BANK FAILURE ASSESSMENT
16 Sea Watch Court, Florence, OR

March 18, 2011

Prepared for:
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Exhibit D

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EXECUTIVE SUMMARY

A catastrophic bank failure occurred on the east bank of the Siuslaw River below 16 Sea Watch Court in Florence on December 26, 2010. In an area approximately 80 feet wide (N-S) and up to 70 feet long (up- and down-slope) sand and imported fill slid downslope along several compound, headward progressive failure surfaces. Since that time, movement has occurred sporadically, resulting in further exposure of the lower portion of a sheet pile sea wall retaining the sand on which the western portion of the house is constructed. After a similar failure in 1997, a sheet-pile seawall had been constructed near the house and a rip rap revetment and two-tiered gabion-basket buttress had been placed at the toe of the bank. The gabion buttress had been pushed into the river by the recent movement along with a portion of the rip rap revetment. At the time of this writing, the exposure of the seawall is at or slightly beyond the maximum for which the sea wall is designed.

In this area, the east bank of the Siuslaw River is underlain in the shallow subsurface by recent dune sand, consisting of fine, poorly graded sand. Albeit stabilized at the surface by vegetation, the sand in these recent dunes is non-cohesive. The most recent dune sand overlies several generations of older dune deposits on which paleo-sol formed at the time they were located at the surface. The paleo-sol consist of dune sand which has been cemented by clay and iron hydroxide compounds derived from weathering of feldspar and ferro-magnesian minerals contained within the sand. These older dune deposits and paleo-sol are grouped together in a unit which is designated as Marine Terrace Deposits (MTDs).

Several mechanisms of erosion/slope movement contribute to the eastward recession of the bank. The MTDs exposed at and near the water level of the Siuslaw River are eroded by the current, wave action (exacerbated by the wakes of water craft) and water dripping and running over the steep edges. Erosion of the uncemented recent dune sand mostly occurs as a result of development of groundwater pore pressures near the base of the unit and resulting mobilization of the sand grains by flowing water or liquefaction of the sand by the pore pressure. The groundwater discharge occurs as a result of precipitation falling on a large area east of the bank, with the groundwater perched on the impermeable, cemented paleo-sol in the subsurface and running off westward following the buried topography. The removal of the sand at the base of the slope results in loss of lateral support at the toe, which, in turn results in sporadic catastrophic sliding movements of larger blocks of sand higher on the slope. Another mechanism of sand removal higher on the slope is the headward progression of minor scarps by flow of the sand during the drier summer months.

Due to the high risk to the house at 16 Sea Watch Court, it is recommended to mitigate the recent catastrophic bank failure as soon as possible. The proposed mitigation involves installation of a sand-retention system at the top of the cliff-forming MTD paleo-sol, reconstruction of the buttress using rip rap instead of gabions and re-construction of the rip rap revetment at the toe of the slope utilizing appropriate filter geotextile. As part of this work, it is proposed to remove additional gabion baskets present to the north of the currently active failure and those gabions currently in the river, which can be reached with the equipment.

INTRODUCTION AND SUMMARY OF SITE HISTORY

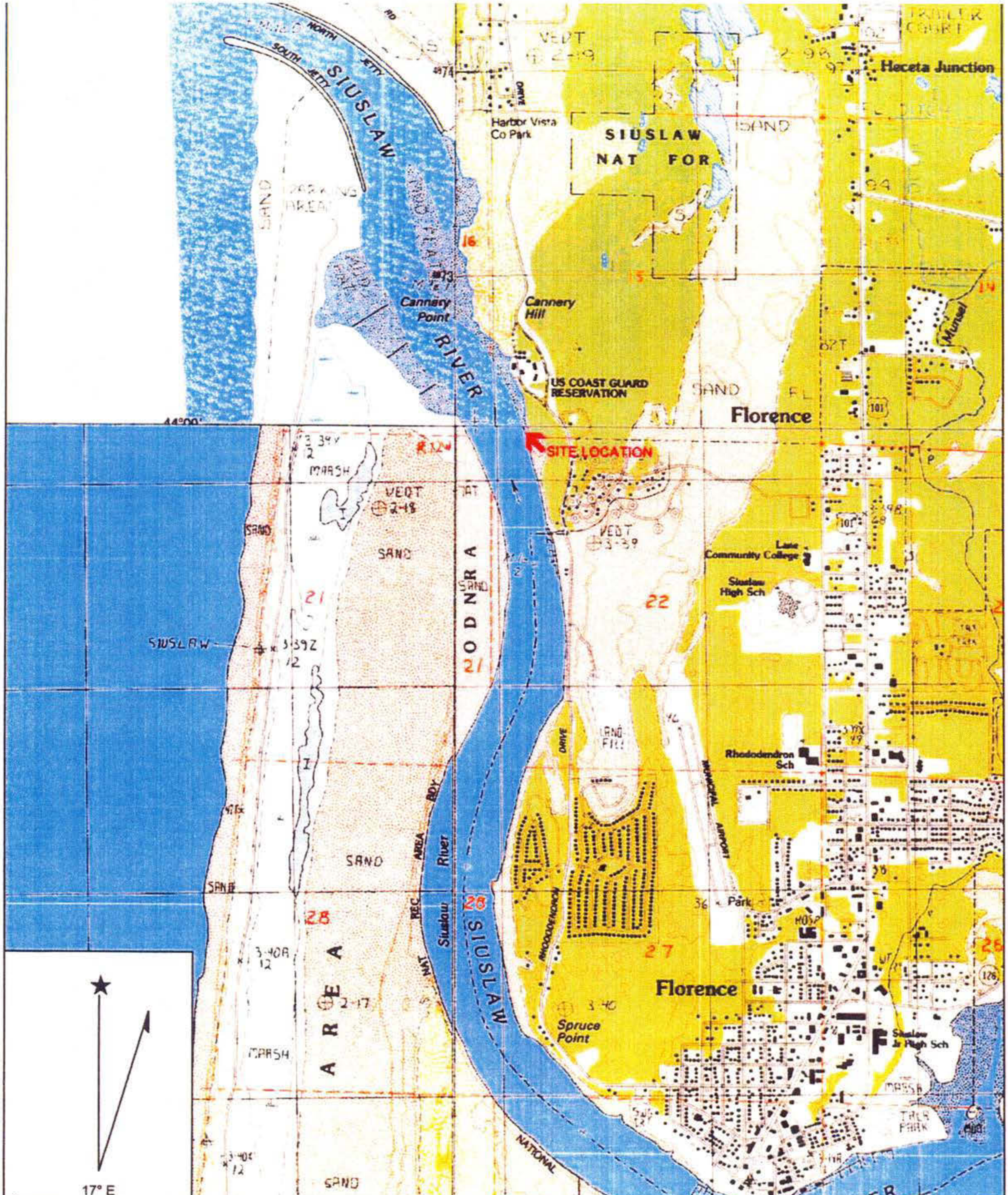
This report presents the findings of an assessment of the bank failure which occurred on December 26, 2010, below the residence at 16 Sea Watch Court in Florence (Figures 1 and 2), following significantprecipitation. The failure has continued to be active and has progressed head-ward since that time. The house, which was constructed in 1992, is the oldest structure in the Sea Watch Estates subdivision, which is located on the east bank of the SiuslawRiver immediately south of the Coast Guard Station. Failures have occurred at the site previously, in 1997 resulting in mitigation using a sheet pile seawall near the top of the slope and rip rap placement along the lower bank. When failures of the slope continued below and adjacent to the seawall, a two-tiered gabion basket system was installed above the rip-rap revetment to retainthe sand. The slope was then restored by importing sand containing organics ("root mat"). This assessment was conducted and the report prepared in its entirety by Dr. Gunnar Schlieder, an Oregon Certified Engineering Geologist.

GEOLOGY AND SOILS (Published Information)

Geologic History

The site is located on the east bank of the Siuslaw River, in an area indicated to be "Sand Dunes" on the geologic map accompanying USGS Water Supply Paper 1539-K *Ground Water in the Coastal Dune Area Near Florence, Oregon* (Hampton, E.R., 1963). The water resources paper indicates that the dune sand is located over a "planed-off" surface of underlying Tertiary *Tyee Formation* (sandstone). Cooper (1958) includes the area in the Coos Bay dune sheet, North Siuslaw Region. Lately, investigators (e.g. Beckstrand, 2001, Peterson, 2002) have described the area as part of the "Florence Dune Sheet". Whereas earlier researchers assumed that the dunes were formed in response to *Holocene* (younger than approx. 10,000 years BP) sea level rise, more recent thermoluminescence and radio-carbon dating has shown that portions of the dunes are up to 37,000 years old or older. Published thermoluminescence and radio-carbon dates (Beckstrand, 2001, Peterson, 2002) on dune deposits and vegetation covered by the Florence Dune Sheet just north of the subject area indicate ages ranging from 6,100 to 24,600 years BP.

Of importance in this context are eustatic (global) sea level fluctuations which are related to the amount of water stored in ice sheets during glacial periods in the *Pleistocene* (appr. 1.64 Million to 10,000 yrs BP). As water is stored on land as ice, sea level drops. The maximum reported drop in the last 80,000 years occurred around 18,000 years ago, at the time of the last glacial maximum. At that time, global sea level is thought to have been approximately 400 feet lower than today (Shackleton, 1986, 1987) and the mouth of the Siuslaw would have been located up to 25 miles farther westward than today. With the *late Pleistocene* and *Holocene* deglaciation, sea level has once again risen and this rise is continuing today. During the previous interglacial high stand, which occurred approximately 135,000 years before present (yBP), sea level was approximately 15 feet higher than today.



Name: MERCER LAKE
Date: 3/1/2011
Scale: 1 inch equals 2000 feet

Location: 043° 59' 32.4" N 124° 07' 19.1" W
Caption: Figure 1: Location Map

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Figure 2: Site Vicinity Map, Tax Lot Map, and 1997 Contour Map

Not to Scale. Base from Google Earth, Lane Co. Tax Map, and Ward Northwest.

Based on the age dates obtained in the vicinity in recent years, a significant portion of the dune sand at the site was likely deposited during the period from approximately 24,000 to 6,000 yBP, including the period of the last glacial maximum. At that time, sea level was around 400 feet lower than today and the mouth of the Siuslaw River would have been several miles to more than 20 miles west of its current location. It is probable that soil horizons formed at that time on several paleo-land surfaces which were subsequently buried by additional advancing dunes. This process of soil formation and subsequent burial was likely repeated several times during the period of deposition, resulting in the presence of several buried soil horizons within the dune sand deposits. The soil horizons are characterized by the presence of organics, buried tree stumps in growing position, and decomposition of some of the mineral grains contained in the sand. Partial or complete decomposition of some silicate minerals other than quartz (e.g. feldspars, pyroxenes, hornblende) has produced both clay minerals and iron-oxides which tend to cement the sand. These cemented sands and paleo-sols have been designated as part of a larger group of sediments known as Marine Terrace Deposits or MTDs.

The Siuslaw River is currently located immediately west of the subject site, although older channels, now buried by dunes, are probably present both to the west and south, and possibly east of the site. Since the early 1900s, the current location of the channel and mouth of the river has been artificially maintained by the US Army Corps of Engineers. Maintenance of the location of the channel is achieved by several means, including construction (and later extension) of the Siuslaw Jetty, dredging of the channel, and construction of several groins along the west side of the channel approximately one half mile downstream from the subject site. The latter measures are designed to prevent the river from shifting its mouth southward by breaking through the fore-dune area of the sand spit which extends northward west of the river for 3.5 miles from the area west of downtown Florence to the current mouth of the river.

Soils

The *Soil Survey of Lane County Area, Oregon* (USDA Soil Conservation Service, 1987) indicates that the site is underlain by *Waldport fine sand, 0 - 12 percent slopes*. The soil is developed on stabilized sand dunes. The typical soil stratigraphy is described as:

> "Typically, the surface is covered with a mat of leaves, needles, and twigs about 3 inches thick. The surface layer is very dark gray and very dark grayish brown fine sand about 5 inches thick. The substratum to a depth of 60 inches or more is yellowish brown fine sand".

The Unified Soil Classification System (USCS) group names are: 0-5": SM; and 5 - 60": SM.

Physical Setting

The residence is located on hummocky ground resulting from its origin as sand dunes. This dune topography terminates against the east bank of the Siuslaw River immediately west of the residence. The bank is approximately 50 feet high and sloped at an overall angle of approximately 1.25H : 1V.

SITE OBSERVATIONS

Methods

The site was visited on several occasions in late January and early February, 2011. On January 19 and 20, three topographic sections were measured in the fall line in the northern, central, and southern portion of the failure, respectively. The sections were measured using a clinometer and 300-ft fiberglass tape measure. Also, two Williamson Relative Density Drive Probes were installed. The method uses a 12-lb slide hammer with a 40-inch drop to drive nominal ½-inch steel pipe with smooth couplings into the ground. Blow counts are obtained for 6-inch intervals and reported as blows per foot (BPF) per six inches. The locations of the sections and drive probes are shown on Figure 3.

Results

The currently active failure is approximately 80 feet wide (Figure 3) and, for the most part, extends from the steel sheetpile sea wall beyond the low water mark of the bank of the Siuslaw River. At the southern end, the failure extends eastward beyond the edge of the sheetpile wall and is encroaching north toward the house behind the seawall (see site photos, Appendix A). Figures 4, 5, and 6 show the three field-developed geologic cross sections measured at the site. The failure area is underlain by imported organic-rich sand ("root mat") overlying native clean, cross-bedded dune sand, which in turn overlies several older dune forms with variably well-developed paleosol horizons. The lowermost two (exposed) paleo-sol appear to be horizontal to very gently sloping. Another, higher paleosol has significant relief, rising towards the east at angles ranging from approximately 10 degrees to 36 degrees. The lower two paleo-sol form both a "ledge" (lowermost paleosol, designated SU-1, and exposed only at low tide) and a "cliff band" (second-lowest exposed paleosol, designated SU-3, mostly exposed even at ordinary high tide) which ranges in height from approximately 4 feet to as much as 8 feet or more south of the immediate failure area. All paleo-sol consist of former dune sand which is cemented by clay, derived from weathering of feldspar sand grains and, in places, by iron hydroxides (rust), derived from weathering of ferro-magnesian sand grains. Even the better-cemented portions of the material can be easily cut and craved with a pocket knife.

SU-1 and SU-3, the two lowermost exposed paleo-sol are separated by a layer of less cemented dune sand which is cross-bedded, and appears to range in thickness from 1 to 2 feet. This unit, which was designated SU-2, forms a "groove" at the base of the cliff-forming SU-3. Erosion of SU-2 proceeds until the overlying SU-2 is sufficiently undermined to fail by toppling of blocks of the better-cemented material. Numerous of these blocks lie on the ledge formed by SU-1,and most of these blocks are covered with barnacles.

SU-4, the uppermost paleosol is exposed only in the center of the failure area, where it is characterized by rust-brown staining. This unit appears the least cemented of three exposed paleo-sol. Nonetheless, groundwater is discharging on top of SU-4 from the overlying un-cemented dune sand.

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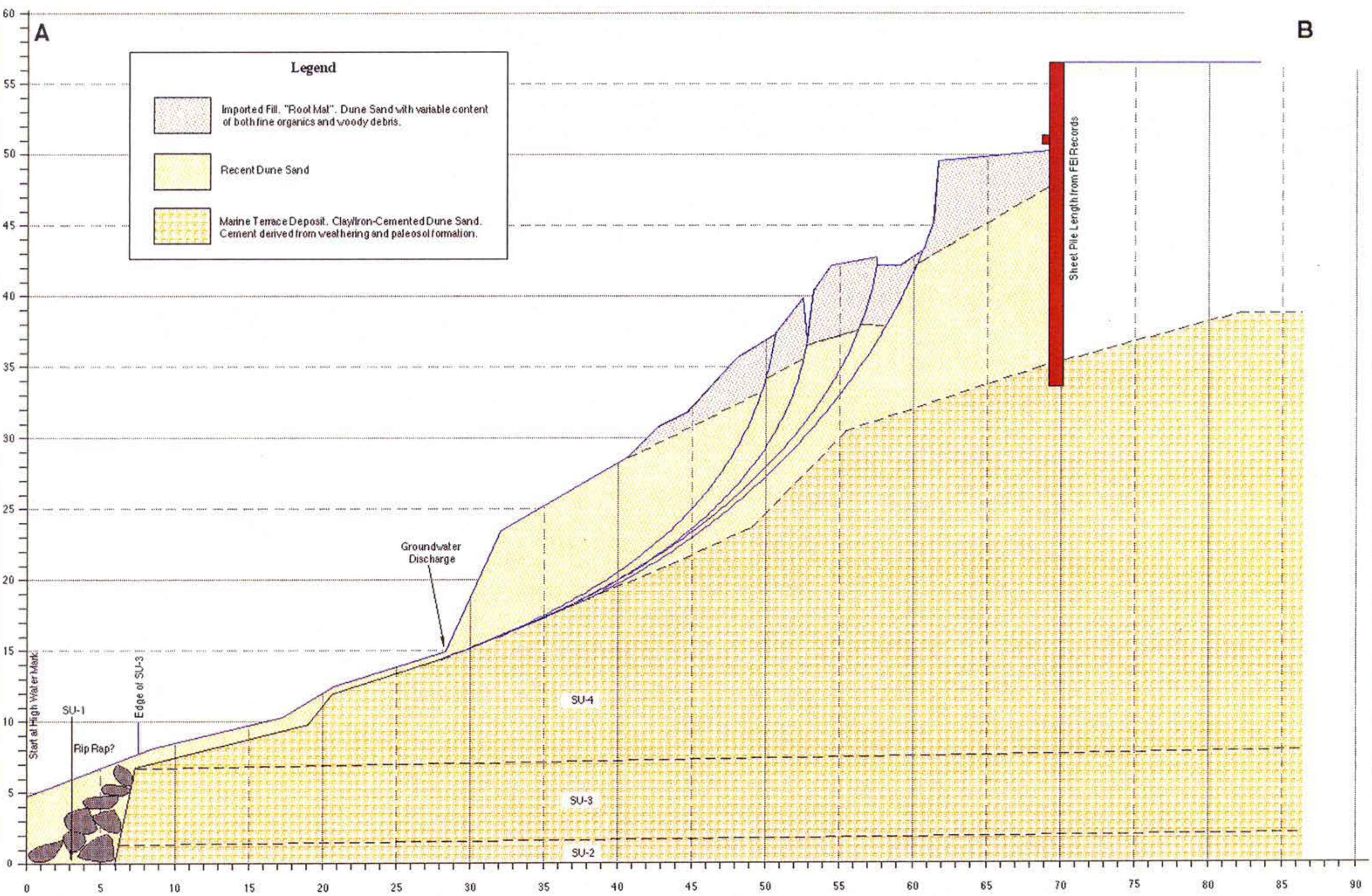
Figure 3: Failure, Field-developed Cross Section and WRDP Locations

Not to Scale. Base from Google Earth, Lane Co. Tax Map, and Ward Northwest.



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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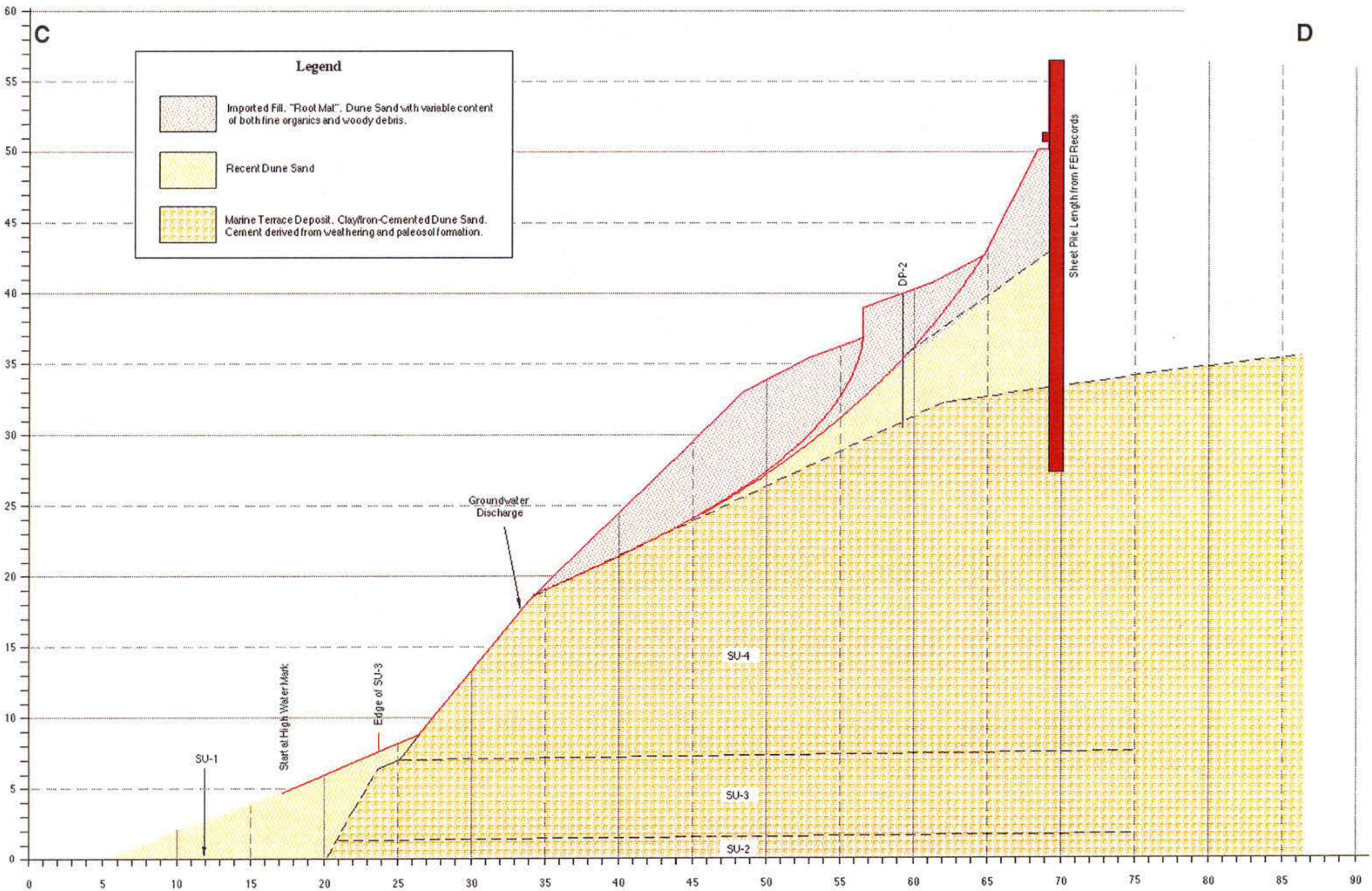
Figure 4: Field-Developed Cross Section A-B

Scale as Shown (1" = 5')



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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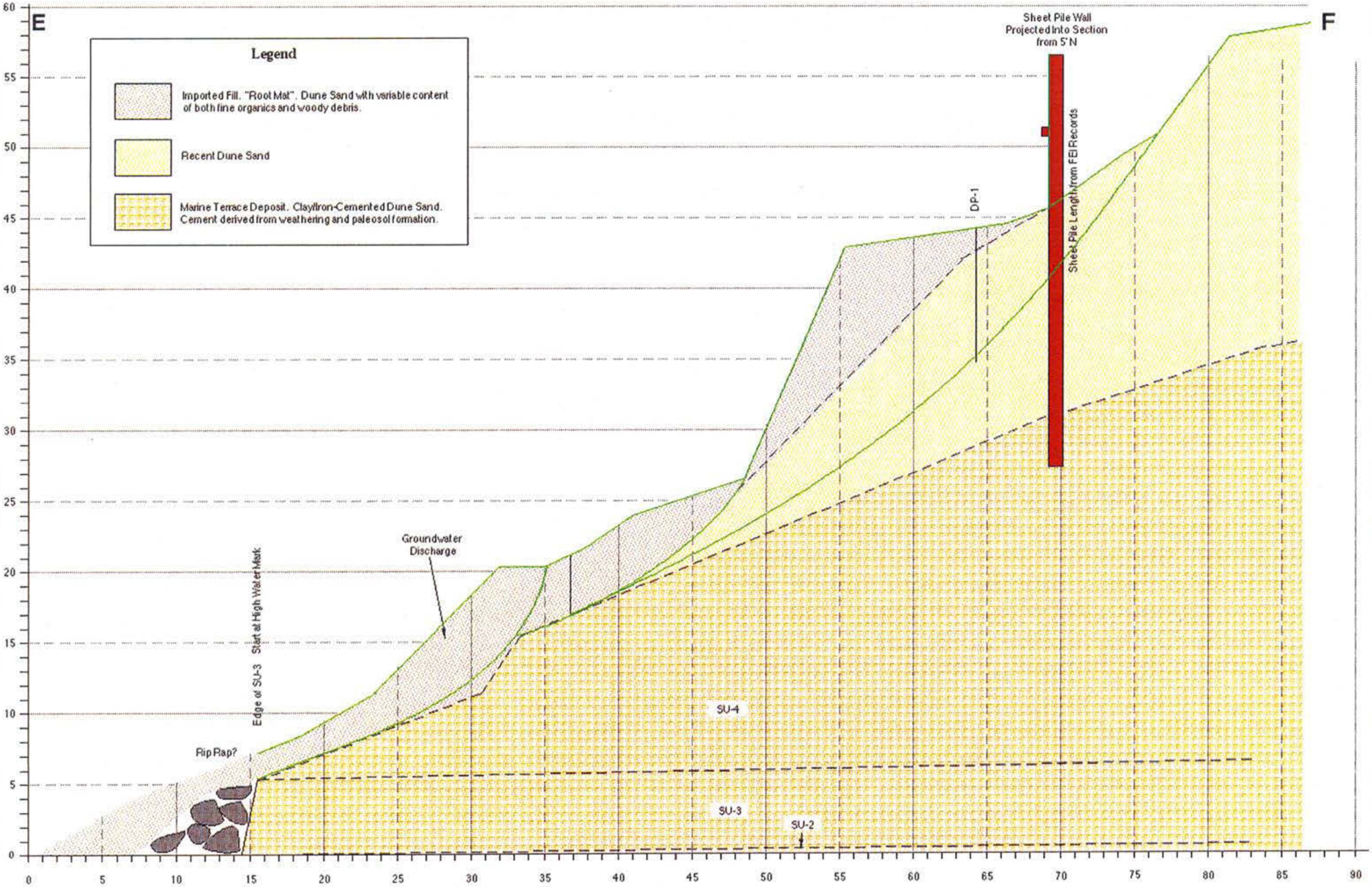
Figure 5: Field-Developed Cross Section C-D

Scale as Shown (1" = 5')



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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	Figure 6: Field-Developed Cross Section E-F
	Scale as Shown (1" = 5')

Significant groundwater discharge is occurring at three distinct locations within the failure area. These locations are near the northern and southern limits of the recent failure and in the central portion. At all three locations, groundwater is discharging sufficiently rapidly to mobilize the un-cemented dune sand on top of SU-3 or -4, which then flows slowly toward the west. At the western edge of the top of SU-3 the sand is deposited, as the water drains downward. However, this area of deposition is located within the tidal inundation zone and, therefore, the sand is removed by the river at high tide. As a result, the failure has not reachedequilibrium, and is progressing headward at all times, accelerating during and following periods with heavier precipitation.

A steel probe was utilized to ascertain that SU-4 extends across the entire lower- to mid-slope from the center to the northern and southern limits of the current failure. The unit was found at different depths, with the maximum depth around 6 feet located about 23 feet north of the central exposure of the unit. Low areas found in SU-4 in this manner correlate well with concentrations of groundwater discharge from the slope.

In addition to the three sand liquefaction areas within the failure area itself, significant amounts of sand were observed in transport off the edge of SU-3 both to the north and south of the boundaries of the current failure. A smaller, recent parasitic failure area is present within the larger older failure extending south across the slope of the adjacent lot. Below the smaller failure, significant amounts of sand were observed in transport over the cliff of SU-3. Similarly, sand was observed in transport over the top of SU-3 in the vicinity of the gabions remaining above high tide level immediately adjacent to the failure area to the north.

Portions of the gabion baskets were observed partially buried under the northern edge of the failure. These gabions appear to have been pushed westward and toppled off the cliff-forming SU-3. It is likelythat the rest of the gabions have been pushed into deeper water below the low tide level near the center of the failure, where they have been buried by the slope failure deposit. Similarly, portions of the older rip rap revetment appear to remain in place both at the northern and southern edge of the failure, but in a portion of the center of the failure, estimated at 15 to 20 feet wide, the revetment appears to have been pushed into the river.

DISCUSSION

The house at 16 Sea Watch Court in Florence was constructed in 1992, prior to development of a clearer understanding of the mechanisms contributing to the eastward retreat of the river bank along the stretch of the Siuslaw River from it's northward turn near downtown Florence to the north jetty at its mouth. Based on observations at this site, at Marine Manor, located approximately 1/4 mile to the south, at Shelter Cove, located approximately ½ mile to the north, and at other sites in between, several mechanisms are active in the recession of the river bank, not all of which are directly related to erosion by the current or waves.

Erosion of Uncemented Dune Sand as a Result of Groundwater Discharge

The primary factor contributing to the erosion of the completely uncemented sand of the most recent generation of dunes along this stretch is piping and liquefaction of the sand by groundwater discharging to the river which is perched on the much less permeable clay- and iron hydroxide-cemented dune sands of the Marine Terrace Deposits (MTDs). The upper surface of these older dune sands appears to be sloping generally to the west for a significant distance (a couple of miles?) eastward. Precipitation falling onto the dune sheet to the east of the subject site percolates downward through the recent dune sand until it reaches the impermeable MTD's and then moves westward through the base of the dune sand until it reaches the bank of the Siuslaw. There, the volume of water discharging during and following times of significant precipitation produces pore pressures of sufficient magnitude to mobilize the uncemented dune sand either as slow-moving flows or within small creeks/rivulets discharging from the base of the dune sand. Based on Hjulström's diagram and Shield's diagram, fine sand is the material which is most easily mobilized by the shear stress imparted by flowing water. The mobilized sand is then transported to the edge of the MTDs either as a flow of liquefied sand or at the base of the small creeks/rivulets. From there the sand is then removed by the current of the river. Because this mechanism is active only directly above the MTDs, in many cases located at the toe of the bank, sand is preferentially removed from there, resulting in removal of lateral support at the toe of the bank. Subsequently, the sand located on the bank above fails in one of several modes. During the winter, while the sand is moist and has apparent cohesion (due to the surface tension of the water), the failure occurs either by toppling of blocks of sand, or by sliding failure along straight or curved surfaces within the sand. Due to the depth at which these failure surfaces occur and due to the mass of material involved in larger blocks, these failures cannot be addressed by vegetation and root strength. During the summer, when the near-surface sand layer dries out and loses the apparent cohesion, failure occurs by dry flow of sand grains, which results in a "knick point" migrating up the slope. Based on observations and testing at the site of the Three Rivers Casino, GeoScience determined that the stable angle of dry Florence dune sand is on the order of 27 to 28 degrees, or very close to 2H : 1V (50% slope). Of course, even if this angle is maintained, wind erosion can still be a factor. However the latter issue can be effectively dealt with by planting vegetation.

In this case, an initial failure of this kind was mitigated in 1997, by installation of the sheet-pile wall and rip rap and gabion baskets on the MTDs at the toe of the slope. However, due to a lack of complete understanding of the mechanisms of bank retreat in this area, at least one of the mechanisms was not addressed during the first mitigation. It is not apparent that provisions were made to allow groundwater to discharge from the base of the uncemented dune sand, while retaining the sand behind the revetment and gabions. If fabric was present behind the gabion baskets, it would have been woven fabric, which is relatively impermeable. Therefore, pore pressures tend to build behind the fabric, which are released by high flow velocity through the seams of the fabric. In this manner large amounts of sand are mobilized from behind the fabric and flushed through the seams. Loss of lateral support at the toe and sliding failure on the slope is the result.

Excessive Backfill Slope Angle

The risk of a repeat of the failure was further exacerbated by the fact that after the last re-building of the toe of the slope using the gabion baskets, contractors hauled large amounts of "root mat" fill to the upper part of the slope, resulting in a final fill slope angle of 36 degrees or steeper. This is significantly in excess of the equilibrium slope angle for the sand.

Erosion of Paleo-sols

Erosion of the more cemented portions of the MTDs (in this case designated SU-1 and -3) appears to occur via two mechanisms. The first is direct erosion of individual sand grains from the surface of the cemented unit by the current, dripping water, and wave action. Of these, the latter process is the most active, often facilitated by the wake of passing motor boats or the Coast Guard cutters, which tend to perform numerous training exercises in this vicinity. In addition, failure of at least the upper paleosol (SU-3) occurs as the unit is undermined by removal of sand from the less-cemented SU-2, located between the two paleo-sol. That removal occurs due to erosion of the sand by the river current, water flowing and dripping from the SU-3 cliff above, and by wave action. It is not known whether water entering SU-2 at high tide also contributes to formation of pore pressures within the unit at low tide, which might be sufficient to mobilize the sand. Once SU-3 has been undermined to a sufficient degree, toppling failure of blocks of the material occurs. The fact that barnacles grow on the blocks of SU-3 lying on the shelf of SU-1 indicates that removal of these blocks is a process which takes at least several years, if not tens of years. Therefore, erosion of SU-2 is the dominant process in the retreat of SU-3. It is possible that similar stratigraphy extends farther down in the section, allowing lower portions of the MTDs to be eroded faster than could be achieved by surface erosion of the cemented portions alone.

The subsurface exploration (Williamson Relative Density Drive Probes) conducted in the upper portions of the slope indicate that in the mid-slope section, the uppermost paleosol (SU-4) surface rises towards the east at an angle of approximately 2H : 1V. This angle then appears to flatten out in the vicinity of the sheet pile retaining wall. According to Tim Pfeifer, PE with Foundation Engineering, the wall had originally been designed to extend to depths of 40 feet below the grade at the house. However, harder material was encountered at a higher level and the final lengths of the sheet piles range from 22 to 29 feet (Appendix B). It is probable that the harder material encountered by the sheet piles is SU-4.

Although the bottom of the sheet pile wall is presumed to be anchored into the top of SU-4 and the sheet pile wall is tied back 5feet from the top with anchors, the wall is designed for an exposure at the top of only 15 feet. At the time of the initial field work, the maximum exposure of the sea wall was 13.5 feet. Since that time, significant additional material has been eroded at the toe of the failure in the three areas where groundwater is discharging from the dune sand and the exposure is currently 15 feet in the worst area near the south end of the sheet pile wall. Additional failure of the slope above these eroding areas carries significant risk of failure of the seawall and portions of the house. As a result, mitigation is required as soon as practicable.

Purpose and Need

The purpose of this project is to remedy failures of the existing bank protection system which have resulted from less than ideal construction practices during the initial placement of the rip rap and gabions baskets. Without mitigation, the residence is in immediate danger of significant distress or complete loss. In addition, Lane County and the City of Florence would sustain significant losses of tax revenue not only due to destruction of this house, but also due to the resulting devaluation of many other high-end residences along this stretch of the Siuslaw River.

In addition, the constant stream of sand from the toe of the bank precludes establishment of a continuous cover of estuarine vegetation along the edge of the MTDs. Such vegetation is present on individual rip rap boulders and on some portions of the MTDs. However, it is generally absent in the areas on the MTD shelf most subject to sand transport and deposition. As a result, the continued erosion of sand from behind the rip rap is detrimental to the estuarine habitat in the immediate vicinity.

Mitigation Options (Alternatives Analysis)

The most pressing issues affecting bank stability at this site can probably be addressed relatively simply. Based on the site observations, the main issue is not related to erosion of the bank by the Siuslaw River, but rather to the development of pore pressures in the dune sand at the toe of the slope due to discharge of groundwater and temporary bank storage during high tide.

Several options for mitigation of the issues have been considered. These include:

- Installation of additional sheet piling to retain the slope.
- Installation of a system to retain the sand while allowing dissipation of pore pressure.

<u>Sheet Piling</u>

Installation of additional sheet piling has been considered at this site. However, such a system was deemed currently infeasible due to cost considerations, the concern that the marginally competent marine terrace deposits located westward of the sheet pile wall would be significantly disrupted during the installation, and the impact that construction of temporary access to the site for the heavy equipment required to add sheet piling. The disruption of the MTDs might result in increased erosion rates of these deposits and subsequent failure of the new sea wall due to active soil pressures. Crane access to the lower portion of the slope could only be achieved via a temporary road along the bank from a vacant lot located several hundred feet south of the site. The construction of a road at least 12 feet wide would result in major disruption of the bank of the Siuslaw.

Sand Retention and Drain System

In order to stop erosion of the dune sand from the toe of the slope directly above the MTDs, GeoScience proposes to install a filtration system on top of SU-3. This filtration system is designed to allow pore pressures to dissipate while retaining the sand behind the rip rap. For this purpose, it is recommended to remove the rip rap, install heavy-duty filter fabric, and then replace the rip rap. However, due to the fact that the sand erosion transport occurs mostly directly at the interface with the MTDs, achievement of a positive seal between the fabric and the MTDs is of utmost importance during the installation. Without an effective seal at the bottom, sand will continue to be flushed from beneath the filter fabric by the groundwater discharge. Based on the site observations, the upper surface of the MTDs is relatively flat but has "micro-topography" on a scale of several inches to a foot.

Whereas it may be possible to reduce this relief by excavation with a "muck plate" to some degree, the sealing mechanism will still need to be able to conform to some minor topography. Therefore, it is proposed to form the seal by placing approximately two feet of pea-gravel onto the filter fabric over a broader area (7 feet wide east to west) of MTDs which will be cleaned of sand as well as possible. This requires excavation of several cubic yards per foot of treated length of existing rip rap, dune sand, and failed "root mat" material. Based on experience with construction of a nearly identical system at Marine Manor, located approximately one quarter mile to the south, it should be possible to excavate the lower approximately 10 feet of bank at a temporary angle of 1/2H : 1V and the next slope segment at an angle of 1H : 1V or steeper. Both the removed rip rap and the other excavated material should be stockpiled on the barge

Once the upper surface of the MTDs has been cleaned, heavy-duty filter fabric (i.e. 16-ounce fabric equivalent to Amoco 5761) should be placed on the cut slope and MTDs. The lower portion of the filter fabric should then be covered with approximately 2 feet of open graded peagravel and the filter fabric folded over the peagravel.

In order to provide protection of the filter fabric during the re-installation of rip rap and from attack by marine fauna (e.g. crabs) it is recommended to install Tenax "ROADRAIN -T 5100-2" composite geo-fabric under the westernmost 2 feet of the heavy-duty filter fabric/peagravel wrap and covering at least the top of the wrap. The western edge of the pea-gravel wrap should then be protected with rip rap approximately one stone deep and the wrap covered with rip rap to the cut slope. These rocks will need to be placed with great care to prevent puncturing of the fabric system.

The rip rap should then be replaced up the slope at an angle not exceeding 1.25H : 1V (38 degrees), to the height required to have a 2H : 1V slope from the top intercept the sheet pile wall no lower than 15 feet from its top. The filter fabric should then be wrapped over the top portion of the rip rap and the top of the slope can be finished to the sheet pile wall with sand which should be installed no steeper than 2H :1V.

The lower portion of this sand slope should be planted with beach grass and willows or similar native vegetation and the uppermost portion of the slope which is most likely to dry out, should be planted with beach grass and salal.

In order to ensure maximum longevity, any mitigation conducted at the site must address all mechanismsof retreat of the bank. This includes retreat of at least the lower two exposed paleo-sol (SU-1 and -3) and the intervening less cemented dune sand layer (SU-2), the erosion of the base of the recent dune sand by discharge of groundwater, and the failures higher on the slope resulting from loss of lateral support at the toe. The proposed typical mitigation is shown on the cross sections on Figures 7 through 9.

Mitigation of the erosion of the MTDs in this vicinity requires both that wave energy is dissipated and that the erosion of SU-2 is stopped or minimized. Rip rap is effective at dissipating the wave energy, but, unless very carefully graded (sizes) with depth, is not effective at retaining sand. As a result, it is recommended to rebuild the entire lower revetment, including those areas where the rip rap remains after the failure. The remaining rip rap should be removed and temporarily stockpiled, the lower ledge of the MTD (SU-1) and the slope (if not near-vertical) of SU-3 should be cleaned of loose debris and sand, and heavy-duty (16-oz) non-woven (felt-type) filter fabric should be placed over the MTD's, taking care to lap individual sections sufficiently to preclude leaks of sand from SU-2 behind the fabric. The fabric should extend sufficiently high on the slope to be covered by the sand retention system installed on the top of SU-3 or SU-4 (depending on location). The rip rap should then be replaced carefully to avoid punctures and tears in the fabric. Additional rip rap will be required both to replace the material lost into deeper water in the center of the failure area, and to ensure that a stable slope angle is reached with the rip rap. The final outside angle of the revetment should be no steeper than 1.25H : 1V, regardless of the size of rip rap used. At this time, the volume of additional rip rap required is not known, mainly because the original configuration of the existing rip rap is unknown and the volume of the revetment which was moved out of reach to deeper water has not been confirmed. It is anticipated that the volume of rip rap required to place a stable revetment is on the order of 1.5 cubic yards per foot in the northern and southern sections and 2.5 cubic yards per cubic foot may be required in the central approximately 30to 40 feet of the revetment where much of the previous revetment may have been moved into water too deep to allow recovery..

Whereas the current failure does not extend past the seawall on the north end, it does so on the south end. In addition, on the neighboring property past the north end of the failure, sand was observed in transport across SU-3 at several seeps of groundwater. As a result, the toe of the slope in that vicinity is being removed and the slope is expected to fail in a similar manner in the near future. The

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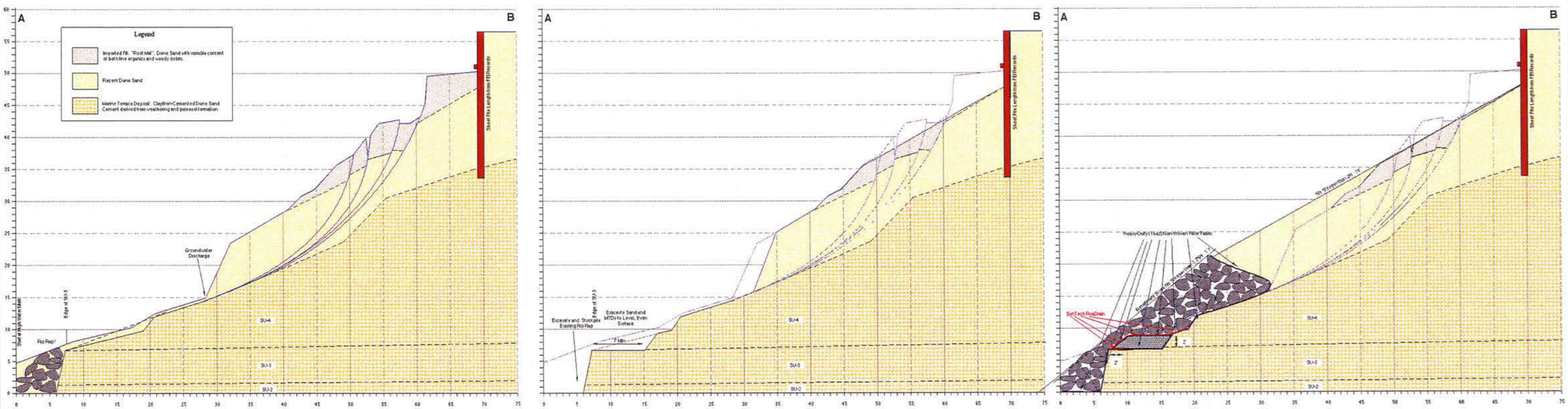
Figure 10: Approximate Extent of Mitigation Project

Not to Scale. Base from Google Earth, Lane Co. Tax Map, and Ward Northwest.



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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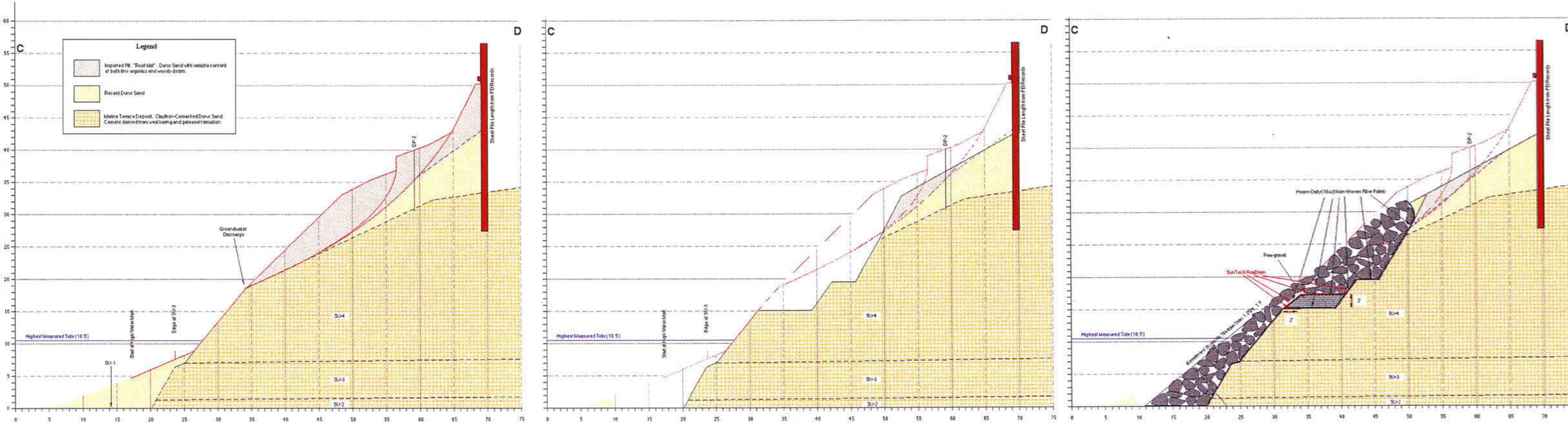
16 Seawatch Ct, Florence, Bank Failure Mitigation Assessment

Figure 7: Cross Section A-B, Proposed Mitigation

Scale as Shown (1" = 5')



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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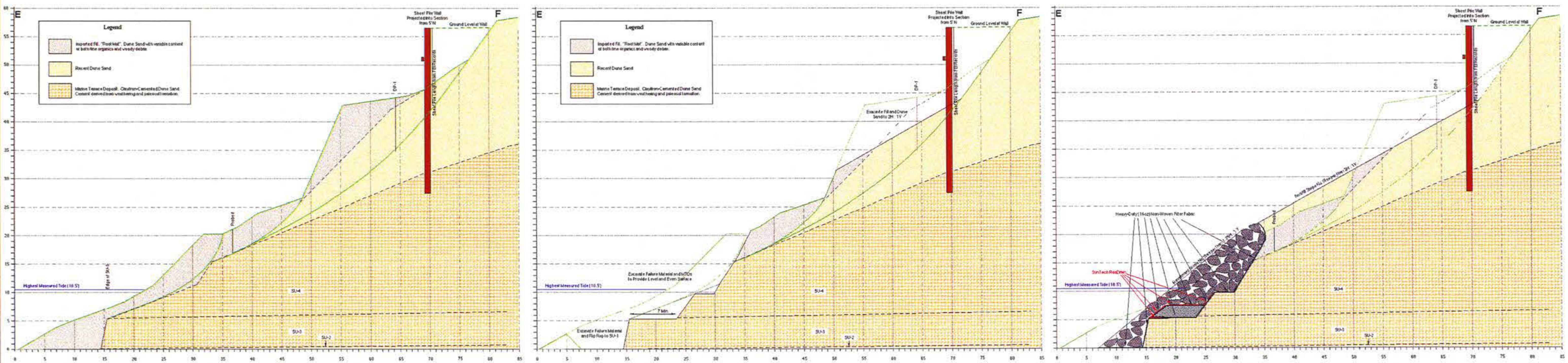
Figure 8: Field-Developed Section C-D Proposed Mitigation

Scale as Shown (1" = 5')



Note: Section measured using clinometer and 300-ft fiberglass tape. This represents only one of numerous possible interpretations of the data. It is based on very limited subsurface information and is subject to change as additional data is developed.

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16 Seawatch Ct., Florence, Bank Failure Mitigation Assessment
Figure 9: Cross Section E-F, Proposed Mitigation
Scale as Shown (1" = 8')

gabion basket system in that vicinity is not expected to perform better than the system did in the failure area itself. In order to preclude the slope failure from encroaching the seawall from the north or south side, it is recommended to extend the mitigation beyond the ends of the seawall and current failure for at least a sufficient distance to allow for a 2H : 1V slope angle from the toe of the sand slope to the ends of the seawall. This results in the trapezoidal shape of the project area as shown on Figure 10. The property to the north already has a rip rap revetment in addition to some gabion baskets on SU-3. However, this rip rap was also placed without appropriate geotextile. Site observations indicate that "Road Fabric" was utilized and sand can be observed being flushed through the seams of the fabric, which is also in poor repair. Therefore, it is recommended to re-build at least the section of the revetment which is located within the 2H :1V slope angle from the north end of the sheet pile wall.

Measures to Minimize Impacts

Long-Term Impacts

The proposed mitigation does not result in an extension of the bank protection structure westward beyond the area already covered with rip rap. Therefore, no long-term impacts to the aquatic or estuarine habitat are expected beyond the impacts of the already existing structure.

Short-Term Impacts During Construction

By necessity, the excavation work must be conducted during low tide conditions. In this case, based on the tide level during the AM high tide on January 20 (+6.11), from the edge of which the cross sections were measured, even a +3.0 low tide allows for the work area (MTD SU-3 shelf) to be more than a foot out of the water. The lower shelf (SU-1) is out of the water only at tide levels around 0. However, at OHW, the MTD shelf is located approximately 2 feet below water. This means that the sand retention system on SU-3 can be installed at almost any water levels other than OHW. However, removal of the existing rip rap on SU-1, placement of filter fabric and replacement of the rip rap can only be performed at low tide.

These constraints to the construction activity significantly limit the impact to the aquatic habitat. The work on the sand retention system on SU-3 will probably need to be conducted from land, because the work area is out of reach of excavation equipment on a barge. Repair of the revetment on SU-1 can be conducted from a barge, which will could also be utilized as the temporary stockpile site for the rip rap removed from the bank and the other soil/dune sand excavated to expose the upper surface of the MTDs. If necessary, a filter fabric containment area will be set up on the barge to preclude turbid water from seeping out of excavated sand while it is stockpiled on the barge. Excavated material left over after replacement of the bank to the configuration shown in the right portions of the sections will be disposed of at an upland site to be determined by the contractor prior to commencement of the construction.

Two types of anadromous fish are listed for the Siuslaw River by the ODFW as "Vulnerable Species". They include the Oregon Coastal Coho Salmon and the Winter Run Steelhead. Coho tend to start their spawning run in October and continue into the winter. Due to the above constraints of conducting the work during the dry season, preferably having completed the work by October, the proposed project should not interfere with spawning runs of either of the two listed species. No federally listed species are known to be on the project site.

Proposed Mitigation

As part of this project, it is proposed to remove the gabion baskets remaining above the shelf of SU-3 to the north of the current failure area, and retrieve as many of the gabion baskets as possible which were pushed into the river during the initial December 26, 2010 slope failure.

CONCLUSIONS

The east bank of the Siuslaw River in the vicinity of the Sea Watch Estates subdivision is underlain in the shallow subsurface by recent dune sand, consisting of fine, poorly graded sand. Albeit stabilized at the surface by vegetation, the sand in these recent dunes is not cohesive. The most recent dune sand overlies several generations of older dune deposits on which paleo-sol formed at the time they were located at the surface. The paleo-sol consist of dune sand which has been cemented by clay and iron hydroxide compounds derived from weathering of feldspar and ferro-magnesian minerals contained within the sand. Three distinct paleosol levels were identified, which were designated SU-1, SU-3, and SU-4, in order of decreasing age. SU-1 is the unit which forms the shelf or ledge which is under water at all times except during low tide. SU-3 extends from approximately the water level at mid-tide to above the ordinary high tide level. These two paleo-sol are separated by a layer of much less cemented dune sand approximately 1 to 2 feet thick which was designated SU-2. The sequence of SU-1 through SU-3 is more or less horizontal to very gently sloping, with some micro-relief on the order of inches to a couple of feet. SU-4 is the youngest (highest) paleosol and is characterized by much more significant relief. Where it is not truncated by erosion or the recent failure, the upper surface of this unit slopes up to the east at an approximate angle of 2H : 1V, leveling off approximately 20 to 25 feet below the top of the seawall. These older dune deposits and paleo-sol are grouped together in a unit which is designated as Marine Terrace Deposits (MTDs).

Several mechanisms of erosion/slope movement contribute to the slow eastward recession of the bank. The MTDs exposed at and near the water level of the Siuslaw River are eroded by the current, wave action (exacerbated by the wakes of water craft) and water dripping and running over the steep edges. The most destructive process appears to be the undermining of SU-3 by erosion of the less cemented SU-2, and subsequent toppling failure of blocks of SU-3. The same or similar processes may be active lower in the MTD section also, in areas which remain submerged even at extreme low tide. However, in those areas, wave action probably plays a very minor role, if any.

Erosion of the uncemented recent dune sand mostly occurs as a result of development of groundwater pore pressures near the base of the unit and resulting mobilization of the sand grains by flowing water or liquefaction of the sand by the pore pressure. The groundwater discharge occurs as a result of precipitation falling on a large area east of the bank, with the groundwater perched on the impermeable, cemented paleo-sol in the subsurface and running off westward following the buried topography. The removal of the sand at the base of the slope results in loss of lateral support at the toe, which, in turn results in sporadic catastrophic sliding movements of larger blocks of sand higher on the slope. Another mechanism of sand removal higher on the slope is the headward progression of minor scarps by flow of the sand during the drier summer months. When dry, the sand loses apparent cohesion and can only maintain a slope angle of 2H : 1V.

The most recent catastrophic failure of a large segment of the bank occurred after significant precipitation in late December, 2010. In an area approximately 80 feet wide (N-S) and up to 70 feet long (up- and down-slope) sand and imported fill slid downslope along several compound, head-ward progressive failure surfaces. The failure appears to have initiated as a result of removal of sand behind the 2-tier gabion basket system installed on SU-3 after a similar failure in 1996/97. The impact of the sliding block toppled the gabion baskets into the river and off the ledge formed by SU-1, it appears to have also removed a portion of the older rip rap revetment which had been placed on SU-1 along the exposed face of SU-3.

Slope movement continued during the time of the site investigation (late January/early February, 2010) with flows of liquefied sand originating at three springs along the base of the recent dune sand and slow movement on the pre-established failure surfaces upslope from there. When the assessment commenced, the maximum exposure of the sheet pile seawall protecting the house above was 13.5 feet. In early March the maximum exposure had reached 15' which, according to the design engineer for the wall, is the design maximum. Therefore, the risk of failure of the wall as a result of continued failure of the slope is judged to be high at this time. Failure of the wall would result in essentially immediate damage to the house.

RECOMMENDATIONS

Due to the high risk to the house at 16 Sea Watch Court, it is recommended to mitigate the recent catastrophic bank failure as soon as possible. In order to preclude the recurrence of another failure within the next several tens of years, the mitigation will need to address all mechanisms of bank failure identified at the site, which include the retreat of the older, more cemented paleo-sol of the MTDs, and the removal of more recent, uncemented dune sand overlying these older dune deposits.

The rate of retreat of the MTD's can be significantly reduced if wave action is mitigated and removal of sand from SU-2 is prevented. Both goals can be achieved by appropriate re-constructionof the rip rap revetment which was placed along this stretch in the late 1990s. It is recommended to remove and temporarily store the rip rap remaining on the shelf formed by SU-1. The upper surface of SU-1 should then be cleaned of debris and sand as well as possible and heavy duty (16-oz) non-woven (felt-type) filter fabric draped over SU-3/-4, SU-2 and the upper surface of SU-1. Seams in the fabric should be lapped at least 3 feet to prevent gaps through which sand could be removed from SU-2.

Seams should be covered with smaller rip rap and the rip rap revetment re-constructed to protect the paleo-sol from wave action and significant currents. The rip rap should be installed at a fill slope angle not exceeding 1.25H :1V, both to reduce the shear stress on the underlying SU-1 and to prevent internal failures within the revetment. It is anticipated that this will require approximately 1.5 cubic yards per foot of revetment in the northern and southern portions of the failure area and 2.5 cubic yards of rip rap in the central portion (around 30 to 40 feet). The amount of rip rap remaining on the shelf, which can be re-used for this purpose is not currently known. Because the area is not subject to impact of large breakers, rip rap of a diameter around 24 inches is judged to be adequate. If possible, the larger stones should be placed toward the base of the revetment, on the outside.

The recent dune sand above the MTDs is also recommended to be effectively stabilized. This appears to not have been achieved by the previous slope repair. For this purpose it is recommended to construct a sand retention system consisting of heavy-duty (16-oz) non-woven filter fabric which is placed on the slope after excavation of a relatively level and flat surface which is seven to eight feet wide on top of SU-3 or SU-4 (depending on location). The filter fabric should be loaded and pressed against the MTD surface using a 2-foot thick section of pea gravel. The fabric should then be folded over the pea-gravel to preserve its permeability. The upper layer of filter fabric and the outside edge of the "wrap" should then be protected from tears and ruptures resulting from rip rap or disturbance by the local fauna by placement of Tenax RoaDrain, which consists of a tough geogrid faced on both sides with additional filter fabric. The lower edgeof the RoaDrain fabric should be folded partway under the pea-gravel section. As shown on Figures 7 to 9, the entire package containing pea-gravel should be from 7 to 8 feet wide with only the outer 2 feet underlain by the RoaDrain fabric. Along the eastern approximately 5 feet of width, the more pliable heavy-duty filter fabric is designed to conform to the micro-topography on the substrate, allowing for a seal against the MTDs. In this manner, water can percolate through the system, but the sand is retained behind the filter fabric. Both the pea-gravel/fabric retention system and a portion ofthe slope above this system will be covered with rip rap. This measure is required both to ensure that the retention system is protected from wave action and current during high water, and to elevate the toe of the sand slope sufficiently to limit the exposure of the seawall above to less than 15 feet given an equilibrium slope of the dry sand of 2H : 1V. The filter fabric behind the rip rap should be extended up the slope to cover all the sand which will be cut or placed steeper than 2H : 1V.

Following installation of the sand retention system and rip rap revetment covering it, the sand slope between the rip rap and sheet pile seawall should be gradedto establish a maximum slope angle of 29 degrees. In some areas, this will require removal of sand from the higher portions and in some areas sand may need to be placed to raise the surface to provide sufficient cover for the sheet piling.

The sand surface between the rip rap and the sheet pile wall should be covered with erosion control matting (i.e. jute matting) and can be planted with native dune grass, salal and willows. It is likely that willows will need to be limited to the lower portions of the slope due to lack of water higher on the slope during the summer. To prevent damage to the sand retention system it is not recommended to plant the area of the slope covered by rip rap. If vegetation grows in this area over time, it should be left in place and not disturbed to retain the integrity of the filter system as well as possible.

LIMITATIONS

This report was prepared for the use of Patricia and Richard Lukens, and their authorized agents for planning and design purposes. Our professional services were performed, and our conclusions and recommendations provided in accordance with generally accepted principles and practices. The analyses, conclusions, and recommendations in this report are based on site conditions as they presently exist and on surficial observations and limited subsurface exploration only. The report is not a warranty of subsurface conditions. If, in the future, conditions are found which differ significantly from those presented here, GeoScience must be advised at once so that these conditions and our recommendations can be reviewed and revised, if necessary. Should a substantial lapse of time occur between this investigation and future site activity, or if conditions have changed due to nearby construction or natural causes, the data contained in this report should be reviewed to determine its continued applicability. This report is not intended to provide a seismic risk evaluation of the subject property. GeoScience cannot be responsible for construction activity on the subject property or other sites which neighbor or abut the subject property referenced in this report.

If you have any questions about this report, please do not hesitate to contact me at (541) 607-5700.

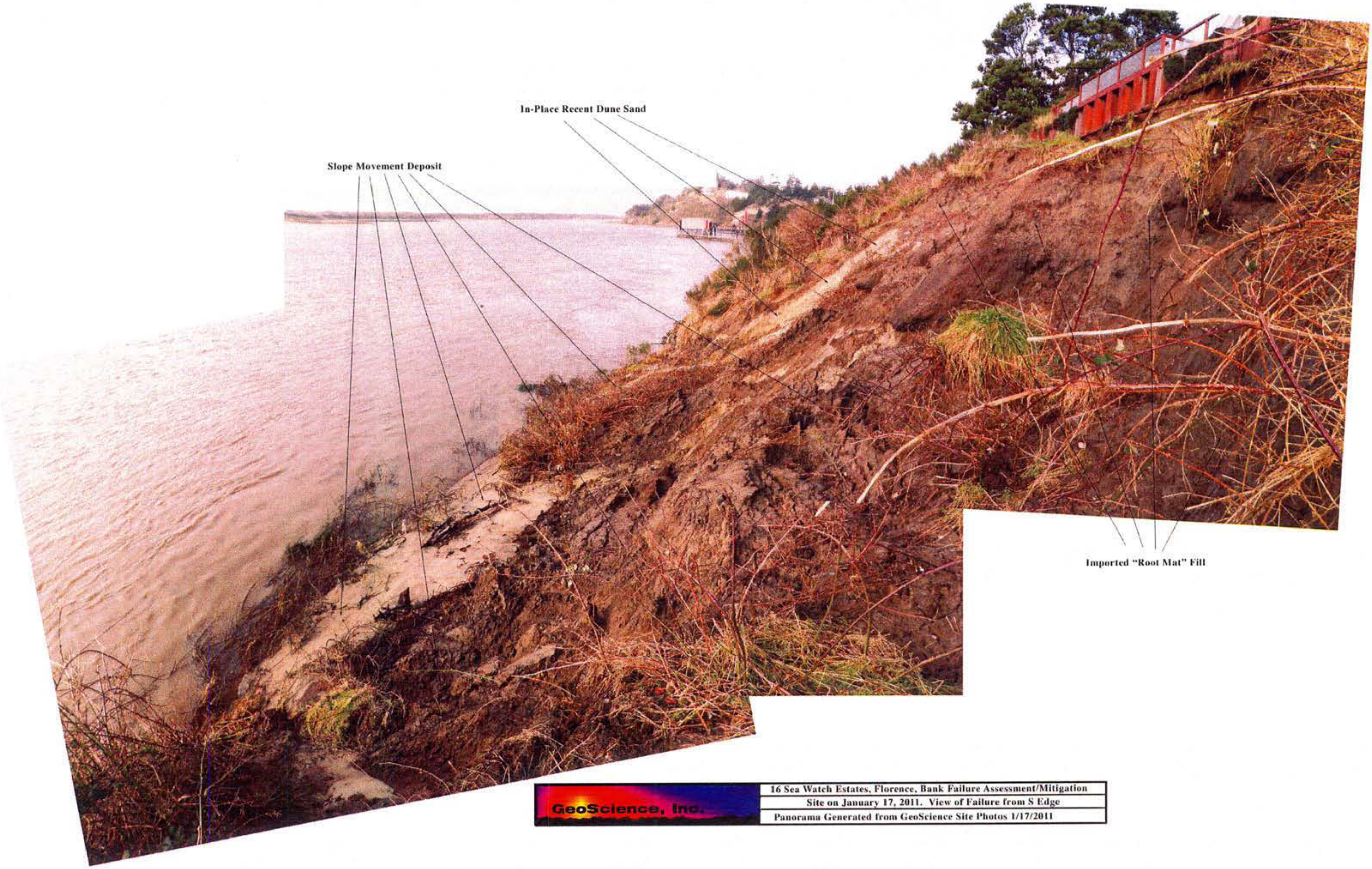
Respectfully submitted,
GeoScience, Inc.

Gunnar Schlieder, Ph.D., CEG

CERTIFIED
OREGON
GUNNAR SCHLIEDER
E1139
ENGINEERING GEOLOGIST

APPENDIX A:

SITE PHOTOS



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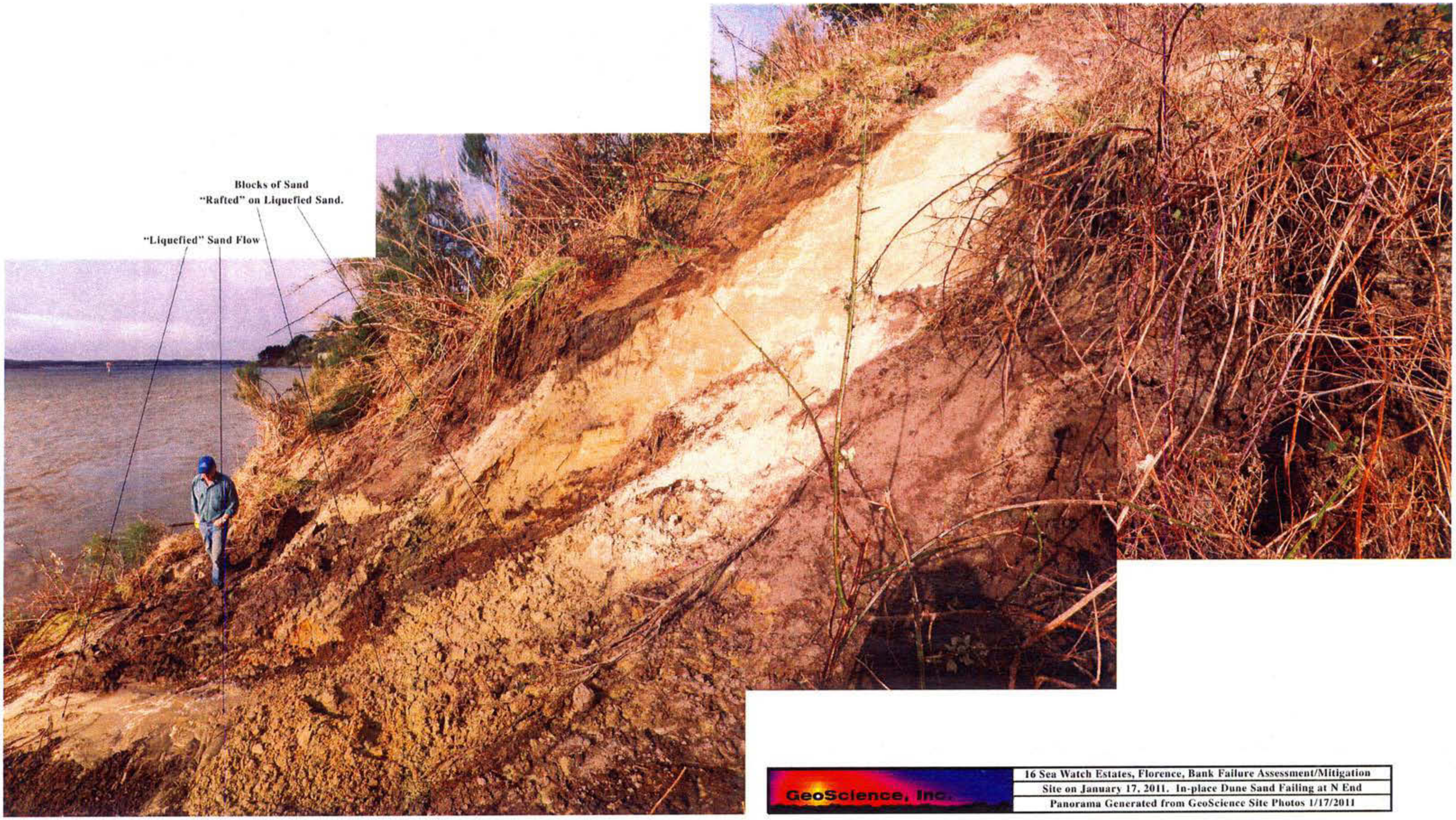
16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
Site on January 17, 2011. View of Failure from S Edge
Panorama Generated from GeoScience Site Photos 1/17/2011



GeoScience, Inc.

16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
Site on January 17, 2011. In-place Dune Sand Failing at N End
Panorama Generated from GeoScience Site Photos 1/17/2011

GeoScience, Inc.

16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
Site on January 17, 2011. View of Failure from N End. View E and S.
Panorama Generated from GeoScience Site Photos 1/17/2011

GeoScience, Inc.	16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
	January 17, 2011. View S Along Cliff-forming SU-3
	GeoScience Site Photos 1/17/2011

Buried Upper Edge of SU-3 Marked

GeoScience, Inc.

16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
View N ALong Buried Upper Edge of SU-3
GeoScience Site Photos 1/19/2011

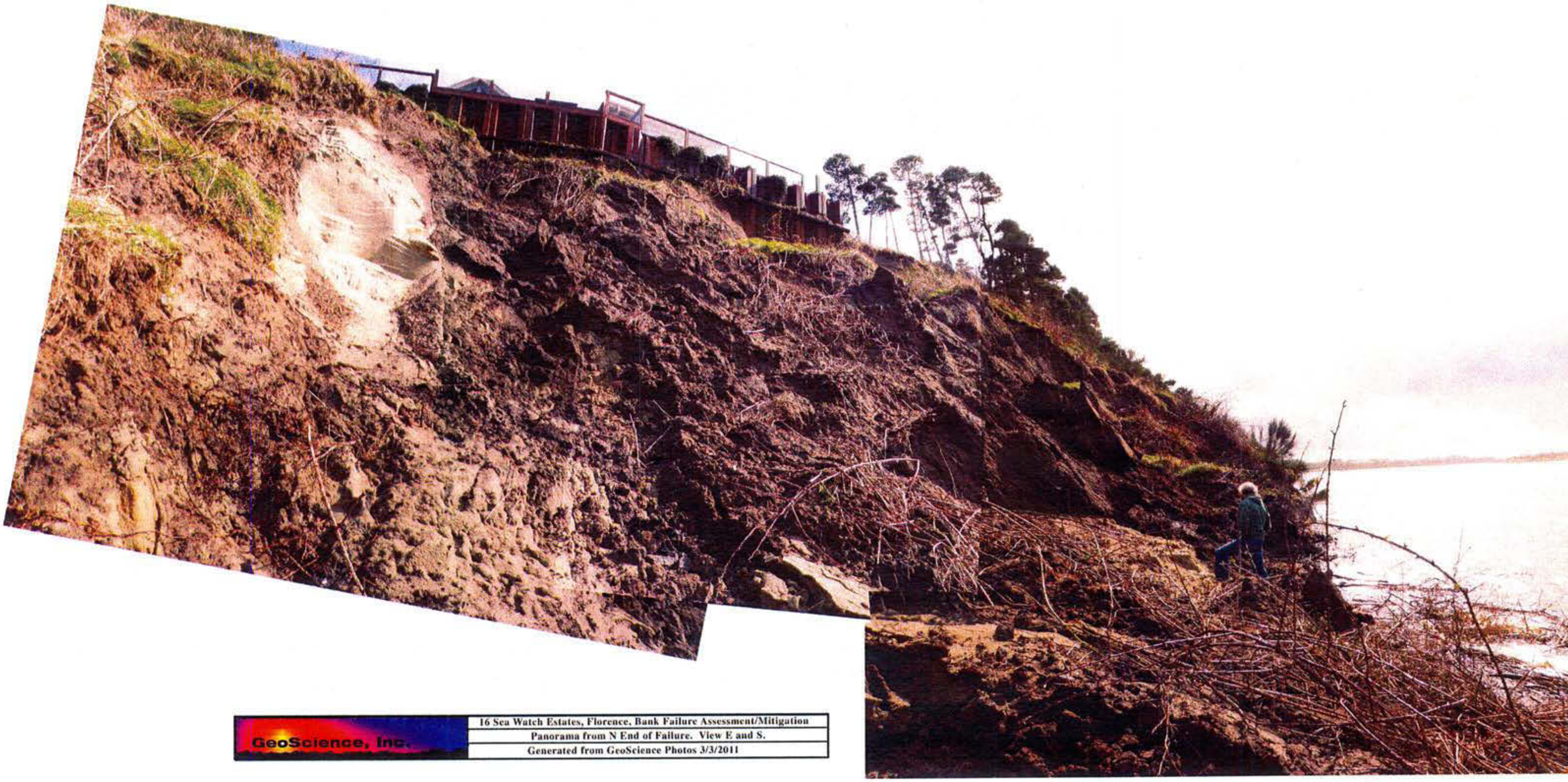
Gabions above SU-3 to the N of the current failure. View S toward failure.

Gabions involved in failure at N end of slope movement deposit. Baskets have been deflected westward by the movement.

Rip rap exposed in S central portion of the toe of the slope movement. Sand to left is slope movement deposit in area under water at OHW.

Rip rap in place exposed in N central area of slope movement deposit.

GeoScience, Inc.	16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
	Remaining Revetments.
	GeoScience Photos 1/25/2011



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16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation	
Panorama from N End of Failure. View E and S.	
Generated from GeoScience Photos 3/3/2011	

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16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation
Exposure of MTDs (SU-3) in North Portion of Failure Area. View N
GeoScience Photo 3/3/2011

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16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation

Sea Wall Exposed by Failure. View N. Wale is 5' from Top.

GeoScience Photo 3/3/2011

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16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation	
Failure Encroaching Behind S End Sea Wall. View N	
GeoScience Photo 3/3/2011	

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16 Sea Watch Estates, Florence, Bank Failure Assessment/Mitigation

Drive Probe Pipe Rotated from Vertical to Nearly Horizontal by Movement

GeoScience Photo 3/3/2011

APPENDIX B:

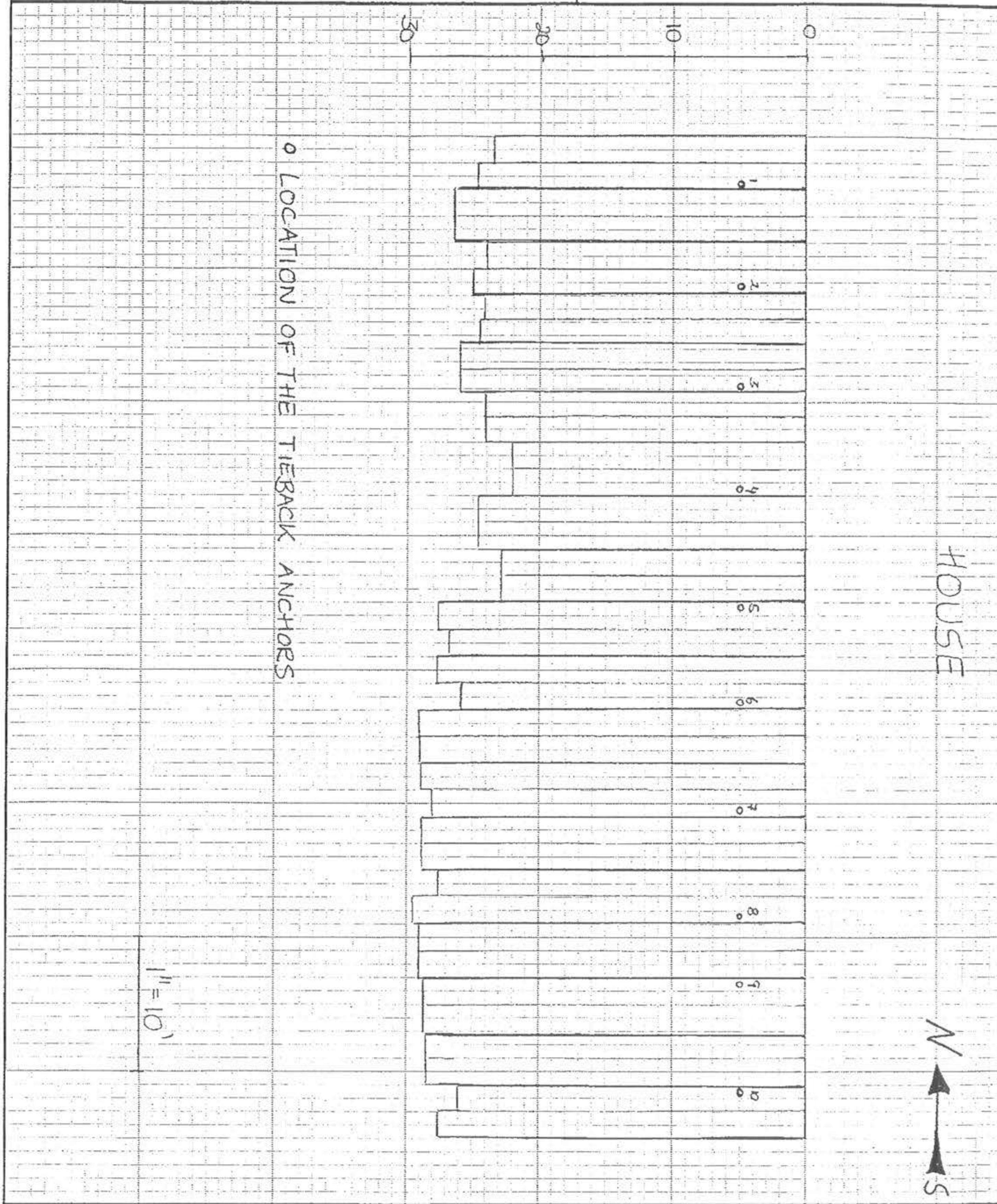
HISTORIC SITE PHOTO FROM EARLY 2000s

APPENDIX C:

SHEET PILE LENGTHS (FROM FEI DRIVING RECORDS)

PROJECT NAME: SEA WATCH ESTATES

PROJECT NO: 96200073

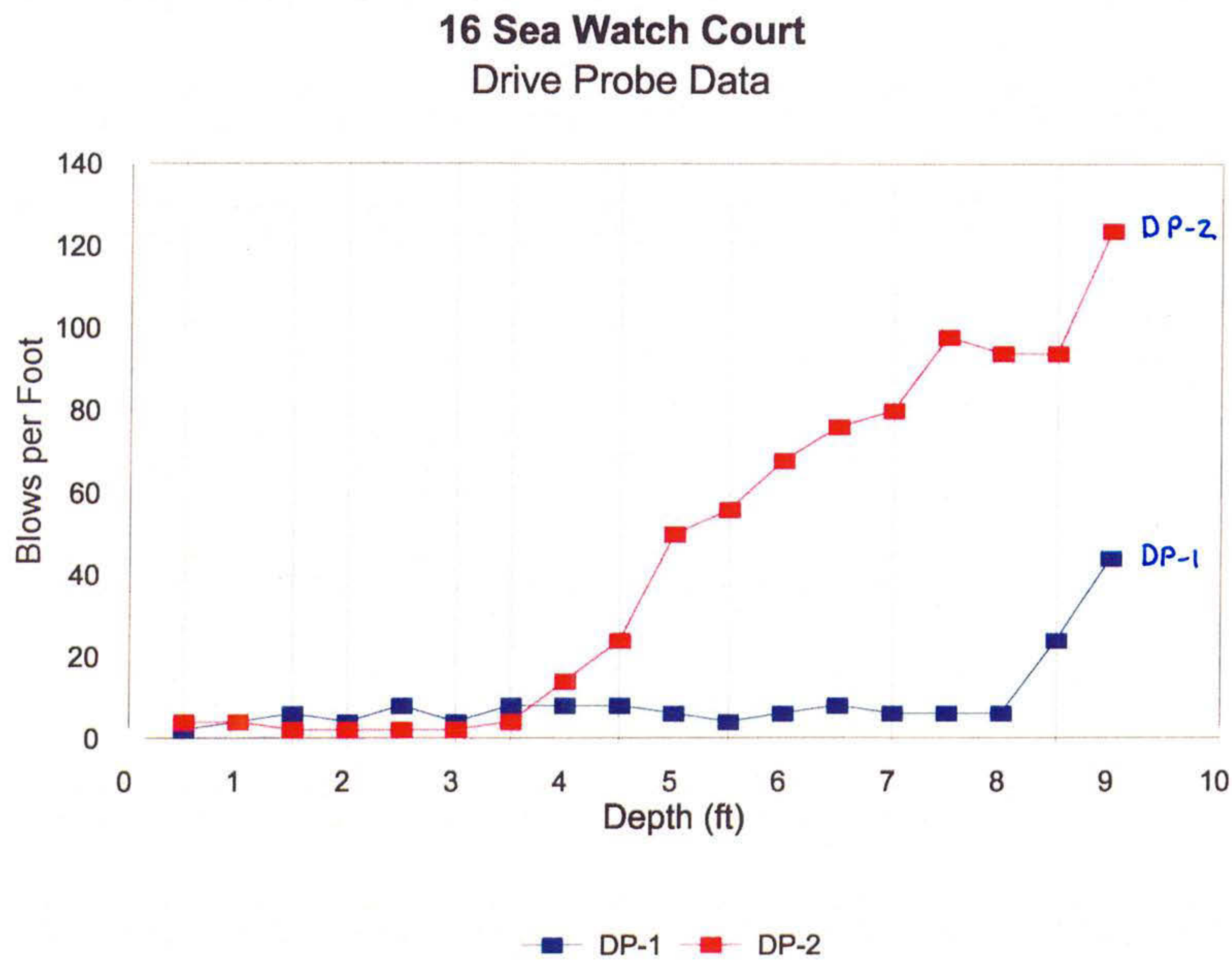


FOUNDATION ENGINEERING

BY	DATE	SHEET NO.
heike	11-18-97	1

APPENDIX D:

DRIVE PROBE DATA


16 Sea Watch Court
Drive Probe Data
Blows per Foot
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
Depth (ft)
DP-2
DP-1
DP-1
DP-2