APPENDIX N

Technical Memorandum on Potential for Seiche

Seiche hazard in the Buena Vista Lagoon basins, San Diego County

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1 Introduction

The purpose of this calculation is to evaluate the seiche hazard of the Buena Vista Lagoon, and in particular the effect of different Enhancement Project alternative alterations to the Lagoon's geometry, depth and vegetation content. The Buena Vista Lagoon consists of four interconnected basins, and given the narrow conduits between them, we regard them here as independent basins, and will refer to them as Weir, Railroad, Highway and I-5 basins, from the seaward side inland.

2 Assumptions

The seiche calculation for Buena Vista Lagoon will be performed based on the following assumptions, all of which are conservative:

- The basins are modeled as equivalent long and narrow, enclosed, rectangular basins of uniform depth with the dimensions given in Table 1. This assumption is conservative. In a natural lake with irregular shape boundary, oscillating long wave can lose energy due to friction and flow blockage by the irregular shoreline. The rectangular lake boundary is smooth and wave can travel without losing energy that will lead to a higher water level due to seiche oscillation.
- The maximum operational water elevation in the basins is 1.7 m and is used as the still water level in the calculation.
- To generate the maximum possible seiche, the wind is assumed to blow over the water surface along the length of each basin. Additionally, the wind duration is assumed to be long enough to establish the initial water setup to cause the seiche in the basins.

3 Approach / Methodology

3.1 Analytical Approach

3.1.1 Estimation of Natural Oscillation Periods for Buena Vista Lagoon

To compute the natural oscillation period of the basins we use Merian's formula (USACE, 1977)

$$T_n = \frac{2L}{n\sqrt{gh}} \tag{1}$$

where L is the length of the basin, h is the average still water depth, and n is number of nodes in the standing wave. The simplest mode of oscillation of a waterbody is at the fundamental oscillation period when $n = 1$ in Merian's formula, where the standing wave has one node.

3.1.2 Estimation of Wind-Induced Setup in Buena Vista Lagoon

This calculation is based on the momentum balance of pressure force and wind-shear force (Dean and Dalrymple, 1984; van Dorn, 1953). The wind shear stress acting on the water surface is expressed as

$$\tau_w = \rho k U^2 \tag{2}$$

where ρ is the mass density of water, U is the wind speed at a reference elevation of 10 m above the water surface, and k is a friction factor of order 10^{-6} (van Dorn, 1953):

$$\mathrm{k} = \begin{cases} 1.2 \times 10^{-6} & \mathrm{U} \leq \mathrm{U_C} \\ 1.2 \times 10^{-6} + 2.25 \times 10^{-6} \left(1-\frac{\mathrm{U_C}}{\mathrm{U}}\right)^2 & \mathrm{U} > \mathrm{U_C} \end{cases}$$

(3)

in which $Uc = 5.6$ m/s. Since the wind shear stress is balanced by the bottom shear stress as well as a hydrostatic pressure gradient, the water surface gradient along the direction of wind can be calculated as:

$$\frac{\partial \eta}{\partial x} = \frac{n \tau_w}{\rho g h} \tag{4}$$

where η is the water surface elevation and n is a factor taking into account the bottom friction. Typical values are $n = 1.15$ to 1.30 (USACE, 1977).

3.2 Potential of Seiche Due to Seismic Activities

The long periods of the fundamental mode seiche oscillations fall well outside of the period range where earthquake ground motions carry most energy, and it is thus unlikely that these modes will be generated in the lake. There have been observations of higher mode seiches, which were excited after the 7.9 Denali, Alaska earthquake in several water bodies around Seattle (Barberopoulou, 2006). These seiche amplitudes are on the order of 3 ft (~ 0.91 m) maximum if the geometric condition of the water body allows. A water body with similar characteristics to Buena Vista Lagoon, Lake Union, experienced ground motions that were amplified by factors of 5-10 by the occurrence of glacial deposits below. The particular circumstances that led to the occurrence of mild seiching (4 ~ 5 inches vertical oscillation or amplitude according to Barberopoulou, 2006) in Lake Union are not likely to occur in Buena Vista Lagoon. Therefore there is very low potential for seiching to occur in the lagoon under existing conditions or any of the Enhancement Project alternatives.

4 Computations

4.1 Natural Oscillation Periods of Buena Vista Lagoon basins

Estimates of the natural oscillation periods of the Buena Vista Lagoon basins were obtained by applying Merian's formula. The results for all basins and all configurations are given in Table 1. Figure 1 presents the hypothetical lakes used to estimate a potential seiche period using the approximation method provided by Merian's formula.

The dimensions of the equivalent rectangular basins of uniform depth were obtained by assuming the length, surface area, and volume to be equal to the corresponding characteristics of the enclosed parts of Buena Vista Lagoon. The width and the depth of the equivalent rectangular lake were obtained via dividing the surface area by the length and dividing the volume by the surface area.

These parameters, for basins and all alternatives, are given in Table 1.

4.2 Wind-Induced Setup in Buena Vista Lagoon

The wind speed data used in this analytical calculation are taken from Isla et al., 2004 and represent peak observed winds in San Diego County: the maximum 10-minute average wind speed at the reference elevation of 10 m above the water surface can reach up to 50 m/s (~ 100 knots, Isla et al, 2004).

We computed the wind setups (i.e. amplitudes at the shorelines) assuming the wind blows over the water surface along the long axis of the basins (along the length *L*) of the equivalent rectangular basin and applying the 10-minute sustained wind speed U_{10} = 50 m/s (~ 100 knots), and the results are shown in Table 1.

5 Results / Conclusions

The static wind-induced water setup at the Buena Vista Lagoon basins are shown in Table 1. We conclude the following:

- The largest of the shoreline amplitudes (aka setup in the length orientation of the basins, column 7 in Table 1) is 2.16 meters in the current configuration in the I-5 basin without vegetation, which is reduced to 1.47 m if we reduce the effective dimensions to account for vegetation. In our estimation, all of the Enhancement Project alternatives would lead to a reduction in potential seiche amplitudes compared to existing conditions.
- For the potential seiche caused by seismic activities in the area, the long periods of the fundamental mode seiche oscillations fall well outside of the period range where earthquake ground motions carry most energy, and it is thus unlikely that these modes will be generated in Buena Vista Lagoon, both under the current conditions and all of the Enhancement Project alternatives.

- The differences for the various alternatives, as summarized in Table 1, show that although there is a decrease of the wind-driven seiche setup (amplitude) for all alternatives compared to the original configuration (Table 1, column 7).
- For the seismic-induces seiches, the changes in natural period are relatively small, and are not expected to increase the seiche hazard since we cannot estimate the seismic spectra to such high precision.

6 References

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Table 1. Summary of model assumptions and results[KC1]

BVL Seiche
10-min av wind speed = 50 m/s
Maximum water level = 1.71 m
Fundamental natural period (T)

Existing

without-vegetation	Average Depth (m)	Length (m)	Width (m)	T-Length (sec)	T-Width (sec)	Setup-Length (m)	Setup-Width (m)
I-5 Basin	0.301	932.706	271.575	1086.090	316.236	2.160	0.709
Coast Hwy Basin	0.665	930.448	435.704	728.745	341.252	1.040	0.513
Railroad Basin	0.664	429.998	108.547	336.903	85.047	0.507	0.130
Weir Basin	0.787	267.147	119.784	192.348	86.246	0.269	0.121

with-vegetation	Average Depth (m)	Length (m)	Width (m)	T-Length (sec)	T-Width (sec)	Setup-Length (m)	Setup-Width (m)
I-5 Basin	0.383	767.245	155.394	791.524	160.311	1.472	0.322
Coast Hwy Basin	0.827	758.060	333.648	532.412	234.333	0.702	0.319
Railroad Basin	0.829	349.099	82.641	244.809	57.953	0.332	0.079
Weir Basin	0.808	267.147	114.731	189.770	81.500	0.262	0.113

Freshwater Alternative

without-vegetation	Average Depth (m)	Length (m)	Width (m)	T-Length (sec)	T-Width (sec)	Setup-Length (m)	Setup-Width (m)
I-5 Basin	1.219	898.550	311.506	519.637	180.146	0.565	0.203
Coast Hwy Basin	1.219	833.628	359.054	482.092	207.643	0.527	0.233
Railroad Basin	1.219	391.973	114.300	226.680	66.100	0.254	0.075
Weir Basin	1.219	224.638	109.423	129.909	63.280	0.146	0.072

Saltwater Alternative

without-vegetation	Average Depth (m)	Length (m)	Width (m)	T-Length (sec)	T-Width (sec)	Setup-Length (m)	Setup-Width (m)
I-5 Basin	1.097	898.550	311.506	547.746	189.890	0.625	0.225
Coast Hwy Basin	1.097	833.628	359.054	508.170	218.875	0.583	0.259
Railroad Basin	2.316	391.973	114.300	164.451	47.954	0.134	0.039
Weir Basin	2.316	224.638	109.423	94.246	45.908	0.077	0.038

Hybrid Alternative Option A

without-vegetation	Average Depth (m)	Length (m)	Width (m)	T-Length (sec)	T-Width (sec)	Setup-Length (m)	Setup-Width (m)
I-5 Basin	1.219	898.550	311.506	519.637	180.146	0.565	0.203
Coast Hwy Basin	1.097	833.628	359.054	508.170	218.875	0.583	0.259
Railroad Basin	2.316	391.973	114.300	164.451	47.954	0.134	0.039
Weir Basin	2.316	224.638	109.423	94.246	45.908	0.077	0.038

Hybrid Alternative Option B

without-vegetation	Average Depth	Length	Width	T-Length	T-Width	Setup-Length	Setup-Width
	(m)	(m)	(m)	(sec)	(sec)	(m)	(m)
I-5 Basin	0.792	898.550	311.506	644.531	223.443	0.854	0.311
Coast Hwy Basin	1.402	833.628	359.054	449.554	193.629	0.460	0.203
Railroad Basin	2.316	391.973	114.300	164.451	47.954	0.134	0.039
Weir Basin	2.316	224.638	109.423	94.246	45.908	0.077	0.038

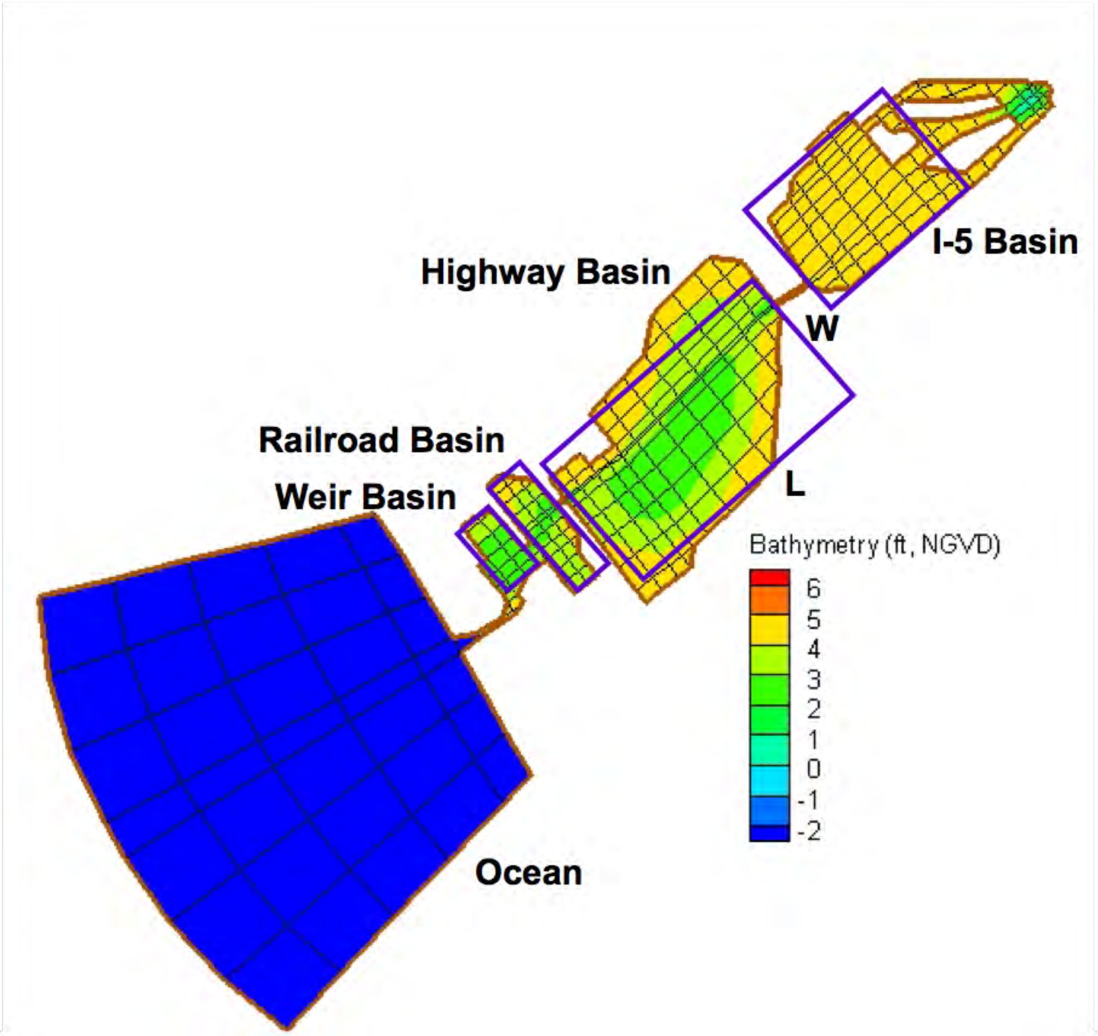

Figure 1. Simplified configuration of the four basins