GEOTECHNICAL ENGINEERING REPORT

Well 4 Corrosion Control Facility

Lacey, Washington

Prepared for:

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Carollo Engineers, P.C.
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Seattle, Washington 98101

Attention: Mr. Trevor Dykstra

Subject: Geotechnical Engineering Report
Well 4 Corrosion Control Facility
Lacey, Washington

Dear Mr. Dykstra:

AMEC Earth & Environmental, Inc. (AMEC) is pleased to submit this report describing our geotechnical engineering evaluation for the above-referenced project. The purpose of our evaluation was to derive design conclusions and recommendations concerning site preparation, foundations, floors, drainage, infiltration, and structural fill.

As outlined in our proposal letter dated October 19, 2007, our scope of work comprised a field exploration, laboratory testing, geotechnical research, geotechnical analyses, and report preparation. We received your authorization via email for our evaluation on February 1, 2008. This report has been prepared for the exclusive use of Carollo Engineers and their consultants, for specific application to this project, in accordance with generally accepted geotechnical engineering practice.

We appreciate the opportunity to be of service on this project and would be happy to answer any questions you may have.

Sincerely,

AMEC Earth & Environmental, Inc.

Stephen A. Siebert, P.E.
Associate

Distribution: Carollo Engineers, Mr. Trevor Dykstra (3)

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1.0 SUMMARY

The following summary of project geotechnical considerations is presented for introductory purposes and, as such, should be used only in conjunction with the full text of this report.

- Project Description: Development plans call for expansion of the existing wellhouse, to facilitate the storage of a caustic soda treatment system as well as the hypochlorite system for Well 4. The proposed facility footprint would be expanded to about 500 square feet, south of the existing wellhouse. The existing infiltration pond would also be moved to the south to accommodate the wellhouse expansion.
- Exploratory Methods: We explored subsurface conditions by means of advancing two (2) boreholes at the project site, to a depth of 16.5 feet below existing grades. One borehole was advanced within the proposed building footprint and another borehole was advanced within the proposed infiltration pond area. We also reviewed the log for Well 4 prepared by Robinson and Noble, Inc. (1973) which extends to a depth of 111 feet.
- Soil Conditions: Soils underlying the site generally consist of 2 to 3 feet of topsoil overlying very loose to medium-dense fine to coarse sand and gravels (Recessional Outwash).
- Groundwater Conditions: At the time of drilling, no groundwater was encountered in our explorations to the maximum depth explored of 16.5 feet; however, the existing well log (Robinson and Noble, 1973) noted groundwater at a depth of about 36 feet.
- Liquefaction Analyses: Our liquefaction analysis indicates that the loose sands below the water table at a depth of about 36 feet are susceptible to liquefaction during a moderate to strong earthquake. However, due to the significant overburden thickness, we do not anticipate that surface damage will occur and that mitigation is not warranted.
- Foundations: The proposed building can supported by conventional spread and continuous footings bearing on at least 2 feet of new structural fill using a maximum allowable bearing capacity of 2,000 pounds per square foot.
- Floor Slabs: A soil-supported slab-on-grade floor can used within the proposed building provided it bears on non-organic native soils compacted to a medium dense condition or at least 2 feet of new structural fill.

- Infiltration Conditions: For design of the new infiltration pond, we estimate a long-term design infiltration rate for the medium to fine, native sands of 1 inch per hour.
- On-Site Soil Considerations: Because the on-site soils are moisture-sensitive and would be readily disturbed when wet, the contractor should install appropriate temporary drainage systems at the construction site and should minimize traffic over exposed subgrades. Ideally, earthwork would be scheduled for the summer and fall months, when drier weather will maximize the potential for reusing on-site soils.

2.0 SITE AND PROJECT DESCRIPTION

The project site is located near Rainer Road and Yelm Highway in Lacey, Washington, as shown on the enclosed *Location Map* (Figure 1). The City-owned parcel is roughly one acre in size and is zoned low-density residential. The well site is immediately surrounded by houses to the north and south, the Capitol City golf course to the east, and West Sarazan Street to the west. At present, site access is via a gravel driveway off West Sarazan Street.

Existing site facilities and features include the following: a building of concrete-block masonry unit (CMU) construction, with dimensions 10-feet by 12-feet; a below-grade vault with flowmeter; a finished water sample stand; and an infiltration pond used for yard drainage and pump-to-waste. The CMU building is used to house the wellhead and submersible pump, process and pump-to-waste piping and control valves, a temporary hypochlorite storage and feed system, and electrical and control panels. Modifications to the existing well and piping system are not anticipated for this project. The enclosed *Site & Exploration Plan* (Figure 2) illustrates these site boundaries and adjacent existing features.

Development plans call for demolition of the existing wellhouse and construction of a new building to facilitate a new caustic soda treatment system as well as the hypochlorite system for Well 4. The proposed facility footprint would be expanded to about 500 square feet, south of the existing wellhouse. The existing infiltration pond would also be modified and moved to the south to accommodate the wellhouse expansion. We anticipate that the new building, including four 1,000 gallon storage tanks will impose moderate foundation loads.

Site improvements also call for an improved access to the facility, including turnaround capability for tanker trucks. The proposed driveway expansion would occur along the western portion of the new facility to provide convenient access to the caustic soda storage tanks, as well as to create hammerhead arrangements that would permit truck turnaround.

The conclusions and recommendations contained in this report are based on our understanding of the currently proposed utilization of the project site, as derived from layout drawings, written information, and verbal information supplied to us. Consequently, if any changes are made in the currently proposed project, we may need to modify our conclusions and recommendations contained herein to reflect those changes.

3.0 EXPLORATORY METHODS

We explored surface and subsurface conditions at the project site on February 8, 2008. Our exploration and testing program consisted of the following elements:

- A visual surface reconnaissance of the site;
- Two borings (designated B-1 and B-2) with Standard Penetration Test, advanced at strategic locations across the site;
- One grain size analyses, performed on a selected soil sample obtained from boring (B-2), beneath the area of the proposed infiltration pond; and
- A review of published geologic and seismologic maps and literature.

Table 1 summarizes the approximate locations, surface elevations, and termination depths of all pertinent subsurface explorations, and Figure 2 depicts their approximate relative locations. Appendix A of this report describes our field exploration procedures, and Appendix B describes our laboratory testing procedures.

Table 1 Approximate Locations, Elevations, and Depths of Explorations

Exploration	Approximate Location	Surface Elevation (feet)	Termination Depth (feet)
B-1	Southeast corner of proposed building footprint	210	16.5
B-2	Center of proposed infiltration pond	210	16.5

Elevation datum: Not available

The specific number, locations, and depths of our explorations were selected and field-adjusted by AMEC in relation to the existing and proposed site features, under the constraints of surface access, underground utility conflicts, and budget considerations. We estimated the relative location of each exploration by measuring from existing features and scaling these measurements onto a layout plan supplied to us, we then estimated their elevations by interpolating between contour lines shown on this plan. Consequently, the data listed in Table 1 and the locations depicted on Figure 2 should be considered accurate only to the degree permitted by our data sources and implied by our measuring methods.

It should be realized that the explorations performed and utilized for this evaluation reveal subsurface conditions only at discrete locations across the project site and that actual conditions in other locations could vary. Furthermore, the nature and extent of any such variations would not become evident until additional explorations are performed or until construction activities have begun. If significant variations are observed at that time, we may need to modify our conclusions and recommendations contained in this report to reflect the actual site conditions.

4.0 SITE CONDITIONS

The following sections of text present our observations, measurements, findings, and interpretations regarding surface, soil, groundwater, and seismic conditions at the project site.

4.1 SURFACE CONDITIONS

The site is located near Rainier Road and Yelm Highway in south Lacey. The site is generally flat, with total topographic relief across the site being on the order of 2 feet. Surrounding the site is a low density housing development and golf course. The area surrounding the wellhouse and infiltration pond consists of a grass lawn. Sparse deciduous trees surround the wellhouse and infiltration pond. Access into the site is via an east-west trending gravel driveway from West Sarazan Street.

The area being considered for the expanded building currently is occupied by an infiltration pond, with approximate dimensions 30-feet by 15-feet. The infiltration pond is approximately 1.5 to 2 feet deep below the surrounding grade, and lined with a layer of rounded gravel and cobbles, approximately 6 inches thick.

4.2 SOIL CONDITIONS

According to published geologic maps, soil conditions in the site vicinity are characterized by glacial deposits from the Pleistocene Era, more specifically Vashon recessional outwash. Recessional outwash generally consists of loose sand and silt, with minor gravel interbeds that were deposited during the prehistoric glacial retreat. As such the recessional outwash exhibits low to medium strength, and moderate compressibility characteristics.

Our on-site explorations revealed somewhat variable near-surface soil conditions but confirmed the mapped stratigraphy to their termination depth of 16.5 feet. In general, our explorations encountered 2 to 3 feet of topsoil over loose to medium-dense, moist, silty sand, which we interpret to be recessional outwash. Review of the exploration log prepared by Robinson and Noble (1973) for Well 4 which extends to a depth of 111 feet indicates fine to coarse sand and gravels is present below a depth of 16.5 feet. The enclosed exploration logs provide a detailed description of the soil strata encountered in our subsurface explorations. The Robinson and Noble well log is also included for completeness.

Our geotechnical laboratory tests revealed that the near-surface native sands have a fines (silt and clay) content on the order of 13 percent. We interpret these soils to be currently at or near their optimum moisture contents, and that the recessional sand and silt to be highly sensitive to moisture content variations. The enclosed laboratory testing sheet graphically presents our test results.

4.3 GROUNDWATER CONDITIONS

At the time of drilling (February 8, 2008), none of our explorations encountered groundwater within their termination depths. However, a previous well log (Robinson and Noble, 1973) recorded a groundwater level present at a depth of about 36 feet (September 12, 1973). Throughout the year, groundwater levels would likely fluctuate in response to changing precipitation patterns, off-site construction activities, and site utilization.

4.4 SEISMIC CONDITIONS

4.4.1 Liquefaction Potential

Liquefaction is a sudden increase in porewater pressure and a sudden loss of soil shear strength caused by shear strains, as could result from an earthquake. Research has shown that saturated, loose sands with a silt and clay content less than about 25 percent are most susceptible to liquefaction. Although other soil types are generally considered to have a low susceptibility, liquefaction may still occur during a strong earthquake. To evaluate the possibility that the on-site native soils could liquefy during a seismic event, we performed a liquefaction analysis using an empirical approach.

We evaluated the liquefaction potential of the site based on soil gradation, depth to water table, and Standard Penetration Test blow counts measured during drilling and sampling. We used the software program SHAKE 2000 to calculate liquefaction potential. This program applies the empirical methodology developed by Seed and Idriss (1971) and later modified by Seed et al (2003). The method calculates the factor of safety as: the ratio of the cyclic stress ratio that the soil can resist under a certain magnitude of earthquake, to the cyclic stress ratio that would be induced by the equivalent ground motion. The method was originally developed for clean sands and was later modified to incorporate fines content (percent passing U.S. No. 200 Sieve) up to 35 percent. For the same SPT penetration resistance, the liquefaction resistance increases with increasing fines content.

For our liquefaction analyses, we used the peak ground acceleration from the USGS Probabilistic Uniform Response Spectra, 2002 Data, ground motion with a 10 percent probability of exceedance in 50 years (return interval of 475 years) equal to 0.30g. A magnitude M = 7.5 earthquake with a peak ground acceleration of 0.30g was selected as the design earthquake.

Based upon the measured soil density, water table elevation, and percent fines of the site soils, the potential for soil liquefaction at the site is considered high. Our analysis indicated that the saturated, loose to medium dense sand present at depths from about 36 to 50 feet are most likely to liquefy during a severe earthquake.

4.4.2 Liquefaction Settlement

AMEC evaluated liquefaction-induced settlements for the soil profile, using the program SHAKE 2000 and the method developed by Tokimatsu and Seed (1987). For a water table at 36 feet, and a moderately strong Magnitude 7.5 earthquake, the predicted ground surface settlement is in the range of 8 to 9 inches. Based on the work of Ishihara (1985), ground rupture and surface settlement is not likely from this deeper layer (which has an overburden thickness of about 2 times the thickness of the liquefiable layer).

4.4.3 Seismic Site Classification

Per 2006 IBC, any site that is underlain by liquefiable soils is classified as Site Class F. However, it also states that for structures with a period of vibration equal to or less than 0.5 seconds, which is typical of short structures, that the site class can be based on average soil properties in the top 100 feet without regard to liquefaction. AMEC infers that this is the case for the proposed well house building. Based on review of IBC maps and more detailed USGS hazard mapping[1] AMEC recommends using IBC Site Class D with the following parameters:

- Ss = 1.553
- S1 = 0.422
- Fa = 1.039
- Fv = 1.578
- SDS = 0.799
- SD1 = 0.444

5.0 CONCLUSIONS AND RECOMMENDATIONS

Development plans call for expansion of the existing wellhouse, to facilitate the storage of a caustic soda treatment system as well as the hypochlorite system for Well 4. We offer the following general geotechnical conclusions and recommendations concerning this project:

1 http://earthquake.usgs.gov/research/hazmaps

- Feasibility: Based on our field explorations, research, and analyses, the proposed expansion appears feasible from a geotechnical standpoint, contingent on the recommendations presented herein.
- Foundation Options: In our opinion, the proposed structure can be supported by conventional spread footings that bear on at least two feet of structural fill.
- Floor Options: Soil conditions are amenable to the use of a soil-supported slab-on-grade floor, contingent on proper subgrade preparation and removal of surface topsoil and organic rich material.
- Stormwater Infiltration: The subsurface conditions are favorable for infiltrating stormwater. We recommend using a long-term design infiltration rate of 1 inch/hour.
- Liquefaction Considerations: Our liquefaction analysis indicated that the soils underlying the project site are susceptible to liquefaction during a severe earthquake. However, the risk of surface settlement and/or damage appears to be low.
- Seismic Considerations: Based on our literature review and subsurface interpretations, we recommend that the project structural engineer use the following seismic parameters for design of buildings, retaining walls, and other site structures, as appropriate.

Design Parameter	Value
Acceleration Coefficient (2002 USGS)	0.30
Seismic Site Class (2006 IBC)	D

- On-Site Soil Reuse: Surface topsoil and organic-rich material will need to be stripped from beneath structural areas to expose the underlying native recessional sands. The exposed recessional sands would need to be compacted to a firm/unyielding condition to provide suitable bearing for foundations and other structures. The native recessional sand is a possible source for needed structural fill. Our visual soil classifications and laboratory testing indicate the on-site soils are moderately to highly moisture-sensitive and susceptible to disturbance when wet. In order to maximize the potential for reusing on-site soils as structural fill, earthwork should be scheduled for periods of dry weather, such as usually occur during late spring, summer and early fall months.
- Subgrade Protection: Due to the moisture-sensitive nature of the on-site soils, the contractor should install appropriate temporary drainage systems to keep water out of the construction areas, and should minimize traffic over any subgrades prepared within these soils.

The following text sections of this report present our specific geotechnical conclusions and recommendations concerning site preparation, excavations, foundations, floors, drainage, stormwater

infiltration facilities, and structural fill. ASTM specification codes cited herein refer to the current American Society for Testing and Materials manual. WSDOT specification codes and plan designations cited herein refer to WSDOT publications M41-10, *2007 Standard Specifications for Road, Bridge, and Municipal Construction.*

5.1 SITE PREPARATION

Preparation of the project site might or should involve demolition, temporary drainage, clearing, stripping, excavations, filling, erosion control, dewatering, and subgrade compaction. The paragraphs below discuss our geotechnical comments and recommendations concerning site preparation.

Temporary Drainage: We recommend intercepting and diverting any potential sources of surface or near-surface water within the construction zones before stripping begins. Because the selection of an appropriate drainage system will depend on the water quantity, season, weather conditions, construction sequence, and contractor's methods, final decisions regarding drainage systems are best made in the field at the time of construction. Nonetheless, we anticipate that curbs, berms, or ditches placed around the work areas will adequately intercept surface water runoff.

Clearing and Stripping: After surface and near-surface water sources have been controlled, the construction areas should be cleared and stripped of all trees, bushes, sod, topsoil, debris, and concrete. Our explorations indicate that an average thickness of about 2 feet of topsoil or organic rich material could be encountered at the proposed building location and about 3 feet at the infiltration pond, but significant variations could exist. Furthermore, it should be realized that if the stripping operation proceeds during wet weather, a generally greater stripping depth might be necessary to remove disturbed moisture-sensitive soils; therefore, stripping is best performed during a period of dry weather.

Erosion Control Measures: Because stripped surfaces and soil stockpiles are typically a source of runoff sediments, they should be given particular attention. If earthwork occurs during wet weather, we recommend that all stripped surfaces be covered with straw to reduce runoff erosion. Similarly, soil stockpiles and cut slopes should be covered with plastic sheeting for erosion protection. We also recommend that a staked silt fence be installed around the area to be disturbed. The base of the silt fence should be buried so that sediment cannot pass beneath it, and the silt fence should be inspected and maintained during the time that the site soils are exposed, on a periodic basis, and after any major rainstorm event. It may be prudent to maintain a berm and swale around the downslope side of stripped areas and stockpiles in order to capture runoff water and thereby reduce the downslope sediment transport. In addition, the stripped areas should be revegetated as soon as possible, also reducing the potential for erosion.

Site Cutting and Excavation: Based on our explorations, we expect site earthwork activities will encounter medium dense sandy gravels with cobbles and small boulders. Given these soil conditions, we anticipate the conventional earthwork equipment could readily perform the site work.

Although our explorations did not reveal any obstacles, the presence of such obstacles as small or large boulders, may require additional effort and / or specialty equipment to remove. Our conclusions regarding the reuse of on-site soils are presented subsequently.

Dewatering: Our explorations did not encounter groundwater at time of drilling. However, an unexpected perched groundwater table could exist during the wet winter and spring seasons. If groundwater is encountered, we anticipate that an internal system of ditches, sumpholes, and pumps will be adequate to temporarily dewater the excavation.

Temporary Cut Slopes: While we do not anticipate large cuts and fills across the site, there may be needs for cuts greater than four feet in depth for underground utilities and other structures may require temporary shoring (i.e. trench boxes). All temporary cut slopes associated with site excavations should be adequately inclined to prevent sloughing and collapse. For the soil layer likely to be exposed in on-site cuts, we tentatively recommend a maximum cut slope inclination of 1½ H:1V However, appropriate inclinations will ultimately depend on the actual soil conditions exposed during earthwork.

Subgrade Compaction: Exposed subgrades for footings, floors, pavements, and other structures should be compacted to a dense unyielding state before new structural fill soils are placed. Any localized zones of loose granular soils observed within a subgrade should be compacted to a density commensurate with the surrounding soils. In contrast, any organic, soft, or pumping soils observed within a subgrade should be overexcavated and replaced with a suitable structural fill material.

Site Cutting and Filling: Current plans indicate that the new building will partially located in undeveloped area and partially in the area of the existing infiltration pond. Our explorations indicate that unsuitable bearing soils are present to depths of about 3 feet in the undeveloped areas. Overexcavation of existing unsuitable subgrade materials within the pond and backfill with suitable structural fill will be required to achieve design subgrades. Our conclusions regarding the reuse of on-site soils and our comments regarding wet-weather filling are presented subsequently. Regardless of soil type, all fill should be placed and compacted according to our recommendations presented in the *Structural Fill* section of this report. Specifically, all fill soil should be compacted to a uniform density of at least 95 percent (based on ASTM:D-1557) within the building pad. For utilities, trench backfill should be compacted to 90 percent with the uppermost 2 feet being compacted to 95 percent in paved areas.

On-Site Soils: Because only minor cuts will likely be planned for the project, we do not expect large quantities of on-site soils will be generated during earthwork activities. Nonetheless, we offer the following evaluation of these on-site soils in relation to potential use as structural fill.

- Surficial Organic Soils: The sod, duff, topsoil, and organic-rich soils mantling most of the site are *not* suitable for use as structural fill under any circumstances, due to their long-term compressibility. Consequently, these materials can be used only for non-structural purposes, such as in landscaping areas.
- Recessional Outwash: The sands underlying the surficial organic soils appear suitable for reuse as structural fill if placed near the material optimum moisture content. However, these soils may become unsuitable for reuse during periods of wet weather.

Wet-Weather Considerations: As discussed above, most or all of the on-site soils would be difficult to reuse as structural fill during wet weather. Consequently, the project specifications should include provisions for using imported, clean, granular fill in case site filling must proceed during wet weather. For general structural fill purposes, we recommend using a well-graded sand and gravel, such as "Ballast" or "Gravel Borrow" per WSDOT: 9-03.9(1) and 9-03.14, respectively.

5.2 SPREAD FOOTINGS

In our opinion, conventional spread footings will provide adequate support for the proposed building if the subgrades are properly prepared. We offer the following comments and recommendations for purposes of footing design and construction.

Footing Depths and Widths: For frost and erosion protection, the bottoms of all exterior footings should bear at least 18 inches below adjacent outside grades, whereas the bottoms of interior footings need bear only 12 inches below the surrounding slab surface level if the existing organic-rich soils are overexcavated and replaced with structural fill, as previously discussed. To minimize post-construction settlements, continuous (wall) and isolated (column) footings should be at least 18 and 24 inches wide, respectively.

Bearing Subgrades: The loose recessional outwash sands underlying the proposed building footprint do not appear well-suited for supporting spread footings. Consequently, we recommend overexcavation below the base of footings at least 2 feet and replacement with suitable structural fill. The lateral extent of overexcavation from the edge of the footing should be equal to the vertical overexcavation depth (i.e. at least 2 feet from each side of the footing). Before footing concrete is placed, any localized zones of loose soils exposed across the footing subgrades should be compacted to a firm, unyielding condition, and any localized zones of soft, organic, or debris-laden soils should be overexcavated and replaced with suitable structural fill.

Subgrade Verification: All footing subgrades should consist of suitable structural fill materials placed over native soils. Footings should never be cast atop loose, soft, or frozen soil, slough, debris, existing uncontrolled fill, or surfaces covered by standing water. We recommend that the condition of all subgrades be verified by an AMEC representative before any fill and/or concrete is placed.

Bearing Capacities: Based on the bearing subgrade conditions described above, we recommend that all footings be designed for the following allowable soil bearing capacities. These values incorporate static and seismic safety factors of at least 2.0 and 1.5, respectively.

	Allowable Bearing Capacity	
Subgrade Soil Type	**Static**	**Seismic**
New Structural Fill	2,000 psf	3,300 psf

Footing Settlements: We estimate that total post-construction settlements of properly designed footings bearing on properly prepared subgrades will not exceed 1 inch. Differential settlements could approach one-half of the actual total settlement between adjacent foundation elements. These settlements would be reduced if the actual design bearing pressures are lower than our recommended maximum pressures.

Footing and Stemwall Backfill: To provide erosion protection and lateral load resistance, we recommend that all footing excavations be backfilled on both sides of the footings and stemwalls after the concrete has cured. Either imported structural fill or non-organic on-site soils can be used for this purpose, contingent on a suitable moisture content at the time of placement. Regardless of soil type, all footing backfill soil should be compacted to a density of at least 90 percent (based on ASTM:D-1557).

Lateral Resistance: Footings and stemwalls that have been properly backfilled as described above will resist lateral movements by means of passive earth pressure and base friction. We recommend using the following design values, which incorporate static and seismic safety factors of at least 1.5 and 1.1, respectively. Base friction can be combined with the respective passive pressure to resist static and seismic loads.

Design Parameter	**Allowable Value**
Static Passive Pressure	300 pcf
Seismic Passive Pressure	400 pcf
Base Friction Coefficient	0.3

5.3 SLAB-ON-GRADE FLOORS

In our opinion, soil-supported slab-on-grade floors can be used in the proposed building if the subgrades are properly prepared. We offer the following comments and recommendations concerning slab-on-grade floors.

Subgrade Conditions and Verification: All soil-supported slab-on-grade floors should bear on firm, unyielding compacted non-organic native soils or at least 2 feet of new structural fill. We recommend that the condition of all subgrades and overlying layers be verified by an AMEC representative before any fill or concrete is placed.

Capillary Break: To retard the upward wicking of groundwater beneath the floor slab and to provide a smooth bearing surface, we recommend that a capillary break be placed over the subgrade. Ideally, this capillary break would consist of a 4-inch-thick layer of pea gravel or other clean, uniform, well-rounded gravel, such as "Gravel Backfill for Drains" per WSDOT: 9-03.12(4). Alternatively, angular gravel or crushed rock can be used if it is sufficiently clean and uniform to prevent capillary wicking.

Vapor Retarder: We recommend that a layer of durable plastic sheeting (such as Crosstuff, Moistop, or Visqueen) be placed directly between the capillary break and the floor slab to prevent ground moisture vapors from migrating upward through the slab. However, vapor retarders can be considered optional for use under floors that will not be covered with moisture-sensitive materials. If a vapor barrier is used, the contractor should exercise care to avoid puncturing it while casting the slab.

Curing Course: A curing course is a thin layer (typically 2 inches thick) of clean sand that is sometimes placed over the vapor barrier to facilitate uniform curing of the overlying concrete slab. Recent studies, however, have indicated that this course is not necessary when moderately strong concrete is used for the slab, and some structural engineers believe it can be detrimental to a slab's long-term performance. Consequently, we recommend that the project structural engineer be allowed to decide whether a curing course should be used.

5.4 DRAINAGE SYSTEMS

In our opinion, the new building should be provided with a permanent drainage system to minimize the risk of future moisture problems. We offer the following recommendations and comments for drainage design and construction purposes.

Perimeter Drains: We recommend the building be encircled with a perimeter drain system to collect seepage water. This drain should consist of a 4-inch-diameter perforated pipe within an envelope of pea gravel or washed rock, extending at least 6 inches on all sides of the pipe, and the gravel envelope should be wrapped with filter fabric to reduce the migration of fines from the surrounding

soils. Ideally, the drain invert would be installed no more than 8 inches above or below the base of the perimeter footings.

Runoff Water: Roof-runoff and surface-runoff water should *not* be allowed to flow into the foundation drainage systems. Instead, these sources should flow into separate tightline pipes and be routed away from the building location. Also, final site grades should slope downward away from the building so that water runoff will flow by gravity to suitable collection points, rather than ponding near the building.

Discharge Considerations: If possible, all perimeter drains should discharge to a municipal storm drain, sewer system, detention system, or other suitable location by gravity flow. Check valves should be installed along any drainpipes that discharge to a sewer system, to prevent sewage backflow into the drain system.

5.5 INFILTRATION SYSTEM

We understand that a new stormwater infiltration pond will be constructed as part of the site improvements to the south of the new building location. We have determined design infiltration rates based on ASTM Gradation Testing in accordance with the *Washington State Department of Ecology Stormwater Management Manual for Western Washington, Vol. III (February 2005).* Based on the soil conditions observed in our explorations and laboratory testing, we estimate a long-term design infiltration rate of 1 inch per hour for the recessional sands.

5.6 STRUCTURAL FILL

The term "structural fill" refers to any materials used for building pads, materials placed under foundations, retaining walls, slab-on-grade floors, sidewalks, pavements, and other such features. Our comments, conclusions, and recommendations concerning structural fill are presented in the following paragraphs.

Materials: Typical structural fill materials include clean sand, granulithic gravel, crushed rock, quarry spalls, controlled-density fill (CDF), lean-mix concrete (LMC), well-graded mixtures of sand and gravel (commonly called "gravel borrow" or "pit-run"), and miscellaneous mixtures of silt, sand, and gravel. Recycled asphalt, concrete, and glass, which are derived from pulverizing the parent materials, are also potentially useful as structural fill in certain applications. Soils used for structural fill should not contain any organic matter or debris, nor any individual particles greater than about 6 inches in diameter.

Fill Placement: Generally, quarry spalls, CDF, and LMC do not require special placement and compaction procedures. In contrast, clean sand, granulithic gravel, crushed rock, soil mixtures, and

recycled materials should be placed in horizontal lifts not exceeding 8 inches in loose thickness, and each lift should be thoroughly compacted with a mechanical compactor.

Compaction Criteria: Using the Modified Proctor test (ASTM:D-1557) as a standard, we recommend that structural fill used for various on-site applications be compacted to the following minimum densities:

Fill Application	Minimum Compaction
Footing subgrade or bearing pad	95 percent
Footing and stemwall backfill	90 percent
Slab-on-grade floor subgrade and subbase	90 percent

Subgrade Verification and Compaction Testing: Regardless of material or location, all structural fill should be placed over firm, unyielding subgrades prepared in accordance with the *Site Preparation* section of this report. The condition of all subgrades should be verified by an AMEC representative before filling or construction begins. Also, fill soil compaction should be verified by means of in-place density tests performed during fill placement so that adequacy of soil compaction efforts may be evaluated as earthwork progresses.

Soil Moisture Considerations: The suitability of soils used for structural fill depends primarily on their grain-size distribution and moisture content when they are placed. As the "fines" content (that soil fraction passing the U.S. No. 200 Sieve) increases, soils become more sensitive to small changes in moisture content. Soils containing more than about 5 percent fines (by weight) cannot be consistently compacted to a firm, unyielding condition when the moisture content is more than 2 percentage points above or below optimum. For fill placement during wet-weather site work, we recommend using "clean" fill, which refers to soils that have a fines content of 5 percent or less (by weight) based on the soil fraction passing the U.S. No. 4 Sieve.

CDF Strength Considerations: CDF is normally specified in terms of its compressive strength, which typically ranges from 50 to 200 psi. CDF having a strength of 50 psi (7,200 psf) provides adequate support for most structural applications and can be readily excavated with hand shovels. A strength of 100 psi (14,400 psf) provides additional support for special applications but greatly increases the difficulty of hand-excavation. In general, CDF having a strength greater than about 100 psi requires power equipment to excavate and, as such, should not be used where future hand-excavation might be needed.

6.0 RECOMMENDED ADDITIONAL SERVICES

Because the future performance and integrity of the structural elements will depend largely on proper site preparation, drainage, fill placement, and construction procedures, monitoring and testing by experienced geotechnical personnel should be considered an integral part of the construction process. Consequently, we recommend that AMEC be retained to provide the following post-report services:

- Review all construction plans and specifications to verify that our design criteria presented in this report have been properly integrated into the design;
- Prepare a letter summarizing all review comments (if required by the City of Lacey);
- Attend a pre-construction conference with the design team and contractor to discuss important geotechnical issues;
- Observe all exposed subgrades after completion of stripping and overexcavation to confirm that suitable soil conditions have been reached and to determine appropriate subgrade compaction methods;
- Monitor the placement of all structural fill and test the compaction of structural fill soils to verify their conformance with the construction specifications;
- Check all completed subgrades for footings and slab-on-grade floors before concrete is poured, in order to verify their bearing capacity;
- Observe the installation of all perimeter drains, wall drains, and capillary break layers to verify their conformance with the construction plans; and
- Prepare a post-construction letter summarizing all field observations, inspections, and test results (if required by the City of Lacey).

In addition to the aforementioned services, AMEC can provide inspection and testing of concrete, steel, masonry, and other structural materials. Upon request, we could submit a proposal for providing some or all of these construction monitoring, inspection, and testing services. Such a proposal is best prepared after the project plans and specifications have been approved for construction.

7.0 CLOSURE

The conclusions and recommendations presented in this report are based, in part, on the explorations that we performed and utilized for this study; therefore, if variations in the subgrade conditions are observed at a later time, we may need to modify this report to reflect those changes. Also, because the future performance and integrity of the project elements depend largely on proper initial site

preparation, drainage, and construction procedures, monitoring and testing by experienced geotechnical personnel should be considered an integral part of the construction process. AMEC is available to provide geotechnical monitoring, soils and concrete testing, steel and masonry inspection, and other services throughout construction.

We appreciate the opportunity to be of service on this project. If you have any questions regarding this report or any aspects of the project, please feel free to contact our office.

Sincerely,

AMEC Earth & Environmental, Inc.

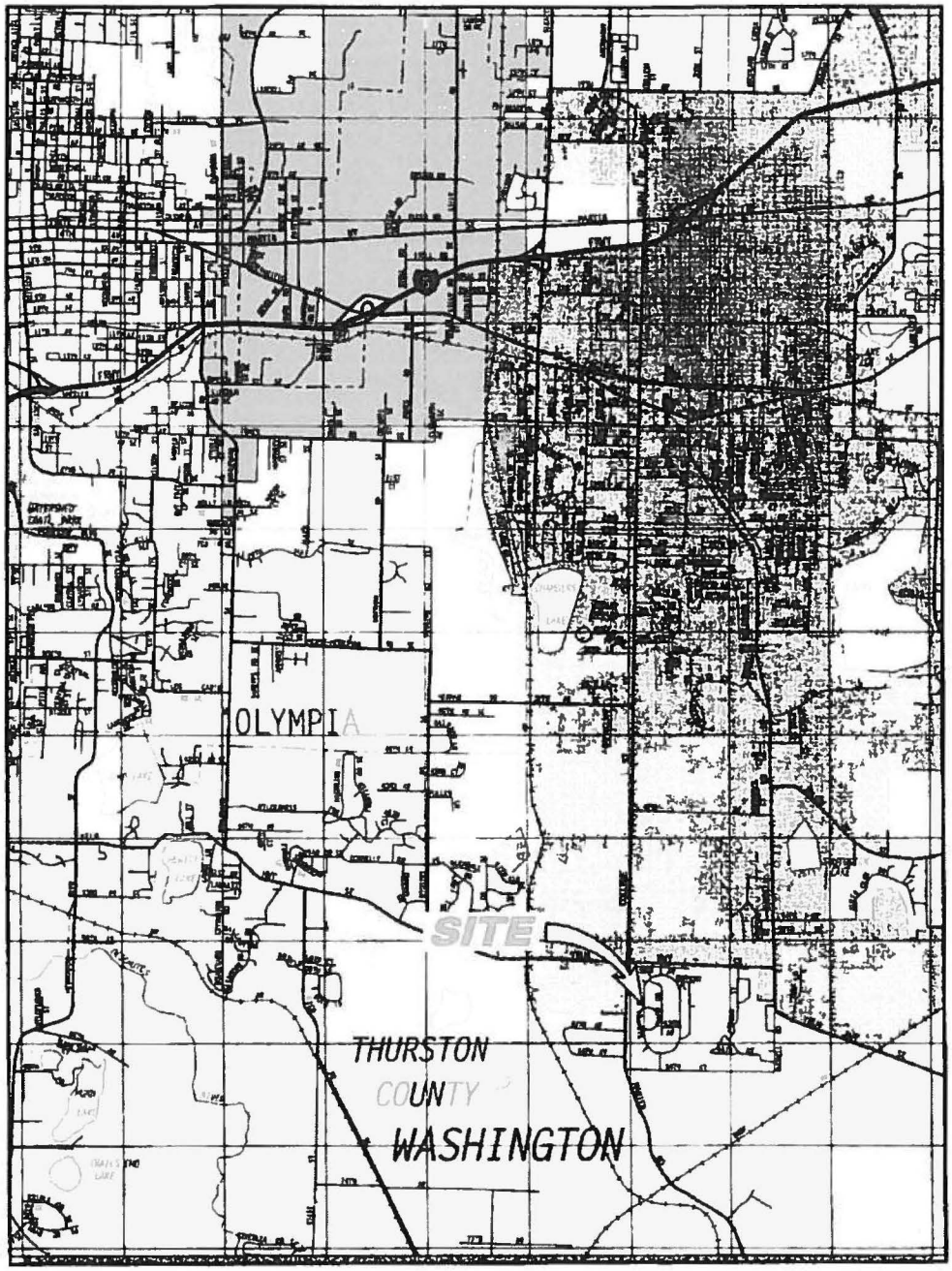
STEPHEN A. SIEBERT
STATE OF WASHINGTON
30829
REGISTERED
PROFESSIONAL ENGINEER

10/15/10

Stephen A. Siebert, P.E.
Associate

Reviewed by:
James S. Dransfield, P.E.
Principal Geotechnical Engineer

FIGURES



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N.T.S.

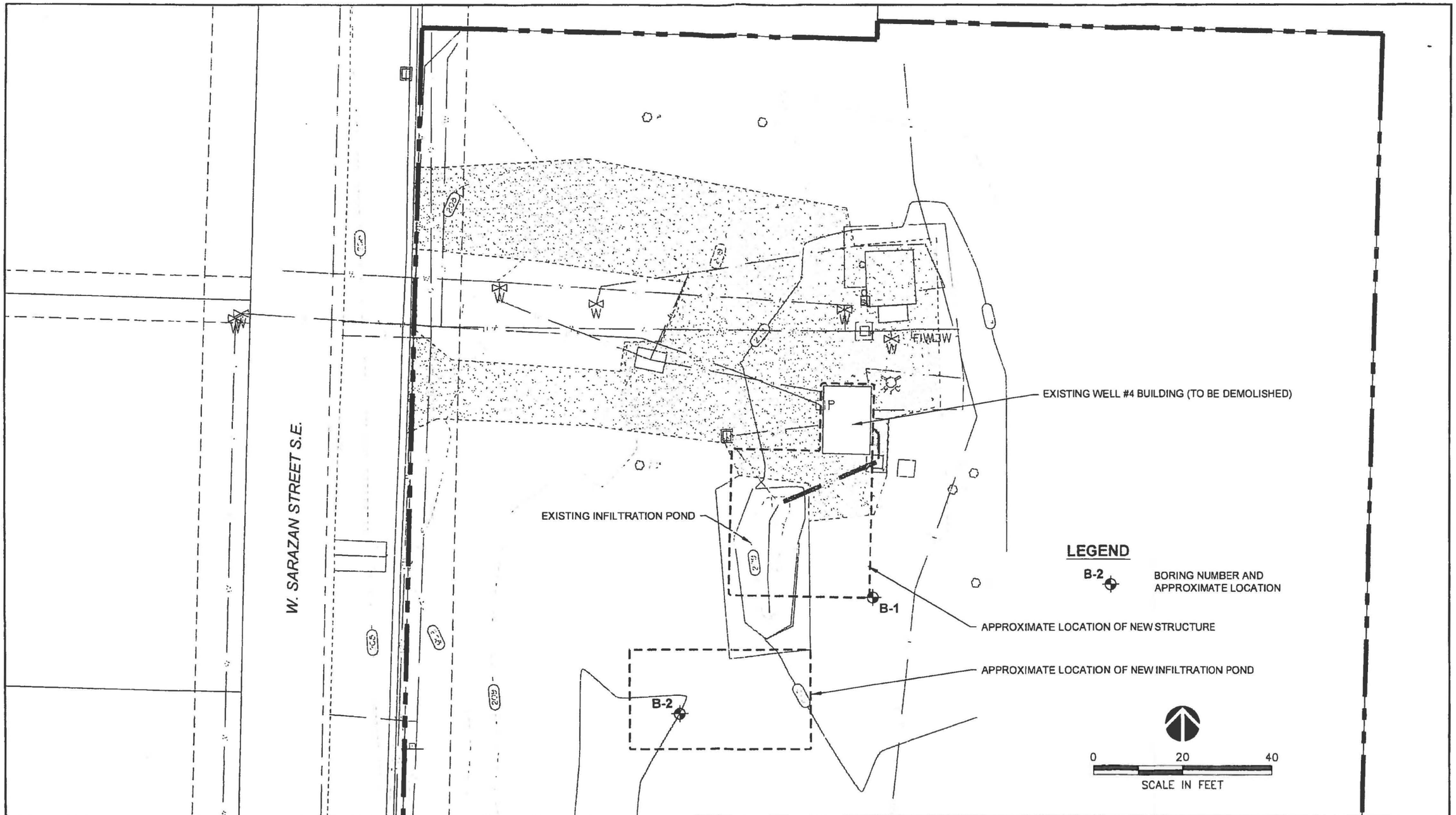
AMEC Earth & Environmental
11264 N.E. 122nd Way, Suite 100
Kirkland, WA, U.S.A. 98034-6918

amec

CLIENT LOGO

CLIENT
CAROLLO ENGINEERS, P.C.

PROJECT: CITY OF LACEY WELL #4 CORROSION FACILITY	DRAWN BY: JRS	DATUM: NONE	DATE: FEBRUARY 2008
TITLE: SITE VICINITY MAP	CHECKED: SAS	REV. NO:	PROJECT NO: 3-917-163123
	PROJECTION: NONE	SCALE: AS SHOWN	FIGURE NO: 1



REFERENCE: DRAWING DEVELOPED FROM PLAN SHEET PROVIDED BY CAROLLO ENGINEERS, DATED 01-31-2008.

CLIENT LOGO

CLIENT: CAROLLO ENGINEERS, P.C.

AMEC Earth & Environmental
11335 N.E. 122nd Way, Suite 100
Kirkland, WA, U.S.A. 98034-6918

amec

DWN BY	JRS
CHK'D BY	SAS
DATUM	
PROJECTION	
SCALE	AS SHOWN

PROJECT: CITY OF LACEY WELL #4 CORROSION FACILITY

TITLE: SITE AND EXPLORATION PLAN

DATE	FEBRUARY 2008
PROJECT NO	8-917-16312-0
REV NO	
FIGURE No	2

G:\91\16000\16312 – Lacey\16312-02.dwg – Layout1 – Feb. 28, 2008 10:09am – jeffrey.sanders

APPENDIX A

Field Exploration Procedures and Logs

APPENDIX A
FIELD EXPLORATION PROCEDURES AND LOGS
8-917-16312-0

The following paragraphs describe our procedures associated with the field explorations and field tests that we conducted for this project. Descriptive logs of our explorations are enclosed in this appendix.

AUGER BORING PROCEDURES

Our exploratory borings were advanced with a hollow-stem auger, using a truck-mounted drill rig operated by an independent drilling firm working under subcontract to AMEC. A geologist from our firm continuously observed the borings, logged the subsurface conditions, and collected representative soil samples. All samples were stored in containers and later transported to our laboratory for further visual examination and testing. After each boring was completed, the borehole was backfilled with a mixture of bentonite chips and the surface was patched.

Throughout the drilling operation, soil samples were obtained at 22- or 5-foot depth intervals by means of the Standard Penetration Test (SPT) per ASTM:D-1586. This testing and sampling procedure consists of driving a standard 2-inch-diameter steel split-spoon sampler 18 inches into the soil with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler through each 6-inch interval is counted, and the total number of blows struck during the final 12 inches is recorded as the Standard Penetration Resistance, or "SPT blow count." If a total of 50 blows are struck within any 6-inch interval, the driving is stopped and the blow count is recorded as 50 blows for the actual penetration distance. The resulting Standard Penetration Resistance values indicate the relative density of granular soils and the relative consistency of cohesive soils.

The enclosed *Boring Logs* describe the vertical sequence of soils and materials encountered in each boring, based primarily on our field classifications and supported by our subsequent laboratory examination and testing. Where a soil contact was observed to be gradational, our logs indicate the average contact depth. Where a soil type changed between sample intervals, we inferred the contact depth. Our logs also graphically indicate the blow count, sample type, sample number, and approximate depth of each soil sample obtained from the borings, as well as any laboratory tests performed on these soil samples. If any groundwater was encountered in a borehole, the approximate groundwater depth is depicted on the boring log. Groundwater depth estimates are typically based on the moisture content of soil samples, the wetted height on the drilling rods, and the water level measured in the borehole after the auger has been extracted.

PROJECT: *Lacey Corrosion Control Facility* JOB No. *8-917-16312-0* BORING No. *B-1*

Page 1 of 1

Location: NE corner of proposed building
Approximate ground surface elevation: 210.0 feet

DEPTH (feet)	Soil Description	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER	PENETRATION RESISTANCE (Standard / Blows over Inches / Other; Blows per foot)	TESTING
0	Grass over very loose, moist, dark brown, silty fine to medium SAND with trace gravel and scattered organics (Topsoil)				N/E		
	Loose, moist, brown, silty, fine to medium SAND (Recessional Outwash)			S-1		3	
5	Loose, moist, brown, fine to coarse SAND with some silt (Recessional Outwash)			S-2		7	
	Very loose, moist, orange brown, silty SAND/sandy SILT (Recessional Outwash)			S-3			
	Loose, moist, brown, fine to coarse SAND with some silt (Recessional Outwash)					6	
10	Loose to medium dense, moist, brown, silty, fine to medium SAND (Recessional Outwash)			S-4		8	
				S-5		10	
15				S-6		12	
	Boring terminated at approximately 16 5 feet						
20							

Penetration resistance scale: 0 10 20 30 40 50

Moisture content scale: 0 20 40 60 80 100 — Plastic Limit — MOISTURE CONTENT — Liquid Limit

LEGEND

2 00-inch OD split-spoon sampler

N/E No groundwater encountered

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Kirkland, Washington 98034-6913

Drilling Method: HSA Hammer Type: Automatic Date drilled: *February 08, 2008* Logged By: *JTL*

Drilled by: *Holocene Drilling*

SOIL_ROCK_COMBO_1-06 LACEY BORING LOGS.GPJ GEOTECH3_05.GDT 2/29/08

PROJECT: *Lacey Corrosion Control Facility* JOB No. *8-917-16312-0* BORING No. *B-2*

Page 1 of 1

Location: Within proposed infiltration pond
Approximate ground surface elevation: 210.0 feet

DEPTH (feet)	Soil Description	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER	PENETRATION RESISTANCE (Standard / Blows over inches / Other; Blows per foot)	TESTING
0	Grass over very loose, moist to wet, dark brown, silty, fine to medium SAND with scattered organics (Topsoil)				N/E		
	Loose, moist, brown, silty, fine to coarse SAND (Recessional Outwash)			S-1		6	13
5				S-2		3	
	Medium stiff, moist, orange brown, sandy SILT/silty SAND (Recessional Outwash)						
	Loose, moist, brown, silty, fine SAND (Recessional Outwash)			S-3		9	
	Grades to silty, fine to medium SAND						
10				S-4		8	
	Medium dense, moist, brown, fine to medium SAND with some silt (Recessional Outwash)			S-5		11	
15				S-6		11	
	Boring terminated at approximately 16.5 feet						
20							

Penetration resistance scale: 0 10 20 30 40 50

Moisture content scale: 0 20 40 60 80 100 — Plastic Limit — MOISTURE CONTENT — Liquid Limit

LEGEND

2.00-inch OD split-spoon sampler

N/E No groundwater encountered

Grain Size Analysis (% fines shown)

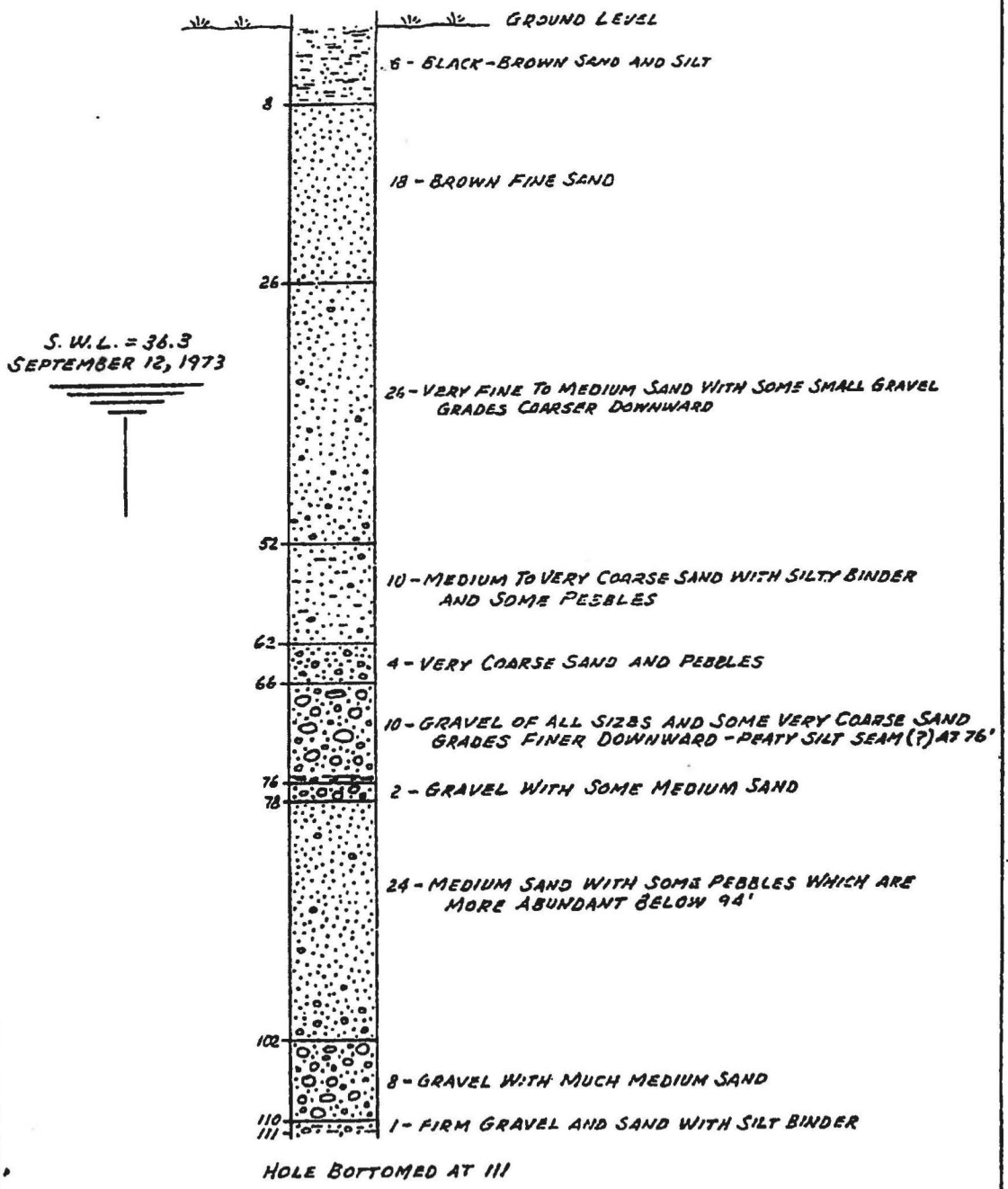
amec
11335 N.E. 122nd Way Suite 100
Kirkland, Washington 98034-6913

Drilling Method: HSA Hammer Type: Automatic Date drilled: *February 08, 2008* Logged By: *JTL*

Drilled by: *Holocene Drilling*

SOIL_ROCK_COMBO_1-06 LACEY BORING LOGS.GPJ GEOTECH3_05.GDT 2/29/08

CITY OF LACEY GOLF COURSE WE - 1973



CITY OF LACEY WASHINGTON	ROBINSON AND NOBLE, INC. GROUND WATER GEOLOGISTS TACOMA, WASHINGTON	SEPT. 15, 1973 DRAWN BY H.N.

APPENDIX B

Laboratory Testing Procedures and Results

APPENDIX B
LABORATORY TESTING PROCEDURES AND RESULTS
8-917-16312-0

The following paragraphs describe our procedures associated with the laboratory tests that we conducted for this project. Graphical results of certain laboratory tests are enclosed in this appendix.

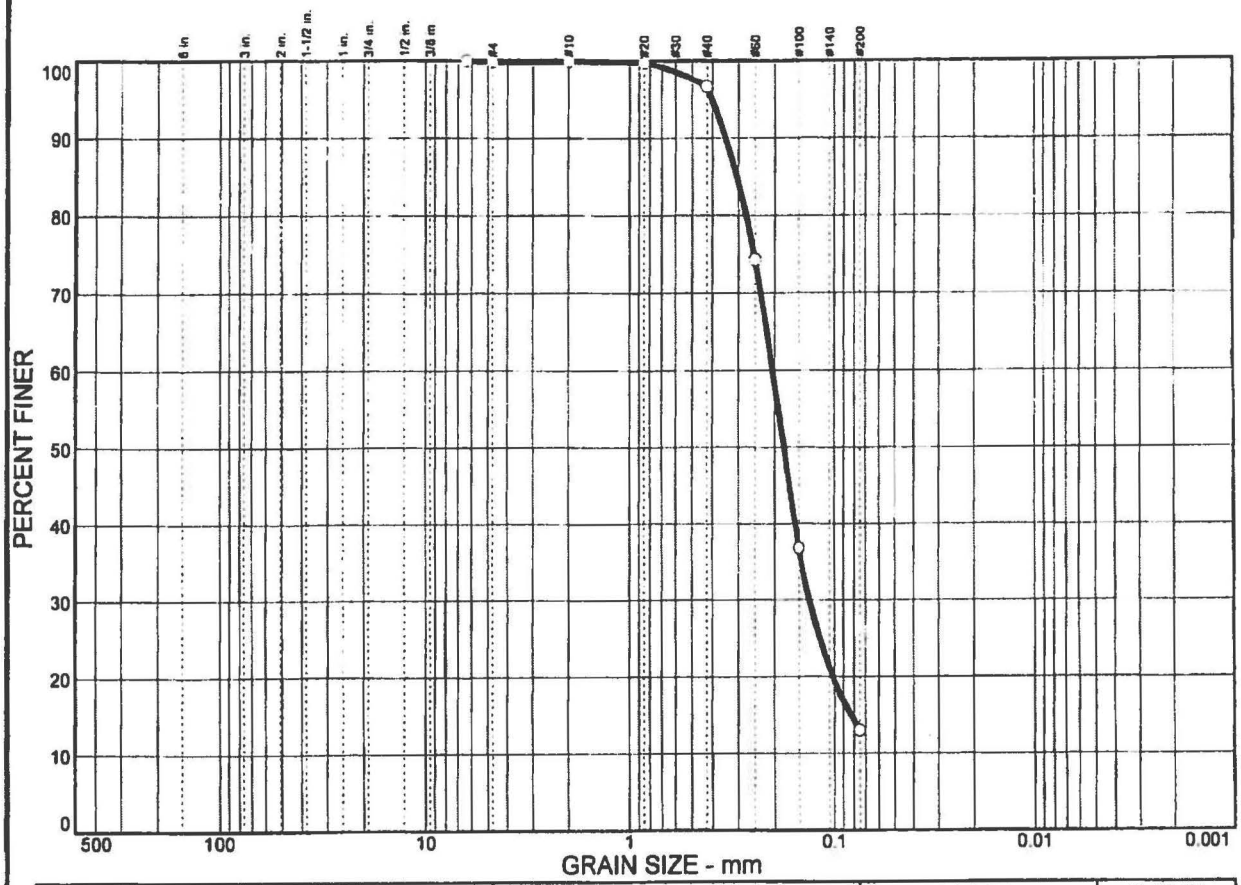
VISUAL CLASSIFICATION PROCEDURES

Visual soil classifications were conducted on all samples in the field and on selected samples in our laboratory. All soils were classified in general accordance with the United Soil Classification System, which includes color, relative moisture content, primary soil type (based on grain size), and any accessory soil types. The resulting soil classifications are presented on the exploration logs contained in Appendix A.

GRAIN SIZE ANALYSIS PROCEDURES

A grain size analysis indicates the range of soil particle diameters included in a particular sample. Grain size analyses were performed on representative samples in general accordance with ASTM:D-422. The results of these tests are presented on the enclosed grain-size distribution graphs and were used in soil classifications shown on the exploration logs contained in Appendix A.

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.1	86.9	13.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/4 in.	100.0		
#4	99.9		
#10	99.9		
#20	99.8		
#40	96.7		
#60	74.3		
#100	36.8		
#200	13.0		

* (no specification provided)

Soil Description

Brown silty Sand
Moisture 18.9%

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.306 D_{60}= 0.205 D_{50}= 0.181
D_{30}= 0.133 D_{15}= 0.0827 D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Sample ID:8839
ASTM:C136-01,D1140-00,D2216-98
Tested by:JW Reviewed by:SS

Sample No.: 8839 **Source of Sample:** **Date:** 2/12/08
Location: B-2 S-1 & 2 **Elev./Depth:** 2'5"-6'5"

amec

Client: Corollo Engineers
Project: Lacey Corrosion facility

Project No: 8917163210 **Plate**