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Memorandum

Date: **April 13, 2018**

To: **Theresa Engle, San Mateo County**

From: **Jennifer Abrams, WRECO**

Project: **Mirada Road Revetment Project**

Subject: **Sand Supply Calculations for Soil Nail Wall**

Introduction

This memorandum summarizes the sand supply calculations performed by WRECO for the County of San Mateo Department of Public Works (County) to quantify impacts from the Mirada Road Revetment Project (Project) soil nail wall. The key tasks performed by WRECO were to:

- Estimate historical rate of bluff recession,
- Calculate the volume of sand retained or covered by the soil nail wall,
- Estimate the beach loss due to the Project, and
- Estimate the cost of nourishing the beach.

The methodology used for these calculations follows the California Coastal Commission's (CCC's) worksheets for sand supply analysis (see attached).

Project Description

The County proposes construction of soil nail reinforced, sculpted shotcrete walls at three locations along the Mirada Road bluff that experienced extensive erosion associated with El Nino storms during the 2015/2016 rainy season. The proposed Project is located approximately 0.15 miles west of State Route 1 from Medio Avenue to the Mirada Road cul de sac south of the current pedestrian bridge. The Project location is shown in Figure 1. The wall would be approximately 125 feet in length at the first location to the north of the pedestrian bridge, 55 feet long at the northeastern abutment of the pedestrian bridge, and 90 feet in length at the third location to the south of the pedestrian bridge. The 125-ft and 55-ft walls are within the County's right-of-way and the 90-ft wall is within the City of Half Moon Bay's (City's) right-of-way. The typical cross section of the proposed soil nail wall, provided by the County, is included in the attachments. The soil nail wall's concrete is 6 inches thick. At the 125-ft segment of wall, there is an average of 2.5 ft of controlled low strength material (CLSM) behind the wall, for a total thickness of 3 ft.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 1. Project Vicinity Map

Armored Width of Property

The proposed 125-ft soil nail wall would be protecting 125 ft of shoreline. However, the proposed 55-ft and 90-ft soil nail walls are oriented at an angle to the shoreline. A straight line approximating the angle of the shore was delineated for each of these two walls and the endpoints of the soil nail walls were projected onto their respective lines. The result is that the 55-ft wall would be protecting 25 ft of shoreline and the 90-ft wall would be protecting 65 ft of shoreline.

Bluff and Wall Height

Survey data of the road, beach, and bluff in early 2017 were obtained from RSE Surveyors and the County. Cross sections of the bluff are shown in Figure 2. Two cross sections were assumed to be representative of the proposed improvements: one near the center of the northern, 125-ft segment of soil nail wall, and the second near the center of the southern, 90-ft segment of soil nail wall. The precise location of the toe in the northern cross section is not obviously defined by the geometry of the cross section, so the 17.0 ft height of wall provided by the County was used. At the southern cross section, the toe of bluff is clearly defined, 18.4 ft below the top of bluff. The bluff heights were used to calculate the volume of sand required to replace 1 square foot of beach seaward of the wall. The results are summarized in Table 1.

Table 1. Wall Height and Unit Sand Volume

Wall Segment	Wall Height (ft)	Volume of Sand to replace 1 ft^2 of beach (yd^3)
Northern (125-ft)	17.0	0.63
Middle (55-ft)	17.0	0.63
Southern (90-ft)	18.4	0.68

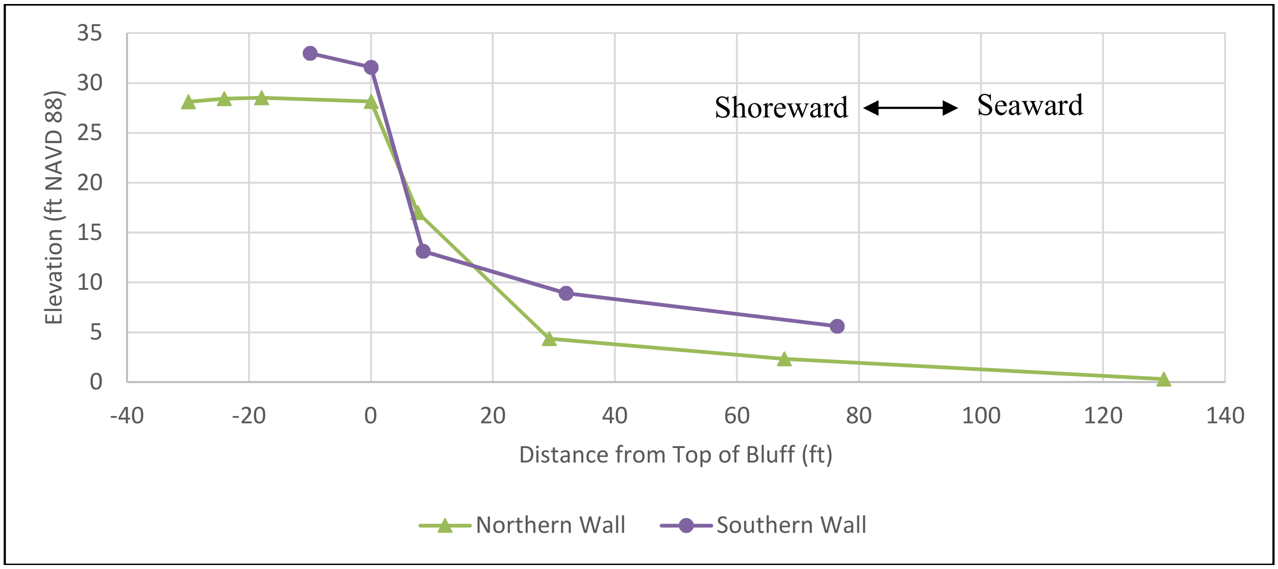

Figure 2. Bluff Cross Sections

Bluff Retreat Rate

The existing bluff has RSP armor, so the historical rate of retreat at the site cannot be directly calculated from site measurements. Therefore, the rate of bluff retreat at the site was estimated based on the rate of retreat at the nearest neighboring unarmored stretches of bluff north and south of the site. The historical top of bluff locations – estimated based on available aerial imagery from 1991, 2003, and 2016 – are shown for reference in Figure 3. The current and past top of bluff locations were delineated based on historical aerial imagery from Google Earth, georeferenced in ArcMap. The edge of vegetation was assumed to indicate the top of bluff, and the toe of bluff was assumed to retreat at the same rate as the top of bluff. North of the site, 1,000 ft of shoreline was traced from 1991, 2003, and 2016. South of the site, 1,000 ft of shoreline was traced from 2003 and 2016, as there was not an earlier image available that was of high-enough resolution to discern the top of slope.

The United States Army Corps of Engineers (USACE) estimated a rate of retreat of 1.64 ft/yr north of the site and 0 ft/yr south of the site under current sea level conditions (Lin, Li, Zoulas, Andes, & Wu 2015). Per coordination with the California Coastal Commission, the average of the two rates (0.82 ft/yr) was selected as the representative rate at the site, for the purpose of calculating sand supply costs.

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Figure 3. Historical Tops of Bluff

Sea Level Rise

Per the *State of California Sea-Level Rise Guidance Document* (Coastal and Ocean Working Group of the California Climate Action Team 2013), projects must consider sea level rise in their design. Per *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (National Academy of Sciences 2012), the anticipated sea level rise in 2100 at the Project site is 1.4 to 5.5 ft (compared with elevations in 2000). As sea levels increase, bluff erosion rates are expected to increase, as wave energy will reach the toe of bluff or higher more frequently. However, given the approximations involved in the sand supply analysis, projection of future sea levels as a function of time, and determining the proportion of erosion due to wave energy, analysis of the increased rate of erosion would be highly uncertain. For the sand supply analysis, the historical bluff retreat rate was assumed to be representative of the future rate.

Sand Fraction

Based on geotechnical analysis, these bluffs do not contain coarse particles that weather into sand-quality material. The only sources of sediment at the site are the creek and shore transport. Therefore, the Project is not preventing any sand from entering the littoral cell and the fraction of beach quality material is zero.

Cost of Sand

The cost of purchasing and transporting sand was estimated based on the Caltrans Cost Data book results for the cost of Sand Bedding in District 4, as $65 per cubic yard in 2017 dollars.

Summary of Input Variables

Based on the analyses discussed above, the variables used in the sand supply volume calculations are summarized in Table 2.

Table 2. Summary of Input Variables

Variable	Description	125-ft Wall	55-ft Wall	90-ft Wall
W	Width of property to be armored (feet)	125	25	65
E	Distance from toe of bluff to seaward limit of protection (feet)	3	0.5	0.5
v	Volume of material required per unit width of beach to replace one foot of beach seaward of the seawall (cubic yards per square foot)	0.63	0.63	0.68
R, R_{cu}	Retreat rate without armoring (feet per year)	0.82		
L	Design life of the armoring without maintenance (years)	50		
S	Fraction of beach quality material in the bluff material	0		
h_s	Height of seawall from the base to top of bluff (feet)	17.0	17.0	18.4
h_u	Height of unprotected upper bluff (feet)	0		
R_{cs}	Rate of bluff crest retreat assuming seawall installed (feet per year)	0		
C	Cost per cubic yard of sand	$65		

Volume and Cost Calculations

The following details the calculations used to determine the volume per the CCC worksheets. Variable names and values used are included in Table 2.

The volume of sand to rebuild the area of beach lost due to the seawall encroachment (V_e) is calculated based on the area of the soil nail wall (A_e) and the volume of material required per unit width of beach to replace or re-establish one foot of beach seaward of the seawall:

$$V_e = A_e \text{ x } v = W \text{ x } E \text{ x } v$$

The calculations are summarized in Table 3.

Table 3. A_e Calculation

	125-ft Wall	55-ft Wall	90-ft Wall
W (ft)	125	25	65
E (ft)	3	0.5	0.5
A_e (ft^2)	375	13	33
v (cy/ft^2)	0.63	0.63	0.68
V_e (cy)	236	8	22

Note: See Table 2 for definitions of variables.

The volume of sand to rebuild the area of beach lost due to long-term erosion (V_w) is calculated based on the bluff recession rate, length of project, and design life of the soil nail wall:

$$V_w = A_w \text{ x } v = R \text{ x } L \text{ x } W \text{ x } v$$

Table 4. A_w Calculation

Variable	125-ft Wall	55-ft Wall	90-ft Wall
R (ft/year)	0.82	0.82	0.82
L (years)	50	50	50
W (ft)	125	25	65
A_w (ft^2)	5,125	1,025	2,665
v (cy/ft^2)	0.63	0.63	0.68
V_w (cy)	3,229	646	1,812

Note: See Table 2 for definitions of variables.

The Project does not prevent beach quality bluff material from entering the sand supply, so the long-term reduction in sediment supply from the reduced bluff erosion (V_b) is 0.

The total volume of sand required to replace losses due to the structure (V_t) is the sum of V_e, V_w, and V_b. The volumes are then multiplied by $65 per cubic yard. The resulting costs calculated by the worksheets are included in Table 5. The total cost within the County's sites is $267,000 and the total cost within the City's site is $119,000.

Table 5. Total Volume and Cost Calculation

	125-ft Wall	55-ft Wall	90-ft Wall
V_e (cy)	236	8	22
V_w (cy)	3,229	646	1,812
V_b (cy)	0	0	0
Total, V_t (cy)	3,465	654	1,834
Cost	$225,000	$42,000	$119,000

References

California Coastal Commission. *Beach Sand Replenishment In-lieu Fee Worksheet.*

California Department of Transportation. *Contract Cost Data.* <http://sv08data.dot.ca.gov/contractcost/> Last accessed: March 31, 2017.

Coastal and Ocean Working Group of the California Climate Action Team. (March 2013). *State of California Sea-Level Rise Guidance Document*.

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National Academy of Sciences. (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*.

Lin, L., Li, H., Zoulas, J., Andes, L., & Wu, F. (January 2015). *North Half Moon Bay Shoreline Imrpovement Project, Pillar Point Harbor, CA Coastal Engineering Appendix.*

WRECO. (2017). *Log of Test Borings*.

Attachments

- CCC Worksheets
- Typical Section and Details

125 ft Wall

W = 125 ft
E = 3 ft
v = 0.63 CY/ft^2
R = 0.82 ft/yr
L = 50 years
S = 0

$$\left.\begin{array}{l} h_s = \\ h_u = \\ R_{cu} = \\ R_{cs} = \end{array}\right\} \text{N/A because } S=0$$

C = \$65/CY

$V_c = A_c \times v$

$V_c = W \times E \times V = 125\,ft \times 3\,ft \times 0.63\,CY/ft^2$
$= 236\,CY$

$V_w = A_w \times v$

$V_w = R \times L \times W \times V = 0.82\,ft/yr \times 50\,years \times 125\,ft \times 0.63\,CY/ft^2$
$= 3{,}229\,CY$

$V_b = (S \times W \times L) \times [(R \times h_s) + (1/2 h_u \times (R + (R_{cu} - R_{cs})))]/27$

$V_b = 0$ because $S = 0$

$V_t = V_b + V_w + V_c$

$V_t = 0 + 3{,}229\,CY + 236\,CY = 3{,}465\,CY$

$M = V_t \times C$

$M = 3{,}465\,CY \times \$65/CY = \$\,225{,}000$

55-ft Wall

W = 25 ft
E = 0.5 ft
v = 0.63 CY/ft^2
R = 0.82 ft/yr
L = 50 years
S = 0

$$\left.\begin{array}{l} h_s = \\ h_u = \\ R_{cu} = \\ R_{cs} = \end{array}\right\} \text{N/A because } S=0$$

C = \$65/CY

$V_e = A_e \text{ x } v$

$V_e = W \times E \times V = 25 \text{ ft} \times 0.5 \text{ ft} \times 0.63 \text{ CY/ft}^2$
$= 8 \text{ CY}$

$V_w = A_w \text{ x } v$

$V_w = R \times L \times W \times V = 0.82 \text{ ft/yr} \times 50 \text{ years} \times 25 \text{ ft} \times 0.63 \text{ CY/ft}^2$
$= 646 \text{ CY}$

$V_b = (S \text{ x } W \text{ x } L) \text{ x } [(R \text{ x } h_s) + (1/2 h_u \text{ x } (R + (R_{cu} - R_{cs})))]/27$

V_b = 0 because $S = 0$

$V_t = V_b + V_w + V_e$

$V_t = 0 + 646 \text{ CY} + 8 \text{ CY} = 654 \text{ CY}$

$M = V_t \text{ x } C$

$M = 654 \text{ CY} \times \$65/\text{CY} = \$42{,}000$

90-ft Wall

W = 65 ft
E = 0.5 ft
v = 0.68 CY/ft^2
R = 0.82 ft/yr
L = 50 years
S = 0
h_s =
h_u = } N/A because S=0
R_{cu} =
R_{cs} =
C = $65/CY

$V_e = A_c$ x v

V_e = W x E x V = 65 ft x 0.5 ft x 0.68 CY/ft^2
= 22 CY

$V_w = A_w$ x v

V_w = R x L x W x V = 0.82 ft/yr x 50 years x 65 ft x 0.68 CY/ft^2
= 1,812 CY

$V_b = (S \text{ x } W \text{ x } L) \text{ x } [(R \text{ x } h_s) + (1/2h_u \text{ x } (R + (R_{cu} - R_{cs})))]/27$

V_b = 0 because S = 0

$V_t = V_b + V_w + V_e$

V_t = 0 + 1,812 CY + 22 CY = 1,834 CY

M = V_t x C

M = 1,834 CY x $65/CY = $119,000