CORNFORTH CONSULTANTS

10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

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Mr. Pat McDougal, P.E.
City of Lake Oswego
380 A Avenue
P.O. Box 369
Lake Oswego, OR 97034

Geotechnical Evaluation
Foothills Road Sanitary Sewer Improvements
Lake Oswego, Oregon

Dear Mr. McDougal:

In accordance with your authorization, Cornforth Consultants, Inc. has completed a geotechnical evaluation for proposed sanitary sewer improvements on Foothills Road. This report summarizes subsurface conditions and presents comments and recommendations regarding constructibility and shoring.

Background and Project Overview

Foothills Road is located east of State Street in downtown Lake Oswego across from Lakewood Bay (see Figure 1). The road provides sole access for businesses, apartment buildings, and the City's Tryon Creek Wastewater Treatment Plant.

The Foothills Road sewer improvement project includes nearly 1,400 feet of new pipeline consisting of approximately 1,200 feet of sanitary sewer and 200 feet of storm sewer (see Figure 2). The main purpose of the improvements is to realign a section of the existing sanitary sewer, currently running through the Oswego Pointe Apartments, onto City right-of-way. The existing sewer line in this section is undersized and in a state of deterioration. The realignment would start near the intersection with State Street and extend down Foothills Road to a driveway accessing business Nos. 91, 93, and 95. The upper end of the project near State Street is at elevation 100 feet, the lower end is at elevation 50 feet.

The sanitary line segments would consist of 960 feet of 36-inch diameter pipe, 200 feet of 42-inch diameter pipe, and 30 feet of 24-inch diameter pipe. The depth of the sanitary pipeline varies from 10 to 29 feet. The average depth to pipe invert in the upper half of the alignment (Sta. 6+00 to 11+91) is approximately 25 feet, while the lower half of the alignment (Sta. 0+00 to 6+00) averages 14 feet.

The storm sewer line would consist approximately of 130 feet of 36-inch diameter pipe and 60 feet of 12-inch diameter pipe. The depth to pipe invert for the storm sewer varies from 7 to 9 feet.

An important project constraint involves the need to maintain at least one lane of traffic on Foothills Road between State Street and Oswego Pointe Drive (approximate Sta. 5+50 to 11+91). From Sta. 5+50 to 10+00 the road width between curb lines varies from 40 to 44 feet and includes a parking lane on the southbound side. From Sta. 10+00 to 11+91 the roadway narrows to a width of 26 feet between curbs and consist of two traffic lanes.

Field Explorations

The field exploration program consisted of drilling five exploratory borings, designated CC-1 through CC-5, at locations along the proposed alignment as shown on the Site Plan (Figure 2). Geo-Tech Explorations, a division of Boart Longyear Company of Tualatin, Oregon, performed the subcontracted drilling from November 1 to November 3, 2005. Borings were drilled using a CME 75 truck-mounted drill rig. All borings were performed using mud-rotary drilling techniques.

Borings CC-1 through CC-5 were drilled to depths of 35 ft, 30 ft, 25 ft, 25 ft, and 20 ft, respectively (approximately 5 feet below proposed pipe invert). Standard Penetration Tests (SPT) were performed at 5-foot intervals and in accordance with ASTM D 1586. Borings CC-1, CC-3, and CC-5 were drilled using a 6-inch tricone bit to provide adequate annulus for the installation of standpipe piezometers. A schematic profile of each piezometer is provided on the Summary Boring Logs for CC-1, CC-3 and CC-5 (Figures 3, 5 and 7).

Borings CC-2 and CC-4 were drilled with a 4-7/8” tricone. Drilling methods, sampling depths, hole depths, and descriptions of materials encountered during drilling are shown on the Drill Logs, Figures 3 through 7. Soil cuttings and drilling mud generated during the work were placed into steel drums and disposed by Boart Longyear.

Borings CC-2 and CC-4 were abandoned in accordance with Oregon State Department of Water Resources (WRD) requirements. CC-1, CC-3, and CC-5 are currently being used as piezometers to measure groundwater level. Geotechnical Hole reports were prepared and submitted to WRD by the driller.

Groundwater

Groundwater levels measured in boreholes CC-1, CC-3 and CC-5 on November 30, 2005, were 33 ft, 23 ft, and 18 ft below the ground surface, respectively.

Laboratory Testing

Cornforth Consultants Inc. performed testing in our laboratory to determine the natural water contents. Visual examination of the soil samples was also performed to verify the field classifications. The natural water contents are plotted on the Summary Boring Logs for each borehole (Figures 3 through 7).

North Creek Analytical, Inc. of Beaverton, Oregon performed environmental testing to analyze soil samples for possible contaminates related to the previous land use. Analytical tests on soil samples from CC-1, CC-3, and CC-5 included organic compounds (creosote-related), polychlorinated biphenyls (PCB), RCRA metals, and diesel and gasoline hydrocarbons. Soil collected from CC-4 was tested for organic compounds only and was selected due to conversations with City personnel regarding recent work near the boring that required disposal of creosote contaminated soil. Results of the analytical tests are included in Appendix A.

Subsurface Conditions

General Site Geology. The geology in the general vicinity of the project consists of Columbia River Basalt (middle Miocene age) overlain by the Coarse-Grained Facies of the Catastrophic Flood Deposits (Pliestocene age). As discussed below, Columbia River basalt was not encountered in our exploratory borings and is not likely to be encountered along the proposed pipeline alignment and depth. The majority of the materials encountered in our borings consist of flood deposit materials. These materials are a complex mixture of boulders, gravels, sand and silt. Boulders within the deposits are composed predominantly of basalt.

On-Site Borings. The results of the exploratory borings indicate that the subsurface conditions along the proposed sewer alignment consist of alluvial (flood) sediments of silt, sand, and gravels with scattered cobbles and boulders. Near the upper end of the project, CC-1 and CC-2 encountered dense sand and medium dense to dense silty, sandy gravel with some cobbles and boulders. CC-3 in the middle portion of the alignment encountered 11 feet of medium stiff silt overlying medium dense to dense sands and gravels. CC-4 encountered approximately 5 feet of silty gravel overlying 8 feet of medium stiff silt, which in turn overlies 13 feet of medium dense to dense sandy gravel. Boring CC-5 encountered 7 feet of medium dense, silty sand overlying 7 feet of stiff, clayey silt. The silt layer is underlain by medium dense to dense, silty sand with some boulders.

Recent Utility Projects. During the past few years there have been two nearby utility projects involving excavation of subsurface materials. It is our understanding that both projects encountered difficult excavation as a result of numerous, large boulders ranging in size from 2 to 5 feet. One project involved excavating a new fiber-optics conduit under the railroad along State Street to a depth of approximately 5 feet. This project was located approximately 100 feet west of boring CC-2. The work was attempted using auger bore and pipe-jacking techniques; however, due to the presence of numerous large boulders the auger bore was abandoned and the work was completed using manual excavation. It should be noted that the boulders could have been placed as ballast during construction of the rail tracks.

The other project consisted of jacking a 36-inch pipeline a distance of 125 feet under State Street. The project was located a half block north of A Avenue and approximately 300 feet west of boring CC-4. This work was also originally contracted for construction using an auger bore. Boulders were immediately encountered, forcing the tunneling work to be completed manually using jack-hammers to clear the boulders. We understand that boulders were encountered at an average interval of every 3 feet during the tunneling work. The project alignment continued west of State Street through a public parking lot using cut-and-cover installation. The depth of the pipe through the parking lot was 8 to 10 feet. Numerous boulders were encountered during excavation and the City estimates that at least 25 percent of the excavation contained boulders of approximately one cubic yard in size.

GEOTECHNICAL RECOMMENDATIONS

General

Based on the results of our subsurface investigation and office evaluation, and on results from recent utility work in the area, we present the following comments and recommendations:

- Subsurface conditions along the pipeline alignment consist predominantly of gravel, sand and silt deposits with variable amount of cobbles and boulders.
- Cobbles and boulders will be a significant construction challenge.
- At least one-way traffic must be maintained at all times on Foothills Road along the upper, deepest portion of the alignment from approximate Sta. 5+50 to 11+91. This will require either hand tunneling to avoid major traffic disruption, or a deep, shored trench in one lane of Foothills Road.
- We understand that Foothills Road could be closed to traffic along the portion of the alignment north of Oswego Pointe Drive. It is possible that this section could be constructed using cut-and-cover technique.
- Groundwater levels measured on November 30, 2005 in the three piezometers were below the proposed pipe invert.
- Based on the anticipated construction difficulties posed by boulders, we recommend short listing prospective bidders and holding a mandatory prebid meeting for the short listed group of contractors.
- The City may want to consider constructing shored test pits to the proposed invert level at one or two locations along the sewer alignment to provide information for prospective contractors.

Pipeline Excavation

Station 0+00 to 5+50. This section of the alignment on Foothills Road is north of the intersection with Oswego Pointe Drive. It is our understanding that traffic can be detoured onto Oswego Pointe Drive to bypass this section of Foothills Road. This would allow a contractor to construct this section of pipeline using cut-and-cover technique, or a combination of a partial cut with a trench box in the deeper portion. The pipe invert for this section ranges in depth from 10 to 18 feet, with an average depth of 14 feet. All excavations should be performed in accordance with OSHA regulations.

Station 5+50 to 11+91. The greatest construction challenge will occur along the upper alignment from approximate Sta. 5+50 to 11+91. Pipe invert for this section varies from 19 to 29 feet deep, with an average depth of 25 feet deep. Constraints include the need to maintain at least one-way traffic, as well as the proximity of large trees, a railroad track, two electrical substations, and existing underground utilities. Based on a review of potential excavation and construction options, it is our opinion that there are two feasible options for construction: a) hand tunneling; or

b) trench excavation with a braced shoring system using soldier piles (H-piles) with steel or wood lagging. Both options are discussed below.

Pipe Tunneling

This option would involve manual tunneling using jack-hammers and hand-held equipment to excavate soil and boulders. The tunnel would be accessed from two shored pits at each end of the tunnel. The approximate length of tunnel for the upper portion of the project is 650 feet. To allow for a two-man crew and faster production rates, a minimum 4- to 5-foot diameter tunnel could be excavated in-lieu of a smaller tunnel.

Liner plates would be installed as the work progresses. Voids behind the liner plate would be grouted immediately to avoid potential ground settlement. The contractor would most likely work "up gradient" i.e. start at the lower end to allow any potential groundwater encountered during tunneling to gravity feed to the access pit. The water would then be pumped out from the pit. To minimize traffic disruption, the access pit at the upper end of the alignment in Foothills Road could be covered with steel plates while the tunneling work is in progress. As an alternative, it may be possible to construct the upper access pit in the public parking area between Foothills Road and State Street to significantly reduce impacts to traffic. Tunneling would also minimize impacts to existing underground utilities.

Depending on the amount of boulders encountered, the work could be difficult and slow. Construction costs would be a direct function of rate of progress. Without encountering boulders, tunneling costs in the sand and gravel could be as low as $400 per foot. With numerous, large boulders requiring jack-hammering and intensive hand work, costs could be as high as $2,500 per foot. Construction costs for tunneling access pits on other projects in the region have ranged from $100,000 to $150,000 per pit (2005 costs).

<u>Cost Estimate:</u> Assuming 20 percent of the alignment encounters nested boulders with the remaining 80 percent encountering sand and gravel conditions the estimated construction cost for completing the tunnel includes:

Tunneling	0.8(650 feet x $400/foot) + 0.2(650 feet x $2,500/foot) =	$535,000
Access Pits	2 @ $150,000 ea. =	$300,000
Contingency	(25 percent) =	$210,000
		$1,050,000

The preliminary cost estimate was developed in 2005 and does not include for final design, preparation of plans and specifications, pipe material and installation costs, or dewatering.

Trench Shoring

This option would consist of constructing an internally braced (strutted), shored trench. H-piles would be driven or installed in pre-drilled holes at approximate 8-foot spacing on both sides of the trench. Steel sheets or wooden timbers would be placed between the webs of the piles for lagging. The design of the shoring system including pile spacing, lagging type and dimension, waler sizing and cross bracing would be developed by the contractor.

Driving H-piles could prove difficult if large boulders are encountered. Even if the piles are able to be driven past boulders, they would likely be knocked out of alignment, requiring the use of custom-fit wood lagging in lieu of steel sheets. Pre-drilled holes would allow H-piles to be installed along a fairly accurate alignment. The holes would be backfilled with a lean concrete that would subsequently be excavated as steel sheets or wood lagging is installed.

Large boulders that are encountered in the sidewalls during installation of the lagging would be hammered, drilled, or excavated. This could create voids on the outside of the lagging that could lead to subsequent settlement. Therefore, when encountered these areas should be post-grouted or backfilled to minimize settlement.

Groundwater levels based on the November 30, 2005 piezometer readings are below proposed pipe invert. This indicates that major dewatering systems (i.e. deep dewatering wells) would likely not be necessary; however, the contractor should be prepared to remove water as needed to complete the project safely and in accordance with OSHA. Similar to tunneling, the excavation work would also likely be performed starting at the low end of alignment and working up hill to allow water to gravity drain toward the bottom end where it could be pumped out.

Trench shoring will create significant surface impacts and one-lane of traffic must be maintained. Construction of a pre-drilled H-pile shoring system could take from 8 to 12 weeks (Sta. 5+50 to 11+91).

Cost Estimate: The estimated cost for constructing the strutted H-pile shoring system is approximately $30 per square foot of exposed wall facing. The approximate length of the shoring system is 650 feet (with both sides of the trench requiring wall facing) and the average depth is 25 feet.

Shoring	2(650 feet x 25 feet x $30/ft^2)	= $975,000
Contingency	(20 percent)	= $195,000
		$1,170,000

The preliminary cost estimate was developed in 2005 and does not include for final design, preparation of plans and specifications, pipe material and installation costs, or dewatering.

Other Construction Options

Other tunneling and trenching options including microtunneling, pipe-jacking, slurry wall, sheetpiling and slide-rail shoring are considered to be either unsuitable for the anticipated ground conditions or would present significant constructibility risk.

Microtunneling and pipe-jacking are not well-suited for ground conditions that vary widely from silt and sand units to large boulders. The tunneling machine face can be fit with hard rock cutter heads, but this configuration has difficulty in softer soil. Boulders situated at adverse orientations can be difficult to cut, especially when confined by loose soil layers that allow the boulder to move during cutting. Boulders can also force the jacked pipe off the design grade alignment. Once out of alignment or unable to cut past a boulder, operation essentially comes to a stop and the microtunneling machine may have to be removed by excavating from the ground surface.

Slurry wall construction techniques could be used to excavate the trench; however, once excavated, sheetpiles and internal bracing would be required before removing the slurry mud to provide access to the base of the trench. This technique only eliminates the drilling of H-piles when compared to the H-pile shoring option. Slurry wall technique also present risks regarding collapsing sidewalls and potential loss of slurry into the ground formation.

Sheetpiles and slide-rail shoring systems are typically driven or vibrated into place. In our opinion, the potential for large boulders makes both systems unfeasible. There are specialty contractors who can install sheetpiles through soil with cobbles (1 to 2 feet in diameter) using an auger tip to drill ahead of the sheetpile. Boulders larger than 2 feet may present a problem for these systems. If larger boulders are encountered, this system would have to be augmented with soil grouting, conventional excavation, or air-track drill splitting.

Construction Groundwater Control

Groundwater levels measured in the piezometers on November 30, 2005, were near or below pipe invert. In general, we recommend that groundwater levels be at least 1 foot below the base of the excavation. The control of groundwater is the responsibility of the contractor. If open sumps are used for groundwater control, they should be constructed in such a manner that native, fine-grained soil is not removed (piped or eroded) by the pumping activity. Collected water should be disposed in accordance with all applicable state and local regulations.

Pipe Bedding and Trench Backfill

For segments of the pipeline constructed with open cut or trench shoring, we recommend that the pipe is bedded and backfilled in accordance with Class B Bedding requirements. In general, a minimum 6-inch layer of crushed rock bedding material should be placed, leveled and compacted in the bottom of the trench. The crushed rock should consist of ¾-inch or 1½-inch minus, well-graded aggregate with not more than 5 percent passing the No. 200 sieve (based on a wet sieve analysis). This material shall also be placed in the pipe zone surrounding the pipe up to a distance of 12 inches above the top of the pipe. The material in the pipe zone should be placed in maximum 9-inch lifts and compacted to not less than 95 percent of the standard Proctor maximum dry density, as determined by the ASTM D 698 test method.

Backfill material in the trench above the pipe zone can consist of native sand and gravel with maximum particle size of 6-inch diameter, with not more than 10 percent passing the No. 200 sieve (based on a wet sieve analysis). Native silt material is not recommended for use as backfill. Suitable material should be placed in maximum 12-inch lifts and compacted to not less than 95 percent of the standard Proctor maximum dry density with the exception of the upper two feet beneath the pavement section. This 2-foot pavement subgrade zone should be compacted to not less than 98 percent of the standard Proctor maximum dry density.

We appreciate this opportunity to be of service and trust this report is sufficient for your current requirements. If you have any questions, please call.

Sincerely,

CORNFORTH CONSULTANTS, INC.

By ______________________________

Andy Vessely, P.E., C.E.G.
Vice-President

APPENDIX A

Soil Test Results

North Creek Analytical, Inc.