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northwest hydraulic consultants

NHC Ref. No. 2004048

February 14, 2020

GREENBANK BEACH AND BOAT CLUB, INC.
P.O. Box 75
Greenbank, WA 98253

Attention: **Judi Moore**
President

Copy to: **Sally King**
Tom Slocum, PE

Via email: jrmmoore@gmail.com
tom@skagitcd.org

Re: **Greenbank Marsh Restoration Design**
Addendum to Hydraulic Modeling Documentation

Dear Ms. Moore:

The Greenbank Beach and Boat Club (GBBC) retained Northwest Hydraulic Consultants (NHC) and its team to provide engineering and environmental consulting services for the Greenbank Marsh Restoration Design Project. After the initial work phase, the NHC team was tasked with conducting additional hydraulic and hydrogeologic analyses to refine the design and evaluate some feasibility issues revealed during the prior analysis phase. This letter report documents the development of the hydraulic model and presents the model findings. Shannon & Wilson, Inc. are issuing a concurrent hydrogeology memorandum for this additional work.

1 INTRODUCTION

1.1 Scope of Work

The current phase of the project is scoped with conducting additional technical investigations including topographic survey, surface water hydraulics and hydrogeology in order to ascertain the project feasibility and refine the design parameters. For hydraulics, NHC was scoped with investigating North Bluff Road culvert sizes and stormwater mitigation options for the North Bluff Road system, including pump stations, detention ponds, and outfalls.

2 MARSH SURVEY AND PROPOSED DESIGN GRADING MODIFICATION

NHC crews used GPS-RTK equipment to survey the entire marsh area. The data was used to generate a new terrain model of the marsh to replace the previous representation (which used a single elevation of 6.4 ft for the entire marsh).

The new marsh surface and revised lagoon grading were then merged with the terrain model used in previous phases. The new terrain model (Figure 1), was used to update the PCSWMM and MODFLOW models used for hydraulics and hydrogeology respectively.

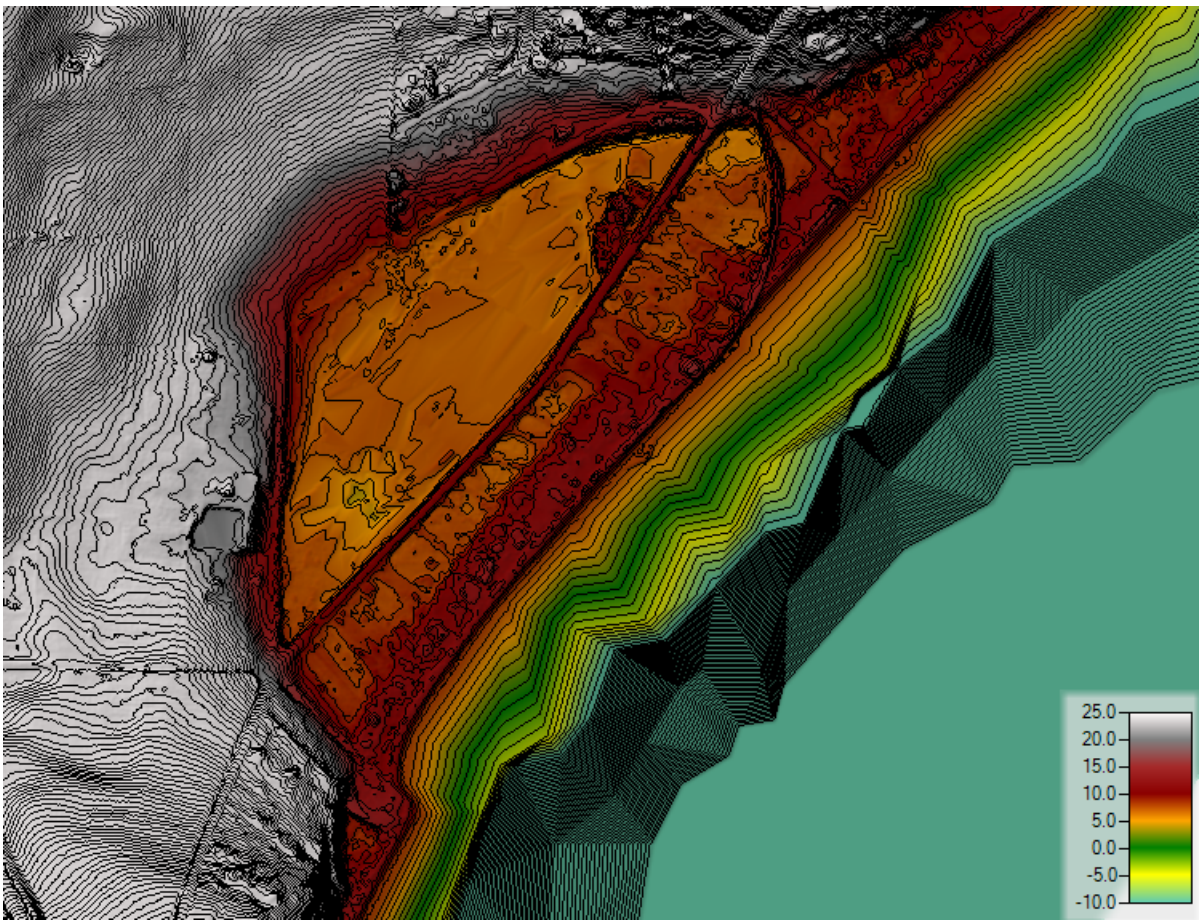

Figure 1: Project terrain model with revised marsh surface. 1 ft contours shown.

3 HYDRAULIC MODEL MODIFICATIONS

3.1 Hydrology

Hydrologic inputs for the PCSWMM model were modified from the previous work based on review of additional stormwater information. Inflows to the North Bluff Road stormwater system were reduced by 33% to account for a ditch on the Wonn Road extension that intercepts flows from the south and directs them to the bay. This reduced the 100 -year maximum peak flows to about 3 cfs and the 2-year event to 1 cfs. In addition, the flows along North Bluff road were distributed along the line rather than lumped at the upper end of the line to better reflect surface runoff inputs.

3.2 Proposed Project Lagoon Grading

Review of the proposed channel grading within the lagoon revealed that the cross sections were undersized and restricting flow reaching the proposed North Bluff Road culvert. The grading within the lagoon was modified to ensure that flows were controlled by the lagoon outlet and culvert and not restricted in between the two.

4 NORTH BLUFF ROAD BOX CULVERT SIZING

Island County, who would be the owner of any new culvert under North Bluff Road, indicated interest in reducing the size of the proposed culvert from the 20-foot-wide culvert modeled in the first phase. A constraint on reducing culvert size was the need to remain within WDFW fish passage criteria requiring culverts velocities to be below 3.0 ft/s 90% of the time. No muted tidal regulators or tidegates were attached to the culverts; the assumption is that a new berm would be built along North Bluff Road to prevent overtopping from the marsh over the road during extreme high tide events. Four new culvert alternatives were modeled:

Table 1 – North Bluff Road Culvert Sizes Modeled

Alternative No.	Culvert Width & Height (ft)	Culvert Invert (ft NAVD 88)	Notes
2-1	18 x 6	4	
2-2	14 x 6	4	
2-3	18 x 6	5	
2-4	18 x 6	4	Included a 2 ft pipe extending from the current drainage structure in the lagoon to the bay; this allows drainage from the marsh below the lagoon outlet elevation of 7.0.

4.1 Box Culvert Sizing Results

The alternatives were simulated for the same summer and winter periods as was done for Phase 1. Results are shown in Table 2 and Figure 2 (for winter only, summer results are very similar). Results for Alternatives 2-1 through 2-3, which varied culvert size and invert elevation only, were virtually identical, indicating the culvert options were not a significant control of flow in the system. The combination of removal of the MTR and expanding the lagoon channel resulted in a significant increase in tidal prism over the Phase 1 MTR Option 3 Alternative, which is shown for comparison.

Alternative 2-4 shows a large difference between inflow and outflow because the pipe from the lagoon carries most of the outflow, rather than draining though the lagoon outlet. Although overall tidal prism in increased, as shown by increase in inflow, the greatly reduced outflow would be expected to reduce the size and sustainability of the lagoon outlet channel. Therefore, this alternative is not recommended.

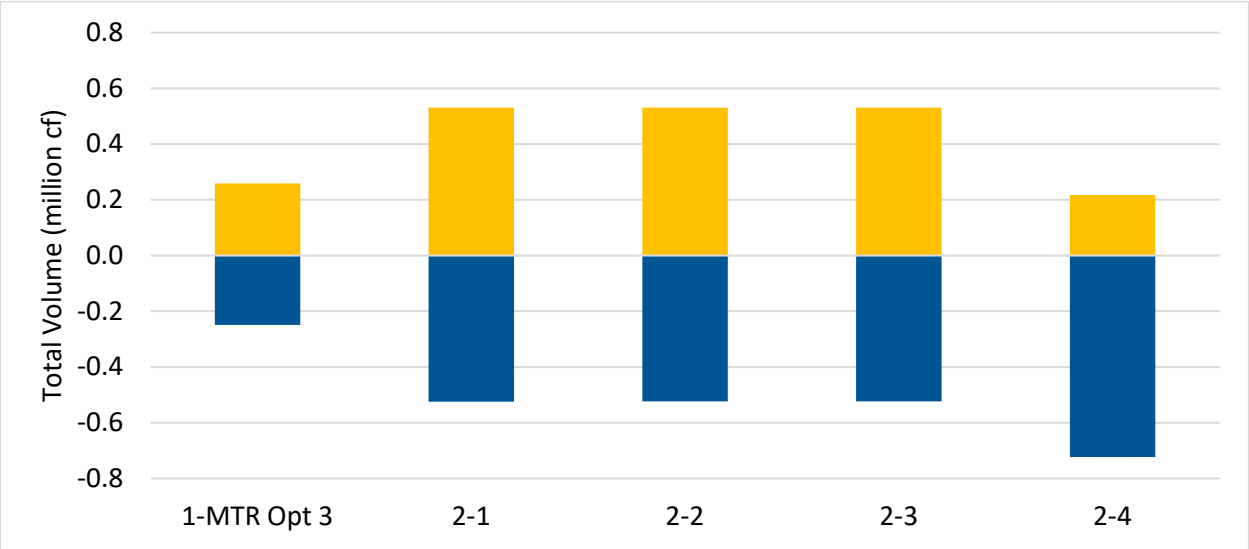

Figure 2: Lagoon outlet average ebb (positive) and flood (negative) tidal volumes, winter season

Table 2: Seasonal average tidal prism volumes by alternative

Analysis Period	Summer	Winter
Start Date	7/1/2008	11/1/2008
End Date	9/1/2008	2/2/2009
Duration (hrs)	1490	2233
Tide Cycles	120	180
	Volume (million cf)	
1-MTR Opt 3 Flood	-0.20	-0.25
1-MTR Opt 3 Ebb	0.20	0.26
2-1 Flood	-0.45	-0.52
2-1 Ebb	0.45	0.53
2-2 Flood	-0.45	-0.52
2-2 Ebb	0.45	0.53
2-3 Flood	-0.45	-0.52
2-3 Ebb	0.45	0.53

Fish passage velocity criteria were evaluated by calculating velocity duration curves for alternatives 2-1 to 2-3. These results are shown in Figure 4. All three alternatives easily met WDFW fish passage criteria. No outflows on ebb tide exceeded 3 ft/s, and only alternative 2-3, with the higher invert, exceeded 3 ft/s on inflow, for about 3% of the time.

Without an MTR, extreme high tides in the marsh are assumed to reach the same level as in the bay. Applying NOAA Seattle extreme tide statistics[1] to Greenbank using datum adjustment factors developed in the previous phase the estimated 100-year high tide is 12.5 feet (NAVD88 datum). Most of North Bluff road is around 10.5 feet, so a berm or floodwall at least two feet high would need to be constructed along the marsh side of the road to prevent extreme high tides overtopping into residential properties. Allowing for lower elevation shoulders and freeboard the berm or floodwall would most likely be between 3 and 4 feet above ground to meet this level of flood protection.

[1] https://tidesandcurrents.noaa.gov/est/stickdiagram.shtml?stnid=9447130

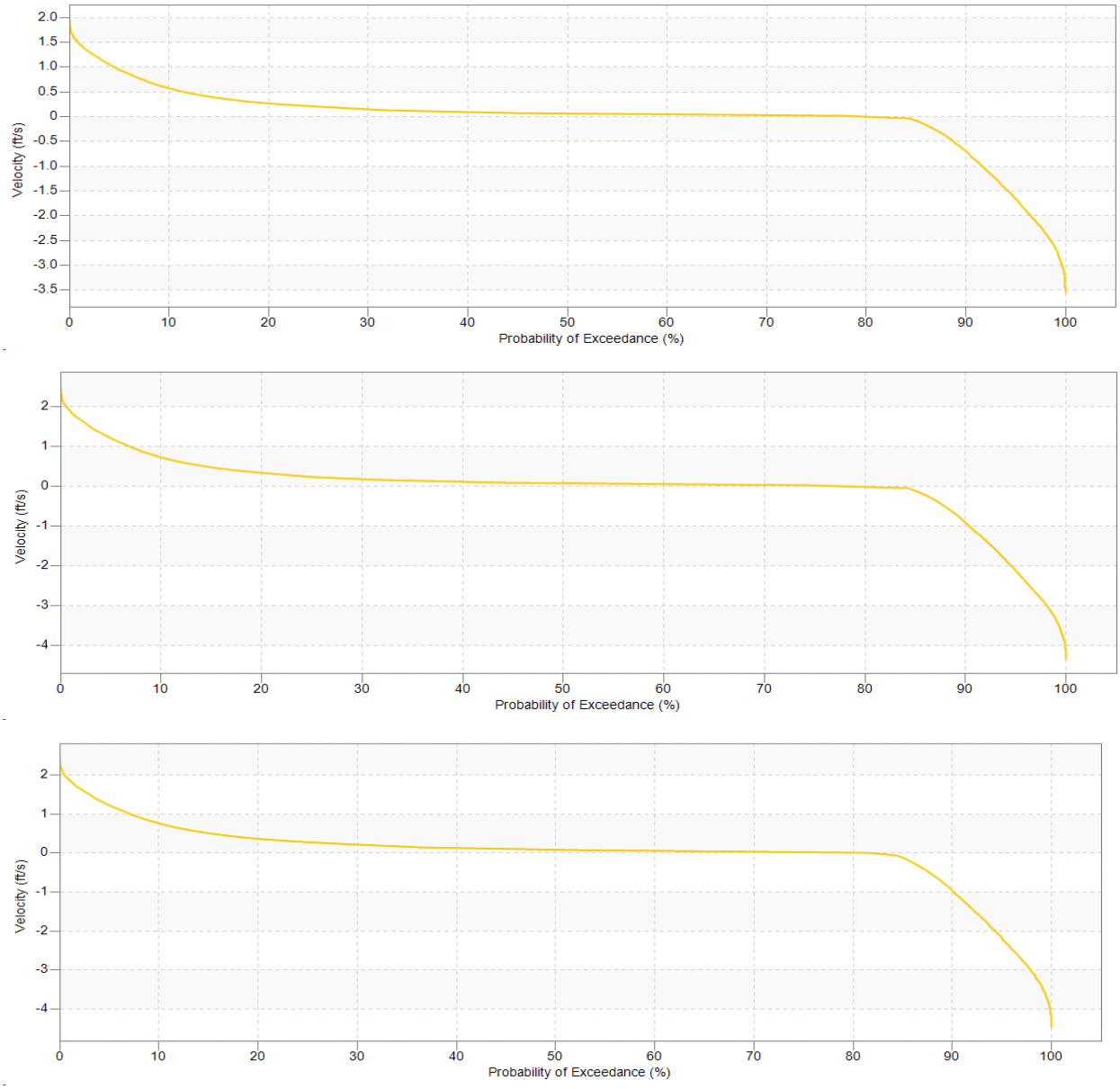

Figure 3: Velocity duration curves for alternative 2-1 (top), 2-2 (middle), and 2-3 (bottom). Negative velocities are into the marsh (flood tide).

5 NORTH BLUFF ROAD STORMWATER MITIGATION ALTERNATIVES

A series of new stormwater mitigation options were investigated. Mitigation is needed because reconnection of the marsh means that the current gravity discharge into the lagoon would have adverse impacts. All the alternatives modeled disconnected the stormwater system from the lagoon and marsh system, so drainage was no longer reliant on lagoon water levels to function. The table below lists the

alternatives considered. Each alternative was run for a two-week period containing a two-year flow event selected from the long-term WWHM results (August 15-September 1, 1968).

Table 3 – Stormwater System Mitigation Alternatives Modeled

Alternative No.	Alternative	Description
2-5	Pumped discharge	A 1cfs pump would discharge into the lagoon. Pump turns on when water surface elevations reach 6.0 feet. A flapgate on the NB Road stormwater pipe would allow additional gravity discharge into the lagoon when water levels are high along the road – i.e. draining coastal storm floodwaters
2-6	Direct gravity discharge to bay	The north end of the stormwater pipe would be connected to a new pipe that would directly discharge into the bay. A flapgate on the end would prevent backflow
2-7	Detention pond and direct gravity discharge to bay	A new pond would be created within the lagoon area, contained by berms. The surface area would be about ½ acre, with a bottom elevation of 4.0. The pond would require lining to prevent groundwater infiltration from filling it. From the pond a new stormwater pipe with tidegate would discharge to the bay.
2-8	Detention pond and direct gravity discharge to bay, with groundwater inflow	The same system as alternative 2-7, with 0.5 cfs of continuous groundwater inflow from a new drain tile line along North Bluff Road added

5.1 Model Results

Figure 4 shows simulated water levels at the upstream (south) end, middle, and north end of the North Bluff Road stormwater system for existing conditions and the four alternatives tested. Pumping the stormwater, Alternative 2-5, works well at the north end, matches existing conditions in the middle, but has the largest increase above existing conditions at the south end. This is due to the pumping cycles tied to north end water levels, leading to no pumping at times while inflows continue to enter the system at the south end. Alternative 2-6, direct discharge to the bay, results in a very flat water surface gradient in the system and water levels about 0.8 feet higher than existing conditions at the north end. This is driven by the loss of storage compared to existing conditions. Only Alternative 2-7 with the detention pond improves or matches existing conditions peak water levels. However, when additional groundwater flow is added (Alternative 2-8) water levels only stay below existing conditions at the north end. The results indicate that the existing pipe system is undersized and capacity limited at the two year event. The existing system also has adverse grades which further limit drainage capacity.

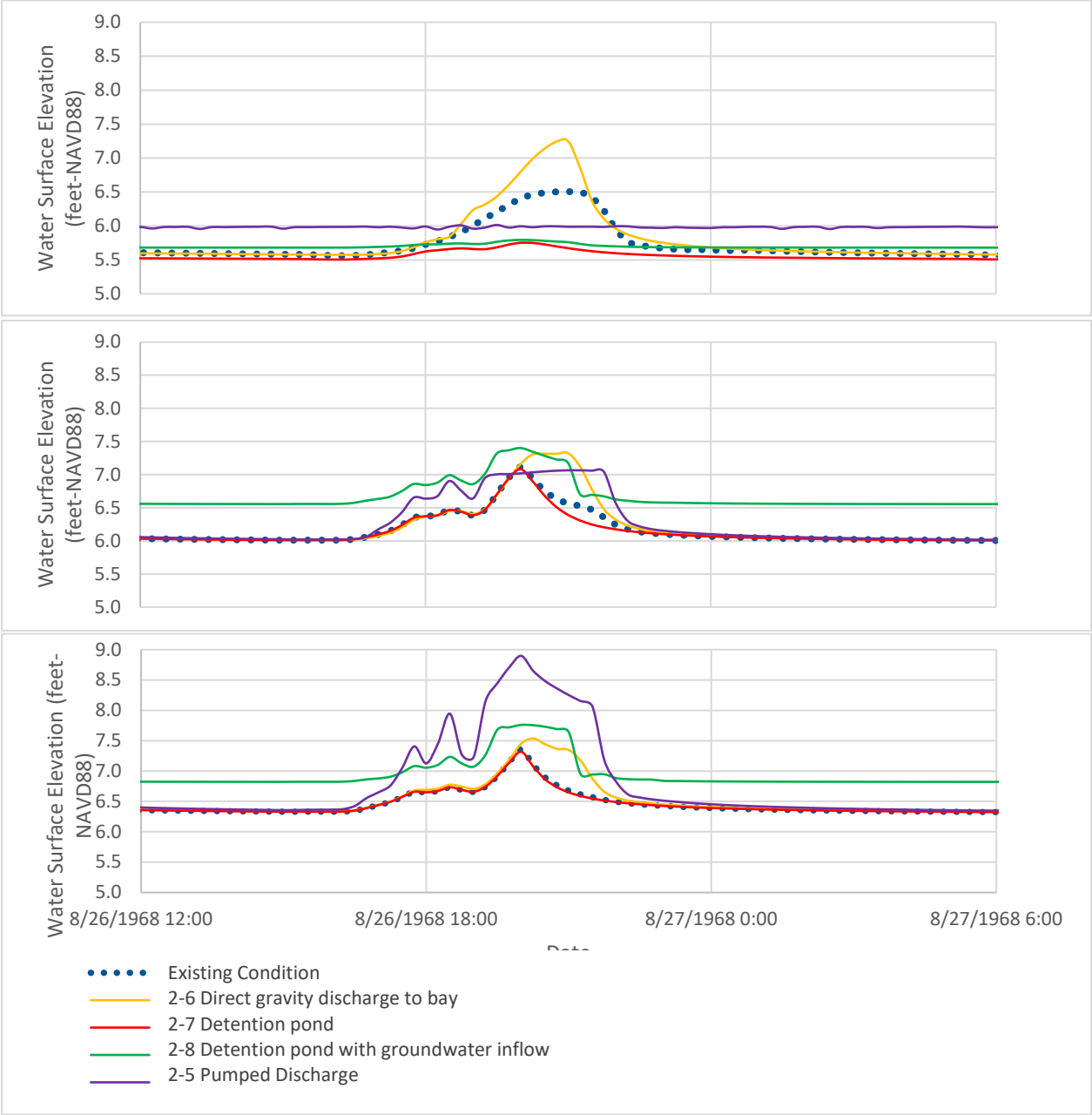

Figure 4: Water surface elevations during 2-year flood event in North Bluff Road stormwater system, North end (top), Center (middle), and South end (bottom)

6 SUMMARY

The main conclusions from the technical work documented here are:

- The proposed North Bluff Road box culvert may be reduced to a 14-foot wide by 6-foot high structure with an invert elevation of 4.0 feet while still meeting WDFW fish passage criteria.

- A berm along North Bluff Road will be required to prevent high tide overtopping if an MTR is not installed on the culvert. The berm will need to be 3-4 feet high to prevent overtopping of a 100-year high tide with some freeboard.
- A detention pond and new outfall to the bay is the most effective stormwater mitigation system evaluated. However, if groundwater flow is added from a drainline installed along North Bluff Road (to mitigate a higher water table due to the project) the existing stormwater line is undersized. Replacement of the entire line with a combination conveyance/groundwater interceptor system would be required to address the existing capacity limitations.

7 CLOSURE

DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Inc. in accordance with generally accepted engineering practices and is intended for the exclusive use and benefit of Greenbank Beach and Boat Club, Inc. and their authorized representatives for specific application to the Greenbank Marsh Restoration Design Project in Greenbank, Washington. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from Northwest Hydraulic Consultants Inc. No other warranty, expressed or implied, is made. Northwest Hydraulic Consultants Inc. and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than Greenbank Beach and Boat Club, Inc.

Sincerely,

Northwest Hydraulic Consultants Inc.

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