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Memorandum

From: Tim Towey, Jeremy Walgrave, LimnoTech

Date: December 16, 2016

To: Mark Pugh, ODEQ

CC: Steve Nelson, GeoDesign
Melissa Peterson, Sulzer Pumps

SUBJECT: Preliminary Evaluation of Bank Erosion Potential – Sulzer Pumps, Portland, Oregon

Introduction

This memorandum presents the results of the Preliminary Evaluation of the Bank Erosion Potential at the Suzler Pumps facility (Sulzer). The purpose of this analysis is to understand the potential for streambank erosion at Sulzer, located along the lower Willamette River in Portland, Oregon. This assessment was performed as part of the Source Control Evaluation activities for the facility. The site and the entire area surrounding the site consist of high density industrial land use. The river and streambanks throughout this area have been significantly altered to accommodate the various industrial uses.

Many of the industrial sites along the lower Willamette River in Portland, including the Sulzer property, have streambanks that are lined with sheet pile, docks, pilings, piers, concrete pieces, rocks, and other hard infrastructure. Vegetation, roots, and exposed streambank areas are sparse.

In the analysis, the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model was utilized. The BANCS model incorporates the method of estimating the Bank Erosion Hazard Index (BEHI), as developed by Dave Rosgen, and estimates of Near Bank Stress (NBS). The BEHI method is typically used for more natural stream systems, rather than for engineered banks such as the Willamette River in the vicinity of Sulzer. However, the BANCS methodology does provide a structure and criteria for assessing primary characteristics that affect streambank erosion.

Streambank Characteristics in Determining BEHI

There are five streambank characteristics used to determine the overall BEHI score. The measurements used for this analysis were taken by Steve Nelson of GeoDesign, Inc. on August 24, 2016. The measurements and photographs are included as an attachment to this memorandum. Each characteristic is described generally below along with the specific index values calculated and limitations related to the streambank at the Sulzer. The bank can be roughly divided into three zones as shown in Figure 1:

- Zone 1 - Under the dock where the dock extends completely back to the streambank.
- Zone 2 - The section with a dock that does not extend all the way back to the bank.
- Zone 3 - The most downstream section, outside of the dock area.

Multiple locations at individual piers were evaluated in Zone 1. One location was evaluated in each of Zones 2 and 3 (see attachment).

The criteria used to evaluate the BEHI are bank height to bankfull height ratio, root depth to bank height ratio, weighted root density percentage, bank angle, and surface protection percentage. Table 1 shows the range of values for each criteria, the corresponding BEHI score, and the BEHI totals corresponding to the BEHI risk ratings.

Table 1. BEHI criteria values and corresponding index scores and risk ratings.

Risk Rating		Bank Height to Bankfull Height Ratio	Root Depth to Bank Height Ratio	Weighted Root Density %	Bank Angle	Surface Protection %	BEHI Totals
Very Low	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80	5-9.5
	Index Score	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	
Low	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55	10-19.5
	Index Score	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	
Moderate	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30	20-29.5
	Index Score	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	
High	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15	30-39.5
	Index Score	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	
Very High	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10	40-45
	Index Score	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	
Extreme	Value	>2.8	<0.05	<5	<119	<10	46-50
	Index Score	10	10	10	10	10	

1) Bank height to bankfull ratio

Bank height and bankfull height were measured at multiple locations along the site and used to calculate the bank height to bankfull ratio. This ratio compares the overall bank height to the bankfull height. As the ratio increases, the erosion hazard increases. The bank height is measure form the top to the toe of the bank; the bankfull height is measured from an estimate of the bankfull level to the toe.

At Sulzer, the bank toe was estimated at 24 feet below the water surface based on a water depth measurement obtained 5 feet from the bank in the vicinity of Outfall 15. This is the depth measurement taken closest to the bank and was the minimum water depth measurement. The top of bank is located at the dock or the paved working surface for the site. Therefore, the elevations of the toe of the streambank and the top of bank are fairly consistent across the site. The bankfull height was estimated based on high water mark indicators, such as staining or the presence of debris.

The bank height to bankfull ratio was in the range of 1.52 to 1.67, which results in BEHI scores from 5.6 to 6.5. Where measurements were not available, a conservative value of 6.5 was assigned.

2) Root depth to bank height ratio

This ratio compares root depths to the bank height. As this ratio decreases, the erosion hazard increases.

In Zone 1, the bank is under the dock and vegetation does not exist on the streambank. However, the bank is covered in concrete riprap and the index value was set at the minimum. In Zone 2, the cumulative root depth was estimated to be approximately half of the bank height, resulting in a BEHI score of 3.9. In Zone 3, the cumulative root depth was set as equal to the bank height, since this root depth appears to completely cover the area not covered by riprap. Estimation of the values was based on photos included as an attachment to this memorandum.

3) (Weighted) root density percentage

The density of the root mass is estimated by visual assessment of the site. Higher root densities correspond to lower erosion hazard.

As previously described, Zone 1 is covered with concrete riprap, and there is no vegetation. Since this area is covered with concrete riprap, the index value was set to the minimum. In Zone 2, the weighted root density was estimated to be 55%, based on an evaluation of the site photos. In Zone 3 the bank is completely covered with concrete riprap to approximately the bankfull mark with vegetation above; the index value was set to the minimum.

4) Bank angle

The bank angle is used to determine the risk of bank failure. As the bank angle increases, the erosion hazard increases.

Field measurements of bank angle could not obtained under the dock in Zone 1 due to safety considerations. For a bit over half of Zone 1 (upstream end of the site to pier 33), the streambank is stepped. Zone 2 has a bank angle of approximately 10 degrees. Zone 3 has an approximately 30 degree angle. For the stepped areas and the areas where the bank angle was not measured, the bank angle was conservatively estimated to be 30 degrees.

5) Surface protection percentage

The surface protection percentage is an estimate of how much of the streambank is exposed to erosion. As the percentage of surface protection decreases, the erosion hazard increases.

In Zone 1, the bank surface is completely covered by sheetpile or concrete riprap and was assigned 100% surface protection. The area in Zone 2 has some exposed bank areas and is estimated to have approximately 65% surface protection, which translates to a BEHI score of 2.7. Zone 3 is completely covered with vegetation and riprap. The surface protection for Zone 3 is estimated to be 100%.

The BEHI values for each zone and streambank characteristic are shown in Table 1, as well as the overall BEHI score and risk rating.

Table 2. BEHI factors and scores for each area of the Sulzer bank.

Pier	Zone (Figure 1)	Bank Height to Bankfull Height	Root Depth to Bank Height	Weighted Root Density	Bank Angle	Surface Protection	Total BEHI Score	BEHI Risk Rating
1	1	6.3	1	1	*2.4*	1	11.7	LOW
6	1	6.3	1	1	*2.4*	1	11.7	LOW
10	1	6.3	1	1	*2.4*	1	11.7	LOW
22	1	*6.3*	1	1	*2.4*	1	11.7	LOW
33	1	*6.3*	1	1	*2.4*	1	11.7	LOW
35	1	*6.3*	1	1	*2.4*	1	11.7	LOW
44	1	*6.3*	1	1	*2.4*	1	11.7	LOW
51	1	*6.3*	1	1	*2.4*	1	11.7	LOW
57	2	6.1	3.9	3.9	1.5	2.7	18.0	LOW
68	3	5.6	1	1	2.4	1	11.0	LOW

italics = interpolated value

underline = set to minimum value

Near Bank Stress (NBS)

The Near Bank Stress (NBS) can be estimated by several different methods, ranging from reconnaissance-level to detailed predictions depending upon data availability and site needs. The available information at Sulzer is most suitable for an NBS evaluation using BANCS Methods 1, 2, and 5 (Starr, 2013).

Method 1 is based on a rapid visual assessment and takes into consideration the channel pattern and depositional features. The Sulzer site bank is positioned on the inside of a broad and gentle bend in the river, with no depositional features within the central channel to force flow toward the banks. This method in the BANCS approach is only intended to screen for banks with potentially high NBS. Based on these conditions, high NBS is not expected for the bank near Sulzer.

Method 2 takes into consideration more detailed measurements of the channel pattern, evaluating the radius of curvature (Rc) relative to the bankfull width (W). Figure 2 shows the position of Sulzer in the context of the broader channel pattern. Ratios of Rc/W greater than 3 result in a NBS rating of VERY LOW, and it is clear from Figure 2 that Rc/W near Sulzer is much greater than 3.

A third method (BANCS Method 5) evaluates the ratio of near-bank maximum depth to mean depth of the river cross-section at bankfull. Higher ratios are indicative of conditions where flow is concentrated near the bank, while lower ratios indicate flow is concentrated through the center channel. Figure 3 shows water depths in the vicinity of Sulzer. The decrease in water depth moving from the center channel to near the Sulzer bank is evident. With a near-bank to mean depth ratio less than 1, the Sulzer bank receives a VERY LOW NBS rating.

Based on the combination of these methods, NBS for the bank near Sulzer is VERY LOW.

Erodibility Curves

The BANCS model estimates a Bank Erosion Rate (BER) as a function of both the BEHI and the NBS assessments. Figure 4 shows BER curves developed for the District of Columbia and North Carolina. The bank in the vicinity of the Sulzer facility has a LOW BEHI and VERY LOW NBS. This combination indicates a lower erosion potential than the lowest values of either the District of Columbia or the North Carolina curves, suggesting an erosion rate less than 0.01 ft/year (0.3 cm/year). The LOW BEHI curve for the District of Columbia does not extend to the VERY LOW NBS value and North Carolina does not include a LOW BEHI curve. Because the combination of LOW BEHI and VERY LOW NBS is lower than the range of BER curves, zero erosion is the most likely scenario.

Conclusions

Although the BANCS model was not developed for evaluating engineered banks, it does provide an appropriate framework for considering the factors that affect erodibility.

The streambank in Zone 1 is well protected by sheet pile and concrete riprap. The BEHI risk rating for this areas is LOW. The streambank in Zone 2 does not have sheet pile or complete riprap coverage, but it does have some concrete riprap and some vegetated cover. The bank angle is lower in this area than elsewhere along the bank, reducing the erosion potential. The BEHI risk for this area is also LOW. The streambank in Zone 3 is covered with riprap and vegetation and has a lower bank to bankfull height ratio than the rest of the bank. The BEHI risk for this area is LOW, bordering on VERY LOW.

The NBS for the entire bank near Sulzer is VERY LOW. Based on BER curves combining BEHI and NBS, the combined erosion potential for the entire Sulzer site is negligible.

References

McQueen, A. 2011. Estimating Sediment Loads using the Bank Assessment of Non-point source Consequences of Sediment (BANCS). Appendix D of the Antietam Creek Watershed Restoration Plan for Washington County, MD. http://www.mde.state.md.us/programs/Water/319NonPointSource/Documents/Watershed%20Plans/Antietam%20Creek%20Plan/Appendix%20D_BEHI.pdf

Rosgen, D.L. 2008. River Stability Field Guide. Wildland Hydrology. Pagosa Springs, CO.

Starr, R. 2013. Maryland Trust Fund Geomorphic Monitoring. Presentation by U.S. Fish and Wildlife Services, Chesapeake Field Office. http://dnr2.maryland.gov/streams/Documents/2013TFTraining_BANCS_Davis.pdf

USACE (U.S. Army Corps of Engineers). 2014. Condition Survey for the Willamette River, River Mile 7.5 to Broadway Bridge. December 10, 2014.

Figure 1. Zones used in Sulzer bank evaluation.

Figure 2. Channel pattern near Sulzer bank.

Figure 3. Bathymetry in the vicinity of Sulzer from 2014 USACE condition survey (USACE, 2014).

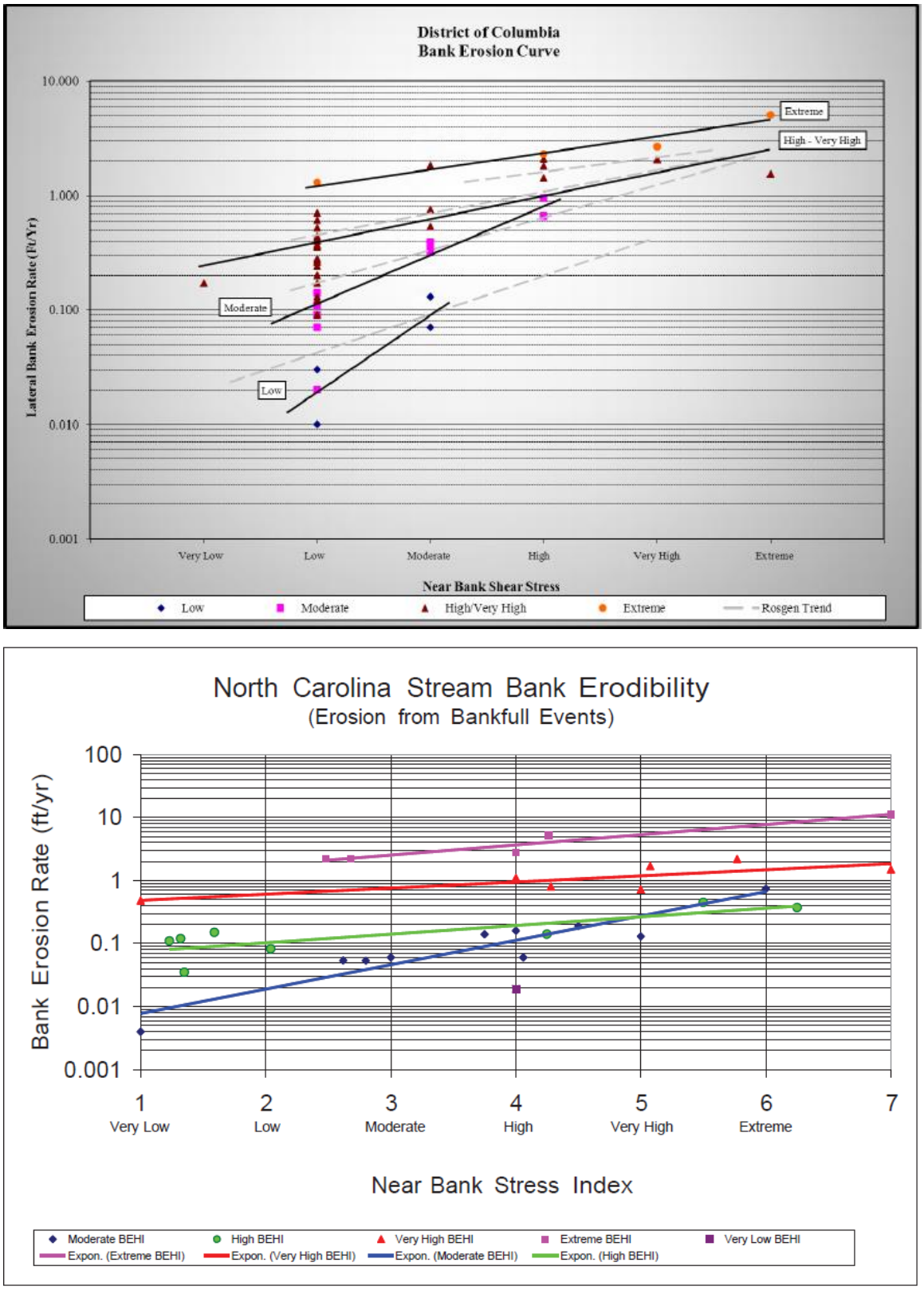

Figure 4. Streambank erodibility curves for the District of Columbia (Starr, 2013) and North Carolina (McQueen, 2011).

Attachment

Field Measurements and Photographs

Sulzer Pumps Bank Observations August 24, 2016							
Pier	**Bank Height (feet)**	**Bank Full Height (feet)**	**Bank Angle**	**Bank Surface**	**Depth to River bottom at Pier (feet)**	**Edge of pier to sheet pile (feet)**	**Photos**
upriver							Figure 10
1	26.5	6.5	stepped	sheet pile	32	30.5	Figure 1
6	26	6	stepped	sheet pile	26		Figure 2
10	26.5	6.5	stepped	sheet pile	30	33.5	Figure 3
22	26	6	stepped	sheet pile	28		
33	25.5		stepped	sheet pile	29	38.5	Figures 3 and 4
35	26			> 10" rock from pier 34 to 36			Figure 4
44	26.5			wood wall 36-39 then bank	24.5	63*	Figure 5
51		6.5		sandy bank to large concrete			Figure 6
57	24.5	6	10 deg/31 deg	sandy bank to large concrete			Figures 7 and 8
68	21.5	6	31 deg	Large concrete rip rap	24.5		Figures 8 and 9
downriver							

* edge of pier to river bank

NOTES:
Stepped wall typical: vertical sheet pile, horizontal-16 feet, vertical-wood lagging, horizontal-16 feet, vertical-wood lagging. Example Fig. 2
Areas between steps are filled with rock
Bank height measured from water surface to bottom of dock
Bank full height measured from surface to high water mark/indicators

Pier notes:

1. Edge of dock at Pier is 30.5 feet from toe (sheet pile)
6. OF-E area
10. Gap in first wood wall back at piers 21-23
22. Sheet pile from pier 29 -34 was 7 tall from water surface
33. 13 feet from sheet pile to first wood wall at pier 33
35. >1' concrete below water surface
44. OF-C area, large rip rap and exposed bank, very large metal piles riverside
51. Wall behind concrete rip rap
57. End of covered dock. Measurements applied to area downstream and right of pier 57 (not covered by dock)
68. Rip rap from water line

OF-15

OF-15 TO PIER 1 THROUGH 6

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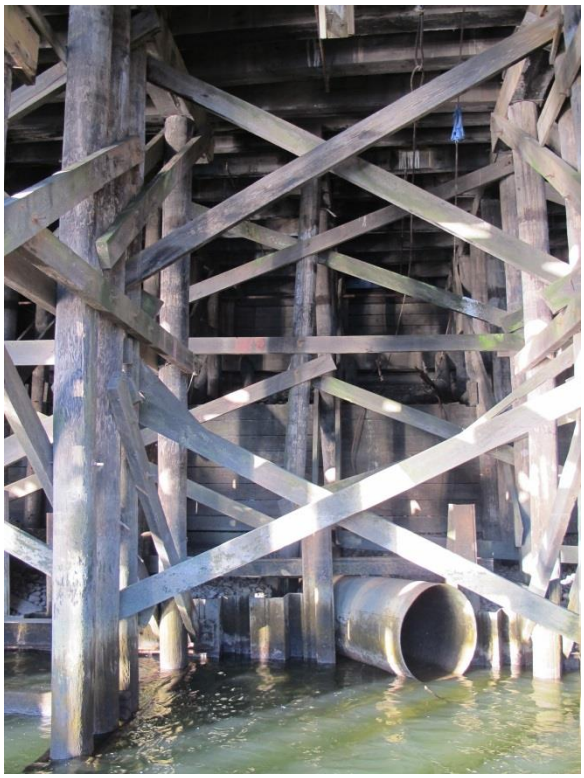
SULZERPUMP-1-09-11	**BANK EVALUATION PHOTOGRAPHS**	
DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 1**



OF-E

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	DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 2**

SulzerPump-1-09-11-F1_10-BEPH.docx Print Date: 12/14/16

PIER 10

PIER 33

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PIER 33 CLOSE UP

PIER 35

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PIER 44

PIER 44 CLOSE UP

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DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 5**

PIER 51

PIER 51 CLOSE UP

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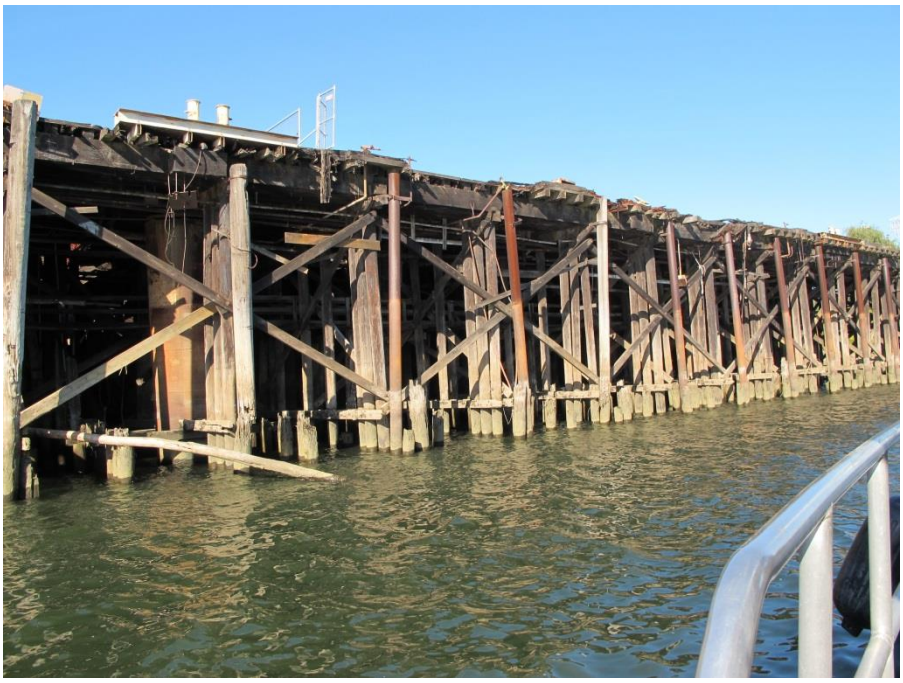
SULZERPUMP-1-09-11	**BANK EVALUATION PHOTOGRAPHS**	
DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 6**



PIERS 45 THROUGH 55

UNDER DOCK UPSTREAM OF PIER 57

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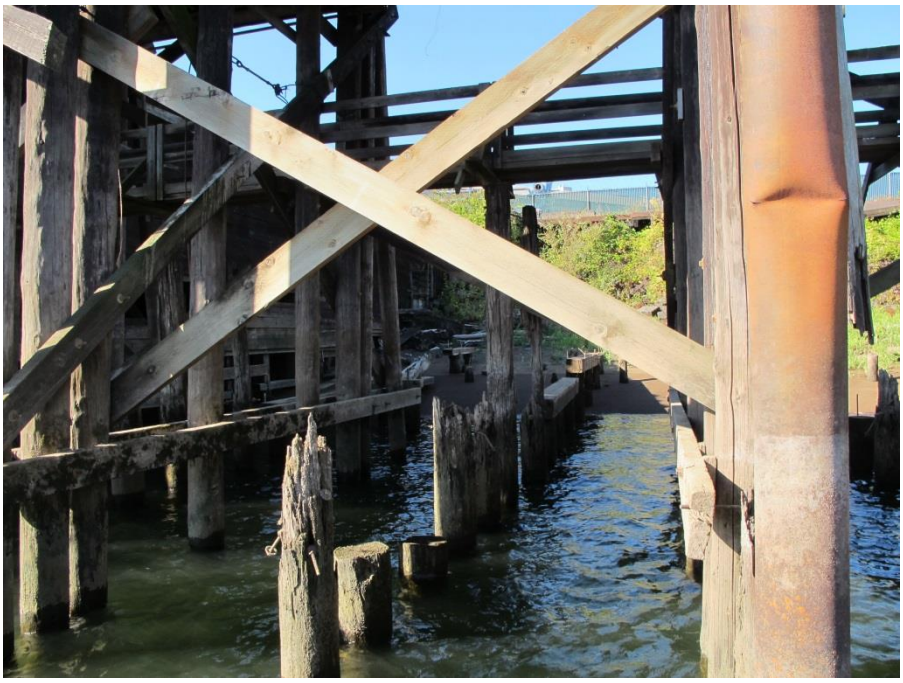
DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 7**



END OF DOCK

NOT UNDER DOCK

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SULZERPUMP-1-09-11	**BANK EVALUATION PHOTOGRAPHS**	
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PIER 68 AREA

WEST END

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SULZERPUMP-1-09-11	**BANK EVALUATION PHOTOGRAPHS**	
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UPSTREAM PROPERTY

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SULZERPUMP-1-09-11	**BANK EVALUATION PHOTOGRAPHS**	
DECEMBER 2016	SULZER PUMPS FACILITY PORTLAND, OR	**FIGURE 10**