TECHNICAL MEMORANDUM

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Company: Kellington Law Group
Date: 27 February 2023
From: Chris Bahner, PE, D.WRE
Subject: LUBA Comments on Pine Beach and Ocean Boulevard Properties Revetment Design

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INTRODUCTION

This memorandum provides additional information related to four items discussed in the Final Opinion and Order issued by the Oregon Land Use Board of Appeals (LUBA) in cases 2021-101 and 2021-104. The application approved by Tillamook County proposed to add shoreline protection for the oceanfront properties of the Pine Beach subdivision and all but one of the oceanfront lots in the George Shand Tracts (Ocean Boulevard Properties), together referred to as the "Subject Properties."

Since the time of the County's approval of the original application, the one "holdout" property located immediately north of the Subject Properties hired WEST to extend the design of the revetment along their property, so that it ties into the Shorewood RV Park revetment. Tillamook County approved the revetment for the holdout lot in an unrelated land use case. The construction work associated with that lot is now completed, which is to say that a revetment now exists on the west side of hold-out lot, and ties into the revetment on the Subject Properties and Shorewood RV Park.

The Subject Properties are located on the Oregon coast about 2 miles south of Rockaway Beach along the northwest coast of Oregon (Figure 1). Before the installation of the revetment, these oceanfront landowners were losing portions of their property due to coastal erosion and experienced coastal flooding as a result of high tides and wave run-up. The Subject Properties experienced coastal flooding during the King Tides in January of 2021, as well as in February of 2020. During these events, the maximum stillwater level reached the then unprotected oceanfront homes and went past the southernmost home for a distance of about 45 feet. Without the proposed revetment, there existed a high level of risk for future damage to the Subject Properties' land, structures, and associated infrastructure. The Subject Properties were subject to potential future damage from coastal erosion and flooding without the approved revetment.

Figure 1. Location map

Due to the emergency nature of the problem, the Pine Beach / George Shand landowners exercised the rights set forth in the land use entitlement and installed the revetment in November and December of 2021. The installed revetment or shoreline protection structure design and information required by Tillamook County was documented in a technical memorandum completed by WEST in March 2021 (WEST, 2021a). WEST also completed five supplemental technical memoranda: (1) in May 2021 (WEST, 2021b); (2) in June 2021 (WEST, 2021c); (3) on July 21, 2021 (WEST, 2021d); (4) on July 27, 2021 (WEST, 2021e); and (5) in August 2021 (WEST, 2021f).

VACANT LOTS

One of the main objections presented in the LUBA opinion is that the County did not explain why the vacant lots are "appropriate development" under Goal 18 which must be protected by the structure. LUBA faulted the county for not explaining "the role of the vacant lots and the relative location of any infrastructure in its analysis." The LUBA decision implicated suggested that the County needed to evaluate whether the vacant lots could be left unprotected, which is to say that BPS design with gaps needed to be evaluated.

To summarize, two of these vacant lots at issue are located in the George Shand tracts, and two were located in the Pine Beach Subdivision. At the time the revetment was being designed, the owner of one of the vacant lots in the Pine Beach Subdivision was planning construction of a home on the lot, and the design of the revetment took this fact into consideration. That home is now nearly completed. Figure 2 shows the location of the three vacant lots and one lot with the newly constructed home.

Leaving the vacant lots unprotected by the revetment or shoreline protective structure and, instead, proposing a shoreline protective structure that has “gaps” is unacceptable for the following reasons:

- There would be no reduction in coastal flood risk to the developed properties since coastal waters would flow through the gaps on the vacant lots and flood the areas east of the revetment, including the developed properties adjacent to the vacant lots. The current design of the proposed structure would reduce the present-day annual chance of coastal flooding of the area from between 20 and 50% to 8%. The gaps would eliminate the project goal/benefit of reducing the coastal flooding risk, and the chance that the area would experience coastal flooding on annual basis would go back to being between 20 and 50%.
- In addition to not protecting against ocean flooding, the gaps would not protect against future coastal “passive” erosion on the developed lots. The passive erosion and the returning of water through the gaps will create eroded shoreline cusps, which are crescentic seaward projections, that would result in damage to the homes and structure that are situated near the gaps. Figure 3 shows example cusps formed near breakwaters, which in this context function similarly to the approved and constructed revetment has gaps. Smaller scale cusps will form because of ocean water flow concentrating through the gaps that result in erosion from increases in the flow velocity. Structural integrity is a concern with these gaps because floodwaters will flow through and around them and undermine the revetment from behind and erode the developed properties as well.
- It is physically not possible to construct end protection measures (like the ecology block wall along the south end of the structure) along the end borders of vacant lot gaps to provide the necessary coastal flood and erosion protection to the developed lots since: (1) the distance between the homes and their property lines is about 5 feet, which is not enough room to construct required protective end measures; and (2) the end measures could not be located on the vacant lots, unless the vacant lot owners gave their permission (easements) or sell their properties to the non-vacant lot owners, which they are unwilling to do. There was sufficient room along the southern boundary of the southernmost home to provide end protection measures to prevent undermining of the revetment structure from future erosion, but that is not the case for the developed lots that are adjacent to vacant lots. The developed lots would once again be in significant peril if the vacant lots were not protected by the revetment.
- Future “passive” erosion could adversely impact both the homes near the gaps as well as the public infrastructure not protected by these gaps.
- An undulating BPS design – i.e., placing the BPS further landward east of the vacant lots – would make such a BPS less effective and have greater impacts than the proposed linear design. It would require deeper toe depths, require more trees to be removed, larger area of disturbance, and potentially cause damage to structures and public utilities. In particular, any east-to-west oriented BPS that is subjected to wave energy running parallel to the rock structure would be a point of vulnerability.

Figure 2. Map of vacant lots

Figure 3. Example of shoreline cusps

- Simply shutting off public facilities and services (i.e., water, sewer, electricity, gas, etc.) in anticipation of a storm surge or directly after a storm surge is not a practical solution. First, public facility lines are interconnected, and a shut off point will not necessarily be limited to the specific infrastructure in peril. Shutting down utilities to infrastructure in peril, will almost certainly result in utility shut offs for people whose properties are not in peril. Second, not all dangerous storms are forecasted with sufficient certainty for a public utility to justify service shut-downs to otherwise paying customers. Third, as a related problem, the impacts of major storms on imperiled utilities are variable. Particularly strong storms attended by large logs and other debris are capable of disrupting public utility infrastructure beyond discrete water, sewer, electrical, gas, television, telephone or other utility lines at the boundaries of unprotected property. Which storm will have such characteristics, and which will not, may not be possible to forecast with certainty. Fourth, during major storms, it simply may not be possible to safely get utility workers and equipment into imperiled areas before disaster strikes to cut off utility service before environmental and other harm occurs. There could also be other logistics issues in getting to the property in a timely manner or shutting down the service impacting other the people in the area.
- There is a high level of uncertainty in predicting the magnitude, timing, and location of any natural disaster. For coastal environment, NOAA tide gage predictions provide estimates of when King Tides will occur, and NOAA's national data buoy centers provide real-time wave data. Forecasts rely on coastal models drawing from these and other data to predict a storm's path and intensity and provide accurate information about the likely impacts of a storm. However, in all but the most extreme cases, such forecasts are unable to identify when a predicted natural event will imperil or destroy public infrastructure to justify a utility shut-down. There is a balance between the adverse impacts of depriving households of heat, lights, internet, gas, water, sewer and other services and shutting down utility infrastructure in anticipation of a forecasted storm that may damage utility infrastructure. Decisions to deprive households of vital public services have significant consequences and do not occur in the absence of the most extreme storm predictions.
- Once infrastructure is damaged, it can take significant periods of time and significant public investment, to repair and restore damaged infrastructure. Moreover, if sewer or other pathogens/toxins are released due to storm inspired infrastructure damage, it can take considerable time to complete required clean-up, during which time public access and enjoyment is foreclosed for damaged areas.

In summary, gaps in the structure would adversely impact the function and purpose of the structure, and it would not reduce the high level of risk for future damage to structures on the Subject Properties that are near these gaps from coastal flooding and erosion. Moreover, not protecting the vacant properties with the approved revetment would expose the public utility infrastructure that is on, under and around the vacant properties to significant damage. That damage risks environmental damage and resultant loss of access to the public beach and ocean recreation, loss of power and other utility outages for developed and occupied properties, exposing occupants of the developed Subject Properties and other area developed properties to wholly avoidable harms.

FLOOD RISK DURING CONSTRUCTION

As mentioned above, the applicants installed the approved revetment between November 13, 2021 and December 4, 2021. The installation process was completed without increasing the potential for flood damage. The Subject Property owners selected a contractor who had experience building the same type of shoreline protection structure that was constructed at the Subject Property. The contractor implemented a construction risk management plan that included procedures and methods to reduce the impact of risk to the contractor and the public during construction. The proposed structure took less than a month to construct.

The contractor built the structure in segments of three properties at a time to reduce the potential for coastal erosion and flooding during the construction. For each segment, the contractor dug the designed trench to put the revetment's rock into at a point that was 10 feet +/- east toward the houses. He left the vegetated dune in front of these lots intact with the vegetation that had previously existed. As the contractors dug the trench, they deposited the excavated sand on top of the westerly dune. That made the westerly dune temporarily much taller than its normal size, thereby preventing potential flood damage during construction. The trench was backfilled with the sand from the excavation, and excess sand was hauled away. That process increased the flood protection of the sites that had previously existed because the deposited sand provided a barrier that had not previously existed. That excavated sand was then distributed into a berm on the ocean side of the revetment. The berm provided a higher level of protection against coastal flooding than had previously existed even had a storm event occurred when the structure was being built, which it did not. No unusual storms occurred during construction. Images of the temporary construction of the revetment are provided at Figure 4 below.

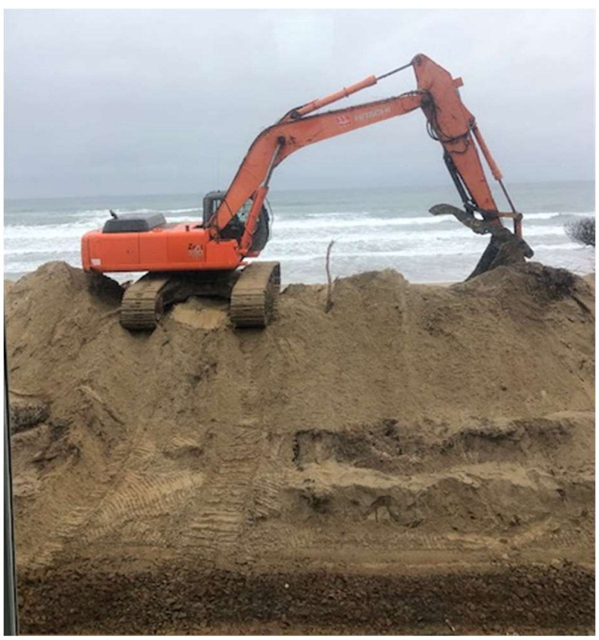

Figure 4. Photos of construction of shoreline protection revetment

FUTURE BEACH CONDITIONS

In the LUBA appeal, project opponents expressed concerns that the revetment might adversely impact the beach in front of the structure. They expressed the concern that the revetment might reduce north-south accessibility, and adversely impact the beach profile that could result in no beach in front of the structure.

The north-south accessibility issue was discussed in great detail in the July 21 WEST technical memorandum (WEST, 2021d). To recap, the revetment has no impact on the north-south beach access in front of the revetment. The beach will continue to be accessible when it is now accessible and will be inaccessible due to extreme high tides and storms. In this regard, the prior WEST analyses indicated that when considering the entire year, the north-south access will be impassable at the Subject Property approximately 1.1-percent of the time. This is associated with extreme combinations of high tides and high waves during winter season where several portions of the beach would be impassable or when less people are walking along the beach due to dangerous or high risk conditions. During the non-winter seasons, the north-south access will be impassable at the Subject Property only 0.1-percent of the time. But again, this is not a result of the installation of the revetment, which is located in the Applicants' vegetated backyards. Rather, the 0.1% figure represents periods of time when the beach is otherwise impassible during non-winter storms or extreme wave runup conditions. The revetment on the Subject Properties is nothing like the Shorewood RV Park revetment which is located 75 feet west of the proposed Subject Property revetment and is at a lower elevation. There is a beach in front of this structure, and it resembles the similar profile shape to the surrounding beach except it has a slightly steeper slope near the structure. The width of beach ranges from about 80 feet for the Mean Higher High Water (MHHW) tidal level to about 500 feet for the Mean Lower Low Water (MLLW) tide level.

Concerns related to the beach profile are addressed by reviewing the beach profile changes reflected in the ongoing beach monitoring data available from the Northwest Association of Networked Ocean Observing Systems (NANOOS) website (NANOOS, 2021) for the period from 1997 to the present. Figure 5 shows the monitoring locations within the Rockaway Beach littoral cell. Rockaway2 is the closest monitoring location to the project site, and it is located about 1,400 feet south of the Pine Beach Development. Figure 6 shows the beach profiles for selected days, ± 1 standard deviation (σ) profiles to capture the 68% of natural variability, and maximum/minimum based on all available survey data. The top figure shows the conditions in early 2021 and the bottom figure shows the conditions in late 2022. Figure 7 shows the contour change plots (heights of 3, 4, 5, and 6 meters). A review of these plots for Rockaway2 indicate: (1) the beach profile has a high level of natural variability, (2) variability is most pronounced at elevation 10 feet and decreases up to elevation 16 feet with no variability existing at elevation 20 feet; (3) the 10 feet contour shoreline has high variability around the mean that has remain relatively constant since 2008; (4) the beach profile has a general parabolic shape with steeper slopes near the beach/dune intersection; and (5) the March profile is to the west of Nov/Dec profile. For references, the MHHW tide level is about 8.3 feet and average water level for the period from 1/2018 to 12/2020 has an average elevation of about 6.1 feet.

The 2014 erosion hazard study (DOGAMI, 2014) is the best study that estimates future projections of shoreline considering sea level rise and a detailed total water level analysis. This study indicates that the high hazard area is not significantly beyond the proposed revetment structure. Based on this information and the NANOOS data, there is a high probability that the beach will remain in front of the Subject Property shoreline revetment in the future.

Figure 5. NANOOS monitoring locations in Rockaway littoral cell

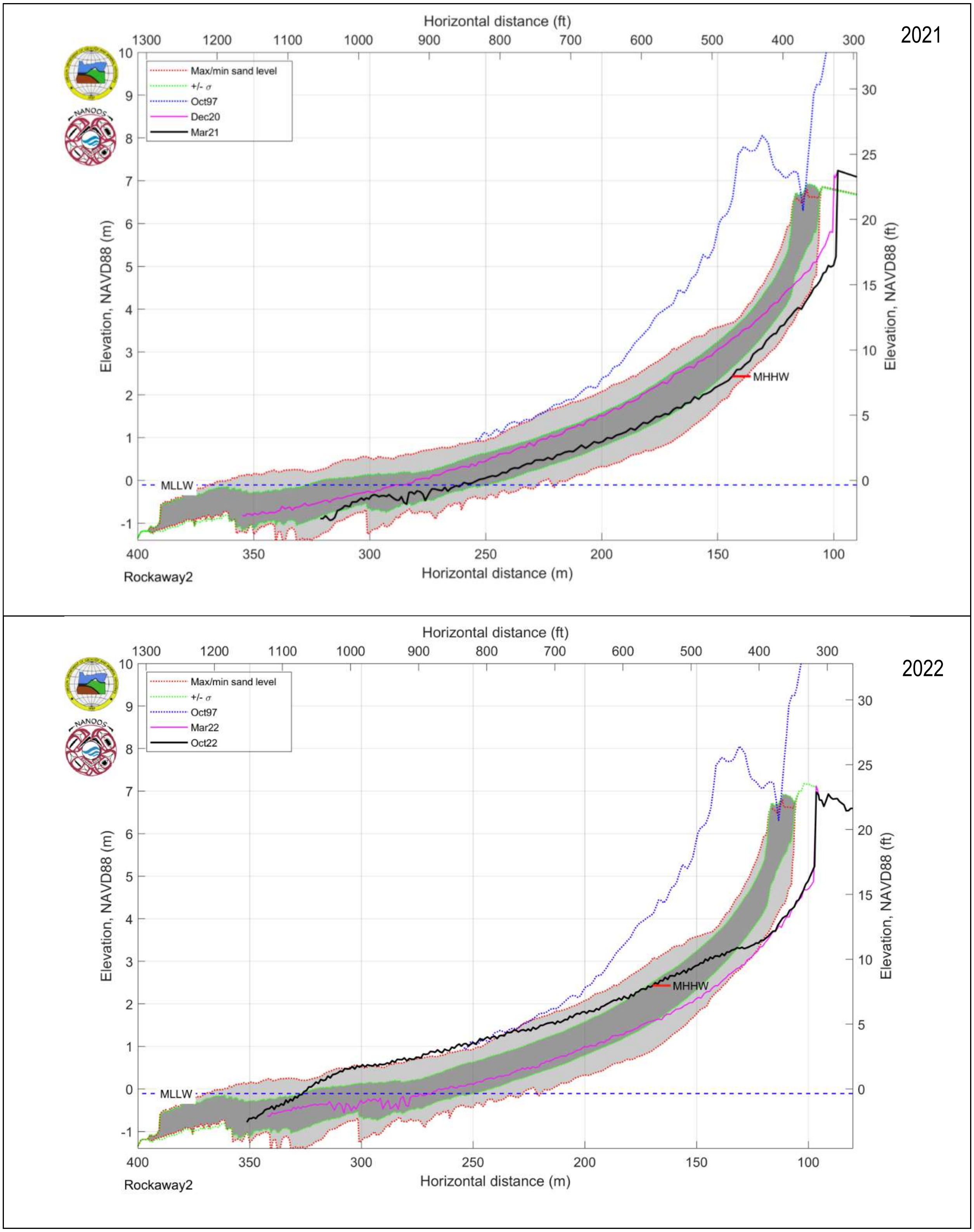

Figure 6. Beach profile along NANOOS Rockaway2 location

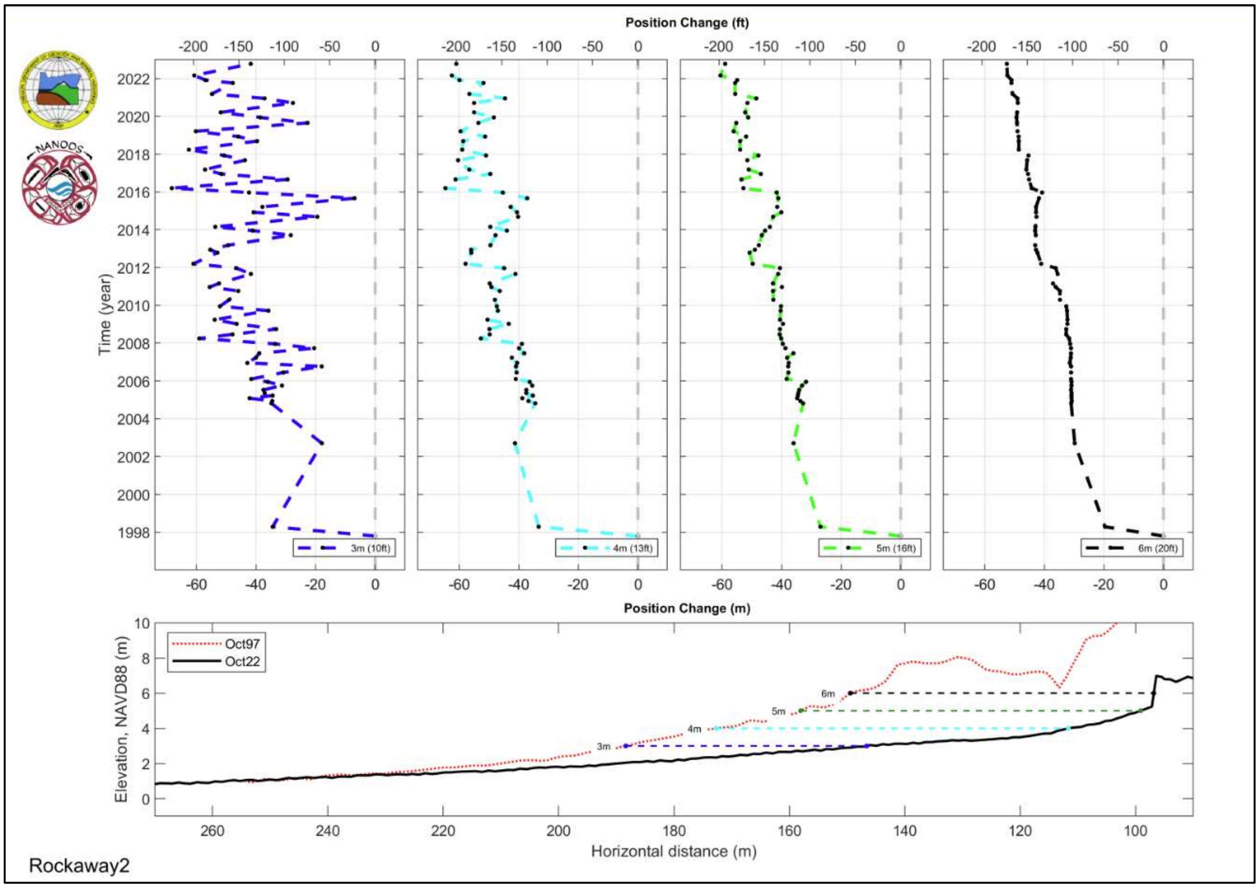

Figure 7. NANOOS Rockaway2 contour (3, 4,5, and 6 meters) changes plots

IMPACTS ON SURROUNDING PROPERTIES

Before LUBA, the Oregon Coastal Alliance argued that there is information that shows adverse impacts historically have occurred with the placement of such shoreline structures, including the most detrimental effect being associated with passive erosion. To properly address this issue, it is important to distinguish the different concepts of coastal erosion related to a shoreline protection measure.

Passive erosion is associated with the shoreline migrating landward on either side of the structure, and it will take place regardless of the structure constructed. It is associated with the fact that the revetment structure is intended to fix the shoreline in place. Active erosion is the assertion that the proposed structure induces or accelerates beach erosion.

By design, shoreline protection measures do have an influence on passive erosion. Indeed, the main purpose of these measures is to protect against future passive erosion. Land not protected by the shoreline protection structure will continue to erode in the same manner as it has in the past. This includes the forested land located south of the Pine Beach lots. Barring any unforeseen changes to the littoral cell, the area to the south will continue to erode at either historical rates or a slightly reduced rate, accounting for the fact that the lands to the east feature more deeply rooted and established forests which should erode more slowly than the younger dunes that eroded over the past 20 years.

As mentioned in the previous section, the beach located west of the approved and constructed revetment structure will not disappear entirely. Due to the physics of wave action, some sand will remain in front of the structure, although it is expected that the beach directly in front of the structure may increase in slope to a certain degree and will take on more of a parabolic shape from a cross-section view.

The more important question is related to active erosion. In relation to active erosion, a detailed literature review (Kraus and McDougal, 1996) and long-term field studies in Virginia (Basco and Ozger, 2001) and California (Griggs etc., 1997) indicate that the shoreline rock revetment structures do not have any long-term adverse impacts with regard to active erosion on the shoreline near the structures. A good summary is provided in *The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary* (Stamski, 2005):

> *Active Erosion*
>
> *Localized, accelerated erosion that might occur because of interactions between armoring structures and waves is referred to as active erosion. This type of erosion includes scour at the base of a protection structure or on adjacent segments of shoreline, and changes in overall beach morphology. Many people feel that seawalls initiate active erosion and are therefore detrimental to coastal environments, yet recent investigations suggest otherwise.*
>
> *A summary of over 40 scientific studies on the interactions between beaches and coastal armoring structures (including seawalls and riprap) found that active erosion may not be as prolific a problem as was once thought (Kraus and McDougal 1996). The review determined that reflection of wave energy off of coastal armor (waves bouncing off perpendicular to a structure) generally does not cause changes in beach profiles or scour in front of the armor. In addition, they ascertained that beach profiles in front of armoring retained the same amount of sand as non-armored beaches during storm events. In an eight-year study by Griggs et al. (1994; 1997), over 2000 beach profiles were collected and analyzed across armored and non-armored beaches around northern Monterey Bay. In this exhaustive investigation, scour was documented in front of an armoring structure only during extreme storm events and the imprint of that scour was ephemeral. The study did find that, as winter approached, the summertime beach berm migrated landward slightly faster in front of coastal protection structures when compared to beaches without armoring. However, once typical, narrow winter beaches were established, there was no significant alongshore difference in the shape of armored and non-armored beaches. In winter months, Griggs et al. (1994) did document some scour on the downcoast end of the structure, extending in an arc-shaped zone for as much as 50 to 150 m. Yet, as summer advanced, the beach width widened and there was no trace of scour or berm erosion caused by the armor.*

Another good explanation related to the Oregon Coast is found in *Impacts of Shoreline Armoring on Sediment Dynamics* (Ruggerio, 2010) and provided as follows:

> *"… three long-term field studies have documented seawall-backed beaches experiencing no significant negative impacts. These studies, in California (Griggs and others, 1994), Oregon (Hearon and others, 1996), and Virginia (Jones and Basco, 1996), each extend over time scales on*

the order of a decade. No measurable or significant differences between profiles for seawall-backed and non-armored beaches were found in these studies, suggesting little long-term effect of seawalls on the beaches. Because these studies spanned periods of only about a decade, however, sea-level rise, and therefore passive erosion, was relatively unimportant. These studies were assessing the impacts of seawalls on beaches that intermittently were experiencing active erosion.

… Weggel (1988) suggested a classification of seawall types based on the seawall's position on the beach and the water depth at the toe of the structure (table 1). The beaches in the Oregon and California field studies would be classified as Type I to Type III, depending on the season and storm condition, whereas the seawalls studied in Virginia can be classified as Type III to Type IV, depending on season and location. In this context, the Weggel (1988) classification helps to explain why the Oregon and California study sites experienced few decadal scale impacts as a result of armoring but sheds little light on the minor impacts experienced in the Virginia study."

In summary, the above citations support the conclusion that the proposed revetment structure, which is considered to be Type II structures under the Weggel Classification system, will not have an adverse impact on the surrounding southern property, which is to say that the structures will cause active erosion. There are no concerns with the northern end of the structure since it ties into the existing Shorewood RV Park revetment.

REFERENCES

State of Oregon Department of Geology and Mineral Industries, 2014. *Evaluation of Erosion Hazard Zones for the Dune-Backed Beaches of Tillamook County, Oregon, Technical Report to the Oregon Department of Land Conservation and Development,* prepared by Laura L Stimely and Jonathan C. Allan

Basco, D.R., 2000. *Beach Monitoring Results and Management Plan FCTCLANT, Dam neck, Virginia Beach, VA*, Beach Consultants, Inc. Norfolk, VA.

Basco, D.R., and Ozger, S.S. 2001. *Toward Quantification of the Active Sand Volume in the Surf Zone, VA*, Beach Consultants, Inc. Norfolk, VA.

Gardner, Meg, DLCD, 2015. *Analysis of Shoreline Armoring & Erosion Policies Along the Oregon Coast*.

Griggs G.B., Tait, J.F., and Corona, W. 1994. *Seven years of monitoring, Monterey Bay, California*, Shore and Beaches, v. 62, p. 21-28.

Griggs, G.B., Tait, J.F., Moore, L.J., Scott, K., Corona, W., and Pembrook D. 1997. *Interaction of seawalls and beaches – Eight years of field monitoring, Monterey Bay, California*, Washington, D.C., U.S. Army Corps of Engineers Waterways Experiment Station Contract R. CHL-97-1.

Kraus N.C., and McDougal, W.G., 1996. *The effects of seawalls on the beach – Extended literature review*, Journal of Coastal Research, Special Issue No. 4, Autumn 1988, p. 1-28.

Northwest Associate of Networked Ocean Observing Systems (NANOOS), 2021. NVS : Beach and Shoreline Changes (nanoos.org), accessed May 2021

Oregon Land Use Board of Appeal (LUBA), 2022 (September). *LUBA No. 2021-101, 2021-104. Before the Land Use Board of Appeals of the State of Oregon, Oregon Coast Alliance, Petitioner, and Oregon Department of Land Conservation and Development, Intervenor-Petitioner vs. Tillamook County, Respondent, and Michael Rogers, Christine Rogers, Bill Cogdall, Lynda Cogdall, Jon Creedon, David Farr, Frieda Farr, Don Roberts, Barbara Roberts, Rachel Holland, Jeffrey Klein, Terry Klein, Dave Hayes, Michael Ellis, Michael Munch, Angela Dowling, David Dowling, Megan Steck Berg, Evan Danno, Mark Kemball, Alice Kemball, Mary Ann Lockwood Family Trust and Heather Steck Von Seggern, Intervenors-Respondents*.

Ruggiero, Peter 2010 (January). *Impacts of Shoreline Amroring on Sediment Dynamics*.

Stamski, Rebecca, 2005. *The impacts of coastal protection structures in California's Monterey Bay National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-05-3*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD. 18 pp.

State of Oregon Department of Geology and Mineral Industries, 2012. *LiDAR Data for Oregon Central Coast*

USACE, 2014. *USACE NCMP Topobathy Lidar: Oregon.* Data accessed from NOAA Digital Coast website, https://coast.noaa.gov/dataviewer/#/lidar/search/where:ID=4906

WEST, 2021a (March). *Technical Memorandum, Subject: Pine Beach Revetment Design*

WEST, 2021b (May). *Technical Memorandum, Subject: Supplement to the March 2021 Pine Beach Revetment Technical Memorandum*

WEST, 2021c (June). *Technical Memorandum, Subject: Second Supplement Memorandum*

WEST, 2021d (July 21a). *Technical Memorandum, Subject: Third Supplement Memorandum*

WEST, 2021e (July 21b). *Technical Memorandum, Subject: Fourth Supplement Memorandum*

WEST, 2021f (August 2). *Technical Memorandum, Subject: Fifth Supplement Memorandum*

Weggel, J.R., 1988. *Seawalls: The Need for Research, Dimensional Consideration and a Suggested Classification*, Special Issue No. 4, Journal of Coastal Research, pp 29-40.

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SENIOR PROJECT MANAGER

Mr. Bahner is a hydraulic engineer with WEST Consultants. He has experience and a strong educational background in hydraulic engineering and numerical modeling. His experience includes performing hydraulic and sedimentation analyses for flood control studies, hydraulic modeling, sediment erosion and deposition modeling, and design of hydraulic structures. Mr. Bahner is familiar with a number of hydraulic and hydrologic computer modeling programs.

Mr. Bahner was the lead engineering in a shoreline erosion study along the southern coast of Oregon; a shoreline erosion protection study near Nome, Alaska; evaluating the hydraulics and scour, and designing bank protection measures from hydrodynamic and wave force for 13 Oregon coast tidally influenced bridges; design revetment structures against waves for three sites in Coos Bay; design revetment structures against wind and ship waves for several sites on the Columbia River; and designing rock revetment against wave action for about 30 reservoirs.

Mr. Bahner has also asssessed the hydraulics and potential scour for proposed bridge modifications in Idaho, Oregon, Hawaii, California, and Mexico; defined flood inundation boundaries for various flood insurance studies and Letters of Map Revisions; and evaluated the hydraulics of the lower Las Vegas Wash for existing conditions and for several proposed grade control structures and a bypass channel. Using HEC-RAS (Unsteady), he has evaluated impacts from upstream improvements on the lower Truckee River floodplain boundaries; analyzed the hydraulics through several quarry ponds along Mill Creek in Salem, OR; assessed the risk associated with the releases from the proposed Systems Conveyance and Operations Program project; evaluated potential impacts of Early Implementation Projects on the Sacramento River; assessed dam and levee breaches and corresponding inundation boundaries; and analyzed spillway alternatives for McMullen Dam.

Additional notable projects include evaluating impacts of a proposed LNG terminal on the lower Columbia River; defining the flood inundation boundaries of several urbanized areas; analyzing the hydraulic characteristics of various waterbodies; and evaluating the Wappapello Dam spillway, bank erosion for several sites along the Columbia River, the hydraulics at McMullen Dam, and the hydraulics of Prickett Creek near NW Stringtown Road.

Notable sediment transport efforts include assessing the sedimentation of slag deposits on the upper Columbia River, deposition within Cochiti Reservoir, and sediment transport potential of Big River and Salt River; designing a bypass channel for the Plattsmouth Bend Project; estimating the long-term degradation depth at Stuart Mesa Bridge over Santa Margarita River; evaluating degradation and aggradation of the lower Las Vegas Wash; and assessing the sedimentation potential for a proposed intake structure on the Missouri River.

Prior to WEST, Mr. Bahner worked at the USACE, Los Angeles District, where he was the lead hydraulic engineer for several flood control projects, performed hydraulic and sedimentation analyses for feasibility studies and design memoranda, and completed final hydraulic designs of flood control structures

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- *Diplomate, American Academy of Water Resources Engineers; AASRE 00097*

Professional Affiliations
- *American Society of Civil Engineers*

TRAINING

- HYDROLOGIC SIMULATION PROGRAM – FORTRAN (HSPF), Aqua Terra
- Unsteady Flow Analysis (HEC-RAS Version 3.0), U.S. Army Corps of Engineers Hydrologic Engineering Center
- HEC-HMS, WEST Consultants, Inc.
- HEC-6, WEST Consultants, Inc.
- HEC-2, U.S. Army Corps of Engineers Hydrologic Engineering Center
- SRH-2D, Bureau of Reclamation
- Corps Water Management System (CWMS), U.S. Army Corps of Engineers Hydrologic Engineering Center
- Sedimentation Investigation of Rivers and Reservoirs, U.S. Army Corps of Engineers Engineering Research Development Center (formerly known as Waterways Experiment Station)
- Hydraulic Design of Flood Control Channels, U.S. Army Corps of Engineers Engineering Research Development Center (formerly known as Waterways Experiment Station)
- Hydraulic Design of Spillway and Outlet Works, U.S. Army Corps of Engineers Engineering Research Development Center (formerly known as Waterways Experiment Station)

BIBLIOGRAPHY

Bahner, Chris D., *Flood Risk Reduction Structure for Morgan Lake Dam,* prepared for SedHyd Conference, December 2022.

Bahner, Chris D., *Columbia River Carbonate Proposed Columbia River Barge Facility Hydraulic and Scour Analyses and Revetment Design,* 2022.

Bahner, Chris D., *Lower Columbia River Stage-Frequency Study Mandatory Task 0008: Lower Columbia HEC-WAT Model,* prepared for U.S. Army Corps of Engineers, Portland District, November 2020.

Bahner, Chris D., *Sediment Transport Analysis of Missouri River for Red River Valley Water Supply Project McLean County, North Dakota,* prepared for SedHyd Conference, January 2019.

Bahner, Chris D., and Duren, Angela, *Hydrologic Risk Analyses for Willamette River Basin Dams,* prepared for SedHyd Conference, January 2019.

Bahner, Chris D., *Newmark Avenue Bank Protection Analysis and Design, Coos County*, 2019.

Bahner, Chris D., *Hollering Place Bank Protection Analysis and Design, Coos County*, 2018.

Bahner, Chris D., *Coos Bay Boardwalk Dike Emergency Bank Protection Design, Coos County*, 2017.

Bahner, Chris D., *Hazard Studies for the Bear River Hydroelectric Project, Development of the Probable Maximum Flood Report,* prepared for PacifiCorp, November 2017.

Bahner, Chris D., *Probable Maximum Flood Report, Willamette River Basin (Oregon),* prepared for U.S. Army Corps of Engineers, Portland District, September 2017.

Bahner, Chris D., *Probable Maximum Precipitation Report, Willamette River Basin (Oregon),* prepared for U.S. Army Corps of Engineers, Portland District, December 2016.

Bahner, Chris D., *Hydrologic Model Calibration and Validation Report, Willamette River Basin (Oregon),* prepared for U.S. Army Corps of Engineers, Portland District, December 2016.

Bahner, Chris D., *Extreme Storms Report, Willamette River Basin (Oregon),* prepared for U.S. Army Corps of Engineers, Portland District, July 2016.

Bahner, Chris D., *Comparison of 2-Dimensional Hydraulic Models for Assessing Levee Breach Inundations,* Association of State Dam Safety Official (ASDSO) 2013 Dam Safety Conference, Providence, RI, September 2013.

Bahner, Chris D., *Life Loss Estimates to Support Levee Safety Risk Assessment Using LifeSim,* Association of State Dam Safety Official (ASDSO) 2012 Dam Safety Conference, Denver, CO, September 2012.

Bahner, Chris D., Goodell, Chris, and Needham, Jason, *Life Loss Estimates to Support Levee Safety Risk Assessment Using LifeSim,* 32nd United States Society of Dams (USSD) Annual Meeting and Conference, New Orleans, LA, April 2012.

Bahner, Chris D., *Dry Bypass Pump Station Feasibility and Alternatives Analysis of the Napa River/Napa Creek Flood Protection Project, Napa County, California,* abstract and presentation for 2011 USACE Infrastructure System Conference, Atlanta, GA, June 2011.

Bahner, Chris D., *Comparison of Estimated Scour Depths for Tidally Influenced Bridges Using One and Two Dimensional Hydraulics Models,* abstract and presentation for Oregon Department of Transportation 2009 Geo/Hydro/HazMat Conference, Sustaining Oregon's Aging Highways, Lincoln City, OR, September 2009.

Bahner, Chris D., Grindeland, Thomas R. and Deering, Michael K., *Documentation and Demonstration of a Process for Conducting Risk Analysis for Hydraulic Impacts of the Proposed Modification to the Sacramento River Flood Control Project,* abstract and presentation for 2009 USACE Infrastructure System Conference, Cleveland, OH, 2009.

Bahner, Chris D., and Grindeland, Thomas R., *Documentation and Demonstration of a Process for Conducting Risk Analysis for Hydraulic Impacts of the Proposed Modification to the Sacramento River Flood Control Project,* abstract and presentation for 2009 Northwest Regional Floodplain Management Association (NORFMA), Yakima, WA, 2009.

Bahner, Chris D., Grindeland, Thomas R., Goodell, Chris, and Bradley Jeffrey B., *Documentation and Demonstration of a Process for Risk Analysis of Proposed Modifications to the Sacramento River Flood Control Project (SRFCP) Levees*, which became PR-71 published by the U.S. Army Corp of Engineers, Hydrologic Engineering Center, 2009.

Bahner, Chris D., *Outlet Tunnel Slab Damage at Seven Oaks Dam,* abstract and presentation for 29th United States Society of Dams (USSD) Annual Meeting and Conference, Nashville, TN, April 2008.

Bahner, Chris D., *Inadequate Evaluation of the "No-Rise" Condition Using a Steady State Hydraulic Model for Unsteady Flow Conditions,* abstract and presentation for the 2007 Annual Floodplain Management Association Conference, Lake Tahoe, CA, 2007.

Bahner, Chris D., *Moses Point to Elim, AK Road Repair, ERFO Design Report,* prepared for Federal Highway Administration, Western Federal Lands Highway Division, 2007.

Bahner, Chris D., *Restoration of Lower Las Vegas Wash – Upper Diversion Weir,* abstract and presentation for the Joint 8th Federal Interagency Sedimentation and 3rd Hydrologic Conferences, Reno, NV, April 2006.

Bradley, Jeffrey B., Richards, Dennis L. and Bahner, Chris D., *Debris Control Structures – Evaluation and Countermeasures, Hydraulic Engineering Circular 9, Third Edition,* published by the U.S. Department of Transportation, Federal Highway Administration, 2005.

Willamette River Basin Winter, Regulated Volume Flow Frequency Curves Report, Willamette River Basin (Oregon), prepared for U.S. Army Corps of Engineers, Portland District, August 2019.

Willamette River Basin Dams, PMF Report, Willamette River Basin (Oregon), prepared for U.S. Army Corps of Engineers, Portland District, March 2018.

Willamette River Basin Dams, PMP Report, Willamette River Basin (Oregon), prepared for U.S. Army Corps of Engineers, Portland District, July 2017.

Willamette River Basin Dams, Hydrologic Model Calibration and Validation Report, Willamette River Basin (Oregon), prepared for U.S. Army Corps of Engineers, Portland District, December 2016.

Willamette River Basin Dams, Extreme Storms Report, Willamette River Basin (Oregon), prepared for U.S. Army Corps of Engineers, Portland District, July 2016.

Dam Breach Study and Flood Inundation Mapping for Silver Creek Dam Marion County, Oregon, NID# OR00622, prepared for City of Silverton, 2020.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 07949A-D, Astoria Megler Bridge, Pacific Coast Highway, Mile Point 0.00, Clatsop County, Oregon Department of Transportation, 2012.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 08306, New Youngs bay Bridge, Pacific Coast Highway, Mile Point 4.91, Clatsop County, Oregon Department of Transportation, 2012.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01820, Yaquina Bay Bridge, Pacific Coast Highway, Mile Point 141.68, Lincoln County, Oregon Department of Transportation, 2012.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01820, Alsea Bay Bridge, Pacific Coast Highway, Mile Point 155.54, Lincoln County, Oregon Department of Transportation, 2012.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01391A, Beaver Creek Bridge, Pacific Coast Highway, Mile Point 149.02, Lincoln County, Oregon Department of Transportation, 2012.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01113, Cape Creek Bridge, Pacific Coast Highway, Mile Point 178.35, Lane County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01823, McCullough Coos Bay Bridge, Pacific Coast Highway, Mile Point 233.99, Coos County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 07020, Coquille (Bullards) River Bridge, Pacific Coast Highway, Mile Point 259.69, Coos County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01143D, Chetco River Bridge, Pacific Coast Highway, Mile Point 358.0, Curry County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 03339A, Hubbard Creek Bridge, Pacific Coast Highway, Mile Point 302.28, Curry County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 08290, Hunter Creek Bridge, Pacific Coast Highway, Mile Point 330.5, Curry County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 09091A, Winchuck River Bridge, Pacific Coast Highway, Mile Point 362.6, Curry County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01822, Umpqua River & McIntosh Slough Bridge, Pacific Coast Highway, Mile Point 211.11, Douglas County, Oregon Department of Transportation, 2010.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01173D, Yachats River Bridge, Pacific Coast Highway, Mile Point 164.73, Lincoln County, Oregon Department of Transportation, 2009.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 08719, Pistol River Bridge, Pacific Coast Highway, Mile Point 339.1, Curry County, Oregon Department of Transportation, 2009.

Bridge Hydraulic and Scour Assessment Detailed Report for Bridge No. 01430A, Big Creek Bridge, Pacific Coast Highway, Mile Point 160.15, Lincoln County, Oregon Department of Transportation, 2009.

Rock Creek Section 103, Shoreline Erosion Study, U.S. Army Corps of Engineers, Portland District, 2002.

Decision Document for Operation and Maintenance, San Luis Rey Flood Control Project, U.S. Army Corps of Engineers, Los Angeles District, 2001.

Hydraulic Appendix, *Decision Document for Operation and Maintenance, San Luis Rey Flood Control Project*, U.S. Army Corps of Engineers, Los Angeles District, 2001.

Hydraulic Appendix, *Feature Design Memorandum, Prado Dam Spillway*, U.S. Army Corps of Engineers, Los Angeles District, 2001.

Hydraulic Appendix, *Murrieta Creek Flood Control Study*, U.S. Army Corps of Engineers, Los Angeles District, 2000.

Hydraulic Appendix, *Prado Dam Water Supply Study*, U.S. Army Corps of Engineers, Los Angeles District, 2000.

Hydraulic Appendix, *Decision Documentation Report for Lower Norco Bluffs*, U.S. Army Corps of Engineers, Los Angeles District, 1999.

Floodplain Evaluation Report, Naval Air Weapons, Point Mugu, California, U.S. Army Corps of Engineers, Los Angeles District, 1998.

Bahner, Chris D., *Physical Model Study of Prado Dam Spillway,* published for the ASCE Water Resources Planning and Management Conference, Anaheim, CA, 1998.

Hydraulic Appendix, *Murrieta Creek Floodplain Maintenance Study*, U.S. Army Corps of Engineers, Los Angeles District, 1998.

Hydraulic Appendix, *Feature Design Memorandum, Prado Dam Outlet Works*, U.S. Army Corps of Engineers, Los Angeles District, 1998.

Hydraulic Appendix, *Decision Documentation Report for Environmental Restoration of Gunnerson Pond*, U.S. Army Corps of Engineers, Los Angeles District, 1997.