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 mechanisms of 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

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 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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	Figure 9: Cross Section E-F, Proposed Mitigation
	Scale as Shown (1" = 5')

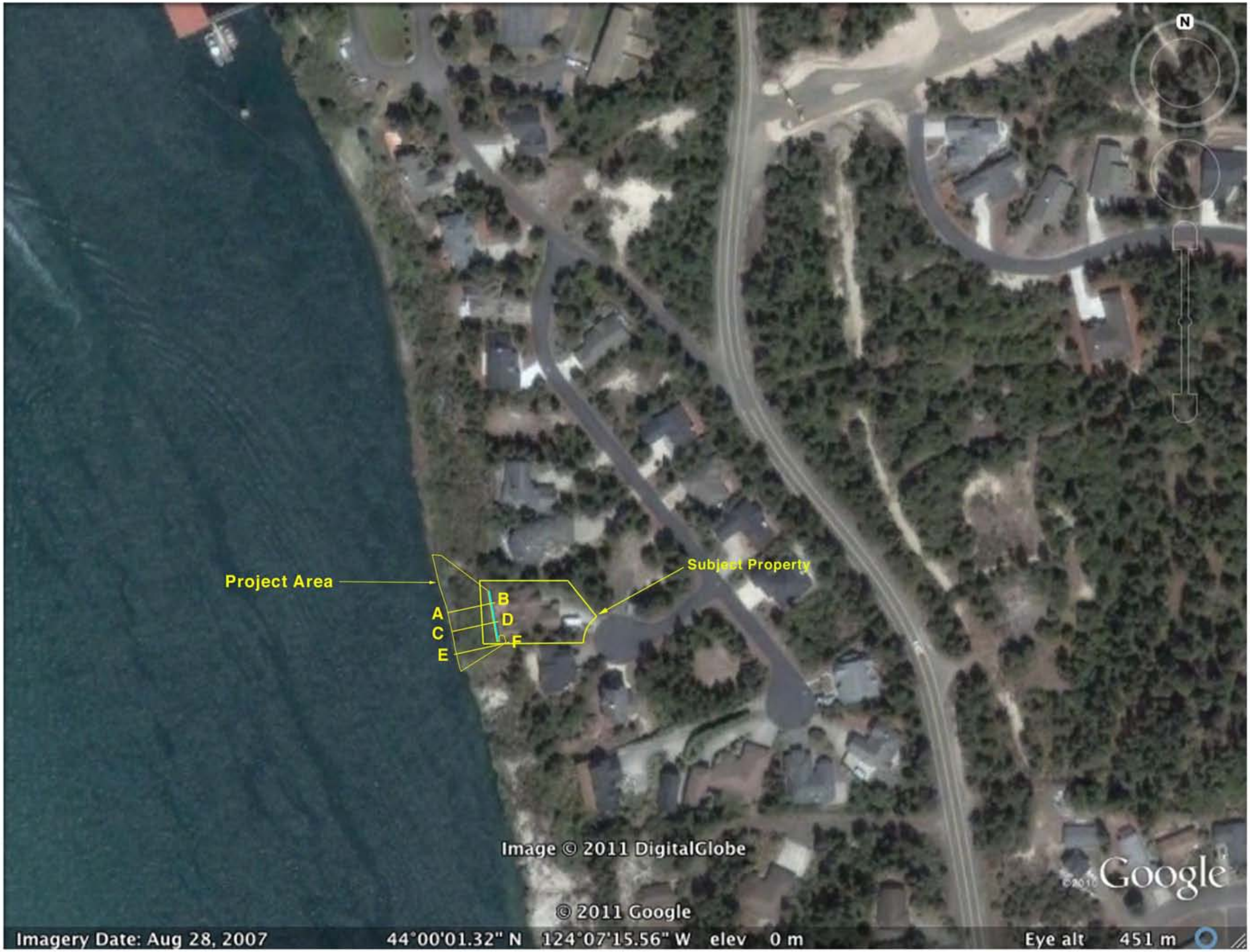

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Figure 10: Approximate Extent of Mitigation Project

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

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