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Technical Memorandum

To: Gina Austin, PE (City of Bellingham Parks and Recreation Department)

From: Younes Nouri, PE, PhD (Moffatt & Nichol)

Date: 6/7/2019

Subject: Coastal Engineering Assessment - FINAL

Project: Squalicum Pier at Little Squalicum Park

CC: Bruce Ostbo, PE, SE and Margaret Schwertner (Moffatt & Nichol)

1.0 INTRODUCTION

The City of Bellingham Parks and Recreation Department (Parks) intends to assess feasibility of acquiring and converting the Squalicum (Lehigh) Pier to a public pier. Moffatt & Nichol (M&N) was tasked with a high-level coastal engineering assessment to identify possible effects of the Squalicum Pier on longshore sediment transport.

M&N conducted this high-level assessment by reviewing existing data and information on coastal and geomorphic processes in Bellingham Bay. M&N analyzed historical surveys as well as a new nearshore survey specifically conducted for this project. This technical memorandum summarizes findings of this assessment. This memorandum supersedes an earlier version dated May 15, 2019.

1.1 Project Location

Squalicum Pier is in Bellingham Bay, Washington (WA) and stretches seaward perpendicular to the shoreline. The shoreline is bordered to the northeast by the BNSF Railroad and by Squalicum Park.

1.2 Pier Structure

Squalicum Pier consists of an approximately 1,800-foot-long by 14-foot wide timber trestle, a 120-foot-long by 50-foot-wide timber wharf, a 2,300-foot-long supply line trestle, 14 timber dolphins, and timber catwalks, see M&N (2013) for further details. The trestle and wharf consist of approximately 1,200 structural piles. The first few rows of piling on the landward side are encased in a concrete footing. The functionality of the concrete casing is most likely to prevent damage to piles from impact by floating woody debris.

The wharf and trestle were originally built in 1912 and were designed to support a single railroad track and vehicular traffic. The mudline at the offshore end of the wharf is approximately -10 feet referenced to Mean Lower Low Water (MLLW).

Figure 1: Squalicum Pier consists of a timber deck supported by structural piles. Photos taken by a M&N coastal engineer on Oct 5, 2018 show (a) pile density, looking southwest and (b) concrete footing encasing the first few rows of structural piles, looking southwest.

2.0 COASTAL PROCESSES

2.1 Tides and Water Levels

Tides in Puget Sound have a mixed (semidiurnal) pattern characterized by two highs and two lows of unequal heights during each lunar day. Tidal datums and water levels at the project site are based on hourly measurements of water level at Bellingham, WA National Oceanic and Atmospheric Administration (NOAA) station ID#9449211, tidal epoch 1983-2001, listed in Table 1.

Table 1: Tidal datums and water levels at project site referenced to MLLW in feet based on Bellingham, WA NOAA Station (ID#9449211), 1983-2001 Tidal Epoch

Datum Description	Abbreviation	feet, MLLW
Highest Observed Water Level (01/05/1975)	HOWL	10.42
Mean Higher High Water	MHHW	8.51
Mean High Water	MHW	7.79
Mean Tide Level	MTL	5.07
Mean Sea Level	MSL	4.95
Mean Low Water	MLW	2.35
North American Vertical Datum 1988	NAVD88	2.35
Mean Lower Low Water	MLLW	0.00
Lowest Observed Water Level (12/30/1974)	LOWL	-3.47

The datums and water levels listed in Table 1 are referenced to Mean Lower Low Water (MLLW) in feet (ft). Mean tide range (MHW – MLW) at this station is equal to 5.44 ft and mean diurnal tide range (MHHW – MLLW) at this station is equal to 8.51 ft.

2.2 Currents

Currents in Bellingham Bay are caused by tidal influence as well as wind and freshwater inflows from the Nooksack River and creeks discharging into the bay. Measurements of surface and middle layer currents in three locations inside Bellingham Bay from 6/10/2009 to 6/26/2009 showed current velocities smaller than 1.1 knots, see Wang et al. (2010) for further details.

2.3 Wind

Predominant (strongest) and most frequent storms over Puget Sound are southerly followed by occasional northerly storms. Hourly measurements of wind speed and direction near the project site are available at Bellingham Airport. Hourly records of wind for the years from 1948 to 2018 were used to develop a wind rose, see Figure 2. This wind rose indicates that predominant winds at Bellingham Airport are southerly.

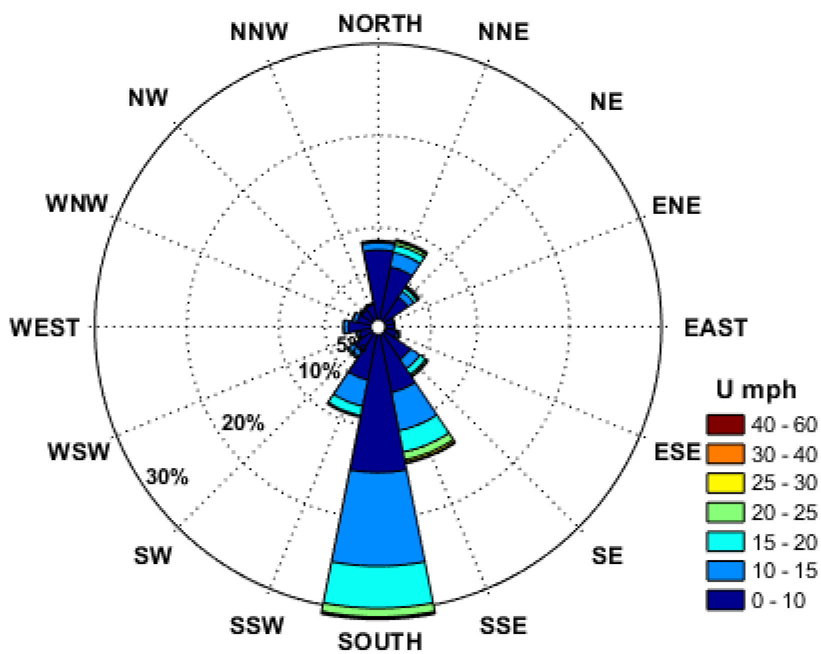

Figure 2: Wind Rose for Bellingham Airport based on hourly measurements of wind speed and direction from 1948 to 2018.

2.4 Wind-Waves

The largest wind-waves (waves generated locally by wind) approaching Squalicum Pier are generated by southerly and southwesterly storms. These two directions have the longest fetch (the unobstructed distance that wind travels over open water) of up to 14 miles. Southerly and southwesterly waves change direction and turn almost perpendicular to the shoreline as they approach shallower areas. Predominant southerly waves approach Squalicum Pier at an angle leading to a northwestward net drift, see Figure 3.

3.0 GEOMORPHOLOGICAL PROCESSES

3.1 Sources of Sediment

Bellingham Bay's primary watersheds include the Nooksack River, Squalicum Creek, and Whatcom creek, see Figure 3. The primary source of sediment to Bellingham Bay, including the areas adjacent to the pier, is the Nooksack River which covers a drainage area of 579 squares miles (1,500 square kilometers). Squalicum Creek and Whatcom Creek also drain into Bellingham Bay, but these watersheds only cover a drainage area of 25 and 10 square miles (65 and 26 square kilometers), respectively. Little Squalicum Creek discharges flow and sediments through a culvert within 200 feet south of Squalicum Pier.

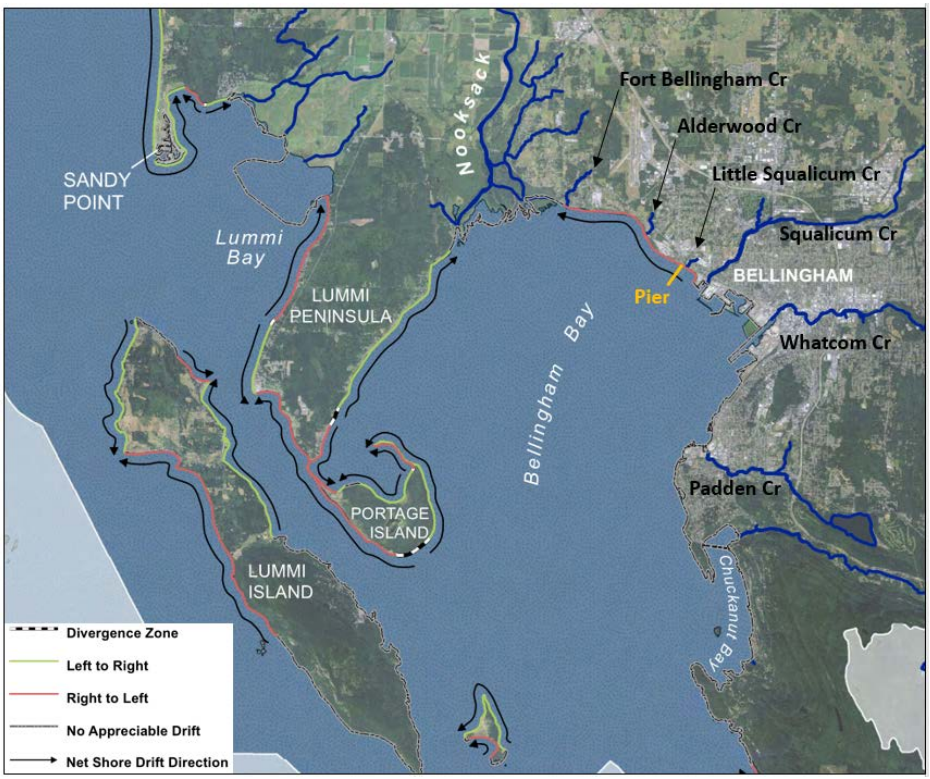

Figure 3: Rivers and creeks discharging into Bellingham Bay as well as net shore drift mapping, modified from CGS (2009)

The Nooksack River discharge of sediments into Bellingham Bay can range from approximately 0.65 to 14 million cubic meters per year. Sediment was more likely to be finer grained silts as the Nooksack Valley was deforested and converted to agriculture. Fine sediments tend to get carried farther away from the river's mouth. As time progressed, sediment accumulation decreased at the Delta while increasing in the Bay, see Higgins (Year Unknown) for further details. Bathymetric change in Bellingham showed sedimentation of up to 20 ft for 1855 to 1956, see Higgins (Year Unknown).

The Nooksack River deposits the mud fraction of the river's sediment load throughout Bellingham Bay. Google Earth Aerial images during low tide events indicate that the Nooksack River delta and resulting mudflats extend all the way to the pier. These muddy, fine sediments were observed during a 2018 site visit by a M&N coastal engineer as depicted by the sunken footprint in Figure 4.

Figure 4: Sunken footprints during a 2018 site visit by a M&N coastal engineer indicate abundance of cohesive fine material on the northwest side of the pier, photo taken between the pier and the supply line looking north.

3.2 Littoral Drift

Washington State Coastal Atlas (Ecology 2018) provides mapped drift cells in Bellingham bay. This mapping is most likely influenced by fetch only and may not account for other factors such as the geology of the material at beach level and local variations in sediment supply and abundance. Net littoral drift is northwestward (from right to left) adjacent to the pier, see Figure 3.

3.3 Shoreline Change

Shoreline change analysis adjacent to the pier was conducted by delineation of vegetation and drift log lines from aerial images dating back to 1950, CGS (2009). This analysis showed both erosion and accretion along the vegetation line for different periods noting that there was not much vegetation adjacent to the pier due to the channel and delta of Little Squalicum Creek.

4.0 PIER'S IMPACT ON LITTORAL TRANSPORT

Review of historical aerial images showed a distinct discontinuity of the waterline at the pier in aerial images from 2006, 2014, and 2015, see Figure 5. This discontinuity of the waterline between the southeast and northwest sides of the pier is evident in these three images at various tides and seems to be consistent over time. This discontinuity indicates ground elevation differences between the two sides of the pier suggesting a higher ground elevation on the northwest side of the pier.

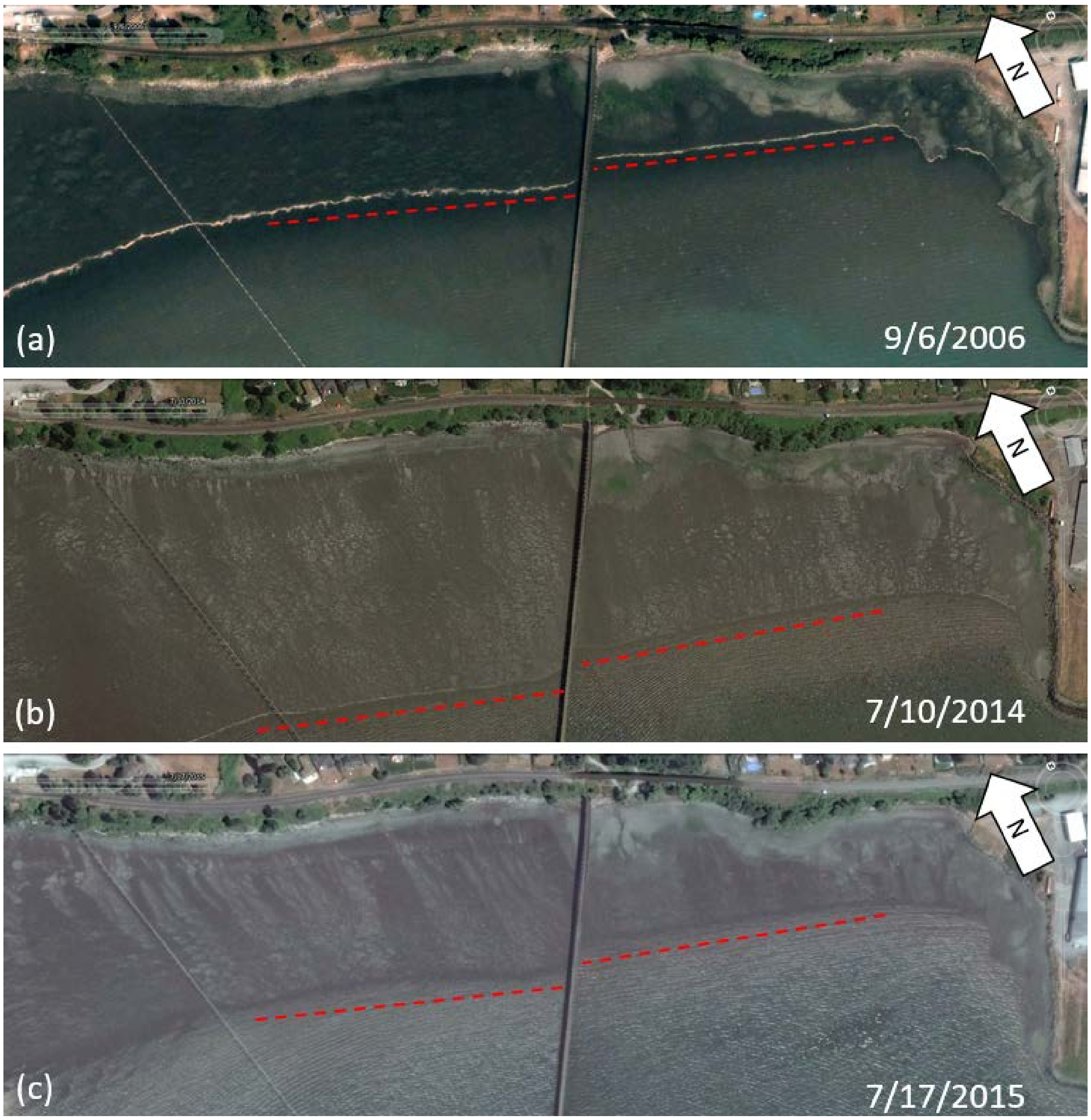

Figure 5: Observed discontinuity in waterline at the pier (highlighted with a red dashed line) in three Google Earth aerial images taken: (a) 9/6/2006; (b) 7/10/2014; and (c) 7/17/2015.

A nearshore ground survey was conducted as part of this project in 2018. This survey identified elevations at half-foot contours along approximately 1,200 feet of the pier within 50 feet of either side of the pier. These Elevations ranged from -2.5 to + 8 ft, MLLW. Elevation contours from this ground survey are shown in Figure 6.

Figure 6: Ground elevation (EL) referenced to MLLW in feet based on a 2018 nearshore survey specifically conducted as part of this project.

Ground elevation transects on each side of the pier confirmed that ground elevation on the northwest (left) side of the pier is approximately 0.25 ft (3 inches) higher than the southeast (right) side of the pier for elevation between -2.5 and +1.0 ft, MLLW (Figure 7). This is consistent with the discontinuity in the waterline observed in aerial images (Figure 5). For elevations > +1.0 ft, MLLW, ground elevation on the southeast side is higher than northwest side because of the Little Squalicum Creek delta.

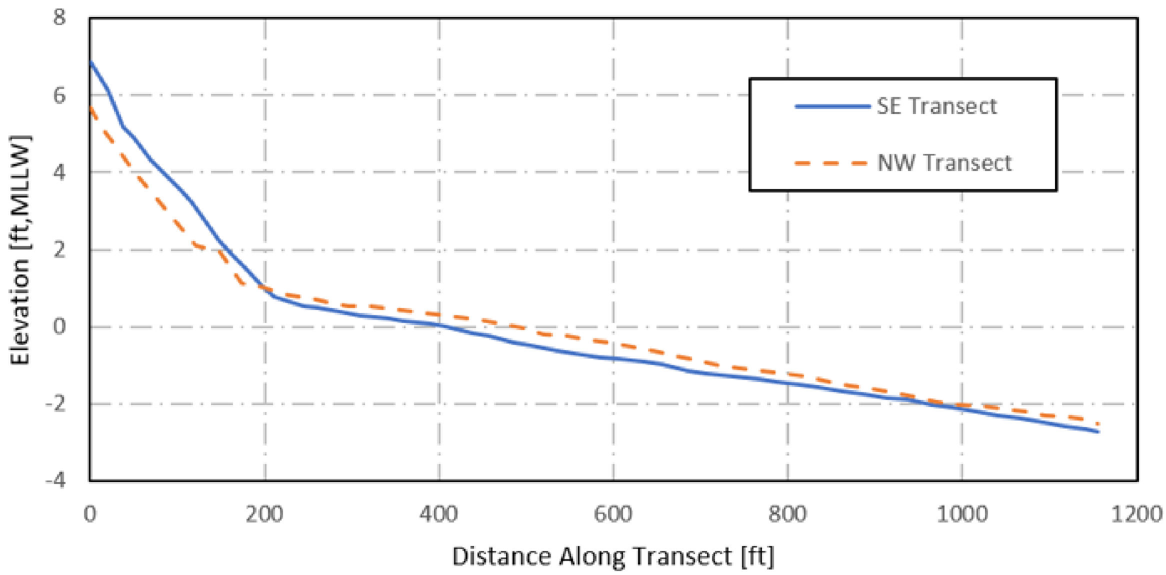

Figure 7: Ground elevation for survey transects on NE and SE side of Squalicum Pier based on the 2018 nearshore survey.

There are two potential mechanisms for the observed waterline discontinuity at the pier:

a) the first potential mechanism is that the pier is partially impeding Nooksack River sedimentation, resulting in higher ground elevations on the northwest side, see Figure 8; and

b) reduced wave exposure on the northwest side of the pier compared to southeast side has resulted in the observed higher ground elevations on northwest side, see Figure 8.

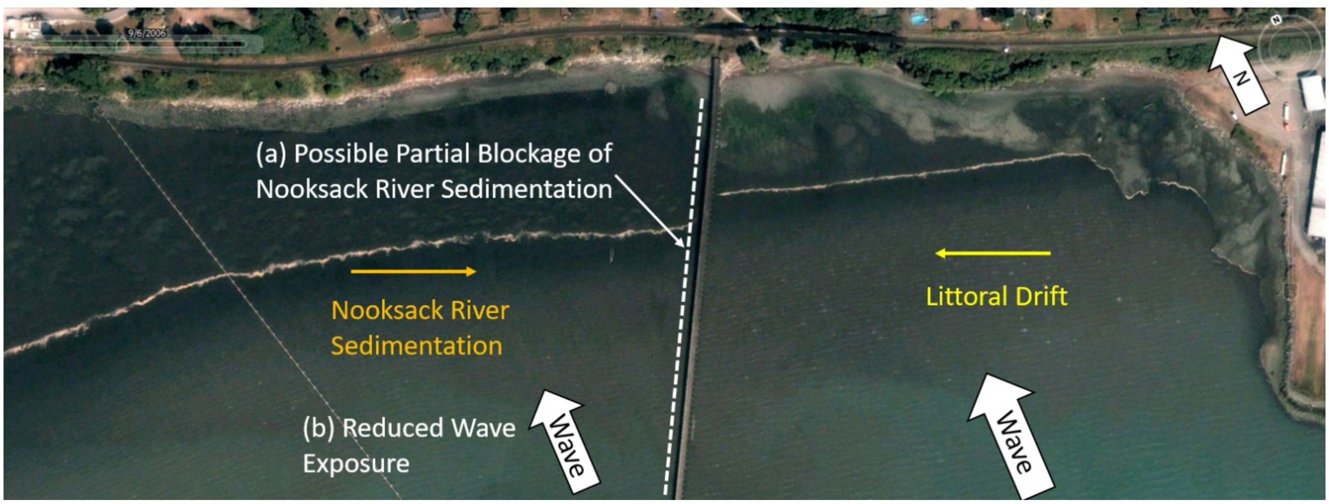

Figure 8: Coastal and Morphological Drivers Adjacent to the Squalicum Pier

Historical NOAA surveys were also reviewed for ground elevation differences at the pier, however this data did not show a clear, consistent discontinuity pattern because most of the available historical surveys did not have adequate soundings adjacent to the pier. However, the surveys were able to clearly show the rise in mudline elevation at the end of the pier from Nooksack delta growth (Figure 9).

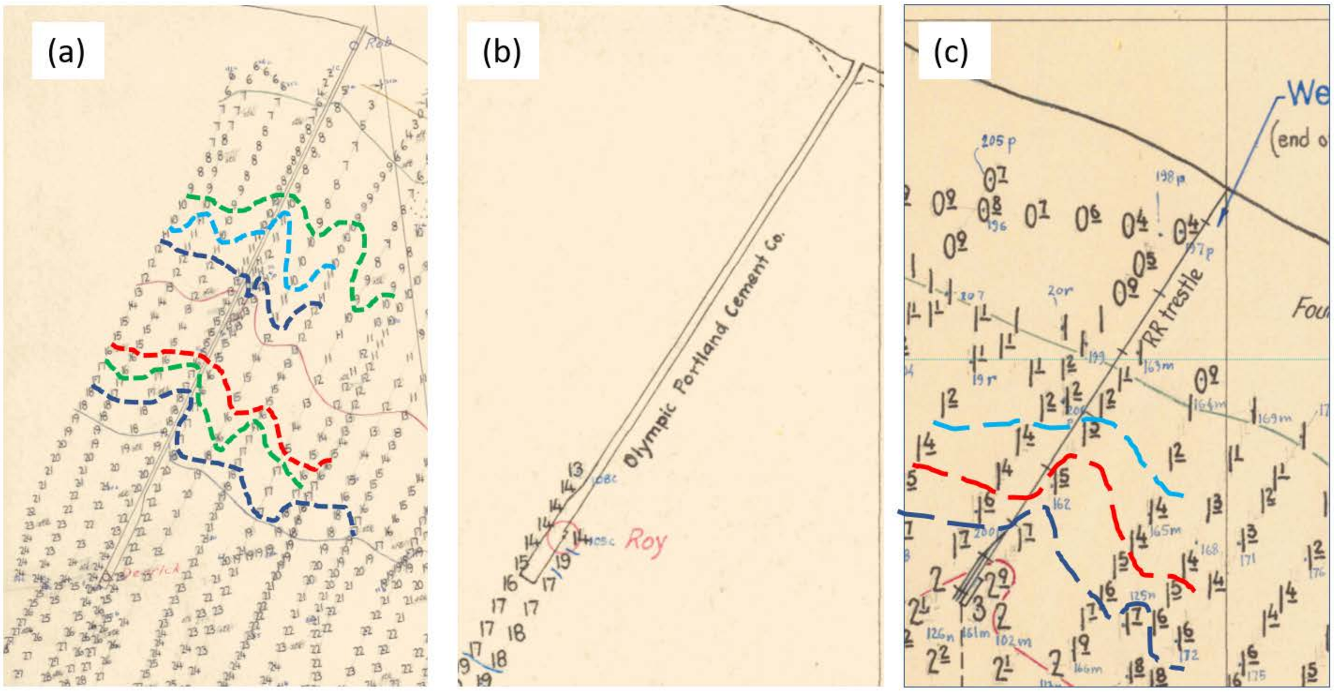

Figure 9: Soundings from NOAA Historical Surveys for: (a) 1914 Survey, Soundings in ft, MLLW; (b) 1927 Survey, soundings in ft, MLLW; and 1956 Survey, soundings in fathoms, MLLW. Approximate contour lines are delineated with dashed lines.

Scattered rocks on the southeast side of the pier within the first five landward rows of piling were observed by a M&N coastal engineer during a 2018 site visit, see Figure 10. In addition, several aerial images show accumulation of large woody debris (LWD) and trapped debris on the southeast side. Accumulation of logs and scattered rocks on the southeast side of the pier indicate the pier's hinderance of sediment and LWD transport in the northwest direction. Trapped logs and rocks on the southeast side of the pier were observed on multiple occasions by CGS (2009) as well.

Figure 10: Ground photos on southeast (SE) and northwest (NW) sides of the pier from an October 5, 2018 site visit by a M&N coastal engineer.

4.1 Adjacent Shoreline & Proposed Shoreline Modifications

The high-bluff shoreline northwest of the pier has been modified by armoring the toe. Scattered rocks northwest of the pier and seaward of the toe of the bluff indicate previous episodes of erosion of the armored toe of the bluff.

5.0 SUMMARY AND CONCLUSIONS

Possible effects of the Squalicum Pier on littoral sediment transport was investigated by reviewing available nearshore surveys adjacent to the pier as well as observing the waterline at the pier in aerial images.

A discontinuity in the waterline observed in three aerial images from 2006, 2014, and 2015 consistent through time suggests that existing ground elevations on the northwest (left) side of the pier are higher than ground elevations on the southeast (right) side of the pier. This discontinuity in elevation at the pier was confirmed by a ground elevation survey specifically conducted for this project. This survey showed that ground elevations on the northwest side of the pier are approximately 0.25 feet (three inches) higher than ground elevations on the southeast side for elevations between -2.5 ft and +1.0 ft, MLLW. It should be noted that for elevations > +1.0 ft, MLLW, ground elevations on the southeast side are higher than northwest side because of the Little Squalicum Creek delta.

Two potential mechanisms for the observed waterline discontinuity at the pier were identified as follows: (a) the pier is partially impeding Nooksack River sedimentation, resulting in higher ground elevations on the northwest side; and (b) reduced wave exposure on the northwest side of the pier compared to southeast side has resulted in the observed higher ground elevations on northwest side.

5.1 Next Steps & Other Considerations

Preliminary planning alternatives for modifications to the pier have been developed as follows:

- Alternative A: Maintain the pier structure status quo as part of the Parks' pier redevelopment plans.
- Alternative B: Reduce the number of piles or (partial) removal of the pier next to the shoreline, as part of the Parks' pier redevelopment plans.

These two alternatives and their associated benefits and constraints, along with other considerations, are listed in Table 2. A preliminary review of these proposed alternatives indicates that removal of the pier could result in the increased risk of wave erosion at the armored toe of the bluff northwest of the pier.

Table 2: Proposed Preliminary Alternatives with Associated Benefits, Constraints, and Other Considerations.

Alternative	Benefits	Constraints	Considerations	Recommendations
Alternative A	System stays in equilibrium.	Adverse impact from creosote piles and overwater structure on aquatic habitat.	Possible increase in effect of pier on littoral transport.	Monitor impact of pier on littoral transport every 5 to 10 years.
Alternative B	Beneficial impact for aquatic habitat / restoration to more natural conditions.	Increase in wave exposure on the northwest side of pier.	Potential for erosion of the bluff northwest of the pier.	Quantify change as a result of proposed conditions with a detailed study using numerical modeling.

5.2 Limitations and Guideline for Use

The information presented in this technical memorandum were developed based on review of existing data and a new nearshore survey, as part of a high-level coastal engineering assessment. Observations and conclusions made herein are site-specific and should not be extended to other sites without discretion.

6.0 REFERENCES

Coastal Geologic Services (CGS). 2009. Little Squalicum Shoreline Restoration Feasibility Study, Bellingham, Whatcom County, WA. Dated August 31, 2009.

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Higgins, S. Year Unknown. Bathymetric Change Analysis of Bellingham Bay. Western Washington University.

Moffatt & Nichol (M&N). 2013. Rehabilitation Options and Cost Report, Lehigh Cement Pier, Bellingham WA. Dated October 9, 2013.

Wang. T., Zang. Z., Khangaonkar, T. 2010. Development of a Hydrodynamic and Transport Model of Bellingham Bay in Support of Nearshore Habitat Restoration.