordinates</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>11/8/2018</td>
<td>35</td>
<td>33.8183043509</td>
<td>-98.933351682</td>
</tr>
<tr>
<td>B-2</td>
<td>11/7/2018</td>
<td>15</td>
<td>33.8205952904</td>
<td>-98.929785687</td>
</tr>
<tr>
<td>B-3</td>
<td>11/7/2018</td>
<td>15</td>
<td>33.8188737289</td>
<td>-98.935547513</td>
</tr>
<tr>
<td>B-4</td>
<td>11/7/2018</td>
<td>5</td>
<td>33.8242110883</td>
<td>-98.937718674</td>
</tr>
</tbody>
</table>

Detailed descriptions of subsurface materials encountered at the boring locations are presented on the Logs of Borings, presented on Plates 3 through 6. Keys to Terms and Symbols used on the logs are set forth on Plate 7. A Generalized Subsurface Profile is presented on Plate 8.

Pocket penetrometer values in tons per square foot, Standard Penetration Test N-values in blows per foot, are also shown on the logs of borings at the respective test depth. Groundwater and/or drilling fluid observations made during drilling are presented on the boring logs. Latitude and longitude GPS coordinates were obtained at boring locations using a hand-held GPS device accurate to about 3 horizontal meters, are shown at the top of the boring logs and should be considered approximate. Boring elevations shown on the boring logs were interpolated from a USGS topographic map and should be considered approximate.

The borings were drilled with a truck-mounted drill rig equipped with 1) continuous flight augers for advancing the holes dry and recovering disturbed samples (ASTM D1452), 2) seamless push tubes for obtaining relatively undisturbed soil samples of cohesive strata (ASTM D1587), 3) split-barrel samplers and drive weight assembly for obtaining representative samples and measuring the penetration resistance (N values) of non-cohesive soil strata (ASTM D1586), and 4) double-tube wireline core barrels equipped with diamond bits for obtaining 2-inch diameter rock cores (ASTM D2113).
LABORATORY INVESTIGATION

The laboratory testing program included identification and classification testing of strata encountered in the subsurface. Soil classification tests, including Atterberg limit determinations (ASTM D4318), partial grain-size analyses (ASTM D422), and natural water content determinations (ASTM D2216). The results of the tests are tabulated on the boring logs at the sample recovery depths.

Descriptions of strata made in the field at the time the borings were drilled were modified in accordance with results of laboratory tests and visual examination. All recovered soil samples were classified in general accordance with ASTM D 2487 and described as recommended in ASTM D 2488. Classifications of the soils and finalized descriptions of soil strata are shown on the boring logs.

SITE AND SUBSURFACE CONDITIONS

Physiography

The project site is currently operating as an active fish hatchery. The Dundee Fish Hatchery was constructed immediately downstream from the embankment dam on the Wichita River which impounds Diversion Lake (see Plate 1b). The reservoir and lake were constructed in 1924. As part of this investigation, Balones was provided with a previous geotechnical investigation report dated October 1990 and the 1991 Construction Plans associated with a pond improvement project that occurred round that time, and another set of Construction Plans for liner improvements around 2006.

The proposed new wet well and lift station will be located at the southern limit of the hatchery ponds. Borings B-1 and B-2 were drilled at the base of south and southeast hatchery berms (see Plate 2). Boring B-3 was drilled along the proposed pipeline alignment at the downstream toe of the dam, and B-4 was drilled on the shoulder of the gravel road which provides access to the hatchery. Boring B-1 was drilled at the location for the proposed wet well, at the toe the southwestern-most hatchery embankment. The wet well is planned to be approximately 15-ft deep, with associated piping on the order of 8 to 15 ft deep. Geotechnical investigation of the pump back pipe penetration through the existing dam is beyond the scope of this report.
Geology

According to the Geologic Atlas of Texas, Wichita Falls – Lawton Sheet\(^1\), the site is mapped as being underlain by alluvium, further underlain by either mudstone of the Waggoner Ranch formation, or mudstone and sandstone of the Petrolia Formation. A Geologic Map is presented on Plate 9. Bedrock of either of these formations is present underlying several tens of feet of alluvial deposits associated with the Wichita River.

Alluvium typically consists of unconsolidated clay, silt, sand and gravel in various proportions, but typically coarsens with depth. The Waggoner Ranch Formation is described as reddish-brown mudstone with calcareous nodules, variegated shale and claystone with gypsum lenses and fossils. The Petrolia Formation underlies the Waggoner Ranch Formation and is described as mudstone, sandstone, and conglomerate. The mudstone is described as unstratified to crudely stratified. Based on these descriptions we believe the bedrock at Boring B-1 is considered a mudstone and is likely within the Petrolia Formation.

Stratigraphy and Engineering Properties

Subsurface conditions can best be understood by a thorough review of the Boring Logs, Plates 3 through 6, and review of the Generalized Subsurface Profile shown on Plate 8. In general, the borings encountered reddish brown alluvial sands and clays underlain by mudstone in Boring B-1 at a depth of about 25 ft below current grade (Elevation 996± ft).

The borings encountered 4 to 6 ft of upper clayey sand, underlain by loose consistency, poorly graded sand with little binder material (silt or clay). Measured plasticity indices (PI) in the upper clayey soils ranged from 5 to 23, with an average of 12. In general, lower PI soils were encountered at the wet well and pipe alignment borings at the ground surface, underlain by poorly graded sand with percent fines (material passing the No. 200 sieve) of 3, 5 and 7.

Unconfined compressive strengths (measured with a pocket penetrometer) of push tube samples of the upper clay stratum ranged from 1.25 to 2.5 tsf with an average of about 1.5 tsf. Standard Penetration Test N-values in the upper clay and sand alluvial stratum ranged from 5 to 21 blows per foot (bpf) with an average of about 11 bpf. These relatively low blow counts are significant because they indicate loose and/or unconsolidated alluvium. This will play a role in recommendations and will be discussed further in sections to follow.

Groundwater

Groundwater was encountered in borings B-1 and B-2 at depths of 7 ft and 3 ft, respectively, below the ground surface at the time of drilling. Upon removal of the drilling tools, groundwater was measured at the 2 ft depth in boring B-2 at the time of drilling. Groundwater conditions are sometimes affected by antecedent rainfall and may be different at the time of construction.

Based on the nearby presence of the Wichita River and Lake Diversion, the presence of groundwater should be anticipated at the time of construction. Because of the granular nature of subsurface soils and the lack of appreciable fines (minus #200 material), groundwater flow into excavations will likely be a significant factor to be addressed during construction. Saturated granular soils will likely be unstable and “flow” into excavations and will require flatter temporary construction slopes, excavation bracing, a dewatering plan, or a combination of all three to maintain the excavation. Handling groundwater will be discussed further in sections to follow.

FOUNDATION RECOMMENDATIONS

The lift station and pump back facility will include a wet well, valve vault, and associated piping. The proposed wet well will be approximately 15 ft by 20 ft in plan, 15 ft deep, and include an adjoining valve vault approximately 20 by 25 ft in plan. The foundation elevation for the wet well is currently planned at elevation 1006.8 ft. The valve vault will have a finished floor elevation of 1015.2 but will be supported by a box structure founded at the same elevation as the wet well.

Both structures will consist of reinforced concrete sidewalls and roof, along with reinforced concrete slab/footing foundation. The existing ground surface elevation is approximately 1021 ft (finished floor elevation of the wet well is 1006.8 ft), therefore, an excavation on the order of 16 ft deep will be necessary for the lift station construction.

Boring B-1 was drilled within the proposed lift station footprint. The boring encountered about 25 ft of alluvium consisting of sandy lean clay and loose to very loose sand. At the planned FFE of 1006.8 ft, the foundation will be situated in loose, saturated sand at least 5 to 10 ft below the static, pervasive groundwater table. In order to provide adequate foundation construction for the lift station, a sophisticated dewatering and excavation plan will need to be implemented by the contractor. The requirements for such a system are discussed in the following section, followed by foundation design recommendations.
Temporary Dewatering, Excavation, and Subgrade Preparation

Based on subsurface information, the permanent groundwater table is present within the alluvial soils at elevations of about 1,015 – 1,016 feet. In order to excavate and construct the foundation for the wet well and valve vault, the groundwater table will have to be temporarily lowered to create a dry substrate upon which to construct the foundation and wet well walls. Since the valve vault is in proximity to the wet well, we suggest that the limits of the dewatering and excavation extend at least 5 ft past the outside of the combined valve vault and wet well footprint.

Dewatering may be able to be achieved by installation of high capacity well points or by sequential sumping an pumping, from multiple sumps, as the excavation is deepened. It is possible that even high capacity well points and/or sump pumps will not be able to effectively dewater the excavation. In this case, it may be necessary to drive sheet piling down into the Petrolia mudstone to effectively seal off water inflow into the excavation. Sumping and pumping would still be required to dry the excavation because there will likely be leaks at sheet piling joints. The sheet piling extent would have to be designed to include not only the wet well but also the valve vault. If sheet piling is used, it is likely they would be required to be left in place, unless it could be demonstrated that they could be removed without adversely affecting the completed lift station and valve vault. The exact excavation and dewatering methodology is the sole responsibility of the contractor and their plans should be submitted to the engineer and owner as part of their bidding package. On this topic, it may be advantageous to have all contractors provide pricing for both options (well points & sumping vs sheet piling) in an effort to avoid later conflicts and/or claims.

In either case, the dewatering system should be capable of lowering the groundwater table at least 4 ft below the bottom of the foundation concrete slab and maintaining that level for the duration of excavation and construction process which will likely extend for several weeks or months. Discharge of groundwater and/or inflows into the sheet piling excavation should be coordinated with the facility owner and civil engineer and should comply with all pertinent state and local regulations and requirements.

After or during the dewatering process, the oversized excavation for the combined wet well and valve vault may be advanced with heavy excavator or backhoe. Unless the sheet piling option is used, side slopes of the excavation should not be excavated steeper than a 1.5H:1V configuration, although the design of safe slopes is also solely the responsibility of the contractor.

Because of the nature of the alluvial soils at planned foundation elevation, we recommend that these subgrade soils be over-excavated at least 2 ft below foundation level and be replaced with compacted 3” by 5” ballast rock (bull rock) to improve the subgrade and provide a stable...
working platform upon which to construct the wet well foundation. The ballast rock should be placed in 8 inch lifts and worked into the subgrade by rolling with a rubber tired loader or other heavy equipment. Typical ballast rock should consist of durable limestone, sandstone, or broken concrete with 100% of the material larger than 3 inches and smaller than 5 inches.

Foundation Design

**Wet Well.** It is our understanding that the foundation for the wet well will consist of a reinforced concrete slab foundation constructed with necessary dewatering and subgrade preparation described in the previous section. The foundation for the wet well may be designed using an allowable net bearing pressure of 2,000 psf, assuming the foundation is constructed atop a 2-ft thickness of 3” by 5” ballast rock placed as stated previously. Settlement of the foundation designed in accordance with this recommendation should be on the order of 1 to 2 inches.

**Valve Vault.** The foundation for the valve vault will consist of a slab-on-grade which is located adjoining the wet well sidewall. The foundation will have a FFE of 1015.2 ft, and will be supported by circular columns bearing on the extended foundation slab of the wet well. Accordingly, the foundation for the valve vault may be designed using an allowable net bearing pressure of 2,000 psf, assuming the foundation is constructed atop a 2-ft thick pad of 3” by 5” ballast rock placed as stated previously. Settlement of the foundation designed in accordance with this recommendation should be on the order of 1 to 2 inches.

If the method of construction of the wet well will consist of excavation sloping, the valve vault foundation will be supported on compacted backfill placed to bring the open excavation to grade.

1. In this case, the compacted fill material should consist of low plasticity, properly placed fill meeting the backfill requirements set forth in the Below Grade Walls section of this report.
2. Because there may be as much as 8 ft of compacted fill material beneath the valve vault foundation, the backfill material may settle as much as 2 to 3 inches, although some of this settlement will likely occur during fill placement.
3. To limit settlement potential, the foundation should be designed using an allowable net bearing pressure of 2,000 psf. This includes a safety factor on the order of 2.5 against bearing capacity failure.
4. As stated above, some potential for settlement and differential settlement between the valve vault and wet well does exist. For this reason, piping connections between the two structures should be flexible enough to allow for
differential movements of about 2 to 3 inches, unless the structures are rigidly connected and will move as one monolith.

Should sheet piles be used, another possibility is that the valve vault could be constructed outside of the sheet-pile-supported excavation after the wet well is completed. In this case, the valve vault foundation should be far enough away from the edge of the sheet piles not to impact their design, or the foundation should only be placed after the sheet pile excavation has been backfilled.

1. If the valve vault is constructed on undisturbed natural soils at a depth of 7 to 8 ft below grade, the foundation may be designed using an allowable net bearing pressure of 2,500 psf. Settlement should be on the order of 1 to 2 inches.

2. If the valve vault foundation is constructed atop structural fill placed within the sheet-pile-supported excavation, use an allowable net bearing pressure of 2,000 psf. Settlement should be on the order of 1 to 2 inches.

3. Both of these allowable bearing pressures include safety factors on the order of 2.5.

**BELOW GROUND WALLS**

The deformation condition imposed by a wall on the soil it retains has a significant influence on the coefficient of horizontal earth pressure. The two general deformation conditions are “yielding” and “nonyielding”. Yielding walls are those that move enough to allow the retained soil to reach a state of limit equilibrium. Nonyielding walls are those that do not move or move very little usually because of restraint at the top, internal bracing, or the geometry of the structure. Based on the configurations of the wet well and valve vault, the walls of these structures are considered “nonyielding” and therefore are governed by “at rest” earth pressures.

The type of backfill also has an important influence on the coefficient of horizontal earth pressure. A low plasticity, granular relatively free-draining material is the preferred backfill. Additionally, the accumulation of water in the backfilled excavations adjacent to the structure walls will influence the horizontal earth pressure and the hydrostatic pressures will need to be accounted for in design. Use the recommended equivalent fluid unit weights set forth below for nonyielding below ground walls.

1. Backfill with on-site materials is permissible, so long as they classify as CL, SC, SP, or SM, with a PI of 4 to 20 and maximum particle size of 2 inches, use an equivalent fluid unit weight of 95 pcf assuming undrained conditions.
2. Select granular backfill may be desired beneath the valve vault or around the wet well to reduce lateral loads used for design. Such select fill should consist of a material meeting the requirements of Texas Department of Transportation, 2004 Standard Specifications for Construction of Highways, Streets and Bridges, Item 247, Type A or B, Grade 3 or better. If this material is used, the equivalent fluid pressure may be reduced to 90 pcf, assuming undrained conditions.

3. On-site fill or select backfill material should be compacted to at least 95% of the maximum dry density as determined using TxDOT Test Method TEX-113-E. Hold water contents within ±2% of the optimum water content, and maintain compacted lift thicknesses to six inches or less.

4. The backfill material should be capped with 18 inches of on-site clay having a plasticity index of between 10 and 25. Compact the lean clay to 95% of the maximum dry density determined using TxDOT Test Method TEX-114-E. Hold compacted lift thicknesses to 6 inches or less and water contents within −1 and +3% of the optimum water content. A filter fabric may be necessary between the clay cap and the backfill material.

5. If the design involves any uniform vertical surcharge adjacent to the wall, use a coefficient of horizontal earth pressure of 0.5. This includes foundation surcharge from the adjoining valve vault foundations if bearing in the backfill zone of the wet well.

RESISTANCE TO UPLIFT LOADS

After construction of below grade structures and termination of the groundwater controls, the groundwater level will rise to near the ground surface within the backfilled excavations. The resulting buoyancy potential should be accounted for in the design of the wet well structure, and even in the valve vault structures. The ultimate uplift capacity of slab foundations is usually limited to the weight of the foundation plus the weight of any soil directly above the foundation. If additional uplift capacity is required, one or more of the following options can increase the capacity:

- Extending a perimeter "lip" of sufficient size around the base of proposed below-ground structures to use the unit weight of the backfill soil directly above the lip. We recommend using a total unit weight of 120 pcf, a submerged unit weight of 58 pcf and assuming the groundwater level at a depth of 2 ft; or

- Using tension soil/rock anchors to resist uplift forces. (If this option is desired, we can provide additional design input.)
The calculated ultimate uplift capacity should be reduced by an appropriate factor of safety to compute the allowable uplift resistance. We recommend using a minimum factor of safety of 1.2.

**CONSTRUCTION RECOMMENDATIONS AND CONSIDERATIONS**

**Site Grading and Drainage**

Grading around the structures should be such that future ponding or standing water around the structures does not occur. All surface drainage measures should be designed to positively direct water well away from the structures.

**Foundations**

Foundation excavations should be observed by the project geotechnical engineer prior to concrete and reinforcing steel placement to confirm suitable bearing conditions and that the footing bottom is free of any loose materials. Contract documents should include pay items for localized undercutting of foundations, if soft or weak material is encountered in the footing subgrade. Undercut foundations may be backfilled with lean concrete (1,000 psi) or deepening the footing excavation below the defect.

**Temporary Construction Slopes**

The design of temporary construction slopes and temporary retainage systems are the sole responsibility of the contractor. The suggestions set forth herein are for estimating purposes, and do not, in any way, change the sole responsibility of the contractor for design.

Suggestions are set forth below in accordance with OSHA\(^2\) for classifying of soils encountered in our investigation. It is stressed that these are suggestions only for preliminary planning and the actual temporary excavation sloping design and safety are the contractor's responsibility.

<table>
<thead>
<tr>
<th>Soil Stratum</th>
<th>OHSA Classification</th>
<th>Recommended OSHA Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reddish brown lean clay to clayey sand</td>
<td>Type C</td>
<td>1.5H to 1V</td>
</tr>
<tr>
<td>Reddish brown sand with clay, near groundwater or submerged</td>
<td>Type C</td>
<td>1.5H to 1V</td>
</tr>
</tbody>
</table>

These classifications are intended for guidance only and not for final slope design. Alternatives for sloping, benching, and shoring should be designed by a professional engineer registered in the state of Texas.

Once the final location of the wet well/valve vault excavation is determined, Balcones should be retained to review the set back of the excavation limits from the toe of the nearby embankment. Preliminarily, the limits of the wet well excavation should be set back a minimum distance from the toe of the embankment of 20 feet, based on an existing embankment height of about 10 ft, and a 2H to 1V set back.

**Pipeline Construction**

Excavation for the pipelines associated with this project should be routine using conventional excavation equipment available in the Archer County area. Depending on depth of pipeline placement, it is likely that groundwater will be encountered at fairly shallow depths. Handling groundwater is the contractor’s responsibility and will likely be achieved by some form of sumping and pumping from the trench excavations.

Placement of the pipe, including bedding material selection and placement, should follow requirements of local utilities operating in the Archer County area, or follow requirements laid out by the Design Engineer. Depending on location, utility backfill may vary, but we recommend the backfill be placed in uniform lift thicknesses not exceeding 6 inches and be compacted to the same standard as described in Item 3 on page 8 of this report.

We understand that some pipe trench backfill distress has been observed on other portions of the site. Although, determination of the possible mechanisms of the distress is beyond the scope of this report, we anticipate that migration of sand backfill may be infiltrating the gravel bedding material, compounded with a fluctuating groundwater table. Accordingly, consideration may be given to installing the new pipes with a concrete cradle to the springline of the pipe, then backfilling with onsite material, compacted as recommended herein. The concrete cradle may consist of flowable fill (CLSM) or lean concrete. The presence of the concrete cradle would replace the need for bedding stone, and allow for proper compaction around the pipe (i.e. cannot achieve suitable compaction beneath the haunches of the pipe).

**Construction Monitoring**

It is recommended that the geotechnical engineer of record, or a qualified representative thereof, be present on-site during construction to observe and monitor construction activities, and perform quality control tests. Construction monitoring performed by qualified personnel independent of the Contractor is recommended because the performance of foundations and
other structures constructed during this project will be directly related to the Contractor’s adherence to the recommendations presented in this report and to the specifications prepared by the Designer. Additionally, unanticipated soil and/or groundwater conditions may be encountered during construction. Qualified geotechnical personnel observing construction on-site can monitor construction activities and may aid in recognizing unanticipated subsurface conditions and assist in reconciling these conditions with design recommendations.

**PAVEMENT RECOMMENDATIONS**

Traffic categories for driveways and parking areas were selected using Baker (1975)\(^3\), modified to fit anticipated traffic conditions. The traffic categories selected are 1) parking stalls (Category 5) and 2) entrances/exits (Category 7). Rigid pavements should be used in areas where heavy traffic (such as garbage trucks) or tight maneuvering is anticipated. Recommendations for flexible and rigid pavement sections are provided in the following sections.

**Flexible Pavement**

The 1993 AASHTO procedure\(^4\) was used to develop pavement sections using the traffic categories selected, associated 18-kip equivalent single axle loads (ESAL) over a 20-year design life, and a subgrade resilient modulus of 3,000 psi estimated from the boring data. Recommended thicknesses of crushed limestone base material (CLBM) and hot mix asphaltic concrete (HMAC) are presented in the following table for the selected traffic categories.

<table>
<thead>
<tr>
<th>Traffic Category</th>
<th>18-Kip ESAL</th>
<th>CLBM Thickness (inches)</th>
<th>HMAC Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (Parking Stalls)</td>
<td>10,000</td>
<td>10</td>
<td>2.0</td>
</tr>
<tr>
<td>7 (Entrances/Exits)</td>
<td>100,000</td>
<td>12</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Construction of the roadway should proceed in accordance with the Texas Department of Transportation 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, and the following recommendations:

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1. Remove all organics, existing pavements, any deleterious material encountered, and surficial soils to a depth of at least 6 inches.

2. Scarify and compact the cut soil subgrade to at least 95% of the maximum dry density determined using TxDOT Test Method TEX-114-E. Hold water contents during construction to within ±2% of the optimum water content.

3. Proofroll the prepared subgrade in accordance with Item 216 of the current TxDOT Standard Specifications. The proof rolling operation should be observed by a representative of the geotechnical engineer. Any soft or weak subgrade should be over excavated and replaced with crushed limestone base material selected and placed as recommended in Item 4 below.

4. On the prepared subgrade, place the recommended thickness of crushed limestone flexible base which conforms to Item 247, Type A, Grade 1-2 or 5 of the TxDOT Standard Specifications. Compact the flexible base to 100% of the maximum dry density determined using TxDOT Test Method TEX-113-E. Hold water contents to within ±2% of the optimum, and maintain compacted lift thicknesses to 6 inches or less.

5. Provide and place the proper thickness tabulated above of hot mix asphaltic concrete which conforms to Type C or D, Item 340, Hot Mix Asphaltic Concrete Pavement, TxDOT 2014 Standard Specifications for the Construction of Highways, Streets and Bridges. Project specifications should dictate that the HMAC thickness specified in the table above be a minimum at any location rather than an average.

**Rigid Pavement**

It is recommended that consideration be given to using rigid pavement in areas subjected to heavy truck traffic and tight maneuvering. The rigid pavement should consist of 6 inches of reinforced Portland cement concrete (PCC) placed on top of at least 6 inches of crushed limestone base material (CLBM).

The Portland cement concrete pavement should have a 28-day compressive strength of at least 4,000 psi and be reinforced with a minimum of No. 4 bars on 18-inch centers. Construction of the rigid pavement should proceed in accordance with the pertinent Standard Specifications listed above for the flexible pavement, TxDOT Standard Specification Item 360 “Concrete Pavement”, and the following recommendations:

1. Support steel with chairs or precast concrete blocks about 2 inches below the top of slab.
2. Space transverse and longitudinal contraction joints (induced cracks) at intervals not exceeding 15 feet. Depth of joints should be at least one-quarter of the slab thickness.

3. Provide load transfer at the interface between areas of concrete placed at different times using tied and keyed construction joints. Place construction joints at planned contraction joint locations.

4. Stage pavement construction such that construction traffic, including concrete trucks, do not travel on newly placed concrete pavement until the concrete achieves at least 75 percent of the design strength.

**Pavement Drainage and Groundwater Control**

It should be noted that control of surface drainage and groundwater is important to the performance and life of pavements. Infiltration of water into the pavement subgrade and pavement structure will result in premature loss of serviceability. Adequate drainage provisions should be included in the pavement design. Additionally, the placement of curbs, islands and irrigation systems should be carefully planned in a manner that will not lead to ponding and saturation of pavement base materials that extend into island areas.

**CONDITIONS**

Since some variation was found in subsurface conditions at boring locations, all parties involved should take notice that even more variation may be encountered between boring locations. Statements in the report as to subsurface variation over given areas are intended only as estimations from the data obtained at specific boring locations.

The professional services that form the basis for this report have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in the same locality. No other warranty, expressed or implied, is made as the professional advice set forth. The results contained in this report are directed at, and intended to be utilized within, the scope of work contained in the agreement executed by Balcones Geotechnical, LLC and client. This report is not intended to be used for any other purposes.

* * * * *
PLATES
VICINITY MAP
Dundee Fish Hatchery Pump Back System
Dundee, Texas

Source: Google Earth Professional
VICINITY MAP
Dundee Fish Hatchery Pump Back System
Dundee, Texas

Source: Google Earth Professional
BORING LOCATION PLAN

Dundee Fish Hatchery Pump Back System
Dundee, Texas
**LOG OF BORING NO. B-1**

**Dundee Fish Hatchery Pump Back System**  
**Archer County, TX**  
**PROJECT NO. 0118-011**

<table>
<thead>
<tr>
<th>DEPTH, FT</th>
<th>SYMBOL</th>
<th>SURF. ELEVATION: 1021±</th>
<th>STRATUM DESCRIPTION</th>
<th>LAYER ELEV./DEPTH</th>
<th>WATER CONTENT, %</th>
<th>LIQUID LIMIT, %</th>
<th>PLASTIC LIMIT, %</th>
<th>PLASTICITY INDEX (PI), %</th>
<th>PASSING NO. 200 SIEVE, %</th>
<th>UNIT DRY WEIGHT, PCF</th>
<th>UNDRAINED STRENGTH, Tsf</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>N=3-4-3</td>
<td>Reddish brown SANDY LEAN CLAY, stiff. CL</td>
<td>1015.0</td>
<td>6.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>N=2-3-4</td>
<td>Reddish brown to reddish tan POORLY GRADED SAND with CLAY, loose. SP-SC</td>
<td>9</td>
<td>19</td>
<td>6</td>
<td>13</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>N=0-0-5</td>
<td>- wet at 13.5 to 15 ft</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>N=4-4-5</td>
<td></td>
<td>14</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>N=6-5-7</td>
<td>Reddish brown to brown SANDY LEAN CLAY, hard, w/scattered gravel. CL (Formation)</td>
<td>996.0</td>
<td>25.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SAMPLE KEY:**
P = Pocket Penetrometer  
N = Standard Penetration Test (bpf)  
U = UU Triaxial Strength (tsf)

---

**BALCONES GEOTECHNICAL**  
**Austin, TX 78731**  
**512.380.9969**

**COMPLETION DEPTH:** 35.0  
**DATE DRILLED:** 11-8-18  
**WATER LEVEL / SEEPAGE:** 7.0  
**UPON COMPLETION:**
Reddish brown to brown SANDY LEAN CLAY, hard, w/scattered gravel. CL (Formation) (continued)

NOTES:
1. Boring was advanced dry to the 35-ft depth, and groundwater was encountered at the 7-ft depth.
2. The borehole was backfilled with a mixture of soil cuttings and bentonite.
SITE AND SAMPLE PHOTOGRAPHS – B-1

Dundee Fish Hatchery Pump Back System
Dundee, Texas

Plate 3c
**Log of Boring No. B-2**

**Dundee Fish Hatchery Pump Back System**

**Archer County, TX**

**Project No. 0118-011**

### Layer Description

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Reddish brown Sandy Silty Clay, stiff to very stiff, trace gravel. CL-ML</td>
</tr>
<tr>
<td>10</td>
<td>Reddish brown to reddish tan Poorly Graded Sand with Clay, loose to medium dense. SP-SC</td>
</tr>
<tr>
<td>15</td>
<td>- Sample wet at 13.5-15 ft</td>
</tr>
</tbody>
</table>

### Sample Key

- **P** = Pocket Penetrometer
- **N** = Standard Penetration Test (bpf)
- **U** = UU Triaxial Strength (tsf)

### Notes:

1. Boring was advanced dry to the 15-ft depth, and groundwater was encountered at the 3-ft depth.
2. Upon completion of the borehole and removal of the drilling tools, groundwater was measured at the 2-ft depth.
3. The borehole was backfilled with a mixture of soil cuttings and bentonite.

### Sample Key:

<table>
<thead>
<tr>
<th>Sample Key</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P</strong></td>
<td>Pocket Penetrometer</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>Standard Penetration Test (bpf)</td>
</tr>
<tr>
<td><strong>U</strong></td>
<td>UU Triaxial Strength (tsf)</td>
</tr>
</tbody>
</table>

---

**Completion Depth:** 15.0

**Date Drilled:** 11-7-18

**Water Level / Seepage:** 3.0

**Upon Completion:**

---

**Balcones Geotechnical**

Austin, TX 78731

512.380.9969

---

**Plate 4a**
SITE AND SAMPLE PHOTOGRAPHS – B-2

Dundee Fish Hatchery Pump Back System
Dundee, Texas
**LOG OF BORING NO. B-3**

_Dundee Fish Hatchery Pump Back System_  
_Archer County, TX_

**PROJECT NO. 0118-011**

<table>
<thead>
<tr>
<th>DEPTH, FT</th>
<th>SYMBOL</th>
<th>SAMPLES</th>
<th>POCKET PEN, tfb</th>
<th>SURF. ELEVATION: 1028±</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=9-10-11</td>
<td></td>
<td>N=4-4-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=4-4-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=2-3-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=8-8-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=8-9-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=4-4-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STRATUM DESCRIPTION**

- Reddish brown SILTY, CLAYEY SAND, loose to medium dense. SC
- Reddish brown SILTY CLAY, stiff to very stiff, w/sand. CL
- Reddish tan POORLY GRADED SAND, medium dense, w/clay and trace gravel. SP

<table>
<thead>
<tr>
<th>LAYER</th>
<th>ELEV./ DEPTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1025.0</td>
<td>6 25 19 6 35</td>
</tr>
<tr>
<td>1022.0</td>
<td>3 0 15 13 8 5 87</td>
</tr>
<tr>
<td>1013.0</td>
<td>6 0 21 3</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Boring was advanced dry to the 15-ft depth, and groundwater was not encountered.
2. The borehole was backfilled with a mixture of soil cuttings and bentonite.

---

**SAMPLES KEY:**

- P = Pocket Penetrometer
- N = Standard Penetration Test (bpf)
- U = UU Triaxial Strength (tsf)

---

**COMPLETION DEPTH:** 15.0  
**DATE DRILLED:** 11-7-18  
**WATER LEVEL / SEEPAGE:**  
**UPON COMPLETION:**
SITE AND SAMPLE PHOTOGRAPHS – B-3

Dundee Fish Hatchery Pump Back System
Dundee, Texas
Reddish brown LEAN CLAY with SAND, stiff to very stiff, w/trace gravel. CL
- tan w/gravel from 2 to 3 ft

NOTES:
1. Boring was advanced dry to the 5-ft depth, and groundwater was not encountered.
2. The borehole was backfilled with a mixture of soil cuttings and bentonite.
SITE AND SAMPLE PHOTOGRAPHS – B-4

Dundee Fish Hatchery Pump Back System
Dundee, Texas
TABLE 7

**TERMS AND SYMBOLS USED ON BORING LOGS FOR SOIL**

**SOIL TYPES**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY (CH)</td>
<td></td>
</tr>
<tr>
<td>SHALY CLAY (CH)</td>
<td></td>
</tr>
<tr>
<td>CLAY (CL)</td>
<td></td>
</tr>
<tr>
<td>SANDY CLAY (CL)</td>
<td></td>
</tr>
<tr>
<td>SAND (SW)</td>
<td></td>
</tr>
<tr>
<td>Poorly-Graded SAND (SP)</td>
<td></td>
</tr>
<tr>
<td>CLAYY SAND (SC)</td>
<td></td>
</tr>
<tr>
<td>SAND (GW)</td>
<td></td>
</tr>
<tr>
<td>Poorly-Graded GRAVEL (GP)</td>
<td></td>
</tr>
<tr>
<td>FILL</td>
<td></td>
</tr>
</tbody>
</table>

**SOIL GRAIN SIZE**

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>12&quot;</th>
<th>3&quot;</th>
<th>3/4&quot;</th>
<th>4&quot;</th>
<th>10</th>
<th>40</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulders</td>
<td>304</td>
<td>0.002</td>
<td></td>
<td></td>
<td>0.074</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Cobble</td>
<td>76.2</td>
<td>0.074</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>19.1</td>
<td>0.074</td>
<td>0.002</td>
<td>0.200</td>
<td>0.074</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>4.76</td>
<td>0.074</td>
<td>0.002</td>
<td>0.200</td>
<td>0.074</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Silts</td>
<td>0.420</td>
<td>0.074</td>
<td>0.002</td>
<td>0.200</td>
<td>0.074</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Clays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STRENGTH OF COHESIVE SOILS**

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Undrained Compressive Strength (Tons Per Sq. Ft.)</th>
<th>Number of Blows</th>
<th>Relative Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>Less Than 0.25</td>
<td>0-4</td>
<td>Very Loose</td>
</tr>
<tr>
<td>Soft</td>
<td>0.25 to 0.50</td>
<td>4-10</td>
<td>Loose</td>
</tr>
<tr>
<td>Firm</td>
<td>0.5 to 1.00</td>
<td>10-30</td>
<td>Medium</td>
</tr>
<tr>
<td>Stiff</td>
<td>1.00 to 2.00</td>
<td>30-50</td>
<td>Dense</td>
</tr>
<tr>
<td>Very Stiff</td>
<td>2.00 to 4.00</td>
<td>Over 50</td>
<td>Very Dense</td>
</tr>
<tr>
<td>Hard</td>
<td>greater than 4.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DENSITY OF GRANULAR SOILS**

- **Moisture**
  - Dry: No water evident in sample; fines less than plastic limit.
  - Moist: Sample feels damp; fines near the plastic limit.
  - Very Moist: Water visible on sample; fines greater than plastic limit and less than liquid limit.
  - Wet: Sample bears free water; fines greater than liquid limit.

**DESCRIPTION TERMS FOR SOIL**

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratified</td>
<td>Alternating layers of varying material or color with layers at least 6 mm thick.</td>
<td>Dry, No water evident in sample; fines less than plastic limit.</td>
</tr>
<tr>
<td>Laminated</td>
<td>Alternating layers of varying material or color with the layers less than 6 mm thick.</td>
<td>Moist, Sample feels damp; fines near the plastic limit.</td>
</tr>
<tr>
<td>Fissured</td>
<td>Breaks along definite planes of fracture with little resistance to fracturing.</td>
<td>Very Moist, Water visible on sample; fines greater than plastic limit and less than liquid limit.</td>
</tr>
<tr>
<td>Slickensided</td>
<td>Fracture planes appear polished or glossy, sometimes striated.</td>
<td>Wet, Sample bears free water; fines greater than liquid limit.</td>
</tr>
<tr>
<td>Blocky</td>
<td>Cohesive soil that can be broken down into small angular lumps which resist further breakdown.</td>
<td>Trace, Inclusion &lt;1/8&quot; thick extending through sample.</td>
</tr>
<tr>
<td>Lensed</td>
<td>Inclusions of small pockets of different soils.</td>
<td>Parting, Inclusion 1/8&quot; to 3&quot; thick extending through sample.</td>
</tr>
</tbody>
</table>

**INCLUSIONS**

- Trace: <5% of sample.
- Few: 5% to 10% of sample.
- Little: 15 to 25% of sample.
- With: 15% to 29% of sample.

**REFERENCES:**
1. ASTM D 2488

*NOTE*: Information on each boring log is a compilation of subsurface conditions and soil and rock classifications obtained from the field as well as from laboratory testing of samples. Strata have been interpreted from commonly accepted procedures. The stratum lines on the logs may be transitional and approximate in nature. Water level measurements refer only to those observed at the times and places indicated, and may vary with time, geologic condition or construction activity.
Dundee Fish Hatchery Pump Back System

Archer County, TX
LEGEND (Youngest to Oldest)
Qal – Alluvium
Qt – Fluviatile terrace deposits
Pwr – Waggoner Ranch Formation
Pp – Petrolia Formation
ss7 – Sandstone Inclusion in Pp

GEOLOGIC MAP
Dundee Fish Hatchery Pump Back System
Dundee, Texas

https://txpub.usgs.gov/txgeology/ Wichita Falls – Lawton Sheet

Balcones Geotechnical
Austin, TX 78731
512.380.9869

Plate 9