

Appendix B

Geotechnical Report

Geotechnical and Civil Engineering Services

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REPORT

GEOTECHNICAL AND CIVIL ENGINEERING SERVICES

WILEY SLOUGH TIDAL RESTORATION PROJECT

SKAGIT COUNTY, WASHINGTON

FOR

SKAGIT RIVER SYSTEMS COOPERATIVE

INTRODUCTION AND SCOPE

This report presents the results of our design geotechnical engineering services related to restoring tidal influence to approximately 175 acres in the Freshwater and Wiley Slough areas of Skagit County, Washington. The location of the site is shown in the Vicinity Map, Figure 1.

We understand that the Skagit River Systems Cooperative (SRSC) is working cooperatively with Washington Department of Fish & Wildlife (WDFW) regarding specific dike breaching, new dike construction and slough channel alterations that will reconnect Freshwater Slough with Wiley Slough. It is proposed that the material from the dike removal and channel excavations be used for the new dike construction. The locations of the existing dikes and proposed new dike are shown in the Site Plan, Figure 2. The existing “exterior” dike in Figure 2 will be breached and a new east-west dike constructed from the west end of the exterior dike shown to Wiley Slough. A new slough crossing with tide gates will be required at the east end of the new dike.

The purpose of our geotechnical engineering services was to explore subsurface soil and groundwater conditions at the site as a basis for providing geotechnical engineering recommendations and design criteria for the propose construction of a new dike and tide gate. Our scope of services included completing three geotechnical borings along the proposed alignment for the new dike, completing a series of test pits along the existing dike to evaluate the material for use in the new dike, performing laboratory tests on the samples obtained from the borings and test pits, subcontract civil engineering and surveying support for the project and the design of tide gates, and providing geotechnical conclusions and recommendations for design and construction of the dike and tide gates. Our specific scope of services is described in our proposal for the project dated February 5, 2004. As discussed below, only limited exploration of the existing dikes could be accomplished. The civil component of the project design was subcontracted to Leonard, Boudinot & Skodje, Inc. (LBS).

SITE CONDITIONS

SURFACE CONDITIONS

The site is located on Fir Island, in Skagit County, Washington, which is essentially the delta at the mouth of the Skagit River. The only topographic relief is due to man made dikes and ditches which criss-cross the area. The dikes in the area have a crest elevation that varies from approximately 7 to nearly 11 feet

(NGVD 29 Datum). The exterior dikes (those dikes bordering the Freshwater Slough and tidal marsh land) all have a crest elevation of at least 9 feet. Vegetation in the area consists of grasses and small deciduous trees. Some areas have been used for agricultural purposes and therefore the vegetation is minimal in those locations. The proposed new dike location is located on the margin of private land and heavily vegetated with brush and small trees. Surface water was observed in ditches and sloughs throughout the site. The site conditions near the slough crossing at the east end of the proposed alignment are shown in the Site Plan prepared by LBS which is included as Sheet C-1 in this report.

GEOLOGY

We reviewed a U.S. Geologic (USGS) map for the project area, "Surficial Geologic Map of the Port Townsend 30- by 60-Minute Quadrangle, Puget Sound Region, Washington" by Pessl, Dethier, Booth, and Minard (1989). Soil deposits in the site area are mapped as Holocene alluvium sands, modified land (dikes), or marsh deposits. The Holocene alluvium sands were placed by the Skagit River since the last period of glaciation. The alluvium material is quite thick and can vary significantly from coarse sands to silt and clay. The marsh deposits consist of silt, sand, or clay with variable amounts of decaying organic matter. The marsh deposits are typically identified west of the dikes.

SUBSURFACE EXPLORATIONS

Subsurface soil and groundwater conditions were evaluated by completing three geotechnical borings along the proposed alignment of the new dike and three test pits within the existing dikes. We had originally identified eight test pit locations in the existing dike, however we were prohibited from completing the explorations by WDFW. The borings were completed on March 9, 2004 to a depth of 31.5 feet below the existing ground surface (bgs). A track mounted M-55 drill rig, subcontracted to GeoEngineers, Inc. was used to complete the borings. The test pits were completed on March 8, 2004 to depths ranging from 6.5 to 8.5 feet bgs using a track mounted Kobelco 120 Excavator subcontracted to GeoEngineers, Inc. The approximate locations of the explorations are shown in Figure 2. Details of the field exploration program, laboratory testing, and the exploration logs are presented in Appendix A.

SUBSURFACE CONDITIONS

Soil Conditions – Proposed Dike Alignment

The subsurface conditions were fairly consistent in each of the three boring completed along the proposed dike alignment. The surficial soils consisted of a sod zone approximately 1 to 1.5 feet thick. A soft layer of gray silt with occasional organic matter was encountered underlying the sod. The soft silt was 3 to 6 feet thick transitioning to a thin layer of silty sand. Loose sand with a varying fines content (that portion passing the No. 200 U.S. sieve based on weight) was encountered underlying the silty sand and extended to the full depth explored. The fines content of the sand was typically less than 6 percent.

Soil Conditions – Existing Dike

The material encountered in our explorations performed in the existing dikes consisted primarily of relatively "clean" (low fines content) sand likely obtained from the project vicinity during the original construction of the dike. A surficial layer of crushed rock was encountered to provide trafficability to maintenance vehicles. The crushed rock was 6 to 18 inches thick. Underlying the crushed rock, silty sand with 20 to 30 percent fines was encountered in test pits TP-1 and TP-2 to a depth of 2.5 and 5 feet below the top of dike elevation, respectively. Cleaner sand with 6 percent fines or less was encountered underlying the silty sand in test pits TP-1 and TP-2 and underlying the crushed rock in test pit TP-3. The

sand extended to a depth ranging from 5.5 to 7.5 feet below the top of dike. Medium stiff silt was encountered underlying the sand in all of the test pits and extended to the full depth explored.

Groundwater Conditions

Groundwater was encountered in each of the geotechnical borings completed along the proposed dike alignment. The groundwater was encountered underlying the upper layer of soft silt, approximately 5 to 7.5 feet bgs. However, our explorations were not left open long enough to allow the groundwater to stabilize nor were monitoring wells installed to monitor groundwater levels. It is our opinion that the groundwater encountered in our borings represents the regional groundwater elevation. Groundwater should be expected to fluctuate as a function of season, precipitation, water level in the slough, and other factors.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

The design and construction for the new dike and slough crossing are provided in the following sections of this report. The general dike design and construction discussion is presented first followed by specific discussion relevant to the Wiley Slough crossing with the tide gates.

The existing dike embankment material we observed in the test pits is not suitable for use in the proposed dikes. Additional explorations are recommended in other portions of the breached dikes. Similar to many areas of Skagit County, a deep cutoff barrier to prevent seepage under the new dike is not economically feasible. Our design includes the installation of a shallow cutoff trench down to the groundwater elevation during summer construction to reduce seepage potential. A deep cutoff barrier is included for the slough crossing where diurnal inundation occurs.

A summary of the primary design and construction considerations for the proposed project are provided below. The summary is presented for introductory purposes only and should be used in conjunction with the complete recommendations presented in this report.

- The dike is designed with a maximum slope of 2.5H:1V (horizontal:vertical) on both sides.
- Because of the variable thickness of the soft silt layers, we estimate that 5 to 10 inches of vertical settlement will occur as a result of placement of the dike material. The settlement will likely occur while the material is being placed and we expect that 90 percent of the settlement will occur within one week after dike completion.
- Based on the subsurface conditions encountered, seepage through and beneath the dike, including piping, is unlikely provided that the dike and cutoff trench are properly constructed.
- Stripping depths for subgrade preparation are in the range of 18 inches for the new dike. This should include clearing and grubbing of brush and small trees.
- For ease of construction and cost-containment, we have designed the dike to be constructed as a homogenous embankment.
- The crossing of the slough will require additional construction considerations including dewatering, subgrade stabilization and pipe installation.

DIKE DESIGN

General

The proposed dike alignment is a true east-west line as shown in Figure 2 except at the proposed location of the tide gates on Wiley Slough. At the slough crossing, the dike will bend to the south approximately 45 degrees in order to cross perpendicular to the slough and minimize the amount of earthwork that would be required. We were provided with a design crest elevation of approximately 9.5 feet (NGVD 29 Datum) to be consistent with exterior dikes in the site vicinity. This elevation matches the crest elevation of the existing exterior dikes, however the interior dike elevation at the location of the proposed tide gates is at approximately Elevation 7 feet. Therefore additional earthwork will also be required on the interior dikes to raise the crest elevation to a similar elevation as the exterior dikes. The other design requirement is a crest width of 20 feet wide to support a service road. The designs for the dike and slough crossing are shown in the plans prepared by LBS and included as Sheet C-2 in this report.

Slope Stability

The dike should be constructed with slopes of 2.5H:1V (horizontal:vertical) on both sides of the dike due to the possibility of water being present on either side of the dike. We have assumed that a saturation level near about Elevation 5 feet could occur. Our analysis indicate that the factors of safety against slope failure in static, dynamic, steady-state and rapid drawdown conditions are in accordance with the "Dam Safety Guidelines" produced by the Washington State Department of Ecology dated July 1993.

Settlement

Placement of the embankment material will result in consolidation of the underlying silt soils and elastic compression of the loose sandy soils. We estimate settlement along the proposed dike alignment may be on the order of 5 to 10 inches, depending on the silt properties, thickness and sequence as well as the height of embankment material needed along the alignment.

Based on our analysis of our laboratory data, we estimate the time required for 90 percent of the settlement to occur to be on the order of two to three weeks. However, it is likely that the majority of the settlement will occur during placement of the embankment material. We recommend that settlement be monitored for a short time period after construction to ensure that the crest elevation is in accordance with the design. Our recommendations for the monitoring program are provided later in the report.

Additional settlement may occur within the embankment material considering the type of soil material and the difficulty in maintaining proper moisture contents. Settlement of the embankment material is difficult to quantify due to the variability in moisture content and compaction techniques. As previously mentioned, we expect up to ½ inch of settlement may occur. This would result in a crest width less than the 20-foot design width. Some extra embankment material can be used as necessary to create a slope no steeper than 2H:1V for the upper few feet of the dike to achieve the 20 foot crest width. We recommend that this procedure be approved by GeoEngineers during construction.

Seepage

Failure due to seepage can occur through two mechanisms: seepage through the embankment and seepage through the foundation soils. Due to the low permeability of the recommended dike material and the assumed short duration of high water against the embankment (diurnal tide and flood conditions only), it is our opinion that seepage through berm material is unlikely.

The foundation materials underlying the proposed dike consist of soft silt with organic matter overlying sand with silt. It is our opinion that the layer of soft silt will serve as an adequate barrier against seepage beneath the dike from a stability standpoint, providing that there is continuity between the cutoff trench and the main portion of the dike. The material placed and compacted for the cutoff trench is an additional protection against seepage and piping, although it will not serve as a complete barrier because sand extends to a greater depth than economically feasible to cutoff. The cutoff material placed in accordance with the compaction recommendations provided in this report will have a permeability significantly lower than that of the layer of soft silt.

Seismic Design

The site is located within the Puget Sound region, which is seismically active. Hundreds of earthquakes have been recorded in the Puget Sound area. Seismicity in this region is attributed primarily to the interaction between the Pacific, Juan de Fuca and North American plates. From the interaction of these plates and their resulting tectonic stresses, seismologists have identified three different earthquake sources in the region: (1) subduction zone earthquakes, (2) deep focus earthquakes, and (3) shallow, crustal earthquakes.

The dike embankment itself will be seismically stable during a design earthquake. However, the foundation soils under the proposed alignment, as well as the soils underlying the majority of the dikes in Skagit County, are highly susceptible to liquefaction during a seismic event. Liquefaction refers to a condition where vibration or shaking of the ground, usually from earthquake forces, results in development of excess pore pressures in saturated soils and subsequent loss of strength in the deposit of soil so affected. In general, soils susceptible to liquefaction include loose to medium dense "clean" to silty sands below the water table.

We did not perform a detailed liquefaction analysis for the soils along the proposed alignment because the liquefiable condition is so pervasive throughout the Skagit Valley. The site is underlain by sands with a high liquefaction potential. Liquefaction-related phenomena include settlement, flow failure, and lateral spreading. Flow failure can occur in soil that is underlain by a liquefiable layer and has a free face, such as near the edge of a fill or embankment. Lateral spreading can occur on gently sloping or level ground and will also move towards a free face such as a river bank or shoreline. Level ground may oscillate during seismic shaking and may result in large, chaotic movement and excessive vertical settlement and sand boils. The liquefaction hazards applicable to the proposed dike alignment include both lateral spread towards the slough and sudden, vertical settlement, which are typical of most dikes in the Skagit Valley.

DIKE CONSTRUCTION

Foundation Preparation

The vegetation, topsoil and surficial soils with high organic content should be removed from the footprint of the new dike and disposed off-site. At our boring locations, the thickness of the topsoil ranged from 12 to 18 inches. For planning purposes, we suggest assuming an average 18-inch stripping depth. The majority of the dike alignment will require the removal of shrub trees and brush. Roots should be grubbed to a diameter less than 1-inch.

Much of the upper site soils contain high fines (silt) content such that repeated construction traffic will result in considerable disturbance during wet weather construction. The embankment material will also have a high fines content. We recommend construction be completed during the dry summer months to reduce earthwork costs.

The dike footprint should be thoroughly rolled and compacted to seal seepage paths created during the stripping process. The foundation subgrade should be evaluated by thoroughly proofrolling with heavily loaded rubber-tired construction equipment if compaction efforts will not identify unsuitable areas. If soft or otherwise unsuitable areas are revealed during proofrolling or compaction, the soils should be excavated to firm soil and replaced with compacted structural fill, or as otherwise directed by the soils engineer. The subgrade suitability should be completed by a representative from our firm to identify areas of remedial action.

Cutoff Trench Excavation

We anticipate that the cutoff trench will be constructed as an open trench excavated as a single bucket width. The trench should have a minimum width of 3 feet, and a depth necessary to encounter groundwater (likely about 6 feet). Backfilling of the trench should occur as soon as time and space allow because of potential caving. Therefore, the cutoff trench will need to be completed in sections. All excavations and other construction activities must be completed in accordance with applicable county, state and federal safety standards. The on-site soils can be excavated using conventional earthmoving equipment. Regardless of the soil type encountered in the excavation either shoring, trench boxes or sloped sidewalls will be required for excavations deeper than 4 feet in which personnel will work under Washington Industrial Safety and Health Act (WISHA) under Washington State Administrative Code (WAC) 296-155, Part N. For planning purposes only, the native silty sand and sandy silt can be considered a “Type C” soil. The WISHA temporary slopes for these conditions are 1.5H:1V. We expect that the trench excavations will be made as unshored, open cuts because it is not necessary to have personnel working within the trench and the trenches will be open for only a short time. We suggest compaction be applied with a backhoe-mounted hoe pack or a sheepsfoot roller attached to an excavator arm such that personnel access is not required.

The stability of open-cut slopes is a function of soil type, groundwater level, slope inclination and nearby surface loads. The use of inadequately designed open cuts could impact the stability of adjacent areas, nearby structures and existing utilities, and endanger personnel. In our opinion, the contractor will be in the best position to observe subsurface conditions continuously throughout the construction process and to respond to variable soil and groundwater conditions. Therefore, we recommend that the contractor have the primary responsibility for deciding whether or not to use an open-cut slope rather than some form of temporary excavation support. No caving was observed in the test pits above the groundwater elevation during our explorations, however the test pits were not left open for more than 30 minutes.

The above guidelines assume that surface loads such as construction equipment and storage loads will be kept a sufficient distance away from the top of the cut so that the stability of the excavation is not affected. As previously recommended, the cutoff trench should not extend below the groundwater elevation. It should be expected that unsupported cut slopes will experience some sloughing and raveling if exposed to surface water. Dikes, hay bales or other provisions should be installed along the top of the excavation to intercept surface runoff to reduce the potential for sloughing and erosion of cut slopes during inclement weather.

Dike and Cutoff Trench Material

General. The dike and cutoff trench should be constructed as a homogenous embankment. The material used to construct the dike and the cutoff trench should meet the following specifications:

Sieve Size	Percent Passing
2" square	100

U.S. No. 40 Sieve	70 (minimum)
U.S. No. 200 Sieve	30 (minimum)

Glacial till or glacial marine deposits found in the Mt. Vernon area will typically meet the specification for this material and these soils have a higher erosion resistance than the native alluvial soils. The till is not typically available for sale at local borrow pits although it is removed as an overburden product.

Additionally many construction sites excavate the till and waste it. Identifying potential sources may depend on the construction season at the time of the dike construction. A sample of the proposed dike material should be submitted to GeoEngineers for laboratory testing and approval prior to earthwork.

Existing Dike to be Removed. The test pits excavated in the existing dike did not encounter soils that would meet the specification for dike and cutoff trench material. However, we were not able to explore a large percentage of the existing dikes that may be used as borrow sources. It is our experience that the dikes in Skagit County consist of layers of varying materials and thus it requires close monitoring and laboratory testing to confirm suitability. It is likely that some separation of unsuitable and suitable material will be necessary during construction. We recommend that additional explorations be completed in the dikes that will be abandoned during construction to identify possible on-site borrow sources.

Placement and Compaction

The embankment fill should be placed in horizontal lifts and uniformly compacted. The embankment material should be compacted to at least 90 percent of the maximum dry density in accordance with ASTM D-1557, but not greater than about 92 percent so that the embankment is not brittle considering the settlement that will occur. We recommend that a representative from our firm monitor the fill placement and perform in-place density tests to verify that adequate compaction is being achieved.

Compaction may be achieved with either a large vibratory smooth drum roller or a sheepsfoot roller. We suggest that cutoff trench compaction be accomplished with a sheepsfoot roller attached to an excavator. A hoepack could be used; however, vibratory compaction in the trench will likely result in sloughing or caving of the sidewalls. A sheepsfoot roller is typically used for compaction of fine-grained material because of the kneading action provided along with the pressure. The appropriate lift thickness will depend on the material and the compaction equipment being used. Loose lift thicknesses of 6 to 8 inches are typical when using a smooth drum roller and when using a sheepsfoot roller, the lift thickness should not exceed the length of the projections on the roller. Smooth drum rollers will be appropriate for finish grading and to seal the site prior to inclement weather.

The embankment material will contain a high content of fine grained material. As such, the material is sensitive to relatively small changes in moisture content and adequate compaction becomes more difficult or impossible to achieve as the moisture content increases. Therefore we recommend that the dike be constructed during periods of dry weather.

Erosion Protection

South Slope. The south slope of the dike will be protected against wave action by the portions of the exterior dikes that will remain in place. Therefore shear forces along the dike will be limited to those generated by flow parallel to the dike during flood stage. Based on hydraulic modeling provided by HDR, we understand that the maximum velocity along the face of the dike will be on the order of 1.6 feet per second. The south slope of the dike should be protected against erosion with a vegetative cover applied as hydroseed at the end of the project. If the vegetation will not have sufficient time to develop

prior to the flood season, a temporary erosion control blanket could be placed along the slope based on the appropriate design parameters. We recommend that the erosion control blanket consist of coconut fibers and provide a minimum of 3 years of protection.

North Slope. We understand that the north slope will typically not be suspect to shear forces from water flow or wave action. The only time that the north slope would be exposed to water would be if Fir Island were to flood. Therefore the north slope of the new dike should be protected against erosion using a grass vegetative cover, installed as hydroseed upon completion of the project. Temporary erosion control blankets could be used if the vegetation will not have sufficient time to develop prior to the flood season.

Crest/Roadway. It is our understanding that crest of the dike will serve as a service road. The compaction recommendations previously provided for the embankment material should be adequate for subbase material. We suggest that a woven geotextile be placed directly over the embankment material prior to the placement of the gravel trail section. The geotextile should consist of a woven fabric with a minimum grab tensile strength (ASTM 4632) of 200 pounds (i.e. Mirafi 500X, Amoco 2002 or Layfield LP 200). The gravel road section should be in accordance with dike district or local jurisdictional standards. We suggest 4 inches of crushed surfacing top course per the Washington State Department of Transportation (WSDOT) *Standard Specification 9-03.9(3)*.

SLOUGH CROSSING AND TIDE GATES

General

The portion of the new dike that crosses Wiley Slough and connects to the existing dike requires additional construction and design considerations due to different foundation conditions and the presence of five 60-inch diameter tide gates passing through the dike. The general geometry, material, and compaction requirements for the dike previously provided have remain unchanged in that portion that crosses the slough. Additional design and construction considerations specific to the section of the dike that crosses the slough are provided below.

Dewatering

The construction of the slough crossing must be done in the dry. The ordinary high water elevation in the slough is slightly below Elevation 1 foot and the base of the slough is at approximately Elevation -5 feet. Groundwater was encountered in the boring closest to the slough at approximately Elevation -4 feet. We recommend that the contractor be prepared to dewater the site to approximately Elevation -8 feet during construction to allow for construction of a base-stabilization pad.

Due to the depth of dewatering required, we anticipate that temporary sheet pile walls placed across the slough outside of the construction area will be required. In order to dewater the site to an elevation of -8 feet, we anticipate that dewatering wells will be required. Sufficient number of wells and pumps should be installed to dewater the dike construction area during the entire time that the dike is under construction. The wells should have a properly designed sand pack to prevent migration of fines and fine sand from the formation. In addition, sumps and pumps may be required to help control additional localized seepage. It may be possible to complete the construction in a staged manner only using localized sumps and pumps if groundwater is low enough. However, if “clean” sand is encountered, it will readily flow in a saturated condition such that this procedure may not provide a stable work environment.

Excavation and Slopes

The geometry of the dike and the installation of the pipes at an invert elevation of -1 foot will require excavation of the existing ground profile. The majority of the excavation will be backfilled as part of the construction of the dike. Therefore temporary slopes in accordance with recommendations below are applicable at those locations. However permanent slopes will be required on the west bank south of the dike and on the east bank north of the dike as shown in Sheet C-1. All temporary cut slopes must comply with WISHA regulations as previously discussed. The contractor performing the work has the primary responsibility for protection of workmen and adjacent improvements. Because the soils at the project site will likely consist of "clean" sand, all excavations extending below groundwater depth must be fully dewatered as discussed previously.

Temporary Cut Slopes. The soils encountered at the site are classified as Type C soil. Temporary unsupported cut slopes should be inclined no steeper than 1.5H:1V, unless they are cohesive to stand such as Type B soil. This applies to fully dewatered conditions. Flatter slopes may be necessary if seepage is present on the cut face. Temporary cut slopes should encroach no closer than 10 feet laterally from roadways, pavements, structures or other improvements.

If temporary cut slopes experience excessive sloughing or raveling during construction, it may become necessary to modify the cut slopes to maintain safe working conditions and protect adjacent facilities or structures. Slopes experiencing excessive sloughing or raveling can be flattened, regraded to add intermediate slope benches, or additional dewatering can be provided if the poor slope performance is related to groundwater seepage.

Permanent Cut Slopes. The cut slopes at the slough crossing that will not be backfilled as part of the dike construction should be cut no steeper than 2.5H:1V, similar to that for the dike. The exposed surface should be protected against erosion using light-loose rip rap as discussed below.

Seepage

The silt unit that underlies the majority of the dike alignment is not anticipated to be encountered at the base of the slough and the construction of a cutoff trench is not feasible due to the water conditions. Therefore our design includes a permanent sheet pile wall beneath the centerline of the dike to control seepage. The piles should consist of straight sheets that are able to resist corrosion from contact with salt water. The piles should extend 85 feet to the west from the top of slope on the east side of the slough as shown in Sheet C-2. The sheet piles should be driven to a tip elevation of -30 feet. Below the pipes the top of the sheet pile should be approximately 1 foot below the invert elevation of the pipes, Elevation -5 feet, and extend up into the dike material. This top of pile elevation should extend 4 feet east and west of the centerlines of the easternmost and westernmost pipes. Beyond the pipe area, the contractor may cut off the top of the sheet pile near the existing ground surface. We recommend that the permanent sheet pile wall be installed prior to the construction of the ground stabilization pad as described below. The dike will settle over the top of the sheet piles during construction.

Subgrade Stabilization

We did not explore the base of the slough during the exploration program. We anticipate that the soils across the bottom of the slough will consist of soft and saturated sediment. This material will not support construction traffic, nor will it provide an adequate surface for compaction of the dike material. Our design includes removing 2-feet of the soft sediment across the base of the slough and replacement with a 2-foot thick blanket of 2- to 4-inch quarry spalls. The overexcavation of the slough material should extend up the side slopes far enough that firm soils are encountered. The top of the quarry spalls should

always remain at least 1 foot below the top of the sheet piles. We recommend that we observe the base excavation during construction to observe the conditions encountered and confirm that this design will provide adequate base support for the dike.

The quarry spall pad is totally wrapped by a geotextile and partially wrapped by an impermeable liner (geomembrane) as shown in sheet C-2. The geomembrane is to prevent water seepage into the quarry spalls layer which could lead to softening of the lower portion of the dike. The geotextile is recommended for two reasons: 1) to limit penetration of the quarry spalls into the underlying subgrade soils and 2) prevent the migration of fines from the overlying dike into the voids in the quarry spalls. The fabric should be placed with a minimum overlap of 18 inches. Because the dike will likely settle overtime, the fabric should not be placed over the permanent sheet pile wall. Instead the geotextile and geomembrane (both underlying and overlying the quarry spalls) should be placed such that a minimum of at least 18 inches of material is placed vertically adjacent to the sheet piles.

The geotextile should consist of a woven fabric suitable for soil stabilization (WSDOT *Standard Specification* 9-33.2, Table 3) with a grab tensile strength (ASTM D 4632) of 315 pounds (e.g., Amoco 2016 or Mirafi 600X). The geomembrane should consist of a 40-mil EDPM (ethylene propylene diene member) because of its elasticity properties. This product is generally available in 50x50foot rolls and can be field seamed or can be special ordered as one piece and delivered to the site. Specialty contractors can put the two materials together and deliver them to the site.

Tide Gates and Pipes

Five 60-inch diameter Hancor Sure-Lok F477 pipes will be used for the tide gates. These pipes consist of corrugated high density polyethylene (HDPE) placed at 9 foot centers. The installation of these pipes into the dike require additional design and construction considerations.

Buoyancy Forces. During high tide and low flow in the slough, the buoyancy forces on the pipe will be significant. Therefore, the south ends of the pipes are anchored using a concrete collar that fits around each pipe. The specific design for the headwall is shown in Sheet C-1.

Compaction. Poor compaction of structural fill around pipes passing through dikes has resulted in piping failure. Therefore, it is critical that compaction of the backfill around the pipe and particularly beneath the haunches of the pipe be done correctly. We recommend that the compaction of fill around the pipes be monitored on a full time basis by a member of our firm.

The spacing of the pipes will provide approximately 2.5 feet between each pipe. Compaction will need to be completed by smaller compactive equipment such as a jumping jack. As a result lift thicknesses will need to be thinner (on the order of 4 inches) to achieve adequate compaction.

Bedding. Bedding materials are included to place the pipes. However, the bedding material is not included within 5 feet of the face of the dike to prevent seepage.

We have included a composite anti-seep collar consisting of two galvanized corrugated metal collars and concrete around each pipe. The two collars will be located 8 and 10 feet downstream (south) of the centerline of the dike as shown in Sheet C-2. The space between the collars should be backfilled with concrete with a compressive strength of at least 3,000 pounds per square inch (psi). The collars should have an outside diameter of at least 10.5 feet and the overlap with the collars on adjacent pipes should be staggered. All of the collars must be in place on all of the pipes prior to placement of the concrete. If an

excavation is completed beneath the pipes for installation of the seepage collars, than the entire excavation must be filled with concrete not just the space between the collars.

Settlement. We expect that the material underlying the dike will consist of loose alluvial deposits or additional soft sediments. These soils will experience settlement due to the weight of the fill embankment. The settlement will occur rapidly as the material is placed, however settlement will result in a sag in the middle of the pipes placed during construction of the dike. This is because the center of the dike will experience more settlement than the edges of the pipe. For this reason, the pipes should be installed with a reverse crown of 4 inches at the proposed centerline of the dike to account for the potential settlement of the dike.

Erosion Protection

Both sides of the dike in the slough channel and the permanent cut slopes should be protected against erosion using 12 inch thick blanket consisting of light-loose rip-rap. The light loose riprap should meet the specifications of Sections 8-15 and 9-13.1(2) of the WSDOT *Standard Specifications*.

MONITORING

Settlement

As mentioned previously, to ensure that the dike crest is at the design elevation, we recommend that a monitoring program be established to accurately measure the settlement. We recommend that surface markers be installed at 200 foot centers along the crest after initial construction is complete. A reference datum must be placed near the fill, but far enough away to not be affected by the settlement. A survey crew should measure the settlement from the markers 1 or 2 times a week. We expect that the settlement will be mostly completed by two to three weeks after initial dike completion. The survey results should be forwarded to us and the results can be plotted against the anticipated settlements.

Depending upon how quickly the contractor constructs the dike, the contractor should be prepared to place an additional 6 to 12 inches of fill material after achieving the initial design elevation. Settlement plates could be installed at the existing grade (similar to standard practice for commercial building preload fills) to monitor settlement as it occurs. This would allow a relatively accurate estimate of the time rate so that we could estimate the 90 percent completion date in advance. However, the rods stickup through the embankment and hinder grading operations such that we expect that this would not be desirable from an efficiency standpoint.

Construction Monitoring Services

We recommend that sufficient construction monitoring services be performed during construction to confirm that the earthwork is being completed in accordance with the intent of our geotechnical recommendations and the project plans and specifications. If the existing dike that will be removed will be used as a fill source, we recommend that representative from our firm observe and evaluate the material as it is excavated for suitability within the new dike. We recommend that a representative from our firm be involved with the following tasks;

- Observation and evaluation of the existing berm material for use in the proposed dike. This includes field testing the soils to determine the silt content. Moisture content determinations could also be taken to facilitate contractor decisions regarding suitability, possible aeration, or other considerations.
- Observation of the dike subgrade soil conditions after stripping and grubbing.

- Observation of the base stabilization in the slough crossing after dewatering has occurred.
- Observe excavation of cutoff trench and monitor placement and compaction of backfill material. No compaction testing will be performed at depths greater than 3 feet for safety reasons. Compaction adequacy will be based on performance observations.
- Monitor and test fill placement during construction of the dike. We work with the earthwork contractor to establish lift thickness and compaction procedures necessary to achieve the recommended compaction criteria while maximizing the rate of fill placement as much as practical.

The construction monitoring will be completed by one or more of our staff engineers or engineering geologists under the direct supervision of our project manager. We may subcontract the compaction testing portion of the monitoring to a testing laboratory with which we have an on-call contractual relationship for such services. We will submit daily field reports to your representative documenting and summarizing our observations for that day. Deviations from specifications, plans and design recommendations will be included in the daily report. Our project manager will review each field report. Any revision deemed appropriate will be made and copies of the revised report will be sent to your representative. At the end of the project, we will summarize our observations, findings and revised recommendations to you in a final report.

LIMITATIONS

We have prepared this report for the exclusive use of the Skagit River System Cooperative and their authorized agents for the proposed Wiley Slough Tidal Restoration Project in Skagit County, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Please refer to the appendix titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

APPENDIX 1
FIELD METHODS

APPENDIX 1 FIELD METHODS

FIELD EXPLORATIONS

Subsurface conditions at the site were explored by completing three borings and three test pits on March 8 and 9, 2004. The borings were completed using a track mounted M-55 drill rig and the test pits were completed using a rubber tire backhoe both subcontracted to GeoEngineers, Inc. The approximate locations of the explorations are shown in the Site Plan, Figure 2. The locations of the explorations were determined by pacing and taping from existing features; therefore, the locations shown in Figure 2 should be considered approximate.

The explorations were continuously monitored by an engineering geologist from our firm who examined and classified the soils encountered, obtained representative soil samples, observed groundwater conditions and prepared a detailed log of each exploration. Soils encountered were classified visually in general accordance with ASTM D-2488-90, which is described in Figure A-1. An explanation of our exploration log symbols is also shown in Figure A-1.

The logs of the borings and test pits are presented in Figures A-2 through A-7 in Appendix A. The exploration logs are based on our interpretation of the field and laboratory data and indicate the various types of soils encountered. It also indicates the depths at which these soils or their characteristics change, although the change might actually be gradual. If the change occurred between samples in the boring, it was interpreted.

LABORATORY TEST RESULTS

Representative laboratory testing was completed on selected samples from the explorations. The testing consisted of moisture content tests and percent fines determinations analyses. The results of the laboratory testing are summarized on the boring logs.

APPENDIX 2
REPORT LIMITATIONS AND GUIDELINES FOR USE

APPENDIX 2 REPORT LIMITATIONS AND GUIDELINES FOR USE¹

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for the exclusive use of the Skagit River System Cooperative and their authorized agents. This report may be made available to other members of the design team. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared.. This report should not be applied for any purpose or project except the one originally contemplated.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the proposed Wiley Slough Tidal Restoration Project located in Skagit County, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;
- elevation, configuration, location, orientation or weight of the proposed structure;
- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

¹ Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

SUBSURFACE CONDITIONS CAN CHANGE

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

MOST GEOTECHNICAL AND GEOLOGIC FINDINGS ARE PROFESSIONAL OPINIONS

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

GEOTECHNICAL ENGINEERING REPORT RECOMMENDATIONS ARE NOT FINAL

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

DO NOT REDRAW THE EXPLORATION LOGS

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

GIVE CONTRACTORS A COMPLETE REPORT AND GUIDANCE

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

CONTRACTORS ARE RESPONSIBLE FOR SITE SAFETY ON THEIR OWN CONSTRUCTION PROJECTS

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

GEOTECHNICAL, GEOLOGIC AND ENVIRONMENTAL REPORTS SHOULD NOT BE INTERCHANGED

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

BIOLOGICAL POLLUTANTS

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of biological pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of biological pollutants and no conclusions or inferences should be drawn regarding biological pollutants, as they may relate to this project. The term "biological pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.