FINAL

PND Engineers, Inc.

MEMORANDUM

PROJECT NO. 174094 **DATE: July 25, 2025**

PROJECT: Mercer Island Beach Club Marina Reconfiguration and Replacement Project

TO: Gardner Morelli

CC: File

FROM: PND Engineers, Inc.

SUBJECT: Log Boom

1. INTRODUCTION

On May 22, 2025 the City of Mercer Island Community Planning and Development Department (CPD) completed their review for compliance with the zoning code, Title 19 of the Mercer Island City code (MICC) for the Shoreline Substantial Development Permit, Shoreline Conditional Use Permit, and SEPA Review applications for the Mercer Island Beach Club. As part of that review, there were concerns that the proposed high-density polyethylene (HDPE) corrugated log boom will enhance wave reflection, which may possibly have adverse impacts on the adjacent properties. According to the City of Mercer Island CPD, the following issue must be addressed as stated in the review document:

- *"The applicant shall provide an analysis of the wake reflection as it relates to the proposed log boom and possible impacts to adjacent properties. Has the project designer considered possible negative impacts to adjacent properties caused by wave reflection?"*

This memorandum presents predicted wave transmission and reflection coefficients for both the existing cedar log boom and the proposed HDPE log boom. Simulated near shore wave heights have been developed selectively for the following scenarios:

- No log boom
- Existing log boom
- Proposed log boom

Lastly, an evaluation of any potential adverse impacts to the shoreline associated with the proposed design has been conducted.

2. SITE

The Mercer Island Beach Club is located near the south tip of the Mercer Island in Washington State. Lake Washington surrounds Mercer Island and I-90 connects Mercer Island with Seattle to the west and Bellevue to the east as shown in Figure 1. Figure 2 shows the location of the existing cedar log boom located south of the Mercer Island Beach Club.

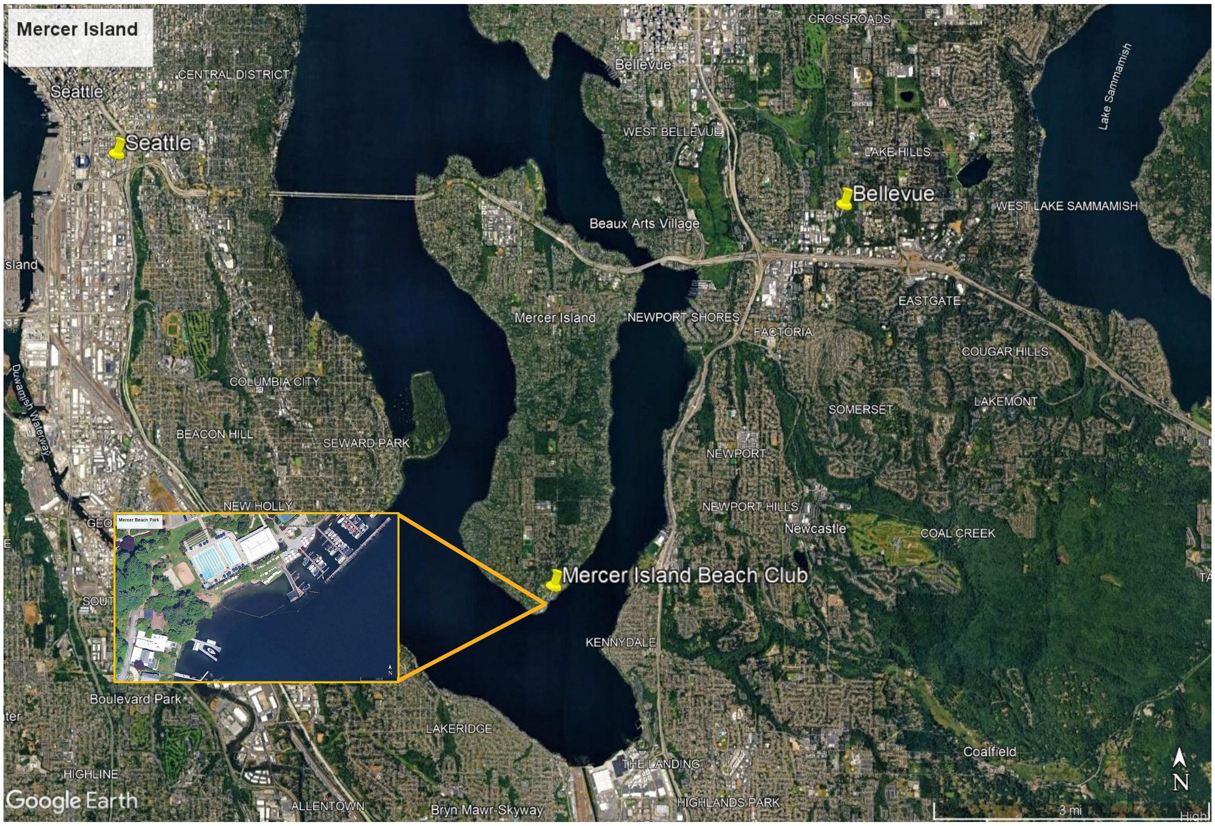

Figure 1: Location of the Mercer Island Beach Club (Google Earth, 2025).

Figure 2: Location of the existing cedar log boom south of the Mercer Island Beach Club (Google Earth, 2025).

3. EXISTING CONDITIONS

The Mercer Island Beach Club currently has a 244 linear-foot long cedar log boom secured with pile stubs as shown in Figure 3. The first 30 feet from the shoreline of the existing log boom, consists of two logs next to each other as shown in Figure 4. Each log is approximately 14 inches to 16 inches in diameter. The remainder of the log boom further from shore consists of a single cedar log which has an approximate diameter of 20 inches as shown in Figure 5. It is estimated that the cedar log boom is submerged by approximately 80 percent. Based on that assumption, the drafts of the existing log booms are as follows:

- Two cedar log booms (near shore): Draft equal to 12 inches
- One cedar log boom (further from the shore): Draft equal to 16 inches

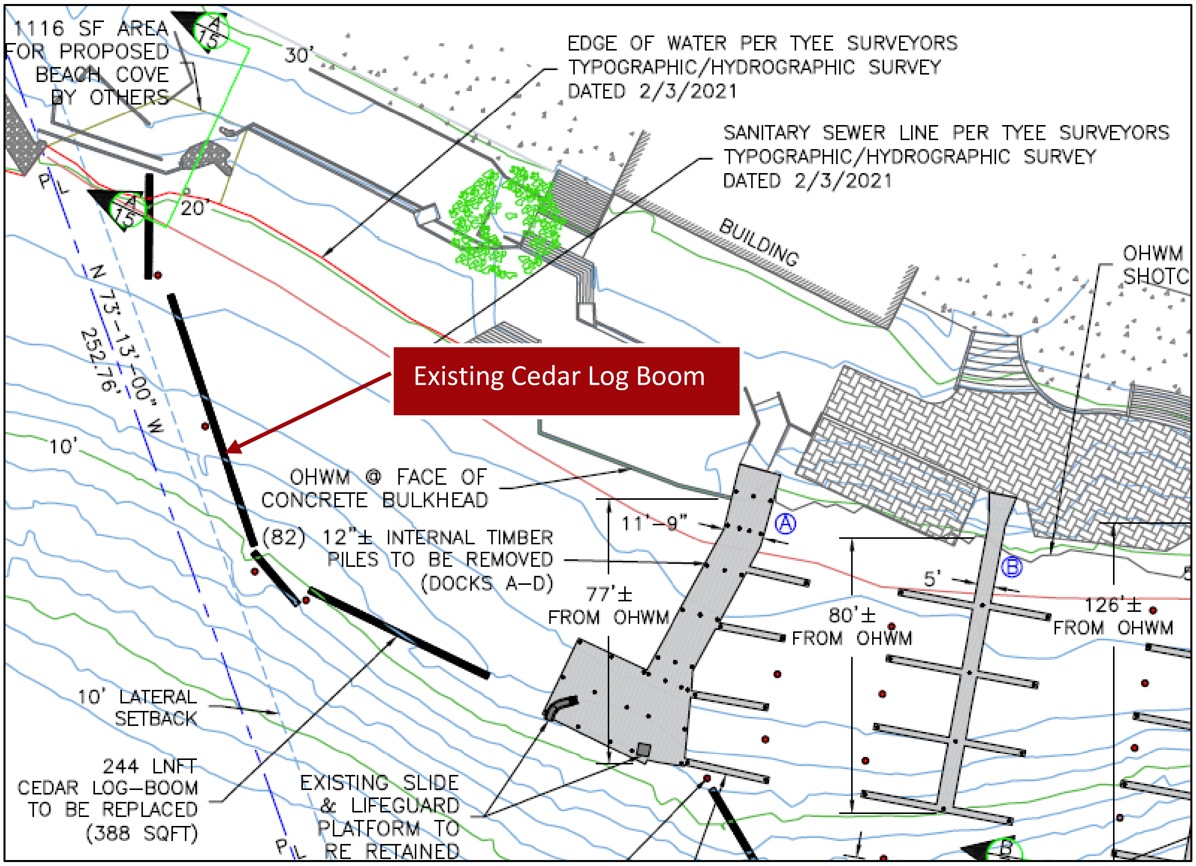

Figure 3: Existing cedar log boom at the Mercer Island Beach Club (Waterfront Construction Inc., 2025)

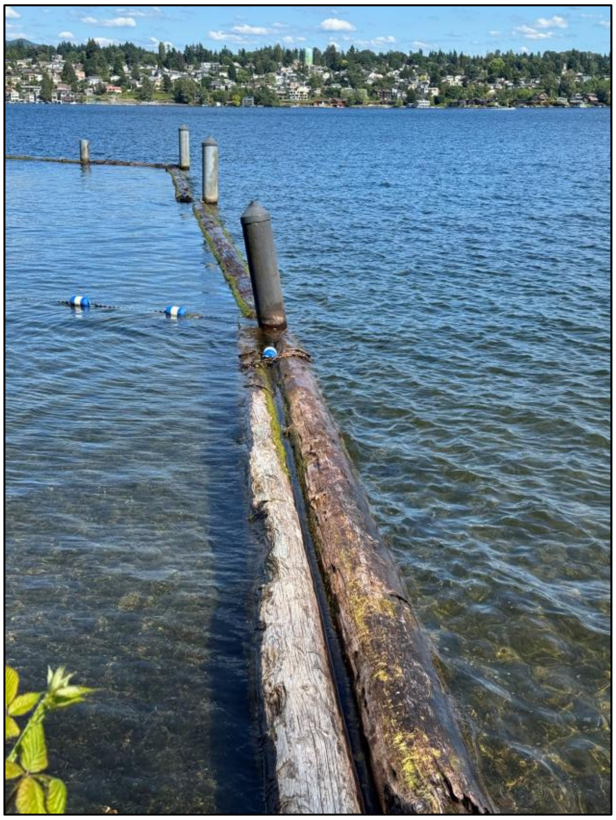

Figure 4: Image of existing cedar log booms near the shoreline at the Mercer Island Beach Club. (Client provided photo, 2025)

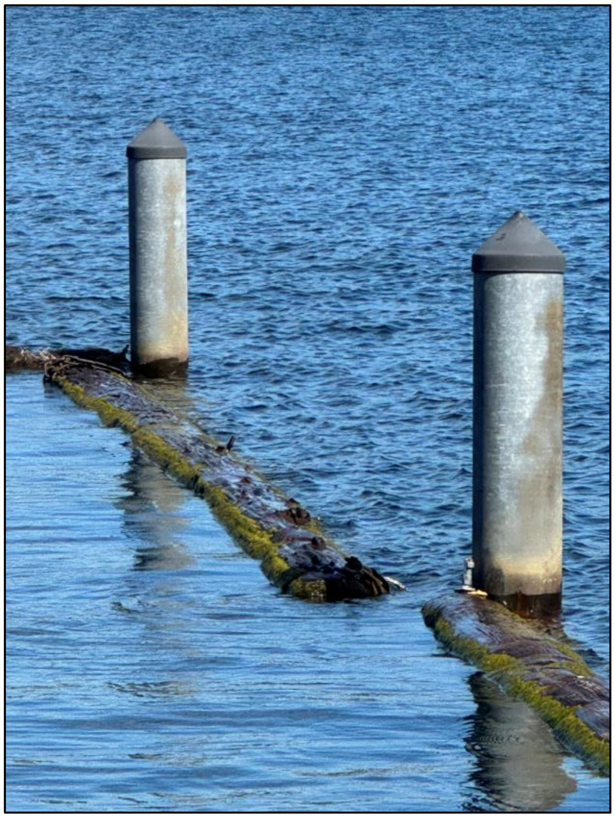

Figure 5: Image of existing cedar log boom further from the shore at the Mercer Island Beach Club. (Client provided photo, 2025)

4. PROPOSED CONDITIONS

The proposed location of the new 320 linear-foot HDPE corrugated log boom is shown in Figure 6. As shown, the proposed log boom is longer than the existing log boom and will be positioned further away from the shoreline. The proposed HDPE log boom is 24 inches in diameter and will consist of 20-foot-long sections. Based on conversations with Paul Wilcox at the Waterfront Construction Company, the proposed log boom will be equipped with additional ballast to achieve a draft of approximately 12 inches. Figure 7 shows a 3D perspective of a 20-foot-long section of a HDPE corrugated tubular pontoon available from the Hallsten Corporation.

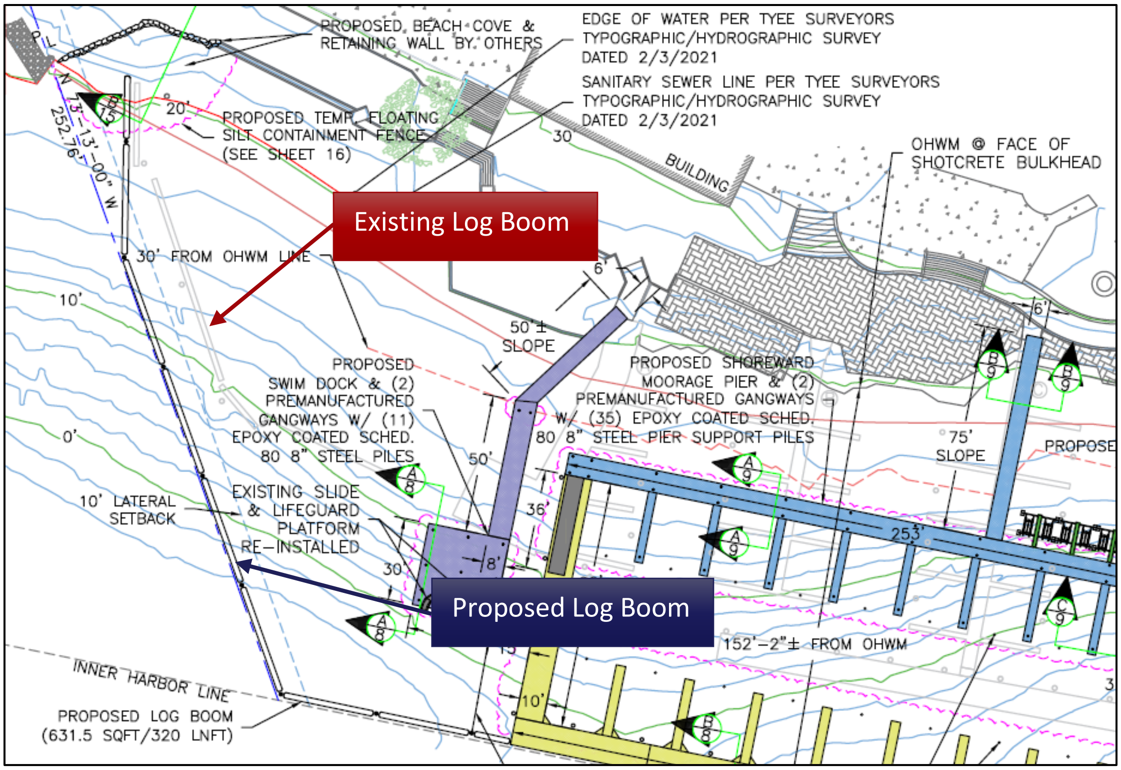

Figure 6: proposed location of the new HDPE corrugated log boom (Waterfront Construction Inc., 2025).

Figure 7: 3D perspective of a 20-foot-long section of a HDPE corrugated tubular pontoon (Hallsten Corporation, 2025).

5. WAVE-FLOATING STRUCTURE INTERACTION

PND’s understanding is that the existing log boom’s purpose is to delineate the swim area. The log boom serves to create a safe space for swimmers by restricting vessel access and acting as a debris barrier. As with any type of structure that is floating in the water, the log boom will interact with incident wave action from wind generated waves and vessel wakes.

When an incident wave impacts a floating structure, the incident wave is partially transmitted, partially reflected, and partially dissipated. The incident wave with a wave height, H_i, contains a certain amount of energy, E_i, as shown in Figure 8. When the wave impacts the floating structure, part of the incoming wave energy is reflected, E_r, which results in a reflected wave, H_r. The transmitted wave, H_t, is caused by energy transmitted under the structure, over the structure through overtopping, and by a radiated wave, H_R, which is caused by the motions of the floating structure. The interaction between the flow and the structure also results in energy dissipation, E_d, due to viscous dissipation, turbulence, and non-linear wave breaking. The movement of the structure is specified in terms of the anchoring, which defines the degrees of freedom of the structure.

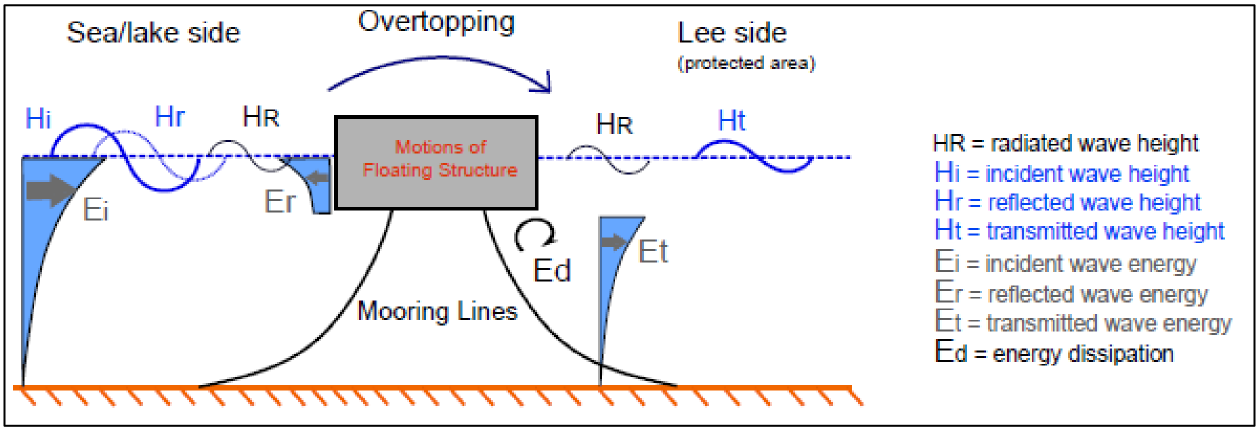

Figure 8: Interaction between wave and floating structure (Biesheuvel, 2013)

Narrow-beam floating structures, such as a pontoon, box, or A-frame designs, typically have higher reflection coefficients. The floats are rigid along the direction of the wave propagation but typically translates and rotates in response to wave attack. Inertia, radius and gyration, and draft are important parameters that control the performance of narrow-beam floating structures. Most effective design feature high hydrodynamic and mooring stiffness to ensure that the natural period of the structure exceeds that of the incident waves.

The relationship between the transmission coefficient (C_t), reflection coefficient (C_r), and the energy dissipation coefficient (C_d) can be formulated according to Koutandos et al. (2005) as follows:

$$C_t^2 + C_r^2 + C_d^2 = 1 \tag{1}$$

Where: $C_t = H_t / H_i$ and $C_r = H_r / H_i$. H_t is the height of the transmitted wave, H_r is the height of the reflected wave, and H_i is height the incident wave.

5.1 APPLICABLE FORMULATIONS AND EXPERIMENTAL INVESTIGATIONS OF CYLINDRICAL FLOATING ATTENUATOR PERFORMANCE

A review of the existing and proposed log booms indicate that they are both restrained laterally. The density of the existing cedar log boom ensures that approximately 80 percent of the log boom is submerged. In comparison, the proposed log boom will need additional ballast to ensure that a draft of 1 foot is achieved. When subjected to short waves, the heave of both systems will be limited and the reflection coefficients will be higher. However, as wave periods increase, the log booms will have more pronounced vertical movement, and the wave reflection will gradually decrease.

Wave transmission and reflection coefficients for existing and proposed conditions were estimated using both semi-empirical formulations and experimental studies. Wiegel (1959) evaluated existing models and theories applying to partial transmission and partial reflection, and based on wave power transmission (time rate of energy propagation) he determined the following relationship between transmitted wave power, $P_{t,}$ to the incident wave power, P_i

$$\frac{P_t}{P_i} = \left(\frac{\frac{4\pi(d-D)}{L}}{\sinh\left(\frac{4\pi d}{L}\right)} + \frac{\sinh\left(\frac{4\pi(d-D)}{L}\right)}{\sinh\left(\frac{4\pi d}{L}\right)}\right) / \left(1 + \frac{\frac{4\pi d}{L}}{\sinh\left(\frac{4\pi d}{L}\right)}\right) \qquad (2)$$

Where: D is the draft, d is the water depth, and L is the wave length.

Jack C. Cox (1989) expanded on Wiegel’s (1959) wave power transmission theory by incorporating long finite width barrier theory developed by Dean (1975). Jack C. Cox’s formulation for wave transmission is applicable to finite width and finite depth structures and is expressed as:

$$C_t = \sqrt{\frac{P_t}{P_i}} \frac{2\sqrt{1+\left(\frac{2\pi B}{L}\right)^2})}{\frac{2+(2\pi B)^2}{L}} \qquad (3)$$

Where: B is the width of the FB.

Ozeren et al. (2011) conducted an experimental investigation of cylindrical floating structures performance with various mooring configurations. Among other shapes and configurations, they estimated the wave transmission and reflection coefficients for pile-restrained single-pipes in a wave flume as shown in Figure 9.

Computed transmission coefficients reported by Ozeren et al. (2011) were compared with the well-established formulations developed by Jack C. Cox. Although Cox’s formulations were originally derived for box-type structures, they served as a useful benchmark for validating the computed transmission coefficients in Ozeren et al. (2011). Cylinder-shaped structures are generally expected to exhibit only slightly higher transmission coefficients than box-shaped ones.

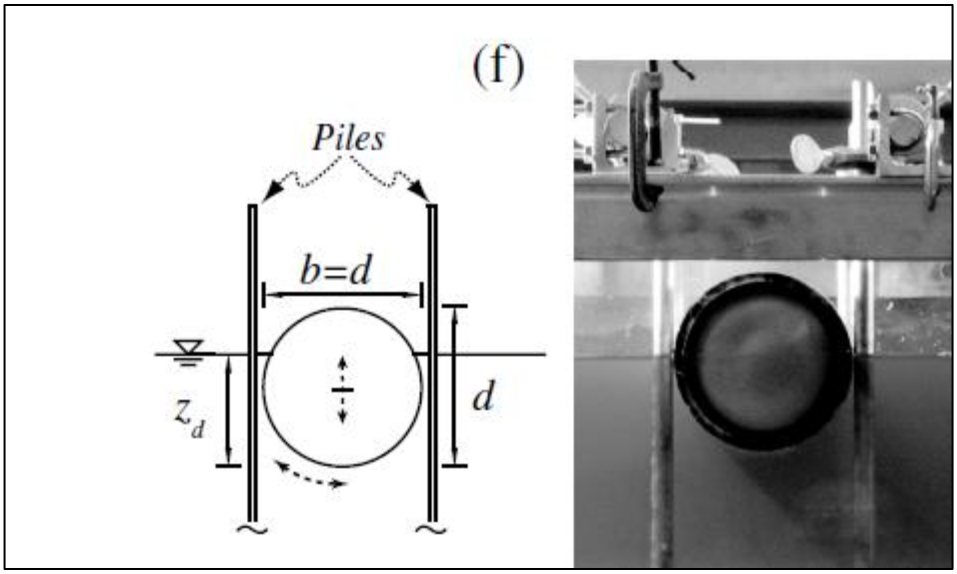

Figure 9: Pile-restrained model as shown in Ozeren et al. (2011).

5.2 DESIGN WAKE CLIMATE

PND Engineers, Inc. (PND) conducted a wave and wake analysis for a proposed floats and log booms at the Mercer Island Beach Club in 2018 (PND, 2018). A part of that analysis, PND determined that vessel wakes are the primary cause of concern at Lake Washington regarding shoreline erosion. A wake height and wake period of 3 feet and 2.5 seconds, respectively, was assumed and deemed to be the controlling factor for the design of the float system. Based on new research regarding wakes produced by wake boards, which can be found in Marr et al. (2022), it is possible that the design wake height in PND (2018) was overstated. Marr et al. (2022) measured wake heights at specific distances from different types of wakeboard boats, and they found that the maximum wake height 100 feet from the wakesurf boats was approximately 1.7 feet.

Based on the vessel traffic on Lake Washington, it was assumed that wakesurf boats will pass the existing log boom approximately 500 feet from the shore.

5.3 ESTIMATED WAVE TRANSMISSION AND REFLECTION

As part of estimating wave transmission of the existing and proposed log boom using formulations by Jack C. Cox (1989), a representative mean water depth of 12 feet (USACE datum) was assumed based to the design drawings by Waterfront Construction.

The relative depth, k*h (k is the wavenumber and h is the water depth), draft ratio, Z_d/d (Z_d is the draft and d is the diameter of the cylinder), and wave steepness, H/L (H is the wave height and L is the wave length) were computed based on the design wake climate. By applying Cox's transmission theory, the wave transmission coefficients were estimated to be 0.74 and 0.80 for the existing and proposed log booms, respectively. The results imply that the transmitted design wave heights would be as follows:

- Existing Log Boom: 1.7 feet * 0.74 = 1.3 feet
- Proposed Log Boom: 1.7 feet * 0.80 = 1.4 feet

Figure 10 and Figure 11 show the effect of draft ratio, Z_d/d, on transmission and refraction coefficients for pile-restrained FB models, respectively, which are available in Ozeren et al. (2011). Based on the relative depths, draft ratios, and wave steepness computed at the log booms, wave transmission and reflection coefficients were inferred from the graphs. According to the graphs, the wave transmission coefficient was higher for the proposed log boom (represented by red line) compared to the existing log boom (represented by yellow line). Consequently, the wave reflection coefficient was higher for the existing log boom. These findings imply that the proposed log boom is likely have reduced wave reflection due to a shallower draft compared to the existing log boom. Another consistent conclusion evident from Figure 10 and Figure 11 is that, for larger relative depths (which correspond to shorter wave periods), the transmission coefficient decreases while the reflection coefficient increases.

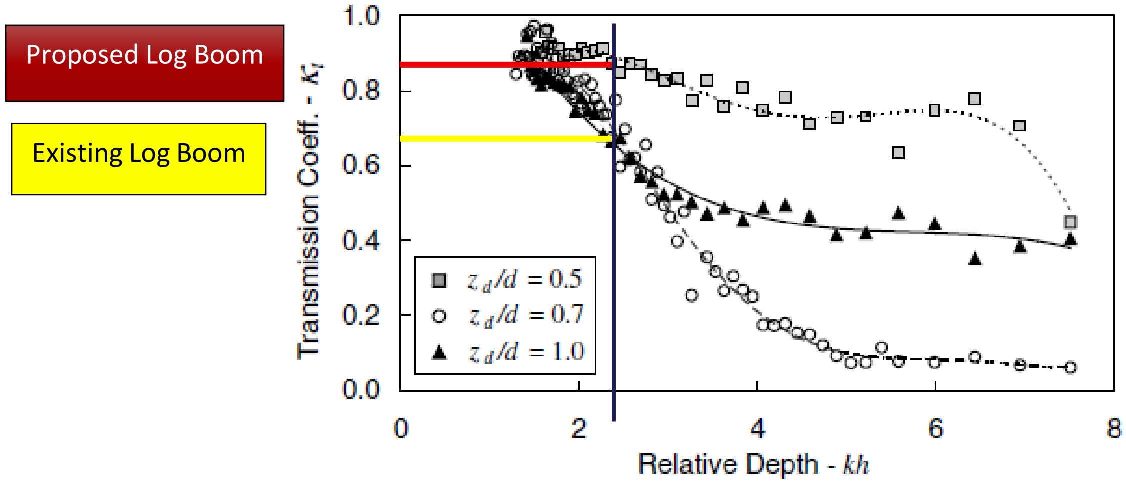

Figure 10: Effect of draft ratio, Zd / d, on transmission coefficients for pile-restrained FB models (Ozeren et al. (2011)).

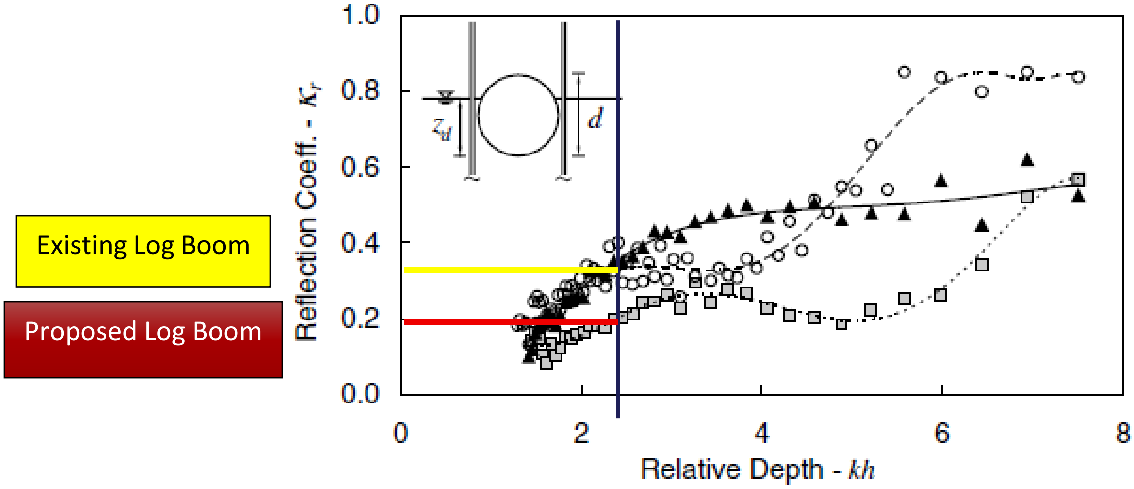

Figure 11: Effect of draft ratio, Zd / d, on reflection coefficients for pile-restrained FB models (Ozeren et al. (2011)).

5.3.1 IMPACT OF CORRUGATED CYLINDER

The corrugated surface of the proposed log boom is expected to dissipate more wave energy than the smoother surface of the existing cedar log boom. This is especially true for shorter period waves. The corrugations generate additional drag and turbulence, which enhances wave scattering and vortex shedding compared to a smooth surface. For example, Romya et al. (2021) found that corrugated semi-circular structures provided enhanced wave attenuation compared to a smooth semi-circular structure under the same test conditions.

It is reasonable to assume that the proposed log boom will provide additional wave dissipation which will lower the wave transmission. It is also reasonable to assume that the corrugations will to some degree enhance directional spreading (dispersing of wave energy) of the reflected wave, which in turn will likely make the reflected waves more diffuse (wave energy is scattered over a range of directions) than specular (angle of incidence equals the angle of reflection).

6. IMPACT OF THE POSITION AND ORIENTATION OF THE EXISTING AND PROPOSED LOG BOOMS

There are concerns that the new location of the proposed log boom will enhance nearby properties' exposure to reflected wave energy. Approximately a 100-foot section (shown in yellow in Figure 12) of the existing FB is expected to be able to reflect an incoming wave towards adjacent properties. In comparison, about a 200-foot section (shown in red in Figure 12) of the proposed log boom could potentially reflect incipient waves towards nearby properties. To adequately be able to compare the reflection of the existing and proposed log booms, a wave model using the Delft3D modeling suite was developed. Based on the findings by Ozeren et al. (2011), and the computed wave transmission coefficients using formulations by Cox (1989), wave transmission and reflection coefficients for the existing boom were estimated to be 0.69 and 0.37, respectively. The dissipation coefficient was set to be 0.62 based on findings by Ozeren et al. (2011). As mentioned earlier, the transmission coefficient was computed to be higher for the proposed log boom. However, to be relatively conservative in the estimate of the coefficients for the proposed log boom, the same coefficients were used for both existing and proposed conditions. Furthermore, it was assumed that the wave reflection would be specular for both conditions.

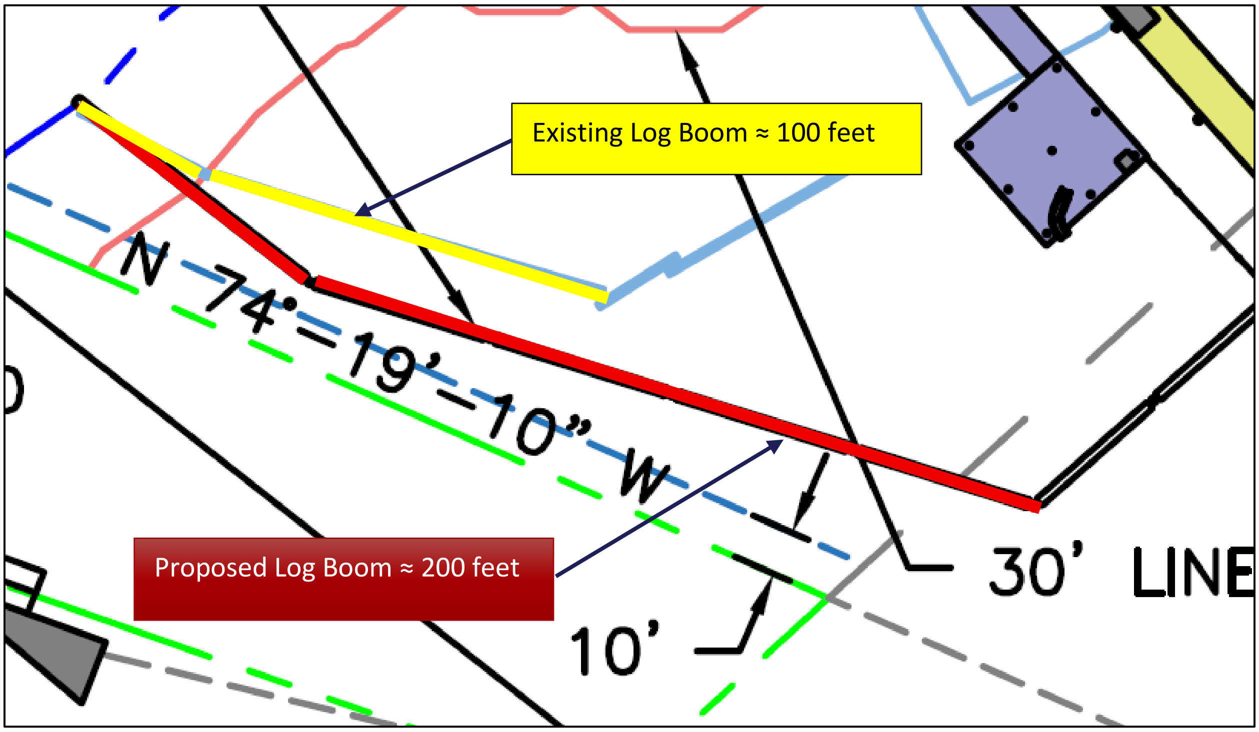

Figure 12: Layout of the existing and proposed log booms (Waterfront Construction Inc., 2025).

6.1 WAVE MODELING

Nested grids were incorporated into the Delft3D-WAVE model to achieve a grid resolution of approximately 3.3 feet by 3.3 feet in the area surrounding the log booms. Bathymetry for the model domain was developed using the Continuously Updated Digital Elevation Model (CUDEM) provided by the National Oceanic and Atmospheric Administration (NOAA). To improve the representation of nearshore conditions, the bathymetry in the vicinity of the log boom was manually refined based on bathymetric contours from GPS Nautical Charts (2025), as shown in Figure 13.

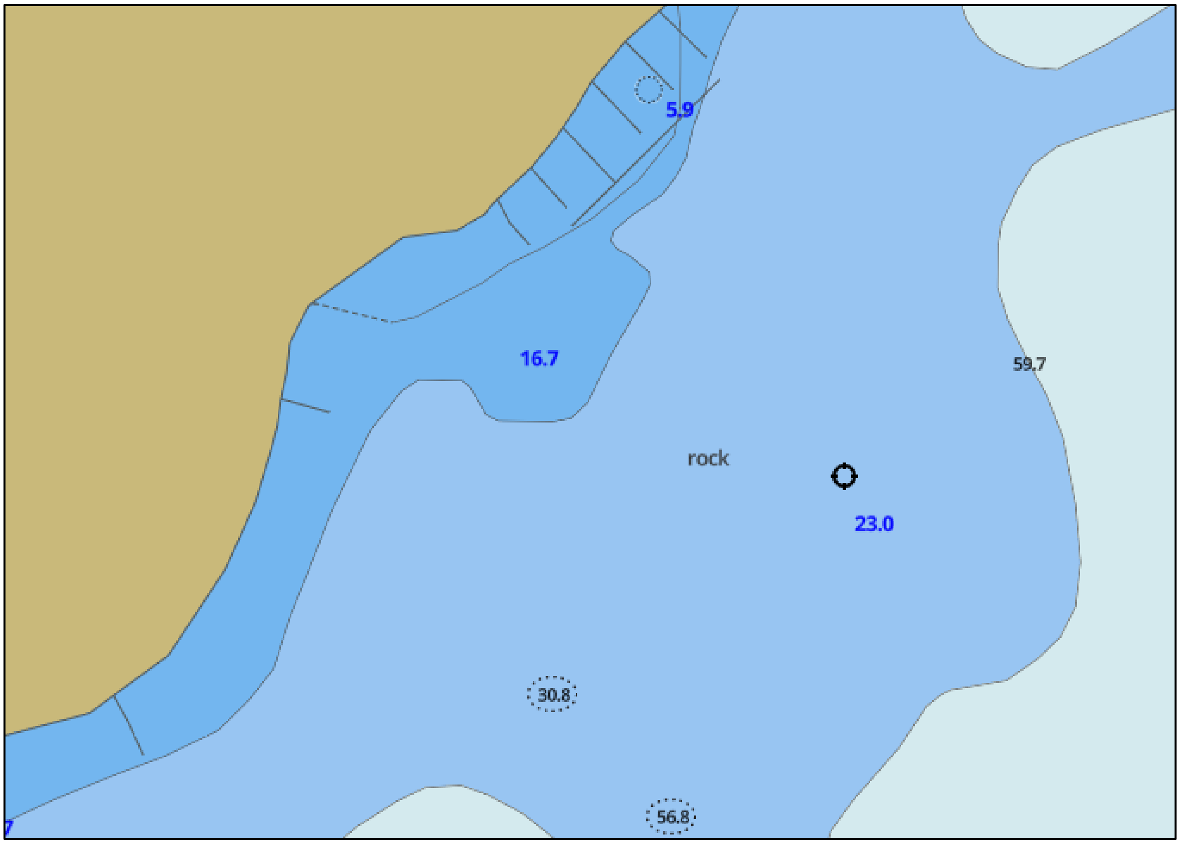

Figure 13: Bathymetry at the Mercer Island Beach Club (Gps Nautical Charts, 2025).

6.1.1 WIND-WAVES

Due to concerns from nearby property owners that strong southeasterly winds during the winter months may generate wind waves contributing to shoreline erosion, the wave climate corresponding to an approximate 2-year return period wind speed (approximately 30 miles per hour (mph)) was predicted at the existing log boom. The modeled significant wave heights and wave periods for two representative wind directions are presented in Table 1.

Table 1: Simulated wave climate at the existing log boom based on a 2-year wind event.

2-Year Wind Event (30 mph)	Significant Wave Height (ft)	Wave Period (sec)
Wind Direction (˚) = 135	1.30	2.5
Wind Direction (˚) = 170	1.35	2.5

6.1.2 VESSEL WAKE

The vessel wake was simulated in Delft3D-WAVE by defining a wave boundary located approximately 500 feet offshore, running parallel to the shoreline. The wake was generated using the following uniform boundary condition:

- Wave Height: 1.7 feet
- Wave period: 2.5 seconds
- Direction: 135 degrees

6.2 OUTPUT FROM DELFT3D-WAVE

Because the period of the wind-waves shown in Table 1 are equal to the period of the vessel wake, it can be assumed that the wave transmission and reflection coefficients would be approximately the same for predicted wind-waves and the vessel wake.

Figure 14 shows simulated significant wave heights along the shoreline without a log boom, while Figure 15, Figure 16, and Figure 17 show simulated significant wave heights near the existing log boom (specular reflection), proposed log boom (specular reflection), and proposed log boom (diffuse reflection), respectively, under a wind direction of 135 degrees. Significant reflection was not expected as the reflection coefficient was set relatively low. Predicted significant wave heights were only slightly higher when a boom was present.

Even when winds originate from an easterly or southeasterly direction, the predicted peak wave energy predominantly propagates from a south-southeasterly direction due to wave refraction. As a result, higher-energy waves, those more likely to contribute to shoreline erosion, tend to impact the log booms at a less oblique angle. Consequently, the reflected waves are more likely to travel along the shoreline, rather than directly toward it, as illustrated in Figure 16.

Table 2 shows only slight variations in significant wave height among the scenarios with no log boom, the existing log boom, and the proposed log boom. The simulated wave reflection is limited, and it appears that wave reflection for the existing and proposed log booms would be similar. Additionally, adjusting the wind direction to 170 degrees resulted in negligible changes in the predicted magnitude of wave transmission and reflection.

Figure 18 and Figure 19 show simulated wake heights along the shoreline for the existing log boom (specular reflection) and the proposed log boom (specular reflection), respectively. Table 3 only shows some slight variation in wake height between existing and proposed conditions. The predicted wake heights were slightly lower at Obs_Point-1 through Obs_Point-3 for proposed conditions. This can likely be attributed to a slight reduction in wave reflection due to the proposed log booms orientation. Most importantly, however, is that the results indicate that an increase in reflection of the wake is not expected.

While a vessel passing within 500 feet of the proposed log boom would result in an increased incident wake height at the structure, the direction of wave propagation and the relative magnitude of reflected wave energy would remain largely unchanged between the existing and proposed log booms.

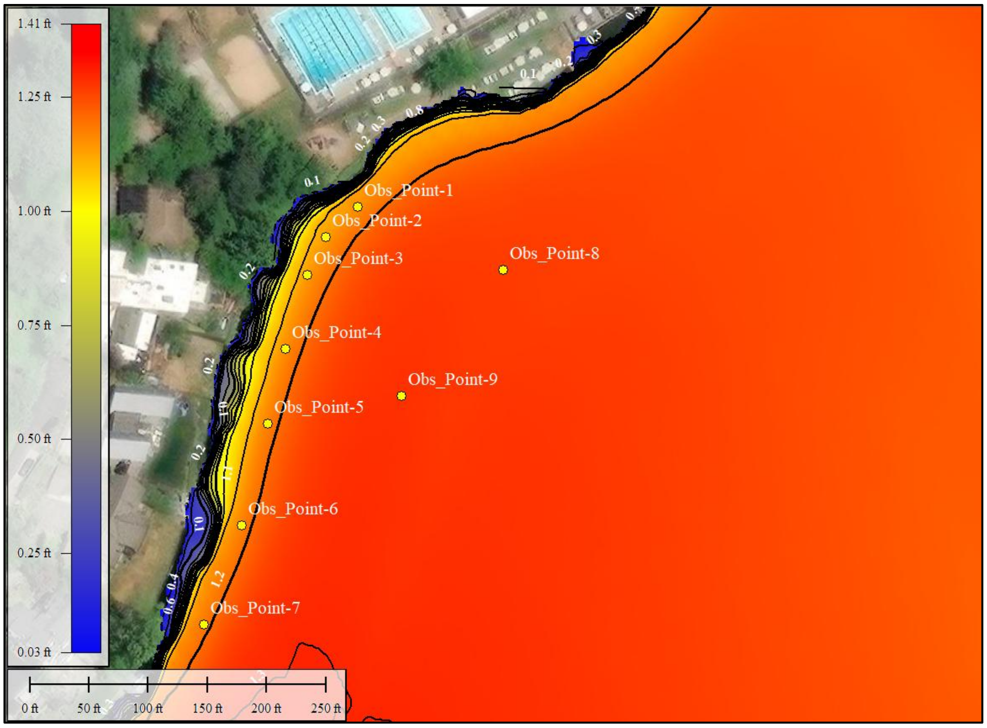

Figure 14: Simulated wave heights without a log boom under on a wind direction of 135˚.

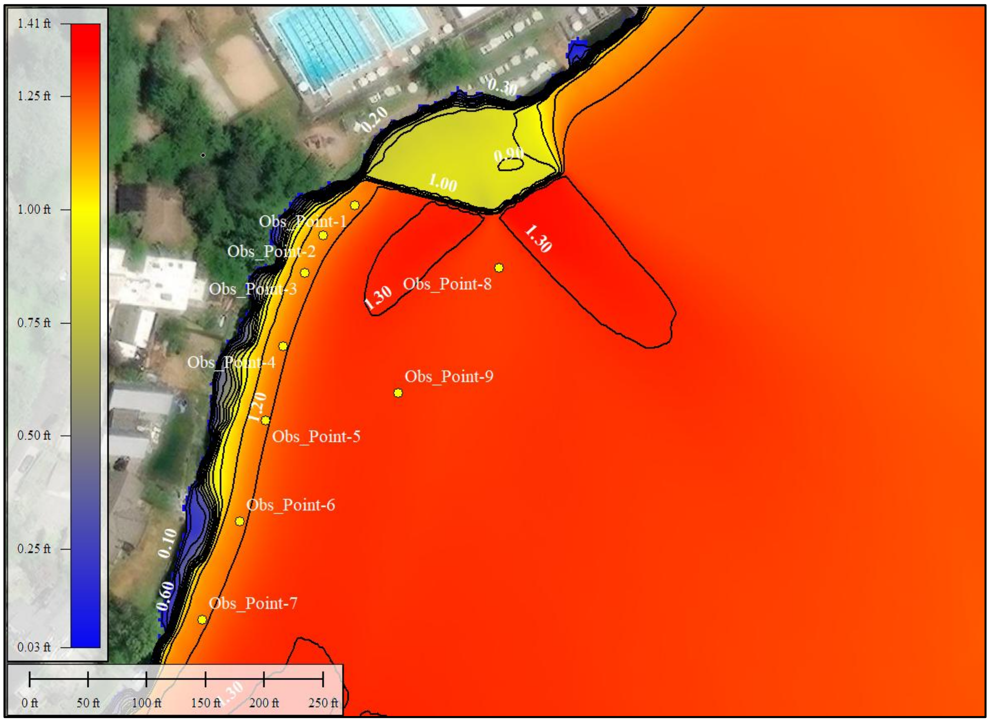

Figure 15: Simulated wave heights near the existing cedar log boom (specular reflection) under a wind direction of 135˚.

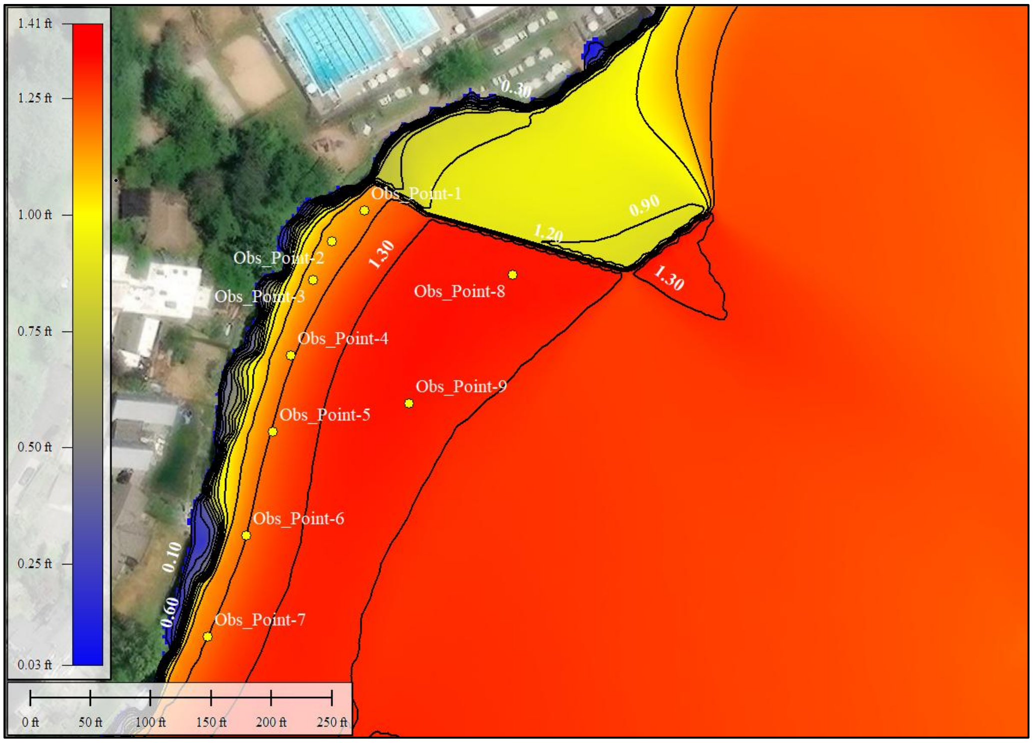

Figure 16: Simulated wave heights near the proposed log boom (specular reflection) under a wind direction of 135˚.

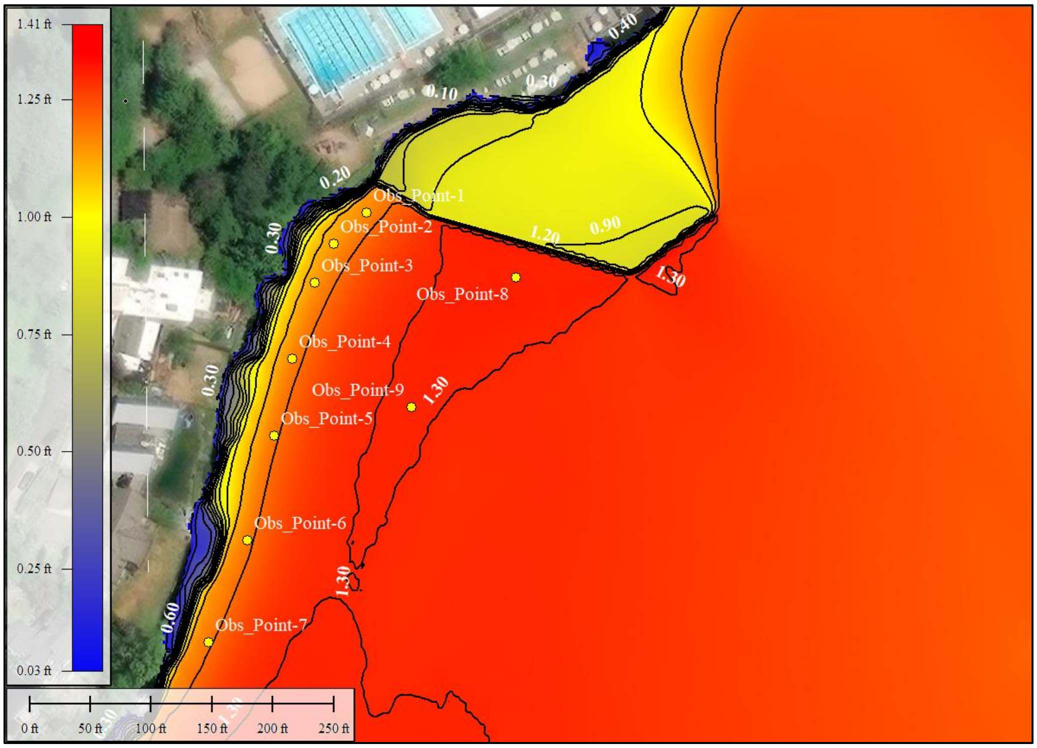

Figure 17: Simulated wave heights near the proposed log boom (diffuse reflection) under a wind direction of 135˚.

Table 2: Predicted significant wave height (in feet) at nine observation points along the shoreline for existing conditions, proposed conditions, and when no log boom is present.

Observation Points	No Log Boom	Existing Log Boom - Specular	Proposed Log Boom - Specular	Proposed Log Boom - Diffuse
	(ft)	(ft)	(ft)	(ft)
Obs_Point-1	1.15	1.17	1.17	1.16
Obs_Point-2	1.14	1.15	1.14	1.14
Obs_Point-3	1.14	1.16	1.14	1.14
Obs_Point-4	1.16	1.18	1.18	1.17
Obs_Point-5	1.17	1.19	1.21	1.19
Obs_Point-6	1.17	1.18	1.20	1.18
Obs_Point-7	1.18	1.19	1.20	1.19
Obs_Point-8	1.27	1.27	1.32	1.31
Obs_Point-9	1.28	1.29	1.32	1.30

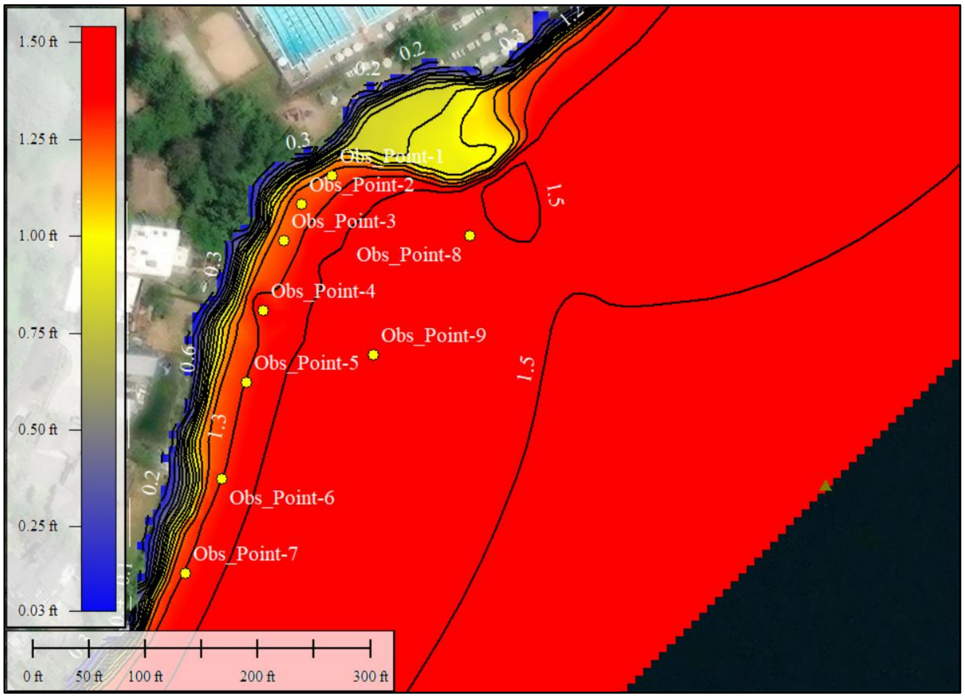

Figure 18: Simulated vessel wake height near the existing log boom (specular reflection)

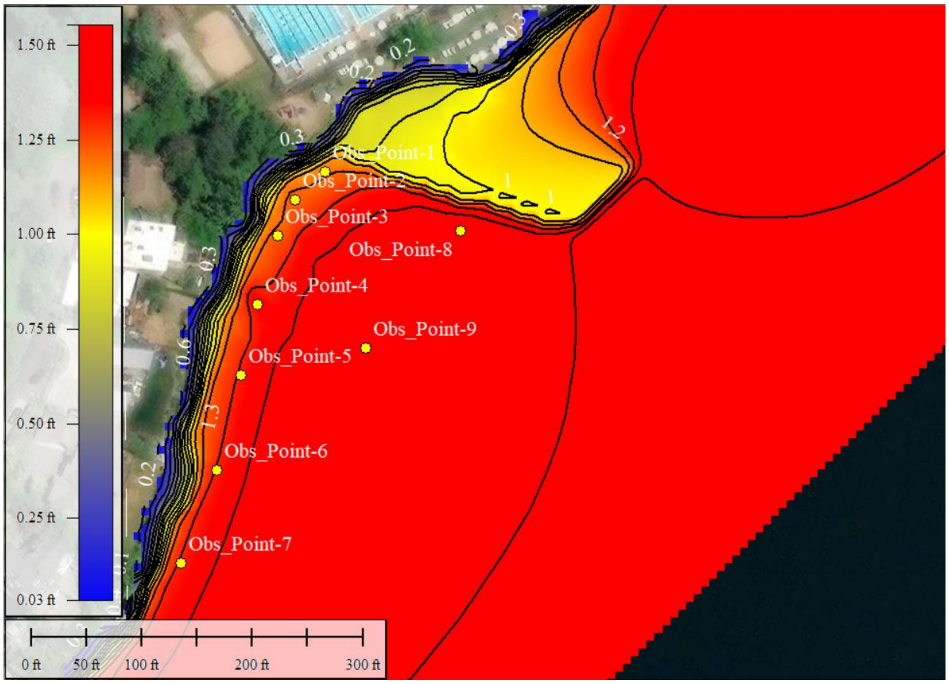

Figure 19: Simulated vessel wake height near the proposed log boom (specular reflection)

Table 3: Predicted wake height (in feet) at nine observation points along the shoreline for existing conditions and proposed conditions.

Observation Points	Existing Log Boom - Specular	Proposed Log Boom - Specular
	(ft)	(ft)
Obs_Point-1	1.23	1.19
Obs_Point-2	1.26	1.23
Obs_Point-3	1.24	1.22
Obs_Point-4	1.35	1.36
Obs_Point-5	1.31	1.32
Obs_Point-6	1.30	1.31
Obs_Point-7	1.31	1.31
Obs_Point-8	1.47	1.45
Obs_Point-9	1.45	1.47

7. CONCLUSIONS & RECOMMENDATIONS

A well-established semi-empirical formulation, supplemented by physical modeling of cylindrical attenuators in a wave flume, was applied to estimate wave transmission and reflection coefficients for both the existing and proposed log booms at the Mercer Island Beach Club on Mercer Island, WA. The influence of the proposed log boom's length and orientation was evaluated using a wave model developed with the Delft3D modeling suite.

The existing cedar log boom has an estimated draft of approximately 16 inches, with the majority of the cedar log submerged due to its density. In contrast, the proposed HDPE corrugated log boom will require ballast to achieve its intended design draft of 12 inches. Because of its greater draft, the existing log boom likely exhibits a slightly higher wave reflection coefficient than the proposed log boom. Both log booms are pile-supported, which prevents lateral movement.

The proposed log boom is expected to provide greater wave dissipation due to its corrugated surface. Corrugations introduce additional drag and turbulence, promoting enhanced wave scattering and vortex shedding compared to smoother surfaces. Additionally, the proposed log boom is designed to extend higher above the water surface than the existing boom, which is anticipated to reduce overtopping.

The planned reconfiguration will result in the marina's footprint extending further from shore. This layout could effectively encourage vessel traffic to navigate at a greater distance from the shoreline. As a result, the increased distance over which wakes propagate will likely lead to greater wake attenuation and, consequently, a slight reduction in wake heights impacting the log booms. Accordingly, it is reasonable to expect that reflected wake heights after construction will be slightly lower than those observed under pre-construction conditions.

A comparison of simulated wave reflection under existing and proposed conditions did not indicate that the proposed log boom would noticeably increase wave reflection toward adjacent properties. The corrugated surface of the proposed log boom is likely to promote more diffuse rather than specular reflection, scattering reflected wave energy in multiple directions. In comparison, the existing cedar log boom is expected to produce more specular wave reflection.

While the methods employed in PND's evaluation of wave reflection at the Mercer Island Beach Club do not account for all possible wave conditions to which the log booms may be exposed, the analysis suggests that an overall increase of wave reflection along the shoreline is not anticipated. Provided that the HDPE corrugated log boom is installed in accordance with the current plans, and that the log booms are not submerged to a greater depth than designed, an adverse increase in shoreline erosion due to the proposed design is not expected.

8. REFERENCES

Cox, J., C. (1989). Design of a Floating Breakwater for Charleston Harbor, South Carolina.

Biesheuvel, A.C. (2013). Effectiveness of Floating Breakwaters – Wave attenuating floating structures.

Koutandos, E., Prinos, P., Gironella, X. (2005). Floating breakwaters under regular and irregular wave forcing: reflection and transmission characteristics. Journal of Hydraulic Research Vol. 43, No. 2 (2005), pp. 174–188.

Marr, J., Riesgraf, A., Herb, W., Lueker, M., Kozarek, J., Hill, K. (2022). A Field Study of Maximum Wave Height, Total Wave Energy, and Maximum Wave Power Produced by Four Recreational Boats on a Freshwater Lake. ST. Anthony Falls Laboratory Project (SAFL) Report No. 600.

Ozeren, Y. Wren, D. G., Altinakar, M. Work, P. A. (2011). Experimental Investigation of Cylindrical Floating Breakwater Performance with various Mooring Configurations. J. Waterway, Port, Coastal, Ocean Eng., 2011, 137(6): 300-309.

Romya, A. A, Moghazy, H. M., Iskander, M. M., Abdelrazek, A. M. (2021). Performance assessment of corrugated semi-circular breakwaters for coastal protection. Alexandria Eng. J. https://doi.org/10.1016/j.aej.2021.08.086.

Waterfront Construction etc. (2025). Marina Rebuilt Plan, “DWG#: 20-37005-A15”.

Wiegel, L. R. (1960). Transmission of Waves Past a Rigid Vertical Thin Barrier. Journal of Waterways and Harbors Division - Proceedings of the American Society of Civil Engineers.