US Army Corps
of Engineers
Portland District
Portland, Oregon

OAKS BOTTOM WILDLIFE REFUGE

FEASIBILITY STUDY REPORT

HYDROLOGY & HYDRAULICS TECHNICAL APPENDIX

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Tetra Tech, Inc.
Portland, Oregon

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1 Introduction

1.1 Background

The Oaks Bottom Wildlife Refuge is a 160-acre floodplain wetland area located along the east bank of the Willamette River at approximately River mile (RM) 16 in Southeast Portland, Oregon (Figure 1-1). The Lower Willamette River is a freshwater, muted semi-diurnal tidal system. Daily freshwater tidal fluctuations typically range up to 2.5 feet in the project area. The project site is also within the 100-year floodplain of the Willamette River. The Wildlife Refuge is owned and operated by the City of Portland Parks and Recreation Department. The proposed restoration project is a collaborative effort between the City of Portland Bureau of Environmental Services (BES), Portland Parks and Recreation, and the US Army Corps of Engineers (USACE). The City has actively engaged additional stakeholders using a proactive collaborative approach for making informed technical decisions regarding the project development and design and long-term maintenance strategies.

1.2 Purpose

The purpose of Oaks Bottom Wildlife Refuge Habitat Restoration Project is to restore more natural hydrologic connections between the river and the refuge, provide fish and wildlife access to the largest remaining floodplain system along the Lower Willamette River, and also to enhance a variety of habitats within the system. Existing habitat quality impairments in the refuge are related to a 60-inch diameter concrete pipe culvert that serves as the only surface water connection between the river and the refuge. The existing culvert is undersized and is often perched relative to Willamette River stages. The culvert passes through a high berm, on top of which lies the Oregon Pacific Railroad line and the Springwater Corridor, a heavily used, paved, multi-use path.

In addition, a large concrete water control structure (WCS) with a 6-foot high by 8-foot wide opening is located upstream of the culvert. This structure regularly impounds water draining the refuge even when the flashboards are removed due to small woody debris and beaver dams on its upstream side. When the flashboards or stop logs are installed, the drop in water surface elevation can range from two to four feet. Together, the culvert and WCS have degraded habitat conditions of the channel and large pond (reservoir) in the refuge, and have essentially eliminated fish and wildlife passage from the river to the refuge.

To address the degraded habitat conditions, the restoration project consists of four major components:

- Replacement of the culvert under the railroad berm with a new larger culvert to allow more natural and less constricted hydrologic connection and significantly improved fish and wildlife passage.
- Removal of the water control structure and excavation of a tidal slough channel to the reservoir for fish rearing and refuge typically from November to June and reduce the potential for fish stranding.
- Removal of invasive plant species and revegetation with native plant species within the construction footprint.
- Recreational enhancements associated with the Springwater Trail.

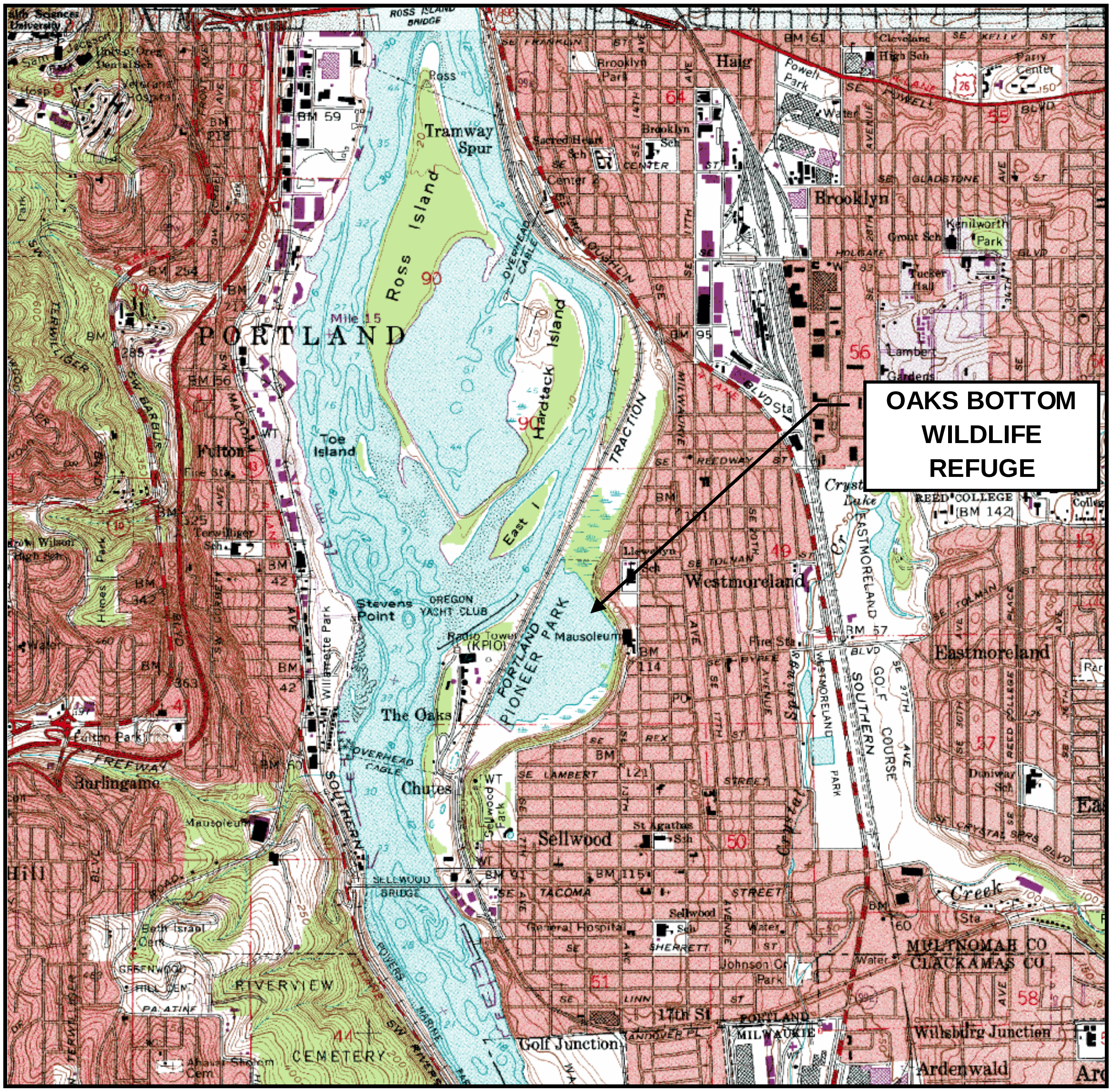

Figure 1-1 Oaks Bottom Wildlife Refuge Project Location.

1.3 Scope

The scope of this hydrology and hydraulics appendix is to (1) summarize previous project documentation of site characteristics and geomorphology, (2) summarize previous hydrologic and hydraulic analyses conducted during project design iterations, and (3) supplement this information with updated analyses to evaluate project feasibility. The focus of the supplemental analyses is on comparison of hydraulic modeling results for the future without project and future with project conditions. Previous analysis includes the following documents, which are included as attachments to this report:

- Oaks Bottom Wildlife Refuge Tidal Restoration Project 90% Basis of Design, prepared by Tetra Tech, July 2010 (Attachment A),
- Oaks Bottom Wildlife Refuge Enhancement Project, Hydrologic and Hydraulic Background Information Final Technical Memo, Prepared by City of Portland BES, April 2010 (Attachment B),

Previous project documentation focused on restoration alternatives and hydraulic analysis of the preferred or proposed alternative (future with project conditions). Consequently, this appendix provides more comprehensive data including an analysis of the existing culvert and wetland channel hydraulic (future without project) conditions. Without project and with project fish passage hydraulics are contrasted under hydrologic conditions consistent with the previous analyses. A brief assessment of flood risks is also included in this appendix.

2 Site Conditions

Characterization of the site conditions for Oaks Bottom Wildlife Refuge and adjacent lower reach of the Willamette River is documented by the City of Portland in a technical memorandum (City of Portland 2010). The City's memorandum included description of site topography, hydrology, climate, seasonal and inter-annual Willamette River hydrology, groundwater data and modeling, and water budget. Relevant sections of the memorandum are summarized in this appendix for convenience.

2.1 General Hydrology

The Oaks Bottom Wildlife Refuge is a nature park located a short distance upstream of the Willamette River's confluence with the Columbia River, between River Mile (RM) 15 and 16, and adjacent to Ross, Hardtack and East Islands (see Figure 1-1). The project site is located on a floodplain terrace on the right overbank (east side) of the Willamette River and is situated below the bluff on the western edge of the Westmoreland neighborhood of southeast Portland. On its west side, the refuge is separated from the river by a high railroad embankment. The primary hydrologic features of the refuge include a relatively small network of channels and ponded areas on the northern portion of the refuge, a relatively large pond or reservoir in the southern portion, and a main channel that drains both of these regions. The main channel continues through the WCS and culvert into the Willamette River. Aside from the connection with the Willamette River through the culvert, the only hydrologic inputs to the refuge are direct rainfall and groundwater inflow via seeps that enter the reservoir at several locations.

A digital elevation map of Oaks Bottom site is shown in Figure 2-1. Color bands represent elevation contours, and the field-delineated ordinary high water mark (OHW) of 12.8 feet in the City of Portland datum (COP[1]), shown as a light green line is also indicated. A similar figure showing inundation frequencies is shown in Figure 2-2. Inundation frequencies are based on daily average water surface elevations from the USGS Morrison Bridge gage, located approximately 4 miles downstream in the Willamette River. The inundation frequencies assume a free-flowing connection between the river and the site (no stop-logs in the WCS). With a free connection, the figure shows that the inundation of the reservoir is controlled by the river approximately 15-30% of the time, although the more frequent inundation is confined to the channel area. Currently, the South Reservoir/Pond is inundated nearly all the time due to the near-continuous flux of groundwater to the site from the base of the bluff. The WCS also has a primary influence on reservoir inundation because, if it does not have stop logs placed in it, it is typically partially blocked by small woody debris and/or beaver damming. The blockage at the water control structure backs water up the main wetland channel to the pond to typically a WSE of about 10 to 12-feet COP.

[1] The City field delineated the ordinary high water mark based on woody vegetation. Corps Regulatory Branch reports jurisdictional OHW as 18.2 feet NAVD88, which corresponds to the 2-year flow in the Willamette.

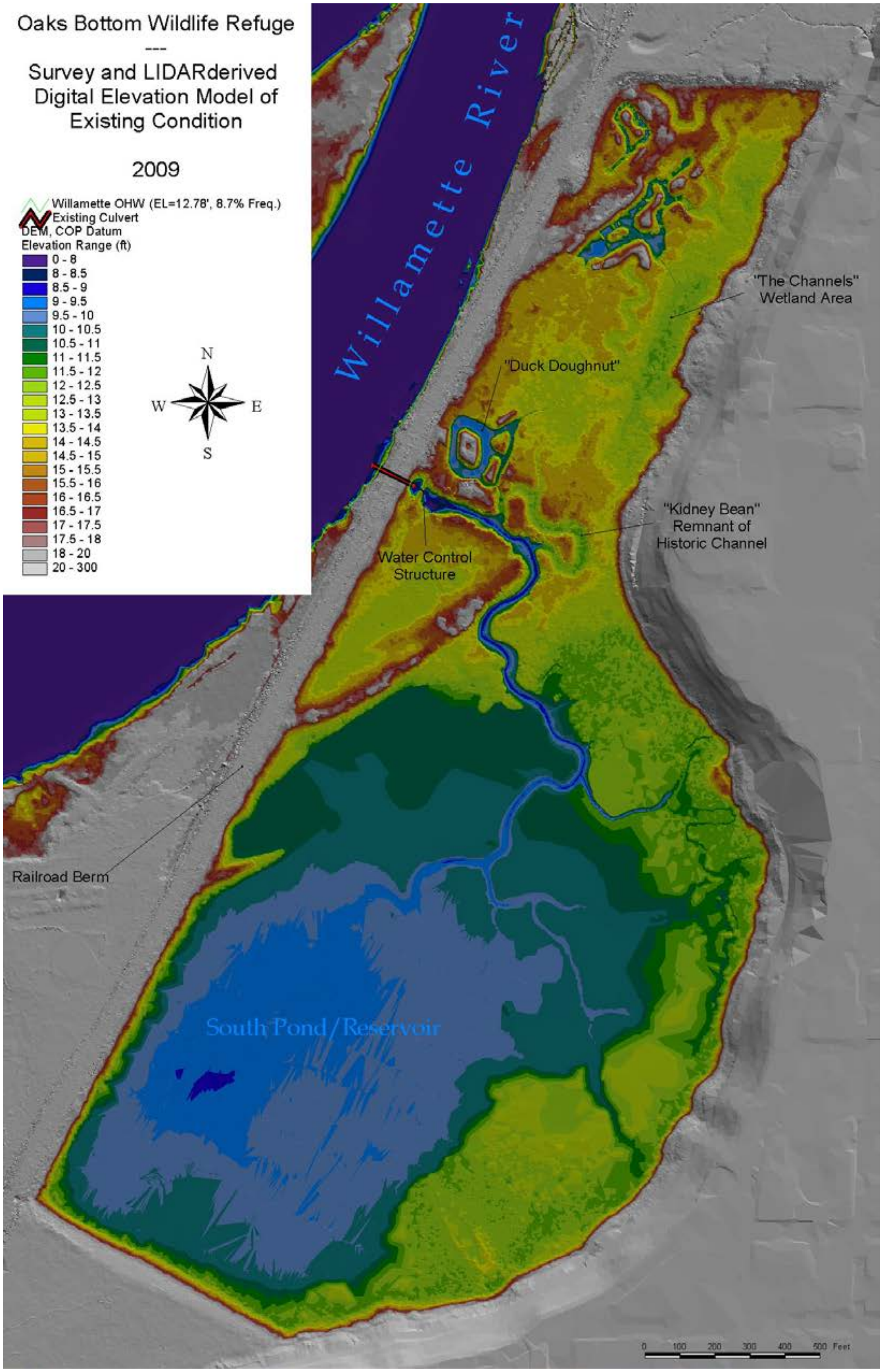

Figure 2-1 Topography and City Designated Ordinary High Water (12.8 feet COP) within Oaks Bottom Wildlife Refuge.

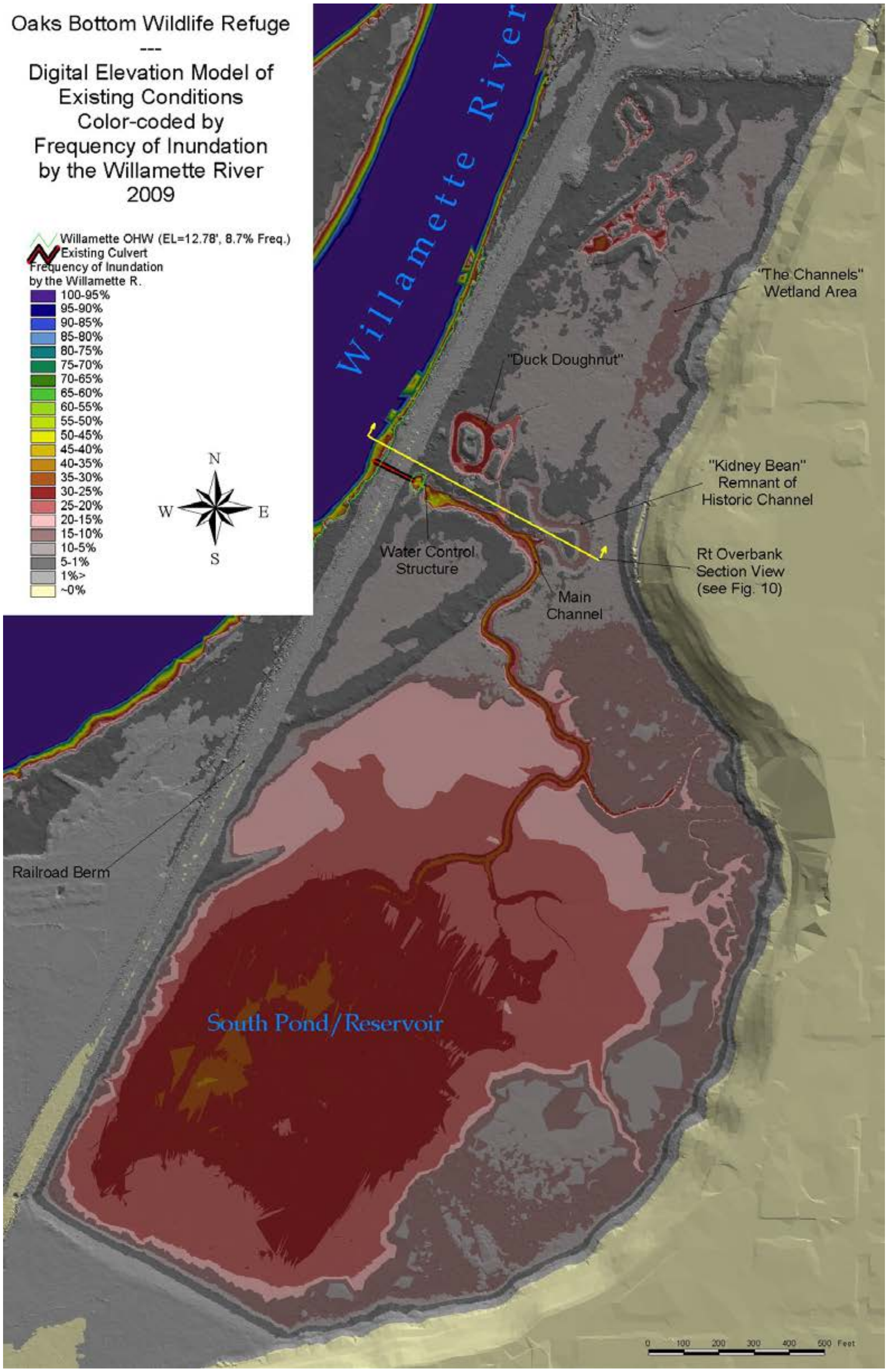

Figure 2-2 Inundation Frequencies for Oaks Bottom Wildlife Refuge.

2.2 Wetland Morphology

Drainage from the main reservoir and wetland area to the north to the Willamette and vice versa is through one primary channel that meanders north-northwest toward the WCS and culvert. This channel has low banks that generally range in height from approximately 2 to 5 feet. Channel widths range from 30 feet near the WCS to 20 feet near the reservoir. These widths are much larger than the opening in the WCS and culvert diameter.

The longitudinal profile of this main channel is shown in Figure 2-3. This figure is shown looking in the northerly direction, with the Willamette River on the left (west) and the reservoir (pond) on the right (east). The dark gray region depicts the thalweg of the channel, and the lighter gray region depicts the top of the right (north) bank. Several of the small tributary channels on the right bank of the main channel are shown in the light gray overbank profile. This profile also shows the high railroad and Springwater Corridor embankment, with a top elevation of approximately 35 feet COP. The culvert is shown in red, through the embankment, and the channel on the downstream (west) side of the culvert (sideslope of Willamette River) slopes down abruptly.

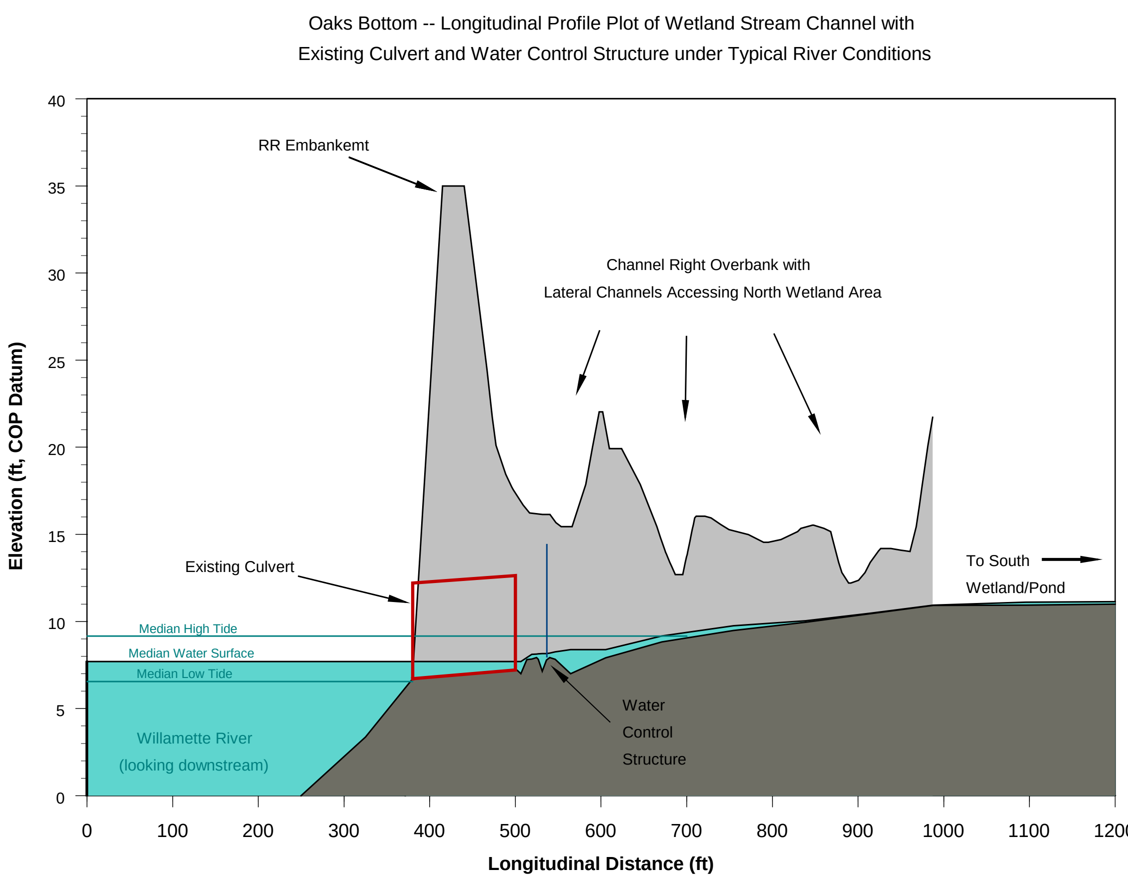

Figure 2-3 Longitudinal Profile of the Primary Wetland Channel Including Water Control Structure and Culvert.

The WCS, approximately 40 feet upstream of the culvert, is shown as a vertical blue line in Figure 2-3. The dimensions of the opening of the water control structure are 8 feet wide, 6 feet long, and 6 feet tall. The slope of the channel varies from approximately 0.002 ft/ft (0.2%) upstream near the reservoir to 0.008 ft/ft (0.8%) near the culvert and water control structure.

2.3 Groundwater and Water Budget

The City of Portland memorandum (2010) included a groundwater and water budget assessment intended to improve understanding of surface water and groundwater interactions and ultimately minimize impacts of with project conditions on shallow groundwater levels near sensitive and high-value wetland plant assemblages in the refuge. Danish Hydraulic Institute's MIKE-SHE hydrologic and IGW groundwater models were used to simulate surface water and groundwater interactions and the overall site water budget (DHI 2007; IGW 2002). A primary finding of this analysis is that groundwater influx is higher than rainfall-runoff contributions to the water budget (not including the direct surface water connection to the Willamette River). Also, groundwater influx to the reservoir and other depressions leaves the site through surface water drainage to a greater degree than it does through infiltration or evaporation. Further, the surface water ponding within the northern wetland areas does have an impact on groundwater elevations near sensitive wetland plant communities in this vicinity. For this reason, only minor grading of the side-channels north of the main channel is part of the with project actions.

3 Hydrology and Hydraulics Evaluation

This section describes future without project and future with project hydraulic conditions in the Oaks Bottom culvert and channel. To evaluate hydraulic conditions the City of Portland, with assistance from Tetra Tech, developed a one-dimensional, unsteady flow HEC-RAS model of the culvert and wetland channel (USACE 2010). Previous reports documented development and application of the model, including hydrology inputs to the model, to simulate with project fish passage conditions in the culvert and channel (Tetra Tech 2008, Tetra Tech 2009, Tetra Tech 2010a, Tetra Tech 2010b, City of Portland 2010). New analyses of without project conditions and associated minor updates to the with project conditions, required for consistency, were conducted for this appendix.

3.1 Fish Passage Criteria

The parameters analyzed for comparison between future without and future with project conditions are culvert velocity and depth. These are primary Oregon Department of Fish and Wildlife (ODFW) hydraulic fish passage criteria for bridges and culverts. The minimum velocity and depth for passage of juvenile salmonids are 2 feet per second (ft/s) and 0.5 feet, respectively. The frequency exceedence criterion for velocity and depth conditions common in tidal channels and appropriate for this project is 95% exceedance (Tetra Tech 2010b).

3.2 Future without Project Conditions

3.2.1 Model Geometry and Boundary Conditions

The wetland channel geometry and storage areas (reservoir to the south and small channel network to the north) of the hydraulic model are based off recent LiDAR and supplemental bathymetric data (Tetra Tech 2010b; City of Portland 2010). Elevations in the model are in units of feet relative to the project datum, COP. Two primary features of the existing wetland and channel are the culvert connecting the Willamette

River with the wetland, and the WCS located approximately 40 feet upstream of the culvert. The WCS and culvert are shown in Figure 2-1.

For the future without project condition simulations, it was assumed that no flashboards are installed. This is a best-case scenario in terms of fish passage and a conservative assumption. If the flashboards are in place, fish passage will likely be further impaired due to the drop in water surface (see center photo of Figure 3-1). The plan-view schematic of the HEC-RAS model is shown in Figure 3-2. As indicated in the schematic, the north storage area (North_SA) and south storage area (South_SA) represent the north broad overbank and reservoir areas, respectively.

Figure 3-1 Concrete Water Control Structure (Left, Center – With Flashboards In Place) and Upstream End of 60-Inch Diameter Pipe Culvert (Right).

To represent the without project condition, the existing culvert was entered into the existing unsteady HEC-RAS model. The existing 60-inch diameter pipe culvert is 120-feet long with upstream and downstream invert elevations of 7.22 feet COP and 6.72 feet COP, respectively. The culvert has a small headwall on its upstream end that extends from the embankment (Figure 3-1), so it was modeled as "protruding from the embankment without wingwalls" The upstream and downstream culvert elevations are shown in Figure 3-3.

Model boundary conditions include time-varying Willamette River stages on the downstream end of the model and a constant inflow on the upstream side. For the downstream boundary conditions, three time-periods were selected to represent a range of river hydrology:

- Dry (water year 2001),
- Typical (water year 2004), and
- Wet (water year 1997)

The winter through spring months (November through June) of each of these years were simulated to represent the period during which juvenile salmonids pass through the system near Oaks Bottom.

The upstream inflow boundary condition was assumed to be a constant 1 cubic feet per second (cfs), representing the total groundwater and spring inflow into the wetland reservoir. Actual inflows to the wetland vary annually and seasonally, but the actual groundwater and spring inflows are unknown during the three representative time-periods. Further, the magnitude of the groundwater and spring inflows are minor relative to the influence of tidal fluctuations. Thus 1 cfs was applied across all scenarios as a conservative and consistent estimate. Model stability was also a factor in selecting/determining the inflow magnitude; smaller inflows tended to cause numerical instability in the unsteady flow computation. This was true particularly during simulations of the dry year. Model boundary conditions are documented in more detail in Tetra Tech 2010b.

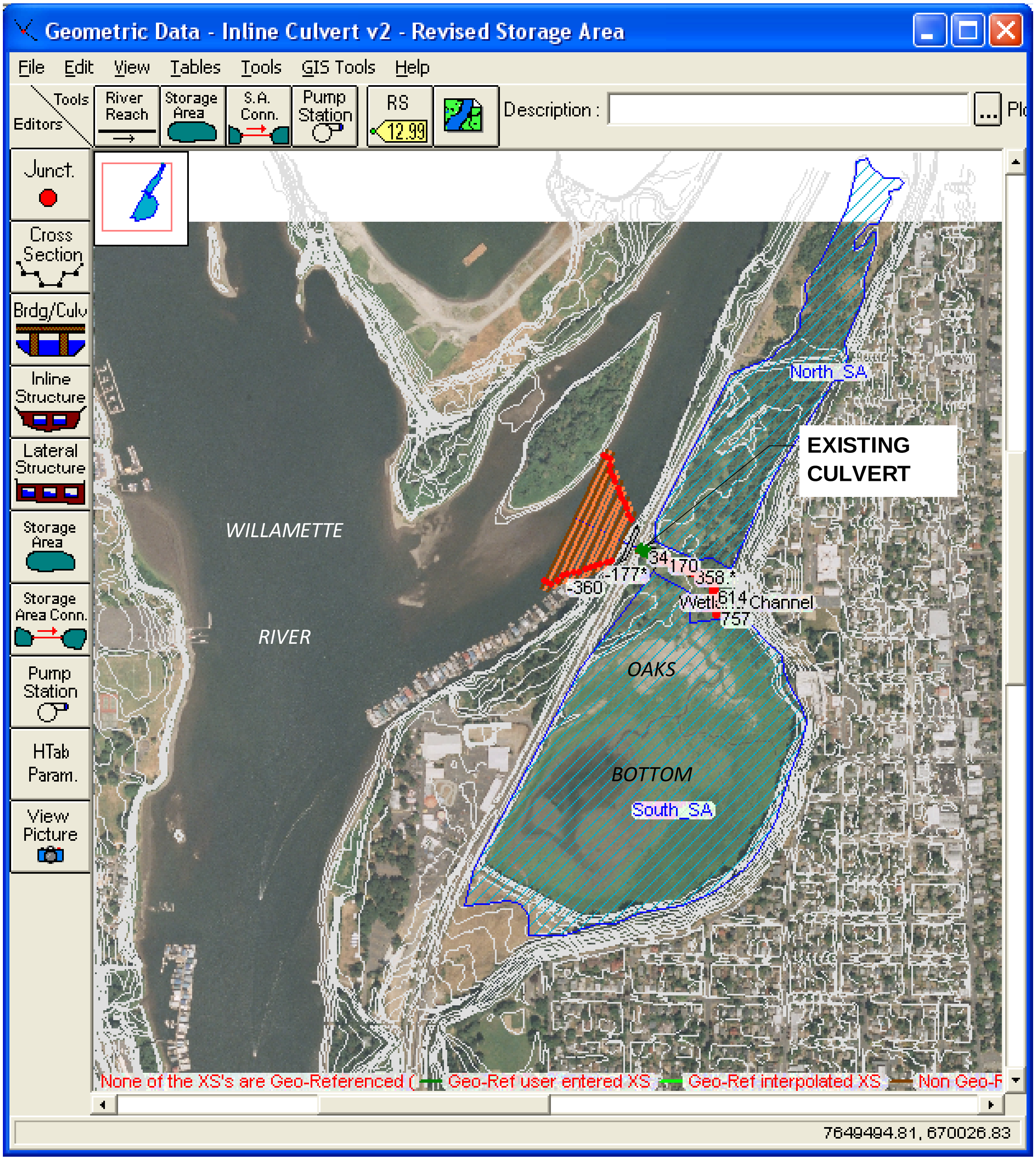

Figure 3-2 HEC-RAS Model Schematic for the Oaks Bottom Wetland and Culvert.

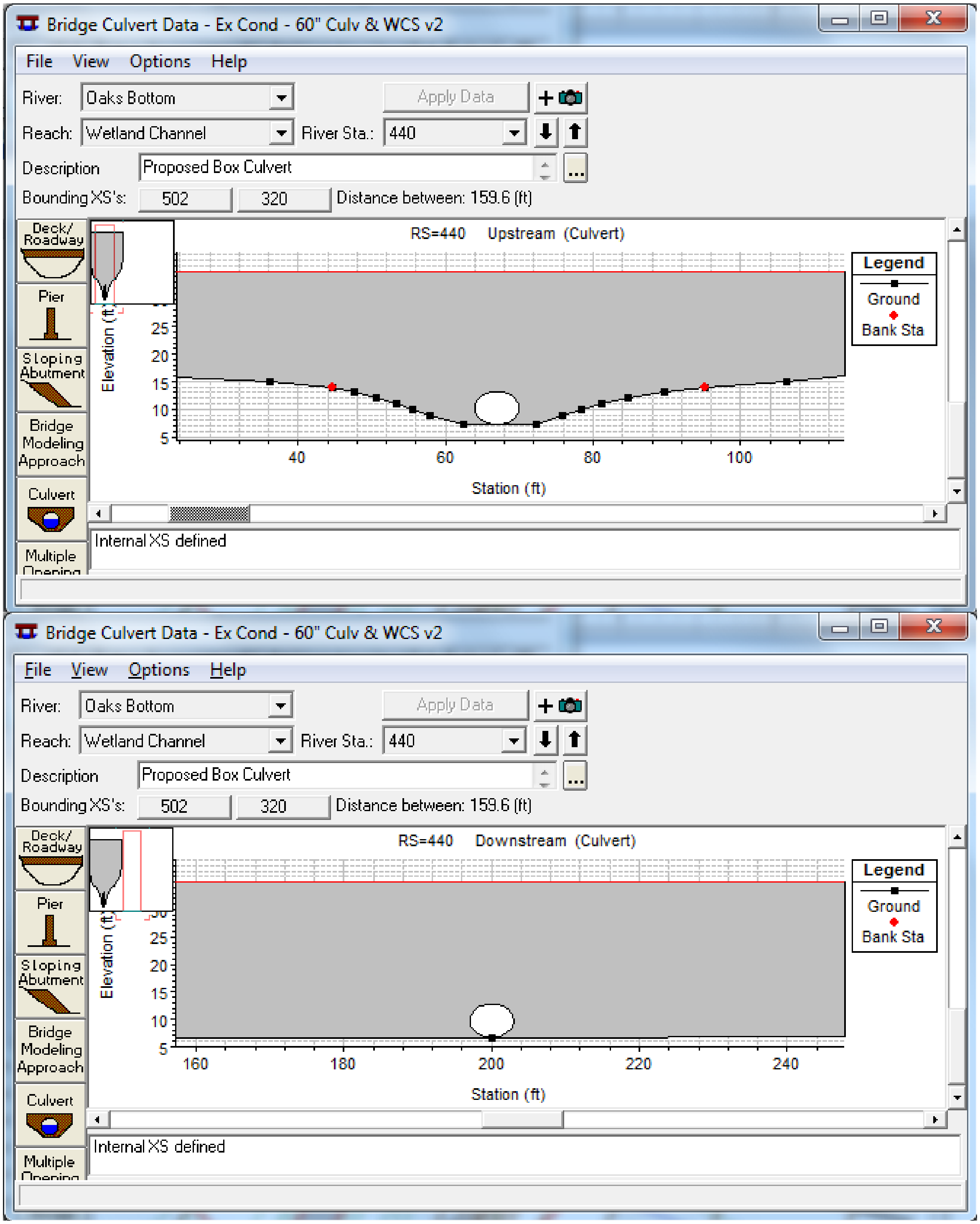

Figure 3-3 Upstream (Top) and Downstream (Bottom) Sections of the Existing Culvert in HEC-RAS.

3.2.2 Simulated Culvert Velocities

Simulations of without project culvert velocities are shown in Figure 2-4. This plot shows percent exceedance curves for simulated velocities at the upstream end of the culvert for the three water year (WY) types analyzed – 2001 (dry), 2004 (typical), and 1997 (wet). The thick red, thin green and dashed blue curves represent WYs 2001, 2004, and 1997, respectively.

In the dry and typical years, culvert velocities are generally less than or approximately equal to 1 ft/s over the simulation period. Both of these curves (red and green lines) show a vertical discontinuity around 1 ft/s; this occurs when the Willamette River stage is below the invert of the culvert, and hydraulics in the culvert are governed by normal depth conditions (free drainage in the downstream direction with no impacts from tidal variations in river stage). All three scenarios experience this condition, with the dry year showing the highest occurrence (over 80% of the time, and the wet year showing the lowest (approximately 20% of the time). During the wet year, peak culvert velocities approach 8 ft/s, with velocities exceeding 2 ft/s approximately 10% of the time.

Culvert velocities were also compared at both ends of the culvert because downstream velocities are somewhat higher than those at the upstream end. And, the higher/downstream velocity is the limiting factor for fish passage. For example, Figure 2-5 compares upstream and downstream velocities during simulation of WY 2004. Peak velocities at the downstream end of the culvert are approximately 2.3 ft/s, and velocities overall are above 2 ft/s over 30% of the time. During WYs 2001 (Figure 2-6) and 1997 (Figure 2-7), velocities at the upstream end exceed 2 ft/s over 70% and over 20% of the time, respectively.

Key observations of these without project culvert velocity simulations are:

- Normal depth flow in the culvert (the vertical discontinuities in velocity exceedance curves) occurs frequently and corresponds with the highest velocities in the culvert except during very high water-years. Normal depth conditions also occur when the culvert outlet invert is above the Willamette River stage, or “disconnected.”
- During high river stages such as those in WY 1997, peak culvert velocities corresponded with fluctuations in Willamette River stage that “push” or “pull” water through the culvert as channels, depressions and the reservoir in the refuge drain or fill. This causes relatively high flows (and velocities) through the culvert, indicating that the culvert is undersized.
- The downstream culvert velocity is typically higher than that at the upstream end when Willamette River stages are below the culvert invert. This is due to the normal depth conditions which are a function of the culvert slope (0.0042 feet per feet, or 0.42%) and smooth concrete pipe surface;
- Culvert velocities during frequent low river stages commonly exceed the velocity criterion and accordingly will likely impact juvenile fish passage.

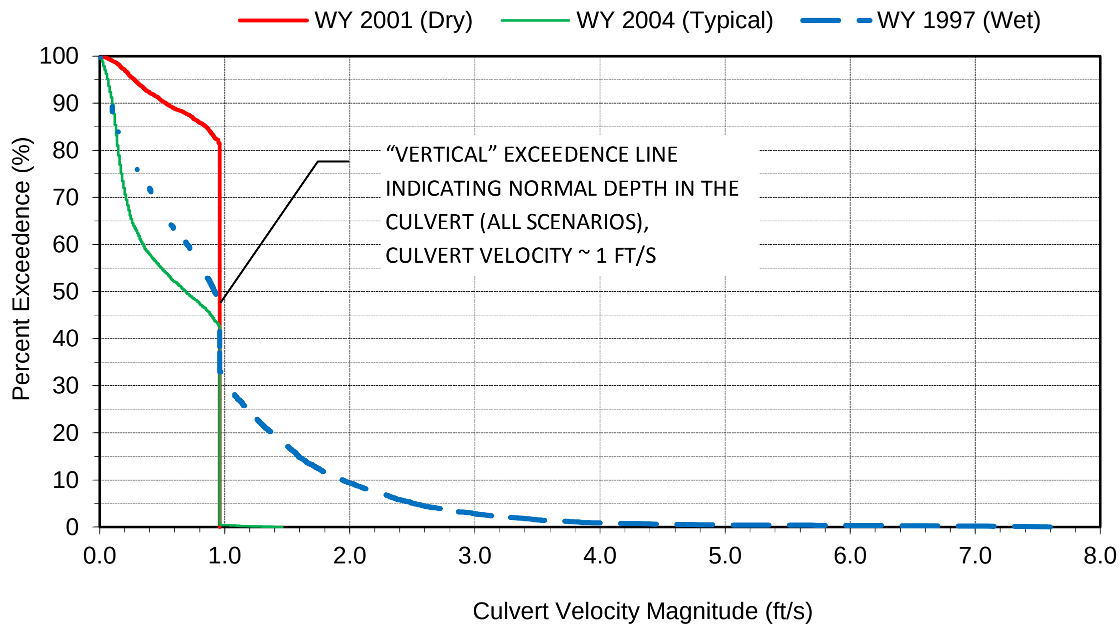

Figure 3-4 Without Project Culvert Velocities under Dry, Median, and Wet Year-Type Scenarios.

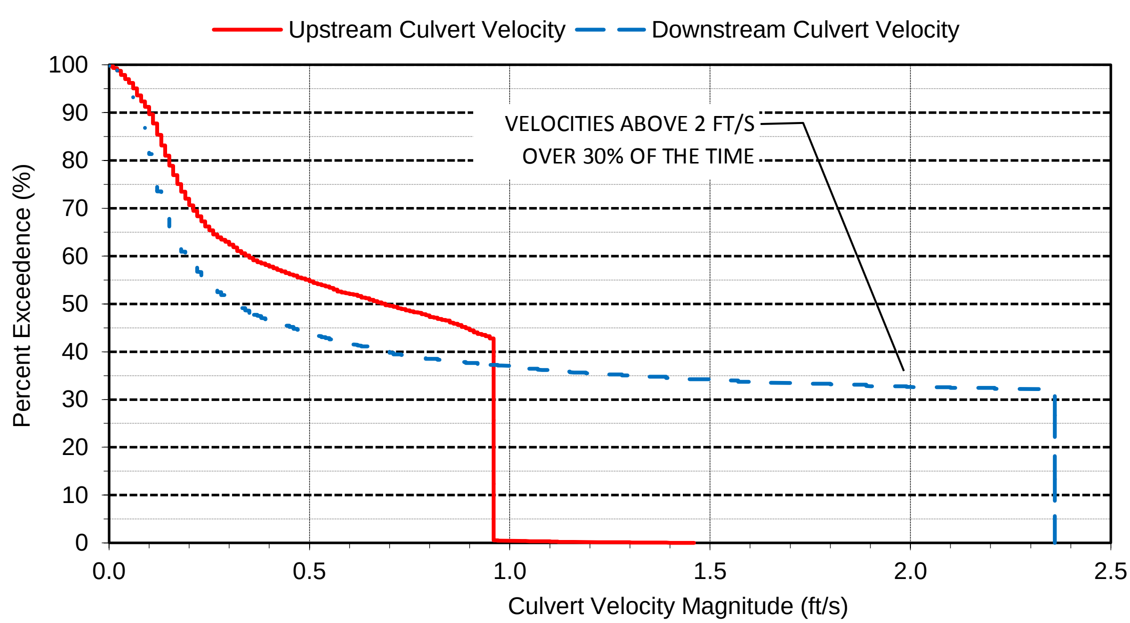

Figure 3-5 Without Project Upstream and Downstream Culvert Velocities during WY 2004.

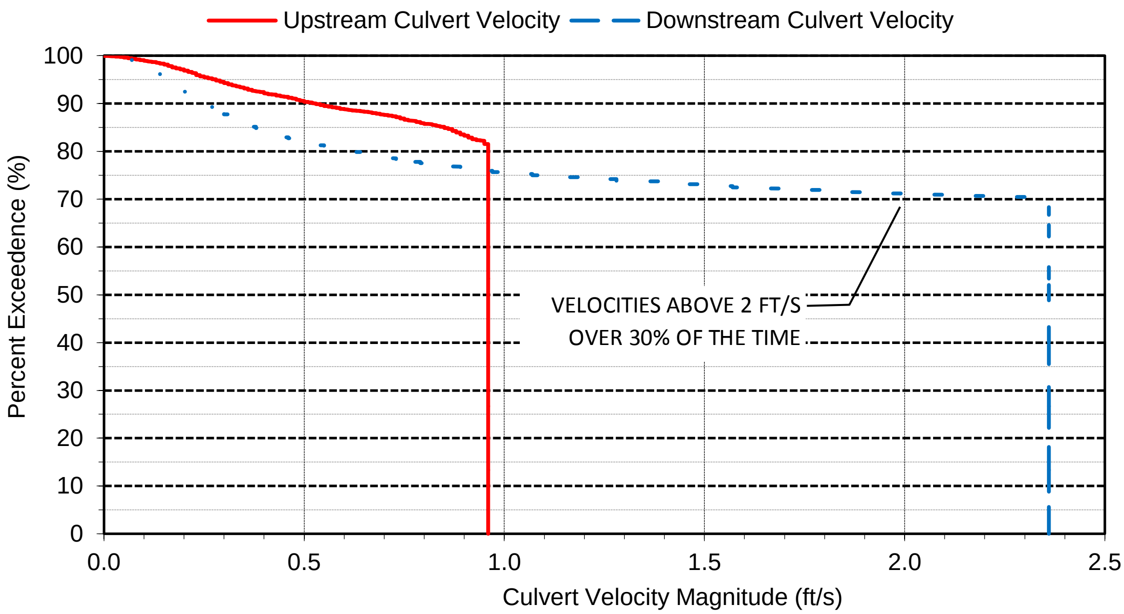

Figure 3-6 Without Project Upstream and Downstream Culvert Velocities during WY 2001.

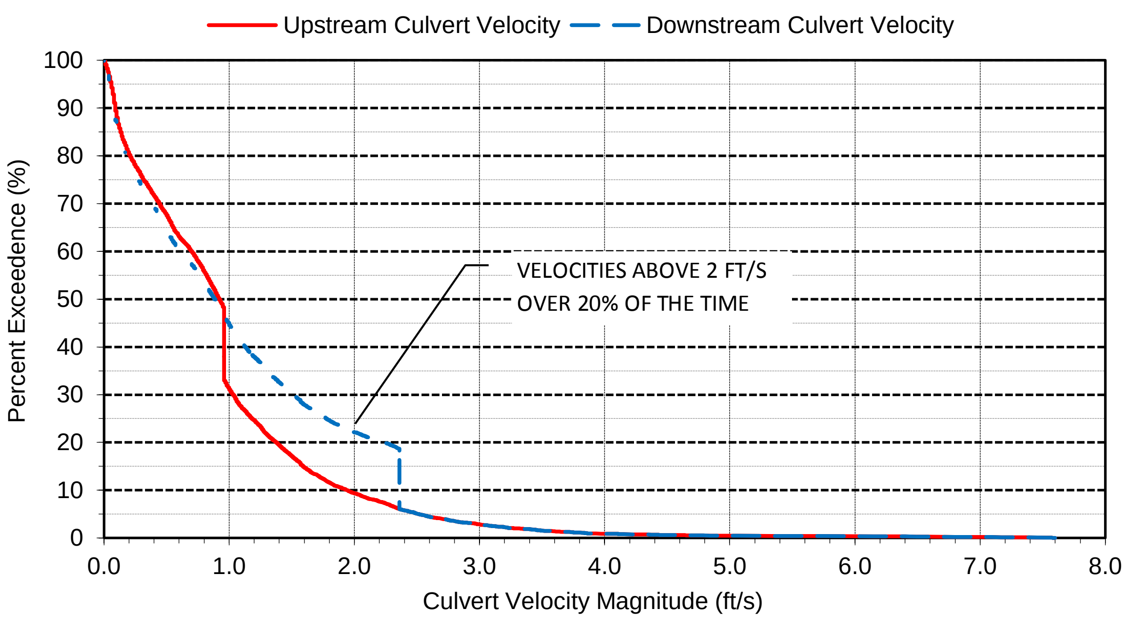

Figure 3-7 Without Project Upstream and Downstream Culvert Velocities during WY 1997.

3.2.3 Simulated Culvert Depths

Simulated depths were compared at the upstream and downstream ends of the culvert. The minimum between these values was reported in this analysis. Because of the tidal fluctuations and reverse flow in the culvert, the lower depth did not always occur at the same end of the culvert. Simulated minimum culvert depths for the three water year types are shown in Figure 3-8. Among the water year scenarios, depths range from approximately 0.3 feet (normal depth – Willamette stage is below the invert) to 6.0 feet (submerged culvert). The extreme scenarios are WY 2001 (dry) and WY 1997 (wet). During WY 2001, the culvert is flowing at normal depth, which is very shallow – 0.3 feet, approximately 70% of the time. On the other end of the spectrum, during WY 1997 depths are greater than 1.0 foot over 80% of the time. However, the percents of time that depths exceed the criterion of 0.5 feet are 15% (WY 2001), 62% (WY 2004), and 85% (WY 1997). None of the modeled without project scenarios meet the ODFW exceedance criterion of 95% compliance.

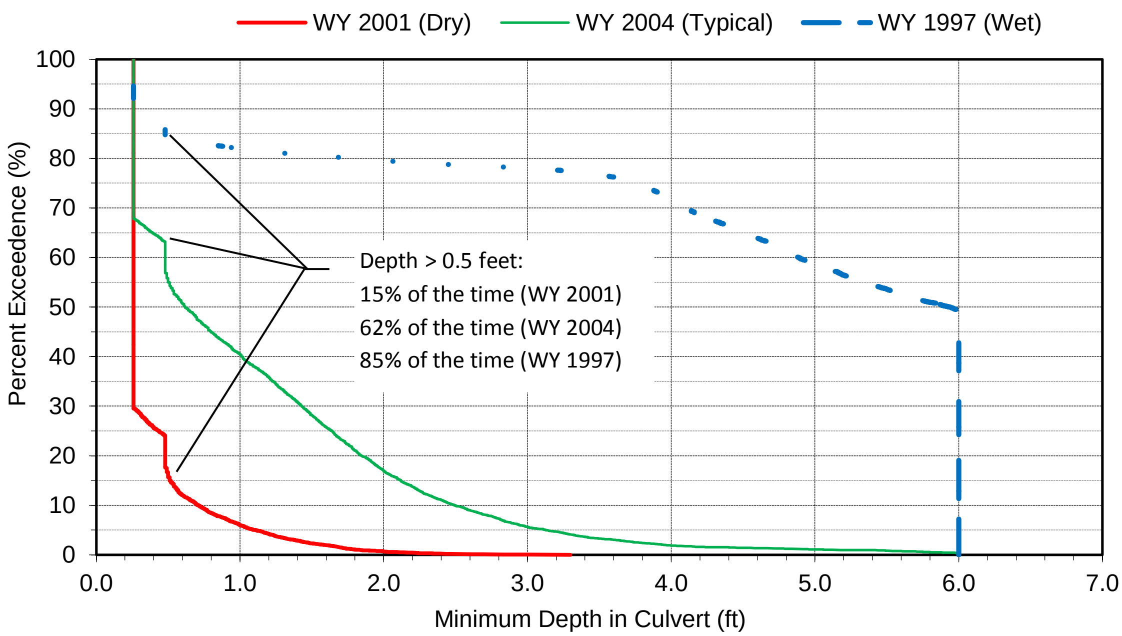

Figure 3-8 Simulated Minimum Depths of Water in the Culvert.

3.3 Future With Project Conditions

Previous simulations of the future with project fish passage culvert and wetland conditions were documented as part of the 90% Basis of Design (Tetra Tech 2010b). These scenarios were updated for this study using upstream flow boundary conditions consistent with those used in the future without project scenarios. The updated boundary conditions included a constant estimated inflow of 1 cfs, along with a corresponding initial wetland reservoir elevation of 7.0 feet COP (revised from 0.2 cfs inflow and elevation 5.3 feet COP, respectively).

3.3.1 Simulated Culvert Velocities

Comparison of with project culvert velocities are made at the upstream and downstream ends of the culvert for comparison with results provided in Section 3.2.2 of this report and shown in Figure 3-5, Figure 3-6, and Figure 3-7. Comparisons of culvert velocities for the three water year scenarios are shown in Figure 3-9, Figure 3-10, and Figure 3-11. In each figure, the thick red line represents with project upstream culvert velocities, and the dashed blue line represents with project downstream culvert velocities. In general, the with project culvert velocities are approximately less than half those of the without project velocities regardless of the water year. For example, comparing upstream culvert velocities for WY 2011 for the with project conditions (Figure 3-9) and without project conditions (Figure 3-6), the without project velocities are near 1 ft/s for most of the simulation period, while those of the with project conditions are less than 0.2 ft/s the majority of the time and less than 0.6 ft/s for approximately 75% of the time. A similar pattern is shown for WY 2004 and WY 1997. There are some minor exceptions at the very low exceedance and high velocity ranges when the curves approach similar velocity magnitudes.

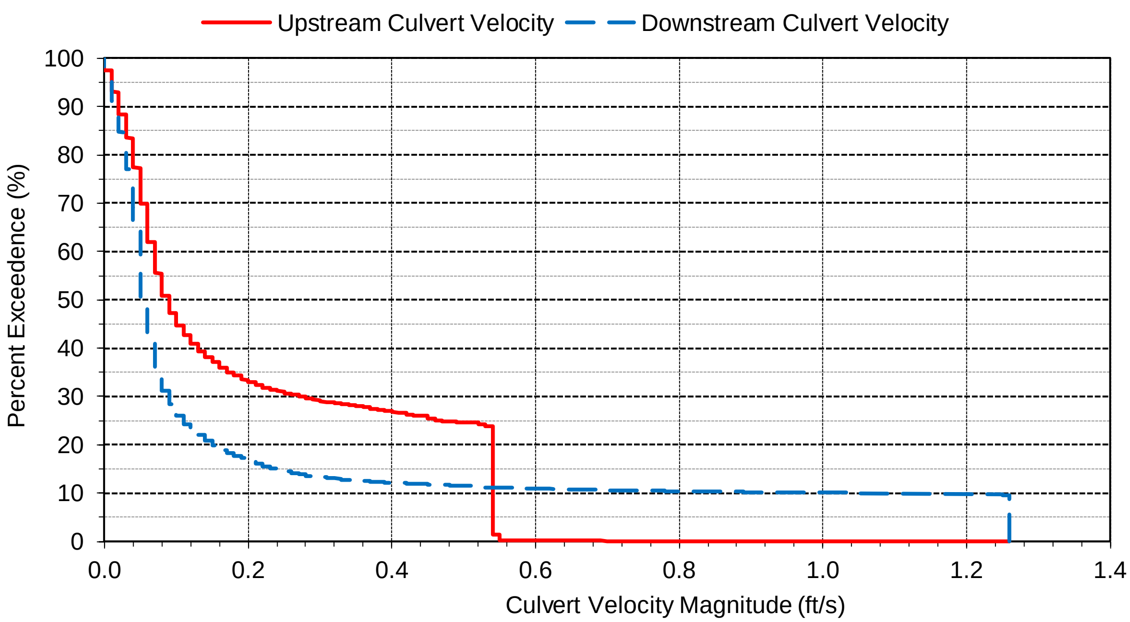

Figure 3-9 Simulated With Project Culvert Velocities for WY 2001.

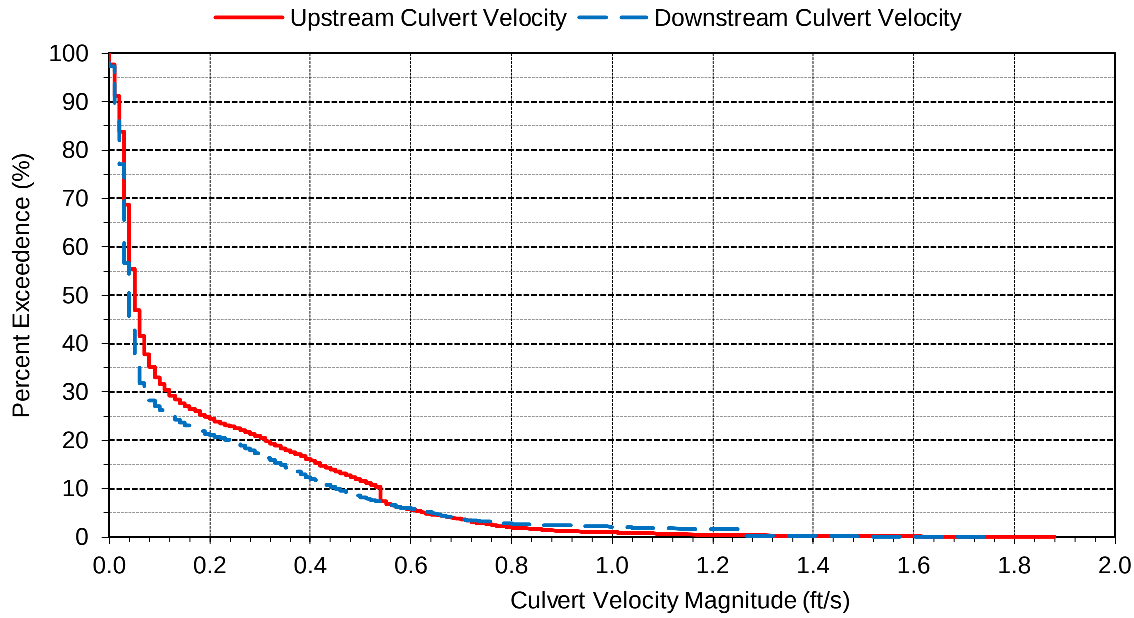

Figure 3-10 Simulated With Project Culvert Velocities for WY 2004.

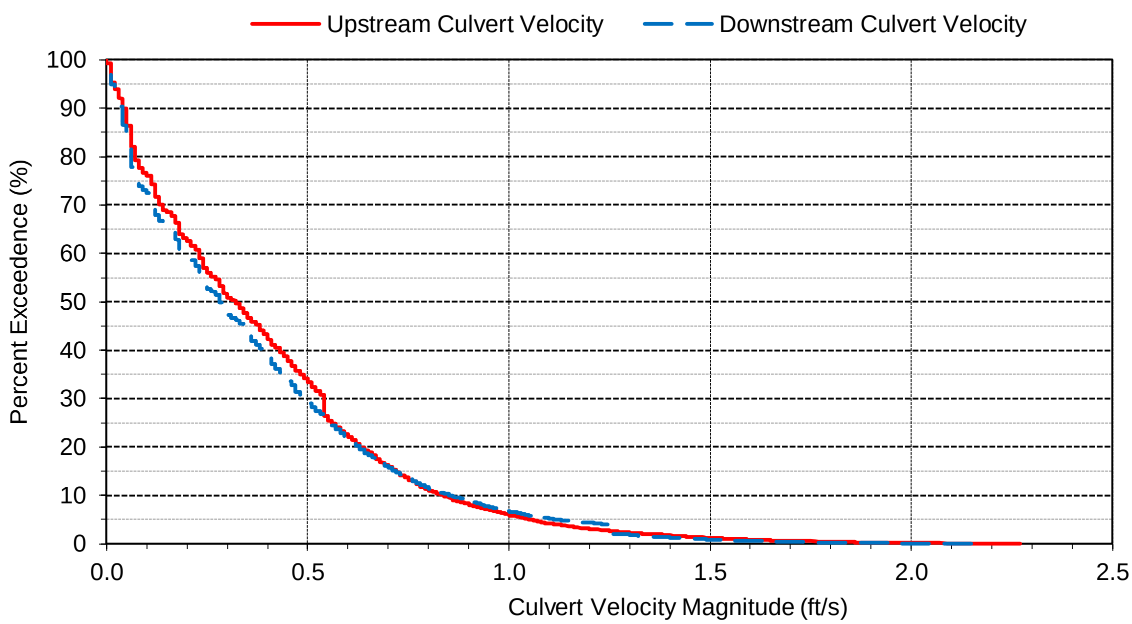

Figure 3-11 Simulated With Project Culvert Velocities for WY 1997.

Numerical results of these without and with project velocity comparisons are summarized in Table 2-1. The table shows the median (50%) values, and also the 95% exceedance values because of it is the fish passage frequency target. This exceedence criterion applies to both culvert velocities (2 ft/s) and depths (0.5 ft). The smallest percent reduction between with and without project conditions (improvement) was 34%, corresponding to the median water year type 5% exceedance level. Other percent reductions ranged from 44% to 93%.

Table 3-1 50% (Median) and 5% Exceedance Velocities for Without Project and With Project Conditions For WYs 2001, 2004, and 1997.

Scenario & Exceedence Level	Without Project Velocity (ft/s)	With Project Velocity (ft/s)	Percent Reduction (%)
WY 2001 (Dry)			
50% Exceedence	0.96	0.09	91%
95% Exceedence	0.96	0.54	44%
WY 2004 (Median)			
50% Exceedence	0.69	0.05	93%
95% Exceedence	0.96	0.63	34%
WY 1997 (Wet)			
50% Exceedence	0.92	0.32	65%
95% Exceedence	2.52	1.06	58%

3.3.2 Simulated Culvert Depths

Culvert depths were also compared between without project and with project conditions and over the various water year types. Exceedence curves for these results are shown in Figure 2-12, Figure 2-13, and Figure 2-14. Results show significantly increased depths under with project conditions over the majority of the depth range, with minor exceptions during the lowest depths. The increase in depths is generally due to the invert of the with project culvert being nearly two feet lower than that of the without project culvert (with project culvert upstream invert of 5.5 feet COP compared to 7.2 feet COP of the without project culvert). Essentially, the lower proposed culvert results in an improved connection to the Willamette River.

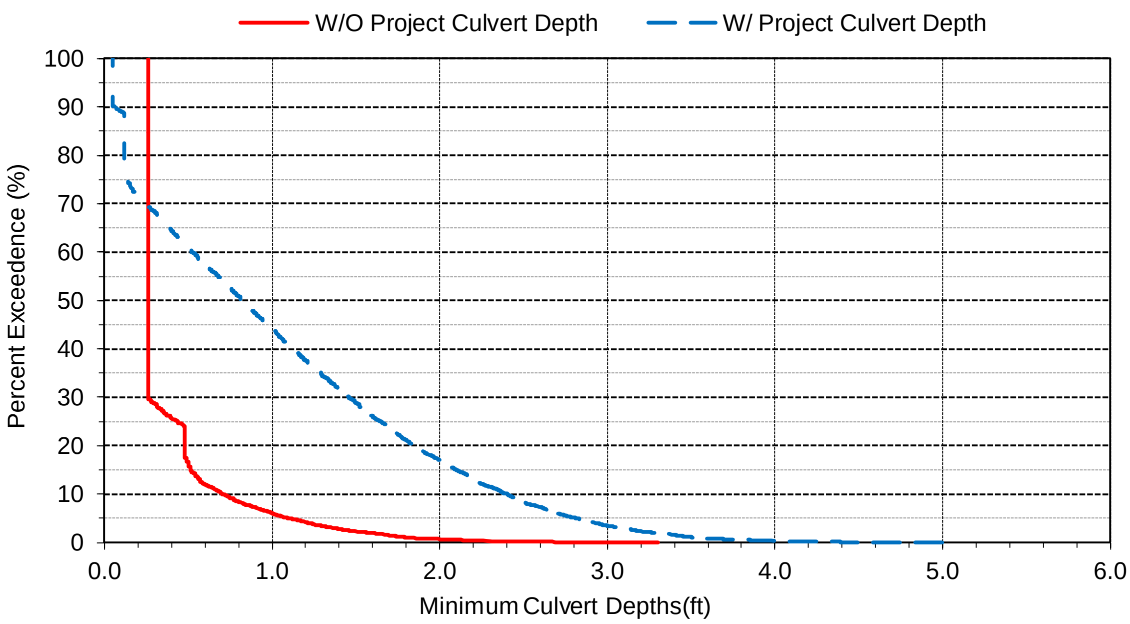

Figure 3-12 Simulated Without Project and With Project Culvert Depths for WY 2001.

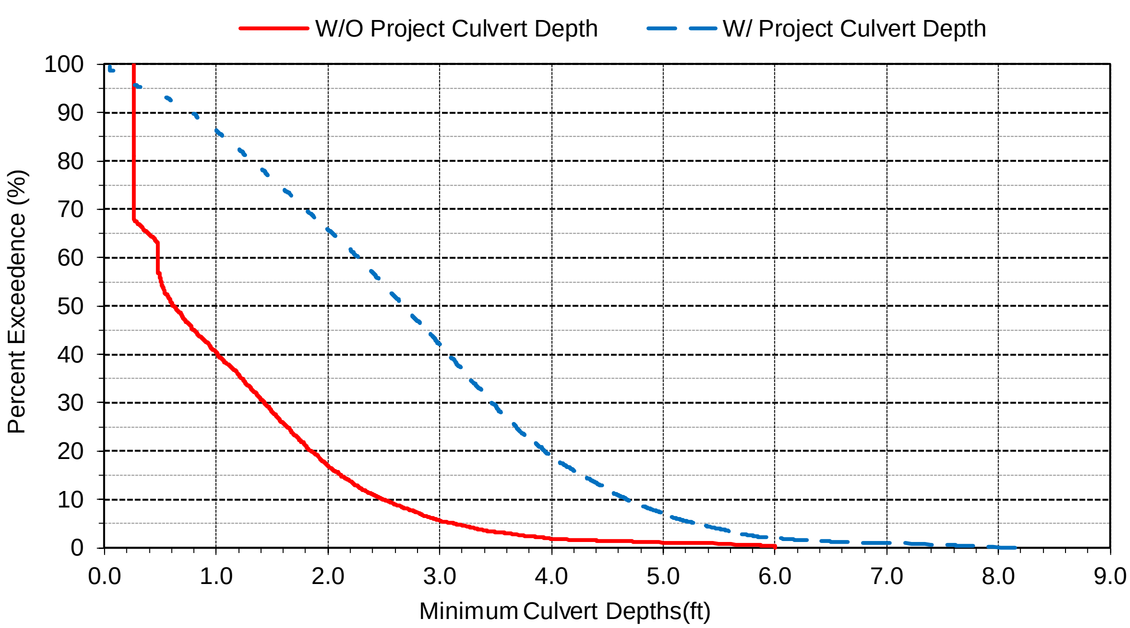

Figure 3-13 Simulated Without Project and With Project Culvert Depths for WY 2004.

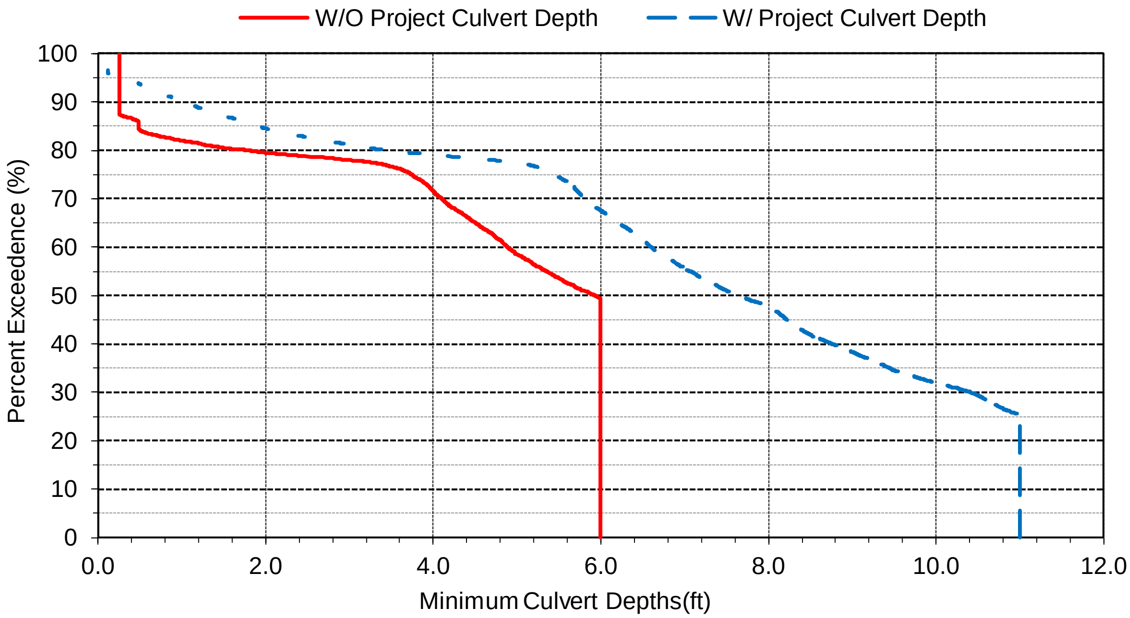

Figure 3-14 Simulated Without Project and With Project Culvert Depths for WY 1997.

Numerical results are summarized by 50% (median) and 95% exceedance levels in Table 3-2. During dry and median WY conditions, median depths in the existing culvert were either below or very close to the minimum depth threshold for fish passage. During the wet year, the river was connected through the culvert with adequate depths for all exceedences. However, as discussed in Section 3.3.1, velocities do not meet passage criteria.

Table 3-2 50% (Median) and 5% Exceedance Culvert Water Depths for Without Project and With Project Conditions For WYs 2001, 2004, and 1997.

Scenario & Exceedence Level	Without Project Min. Depth (ft)	With Project Min. Depth (ft)	Percent Increase (%)
WY 2001 (Dry)			
50% Exceedence	0.3	0.8	215%
95% Exceedence	1.1	2.8	156%
WY 2004 (Median)			
50% Exceedence	0.6	2.7	332%
95% Exceedence	3.1	5.3	70%
WY 1997 (Wet)			
50% Exceedence	5.9	7.6	29%
95% Exceedence	6.0	11.0	83%

Improvements in depth from the without- to with project conditions are on the order of 30% to over 300%. Median depths for the median WY 2004 show the largest increase in depths (over 300%).

4 Flood Impacts

4.1 Base Flood Extent

The FEMA base flood (100-year flow) limits for the Willamette River adjacent to Oaks Bottom extend into the refuge, coinciding closely with the project limits (Figure 4-1). This map is based on a FEMA Flood Insurance Rate Map updated in October 2004 (FEMA 2004). The refuge is primarily within the Zone AE floodplain in which base flood elevations have been determined. The Zone AE floodway is limited to the mainstem Willamette River on the west side of the railroad berm, and it does not extend into the refuge. Willamette River flood flows enter the refuge through the existing 60-inch diameter culvert.

Figure 4-1 FEMA FIRM Showing The Willamette River and Adjacent Oaks Bottom Refuge Floodplain Region.

4.2 With Project Impacts

The with project conditions are expected to have insignificant impacts on the base flood elevation (BFE). One reason is that with project conditions include a net removal of approximately 8,000 cubic yards of material within the floodplain (Tetra Tech 2010b). This includes primary and secondary channel excavation, the WCS, and material removed from the railroad berm for placement of the new culvert.

Another reason that no significant impact is expected on the BFE is that the existing culvert does not reduce flood stages within the refuge. The culvert is undersized and has high velocities at times, but it allows free exchange with the river so that water levels equilibrate on either side of the railroad embankment. Constructing a larger culvert will reduce velocities but result in similar flood stages within the refuge.

5 Summary and Conclusions

A one-dimensional unsteady flow HEC-RAS model was developed and applied to evaluate hydraulic characteristics of the Oaks Bottom Wetland system. The focus of this evaluation was the culvert connecting the Willamette River with the broad wetland that is separate from the river by the railroad and Springwater Corridor berm. This culvert is undersized, perched, is much smaller than the wetland channels upstream, and is not adequate to allow fish and wildlife passage.

Future without project and future with project culvert and wetland conditions were compared to understand existing fish and wildlife passage impairments, as well as improvements related to the new culvert, regraded channel, and removal of the 8-foot wide concrete WCS. This analysis focused on culvert hydraulics, even though the WCS is a more significant barrier to fish passage when the stop logs are installed due to the vertical drop of two to four feet. The stop-log and debris barriers were not represented in the model to be conservative and because conditions at the WCS vary with seasonal operation by the City and with debris blockages that occur naturally throughout the year.

Findings of this study were that there are significant reductions in culvert velocities and increases in culvert water depths associated with the with project conditions. Velocity improvements were due to two factors. The first factor was a larger culvert flow area. Benefits of the increase in conveyance are most significant during moderate or high river stages and when large volumes of water flow into or drain from the broad wetland overbank and reservoir areas. The second factor was a reduced percent of time that the culvert was flowing under normal depth conditions. This was attributed to lowering the culvert invert elevations. In this way, velocity and depth improvements were related: improving depths and general connectivity to the river also improves culvert velocities.

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Attachment A
Oaks Bottom Wildlife Refuge Tidal Restoration Project 90% Design Report (Tetra Tech)

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City of Portland
Bureau of Environmental Services

Oaks Bottom Wildlife Refuge
Tidal Restoration Project
90% Design Report

Portland, Oregon

July 2010

Prepared by:

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In association with:
Cascade Design Professionals, Inc.
Northwest Geotech, Inc.

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1.0 INTRODUCTION

The Oaks Bottom Wildlife Refuge is a 160-acre floodplain wetland area located along the east bank of the Willamette River at approximately River mile (RM) 16 in Southeast Portland, Oregon (**Figure 1**). This is within the tidal reach of the Lower Willamette where freshwater outflows are backed up by tidal flows in the Columbia. Daily freshwater tidal fluctuations typically range up to 1 foot in the project area. The project site is also within the 100-year floodplain of the Willamette River. The Wildlife Refuge is owned and operated by Portland Parks and Recreation. It is a unique opportunity for such a large natural wetland area to exist in the heart of a city. Historically, the Oaks Bottom area was a low floodplain connected to the Willamette River. **Figure 2** shows the 1852 river alignment. The entire area was most likely a historic main channel or side-channel of the Willamette River, but over time, an island or natural river terrace became vegetated between the main channel and Oaks Bottom. Eventually the site became cut off during low flows but still likely flooded regularly during high flows and is shown as primarily a wetland with a ponded area in the vicinity of the existing reservoir.

A railroad trestle and then berm was constructed in the early 1900s which separates Oaks Bottom from the Willamette River along its entire western perimeter. A 5-foot diameter culvert under the embankment allows water to exchange between the river and Oaks Bottom, but does not provide effective fish access and significantly mutes the hydrologic connection with the river. A water control structure was constructed in 1988 to allow a reservoir to be maintained in the park, to increase the area of open water habitat for waterfowl, reduce the area of reed canary grass and willows, and reduce mosquito populations (City of Portland 1988). The reservoir can be managed between elevation 8 and 14 feet in elevation (City of Portland datum). Portland Parks has also been managing vegetation, particularly the upland prairie habitats, to remove noxious weeds and promote native species.

The north and south areas of the park have been used as landfill sites in the past. The City of Portland acquired the south landfill property from the Donald M. Drake Company in 1969 to block its development as an industrial park. The area was believed to be one of the few remaining tidal marshland areas in Portland, and local residents were strongly opposed to its development as industrial property. Local residents, students, and other groups campaigned during the 1970s to protect the wildlife habitat and provide park amenities. In 1988, Oaks Bottom was designated as the City’s first wildlife refuge.

The proposed restoration project is a collaborative effort between the City of Portland Bureau of Environmental Services and Portland Parks and Recreation. The City has actively engaged additional stakeholders using a proactive collaborative approach for making informed technical decisions regarding the project development and design and long-term maintenance strategies.

The Oaks Bottom Wildlife Refuge Habitat Restoration Project includes four major design and construction tasks, including:

- Replacement of the culvert under the railroad berm with a new larger culvert to allow significantly improved hydrologic connections and fish and wildlife passage.
- Removal of the water control structure and excavation of a tidal slough channel to the reservoir for fish rearing and refuge typically from November to June and reduce the potential for fish stranding.
- Removal of invasive species and revegetation with native species within the construction footprint.
- Recreational enhancements associated with the Springwater Trail.

This report presents the draft 60% design analysis and recommendations for the restoration project. These design recommendations will be brought forward into further stages of design plans, specifications, permits and construction contract documents to support the final project implementation of the restoration project.

1.1 BACKGROUND INFORMATION

Restoration planning has been underway for the project since at least 2001, when Portland Parks and Recreation hired Montgomery Watson Harza to conduct a habitat assessment and develop restoration recommendations (MWH 2002). In 2003 and 2004, the Corps of Engineers began a feasibility study to evaluate restoration alternatives and develop a recommended restoration plan. The feasibility study was not completed due to a loss of federal funding.

In 2007, the City and Tetra Tech conducted a pre-design study to evaluate the key components of the project and prepare preliminary designs (Tetra Tech 2008). Issues identified in the pre-design study included effects of the project on existing wetlands, concerns regarding the levels of sediment contaminants and required management or clean-up, geotechnical concerns, and construction methods for the culvert or bridge depending on which was selected. The City has collected hydrologic (groundwater and surface water) data, temperature data, and sediment and water quality samples to help resolve these issues. The 30% design report (Tetra Tech 2009) included an extensive analysis of construction methods, whereby it was determined that the existing culvert would be replaced by a larger culvert rather than a bridge, and a shored open cut would likely be the most economical and timely method of construction. Additionally, the preferred alignment for the tidal slough channels was also selected based on the extensive hydrologic data collection and analysis. This report builds upon the work prepared for the 60% design report (Tetra Tech 2010) and comments received. On-going data collection and analysis by the project team is continuing to help finalize the proposed plan to address all remaining issues.

Tasks remaining in the design phase include preparation of the 100% and final designs, costs, and specifications; coordination with stakeholders and the public; and preparation of the final bid package. Final design plans are scheduled to be completed in December 2010, with construction planned for July through November 2011, which is contingent upon availability of project funding and approval of permits.

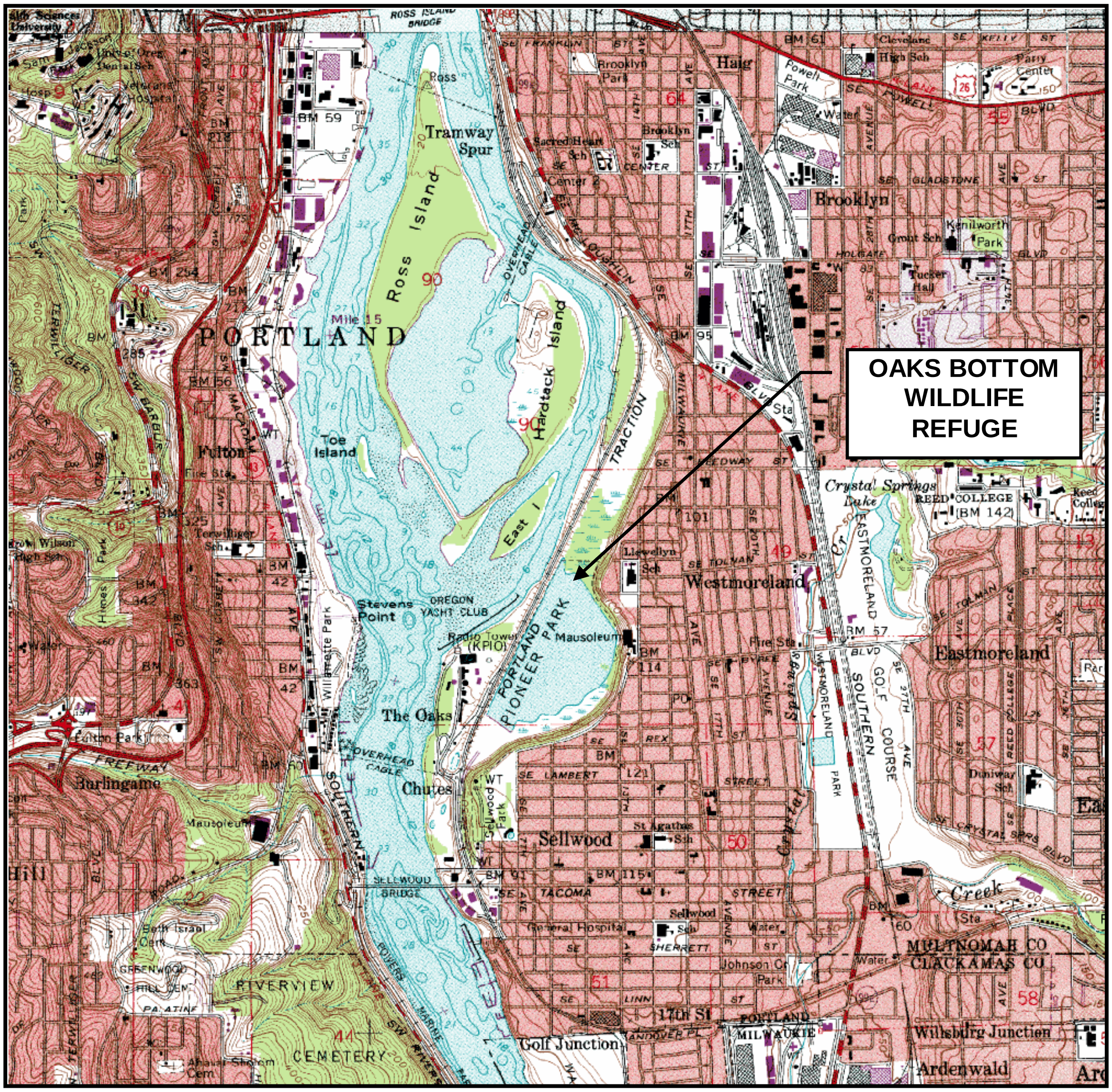

Figure 1. Oaks Bottom Wildlife Refuge Project Location Map

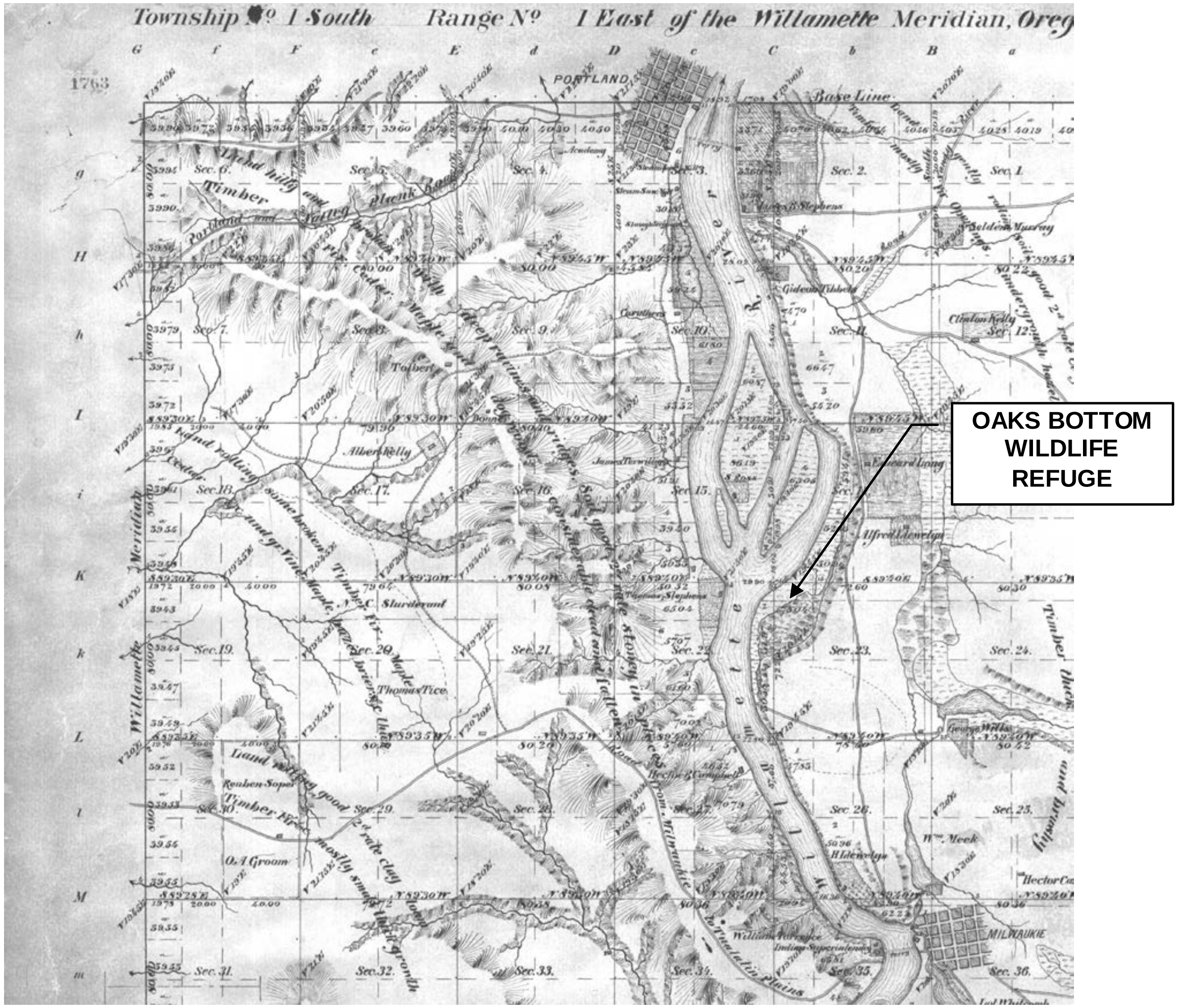

Figure 2. 1852 General Land Survey Office Map of Oaks Bottom Area

1.2 PROJECT RESTORATION OBJECTIVES

This project is primarily intended to restore a now rare floodplain system along the Lower Willamette River and enhance habitat conditions for a variety of fish and wildlife species. To achieve that goal, a number of more specific objectives were developed.

1. Allow Salmonid Access and Reduce Entrapment or Stranding of Salmonids

The refuge is separated from the Willamette River by a high railroad berm that has altered the natural fluctuation of surface waters. A 60-inch diameter culvert through the berm provides the only hydrologic connection between the river and the floodplain and that connection is further regulated with a water control structure located immediately upstream. Water flows out of the reservoir or from springs through a channel to the culvert year-round. The outlet channel is spanned by a 6 foot high water control structure that is located approximately 40 feet upstream of the railroad berm culvert. The structure is equipped with 13 flashboards that can be added or removed to control the reservoir levels.

Salmonids may enter the channel through the culvert. However, passage up the channel to the reservoir is blocked at all normal tidal fluctuations when the flashboards are in place in the water control structure (normally October through May). During high water events that raise water elevations above the lowest point of the water control structure, salmonids could enter the reservoir. However, salmonids would need to dive down in the Willamette to the culvert depth and swim through the culvert. This is assumed to occur only rarely. Salmonids may also enter the project area during flood events that overtop the railroad berm. However, according to the hydrologic analysis, the railroad berm is only overtopped by floods greater than the 100-year event. Fish passage into Oaks Bottom is thus assumed to be very limited.

However, for those few fish that may enter the reservoir, passage out of the reservoir is very difficult due to the water control structure. Once salmonids enter the reservoir, they may become trapped behind the water control structure since outflow is very small and flow is often through narrow leaks between flashboards. Furthermore, lethal or sub-lethal water temperatures, predators, and low water levels contribute to mortality of salmonids if they do become trapped behind the water control structure.

Key project components to improve salmonid access and reduce entrapment include replacement of the existing culvert with a larger culvert, removal of the water control structure, and excavation of additional tidal channels or sloughs to allow salmonid access into the reservoir and reduce stranding from other isolated areas.

2. Improve Habitat for a Variety of Fish and Wildlife Species

Currently, the refuge is comprised of several habitat types, including the open water reservoir, emergent wetlands, scrub-shrub and forested wetlands, two higher elevation fill areas, and upland savannah (bluff slopes). Between and surrounding these areas are riparian and upland forests. The south fill consists of open grassland habitat comprised of upland weedy species. The north fill has a combination of riparian and upland species and has small isolated wetlands where soils are highly compacted and ephemeral ponds form during seasonal rainfall. Bluffs on the east edge of the refuge are comprised of sparse Douglas fir and oak-madrone savannah, interspersed with many non-native and ornamental species. Within and around the reservoir are a variety of habitats, including mudflats, emergent wetlands, scrub-shrub wetlands, and forested riparian and wetlands. Between the reservoir and north fill is a transitional area comprised of forested, shrub, and emergent wetlands, and distinct ponds.

Many of these habitats have been degraded by disturbance, fill and invasive species. Although several species utilize the area for foraging, nesting, stopovers, or overwintering, the habitats could be significantly enhanced to benefit native fish and wildlife species. Restoration measures that benefit wildlife species will also provide benefits to salmonids, and vice versa.

Restoration elements included in the design that will improve habitats include replacement of the existing culvert and removal of the water control structure to allow unhindered fish and wildlife passage, excavation and filling to restore tidal slough channels and more seasonal wetlands in the duck donut, placement of large woody debris and boulders, and removal of non-native plant species and plantings of native riparian, wetland, and upland species along the new channel and around the perimeter of the reservoir.

3. Control Non-Native or Pest Populations

Exotic plants and animals are common throughout the project area, including warmwater fish species, nutria, reed canary grass, purple loosestrife, English ivy, clematis, locust, and Himalayan blackberry. The reservoir has been managed to reduce the coverage and presence of non-native or pest species. In particular, the primary management concerns are the control of mosquitoes and reed canary grass.

In the late 1980s, the addition of the water control structure allowed filling of the approximately 60 acres of reservoir area in the refuge. Inundation successfully suppressed specific mosquito populations and some areas of reed canary grass. Flooding is still used as a measure to suppress reed canary grass, which quickly becomes established in disturbed areas with little vegetation and only seasonal or shallow flooding. However, mosquito control has become much more difficult to achieve through reservoir management, as a result of the variety of species that breed at the refuge and their wide range of preferred habitats. Controlling reservoir water levels for one species of mosquito may now provide better habitat for another species. In particular, because of the concern about West Nile Virus, it may be more effective to reduce open water areas to reduce breeding habitat for the species that carries West Nile Virus.

Flooding of the reservoir is an effective way to suppress non-native plants, such as reed canary grass. However, purple loosestrife and some other species prefer inundated areas. It is an objective of this project to maintain a smaller open water reservoir, while introducing other options of control, such as mechanical removal of non-native plant species, revegetation with native species that can shade out non-native species, and restoration of the natural seasonal hydrology that native species are adapted to. Additionally, conversion of the duck donut to a more seasonal channel will reduce nutria and bullfrog populations and enhance habitat for native amphibians and mammals.

4. Maintain Open Water and Mudflat Habitats

The Oaks Bottom Wildlife Refuge is a highly popular feature of the Sellwood-Moreland neighborhood in southeast Portland. It is a unique and popular recreation area with several trails, including the paved bike trail adjacent to the railroad line. The reservoir has become the centerpiece of the refuge, in particular, due to the large number of birds that visit the area throughout the year. Waterfowl, wading birds, shorebirds, songbirds, and raptors are all visitors to the refuge. The great blue heron is a common visitor and is the official bird of the City of Portland. It is an objective of this project to maintain the recreational and bird watching value of the refuge by enhancing habitat for these bird species. Also, the local community has expressed a wish to maintain a suitable environment for bird watching by retaining open water to the extent necessary to allow viewing from hiking trails. For these reasons, the restoration project will maintain a minimum of 4-5 acres of open water habitat, which will be surrounded by a diverse transition from open water to mudflat to emergent wetland to shrub wetland to riparian forest.

1.3 KEY DESIGN ISSUES AND RESOLUTION

As identified above, during development of the previous iterations of the design, it was evident that there were several technical elements that needed further investigation and evaluation, including the following action items:

- ***Potential effects of channel/slough excavation on existing wetlands***. The proposed tidal slough channel alignment is directed towards the reservoir and avoids excavation to the north. A secondary channel will be excavated to connect the pond (south duck donut) immediately to the north of the culvert to prevent fish stranding. Grading in this pond area will return it to a more seasonally inundated pond feature that dries out during low water. The City has conducted groundwater modeling analysis to confirm that the selected channel alignment does not significantly affect groundwater levels in the high quality *Fraxinus/Polygonum* wetland north east of the proposed channel (See Appendix A.1).

- ***Fish passage and use criteria***. The selected culvert invert and tidal slough channel length and location provide a 95% frequency connection (6 inches of depth) to the Willamette River during the rearing season (October to June). Velocities are less than 2 fps 95% of the time or greater when the culvert is accessible. There will be a continuous outflow of spring water from the reservoir to the tidal slough channel of 1-2 cfs. Fish will be able to enter the tidal slough channel and reservoir during the rearing season and positive drainage out to the culvert will allow egress as surface water recedes.

- ***Sediment and water quality contamination***. During the Corps feasibility study, sediment and water quality sampling and analysis indicated that there are concentrations of DDT and other pesticides above screening levels in the channel, wetlands, and in the reservoir. Significant additional sediment and water quality sampling has been conducted by the City in several areas to determine what the current concentrations of pollutants are and if the reservoir is likely to provide suitable habitat for salmonids. There are multiple locations where DDT and its breakdown products occur at levels above the Sediment Evaluation Framework screening levels. An ecological risk assessment has been developed to address this issue. In the tidal slough channel, the surface material will be excavated and removed, thus exposing a new clean surface. In the reservoir, a combination of restoring natural hydrology (and wetting/drying cycles) and phytoremediation (revegetation with native species) will facilitate the more rapid breakdown of DDT that will reduce DDT concentrations below regulatory thresholds over time. (See Appendix A.2)

1.4 REPORT CONTENTS

The contents of this report include information necessary to support the design and costs and future design products. The following topics are presented.

Supplemental Technical Data

Supplemental technical data developed since the 60% design was completed are provided, including hydraulic information, updated sediment sampling and results, and geotechnical data (Draft Geotechnical

Report is provided as Appendix A.3). The Geotechnical Report has not been finalized, but additional evaluation has been done for the current proposed design.

Design Criteria
Design criteria for fish passage, wildlife passage, fish habitat and use, and structural design are provided.

Design Elements
The restoration plan and each major design element are described. Appendix B includes design drawings.

Permits
An overview of all necessary permits required for the Oaks Bottom Wildlife Refuge Habitat Restoration Project is provided in the report.

Construction Cost Estimate
An estimate of the project construction costs is presented in this section. Assumptions, methods, and references used to derive the cost estimate are also described. Technical specification item numbers are listed for each cost item, and a table outlining the specifications for the project is included in Appendix E.

Project and Construction Schedule
A schedule of the project design submittals, permitting, funding and project construction is presented in this section of the report.

2.0 SUPPLEMENTAL TECHNICAL DATA

2.1 CULVERT HYDRAULICS

The City of Portland with assistance from Tetra Tech conducted hydraulic analysis to support design of the culvert and of the channel through the culvert connecting the Willamette River to the reservoir. A summary and review of this analysis is included in this section. This analysis determined flow velocities and water depths in the vicinity of the proposed culvert. Velocity and depth of water are the two primary ODFW criteria for fish passage culvert design.

A 1-dimensional, unsteady HEC-RAS model (USACE 2008) was developed to predict culvert hydraulics under proposed conditions. The model geometry is based on the following topographic and bathymetric data:

- ⇒ 2005 LiDAR topographic data from the Puget Sound LiDAR Consortium
- ⇒ Supplemental topographic survey in the vicinity of the culvert and water control structure in 2007 by the City of Portland
- ⇒ Supplemental bathymetric survey of the reservoir and drainage channel between the culvert and reservoir conducted by the City of Portland in 2009

The topographic survey near the culvert and the bathymetric survey, both conducted by the City of Portland, were used to provide more detail and accuracy to the overall LiDAR coverage. The HEC-RAS model schematic is shown in **Figure 3**.

Revised Culvert Size

In February 2010, Tetra Tech revised the HEC-RAS model provided by the City of Portland to include a 16 foot span by 10 foot rise three-sided concrete culvert with 3 foot stem-walls. The stem-walls are intended to provide additional height to the culvert for wildlife passage. The pre-cast reinforced concrete culvert sections rest on top of pre-cast concrete stem-walls, which are set on top of spread footings. In the model the culvert was incorporated using a net 16-ft by 11-ft opening size to account for the cobble and gravel backfill required as scour protection over the spread footings. A schematic of the 16-ft x 11-ft (net) culvert is shown in **Figure 4.** Note the details of the channel shape within the culvert are not represented in the model and are not believed to significantly impact culvert hydraulics, particularly during river stage periods when velocities are highest**.**

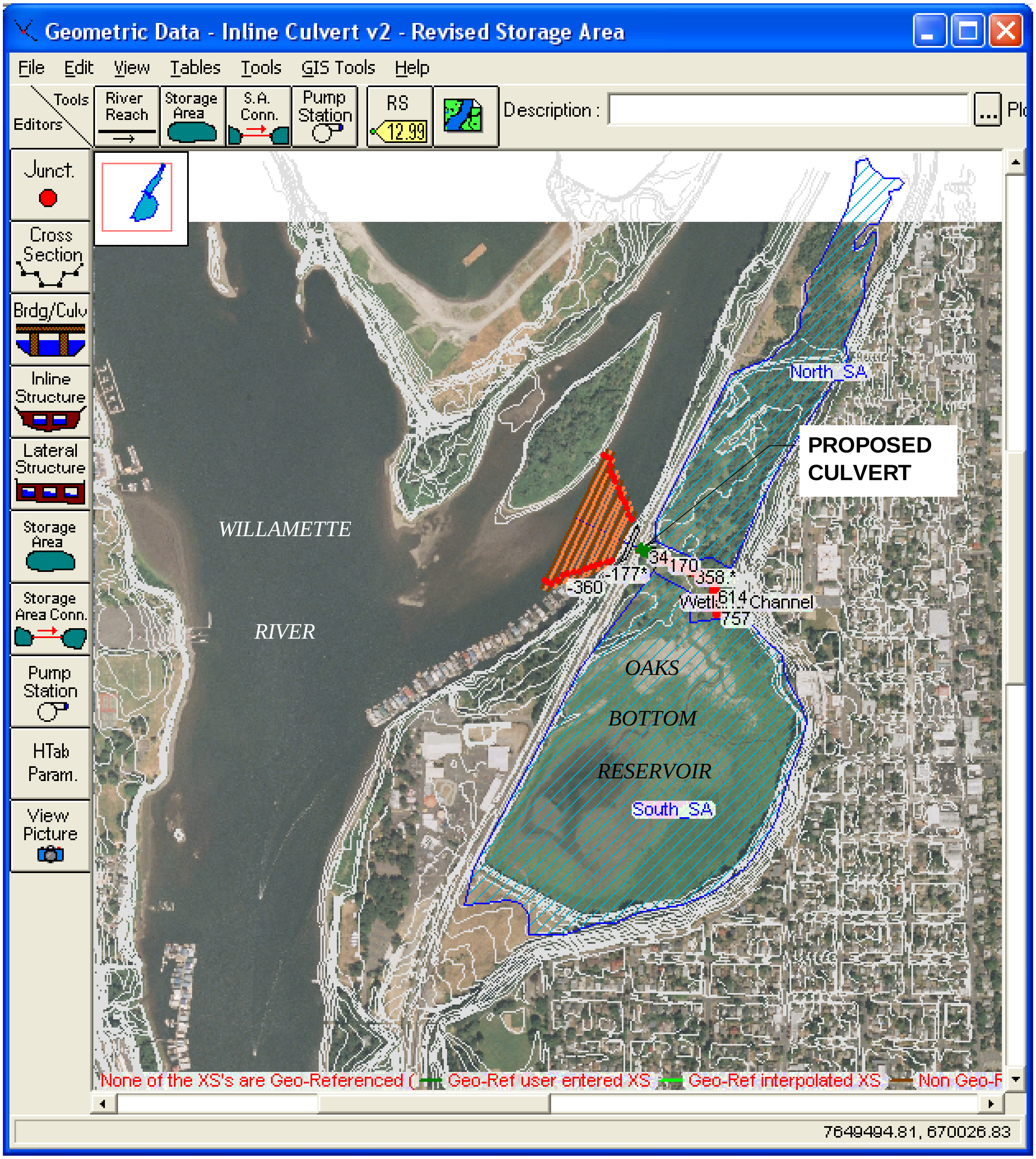

Figure 3. HEC-RAS Model Schematic for the Oaks Bottom Wetland and Culvert.

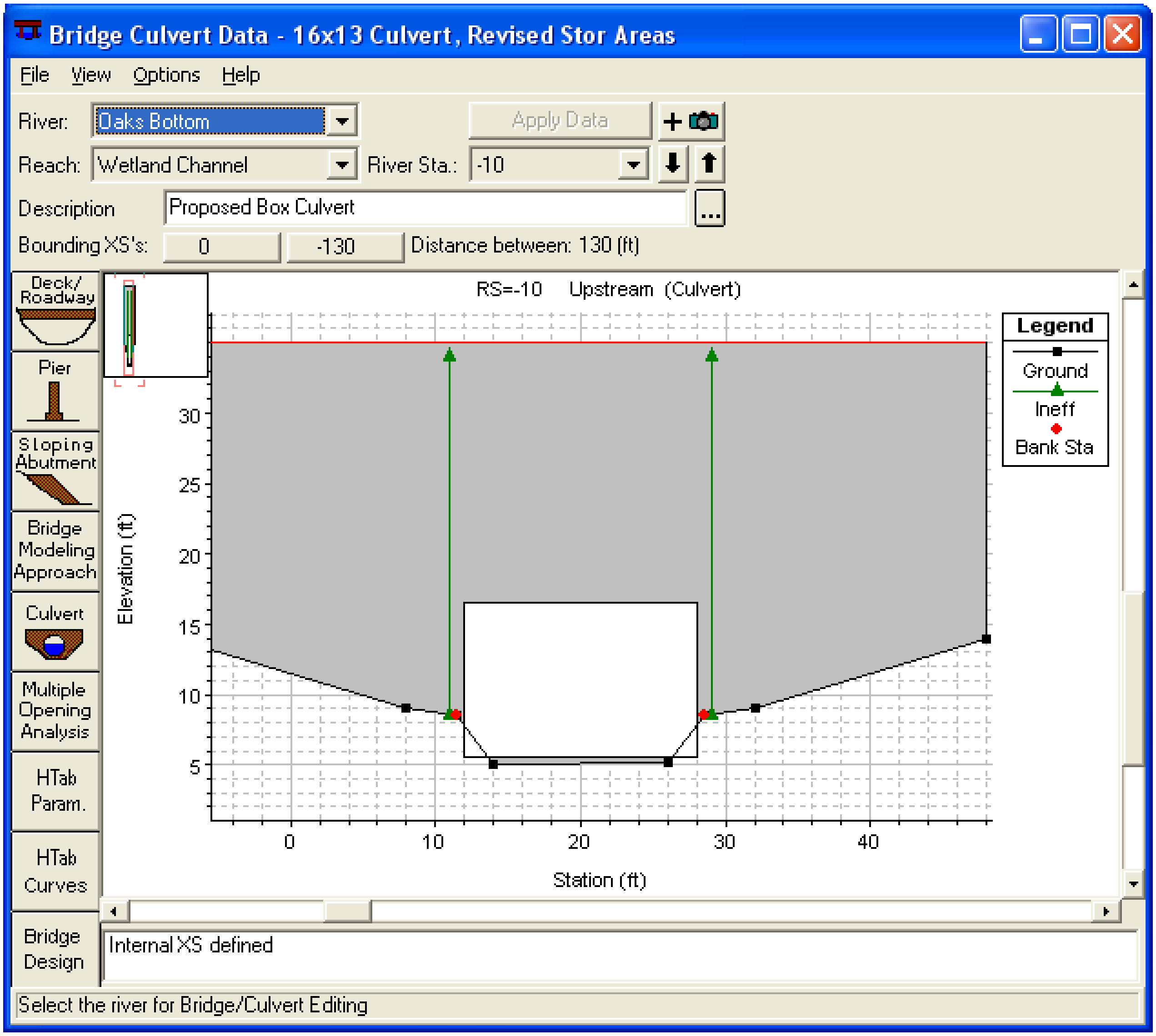

Figure 4. Schematic of the 16-ft Span by 11-ft (net) Rise Three-Sided Culvert in the HEC-RAS Model.

Boundary conditions to the model include a small upstream inflow of 1 cfs to represent groundwater and spring inflow into the refuge, and time-varying downstream stages in the Willamette River. The refuge receives groundwater and spring inflow from the bluffs along the eastern boundary of the site. This inflow is not likely to impact hydraulic conditions in the channel and culvert, and is used primarily to allow the model to stay wet during periods when river stages are below the invert of the culvert.

Two storage areas are used in the model to represent the volume of water that enters and leaves the refuge when the Willamette River rises and falls. One storage area represents the small area to the north of the culvert, and another represents the main reservoir to the south of the culvert. These storage areas are connected by lateral overflow weirs along the main channel, and they are defined by stage-volume curves created using topography and bathymetry data.

Storage area curves were updated in February 2010 to reflect the most recent topographic and bathymetric data provided by the City of Portland. The revised curves showed significantly larger volumes than previous versions. A color-shaded topography/bathymetry plot showing storage area boundaries is shown in **Figure 5**. The revised stage-volume curves in the model are shown in **Figures 6** and **7**. Elevations shown in the figures are in feet relative to the project datum, City of Portland local datum (COP).

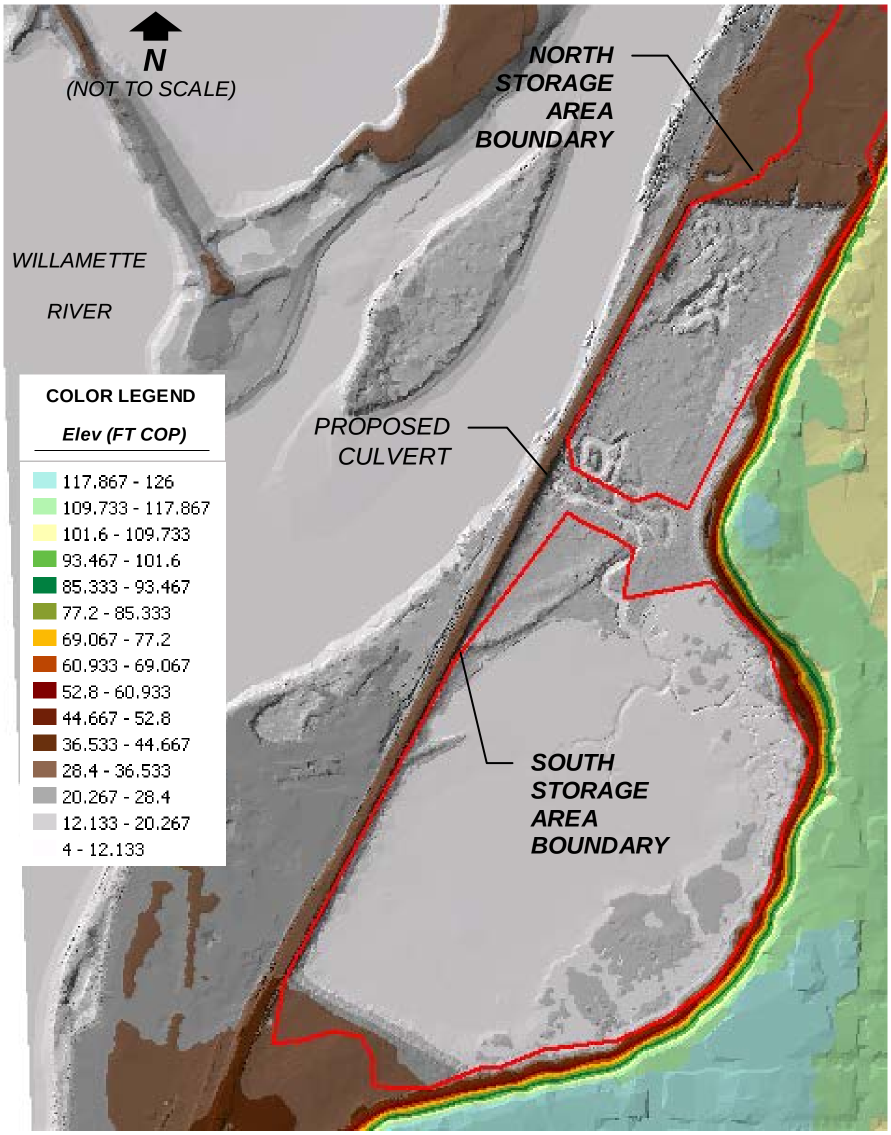

Figure 5. City of Portland Digital Elevation Data and Storage Area Boundaries used to revise Storage-Volume Curves in the HEC-RAS Model.

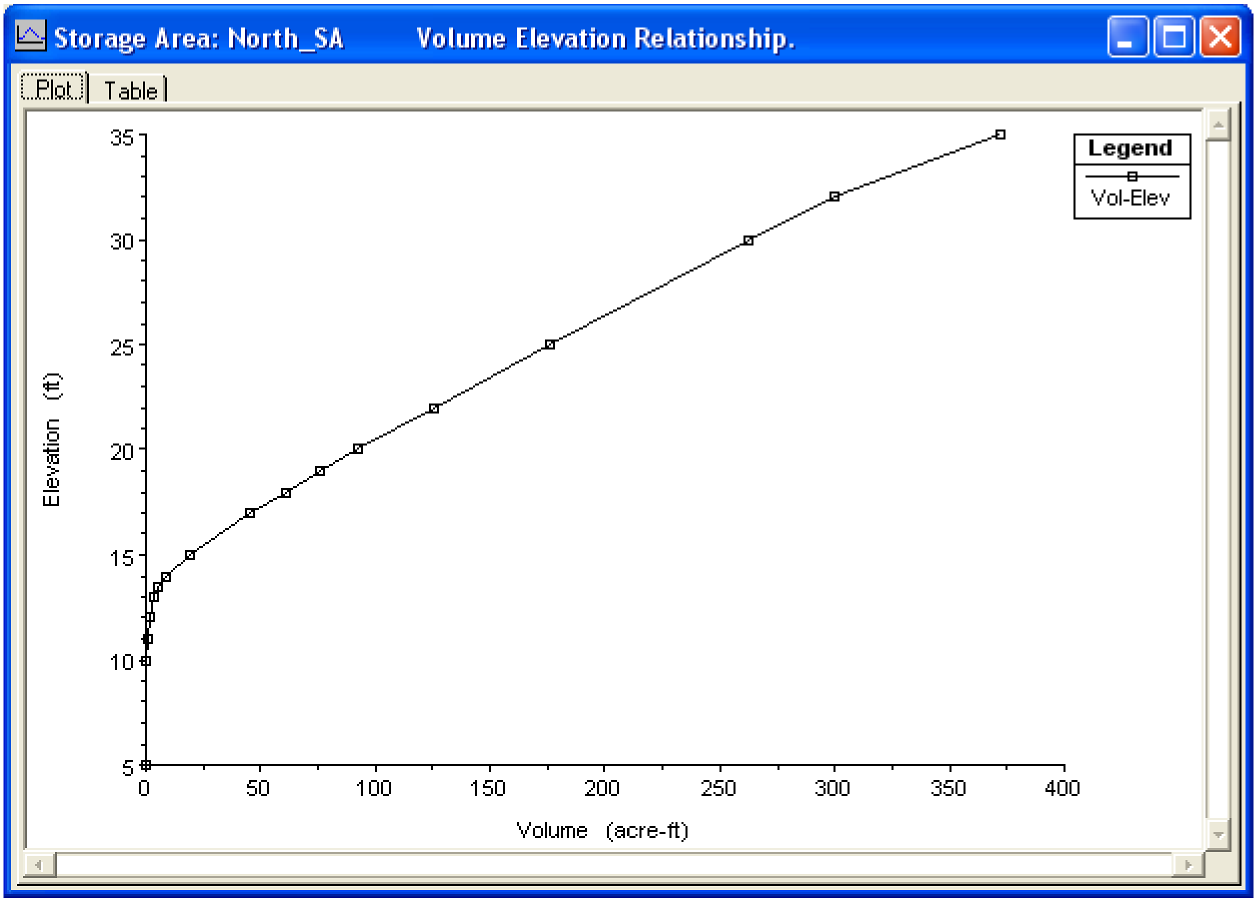

Figure 6. Stage – Volume Curve for the North Storage Area Element

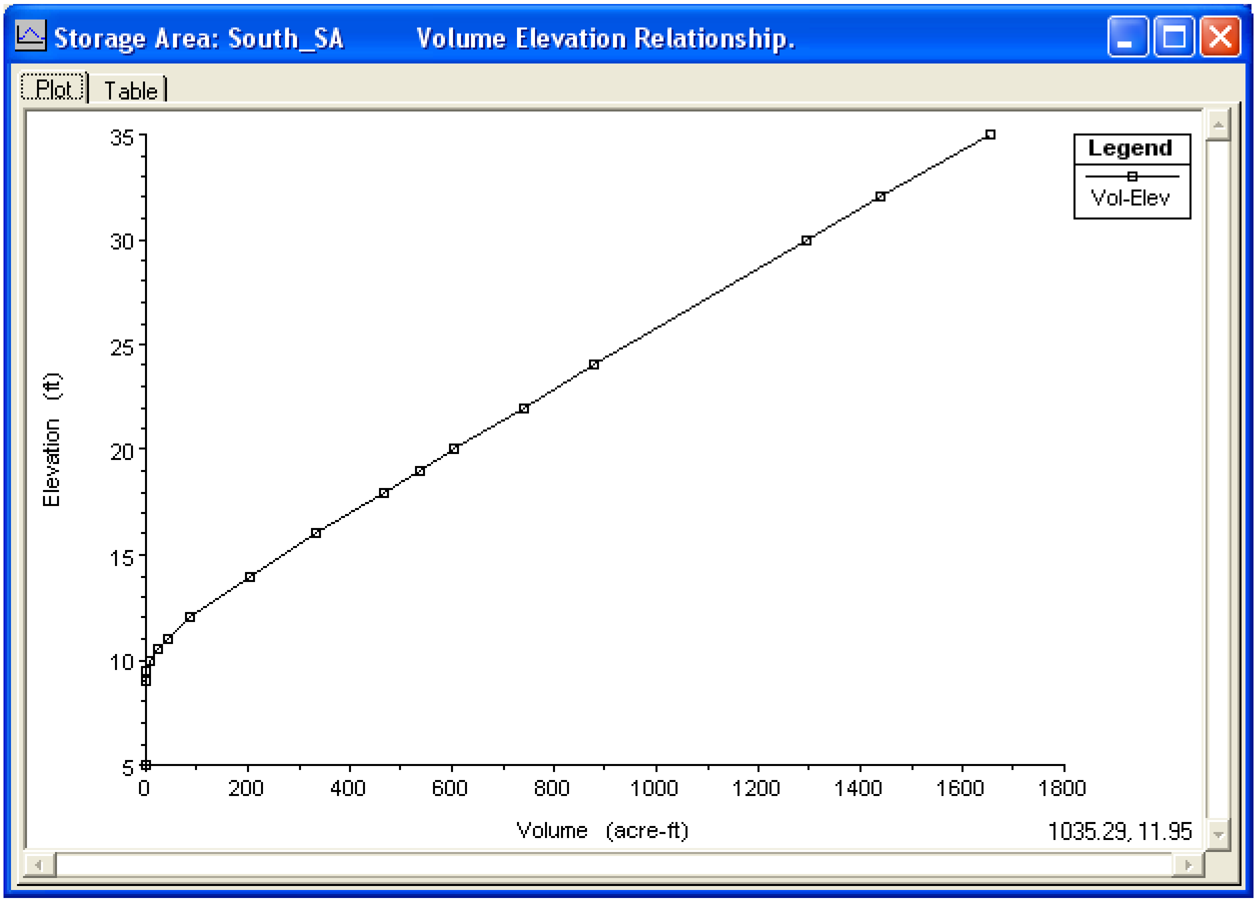

Figure 7. Stage – Volume Curve for the South Storage Area Element

To assess culvert hydraulics relative to fish passage criteria for water depth and flow, a range of historical hydrologic conditions were evaluated. Historical conditions are necessary so that model results can be tied to actual frequencies of occurrence. Low-runoff (low or dry), median-runoff (median or typical), and high-runoff (high or wet) water year types were selected because it is was not known which type of Willamette River stage and/or tidal exchange would govern culvert hydraulics for fish passage, e.g. high stage and relatively small diurnal tidal fluctuation, low stage and relatively large diurnal tidal fluctuation.

Total annual runoff volume in Oregon was used to rank water year types. Total runoff is recorded by the USGS for major drainage basins in Oregon. The USGS ranks water years by the sum total of runoff throughout the state. The summary of runoff volumes for the most recent 30 years is shown in **Table 1** (USGS 2009a). The table lists the water year, the number of stream gages used to derive the runoff, the runoff volumes (in millimeters per day and inches per month), ranking based on the overall 100-year period of analysis, and ranking based on the most recent 30 years.

Table 1. Water Year Ranking by Total Runoff in the State of Oregon, Most Recent 30 Years

Year	No. of Stream Gages	Runoff (mm/day)	Runoff (in/ month)	100-Year Rank	30-Year Rank
1979	268	1.57	1.89	78	23
1980	260	1.87	2.24	61	19
1981	260	1.61	1.93	75	22
1982	240	2.93	3.51	8	4
1983	245	2.77	3.32	12	6
1984	250	2.66	3.19	15	7
1985	247	1.98	2.38	51	18
1986	239	2.01	2.41	50	17
1987	221	1.71	2.05	74	21
1988	234	1.39	1.67	89	26
1989	230	1.84	2.21	63	20
1990	233	1.39	1.66	91	27
1991	228	1.53	1.83	81	24
1992	180	1.24	1.49	96	28
1993	183	2.11	2.53	47	16
1994	184	1.13	1.36	97	29
1995	180	2.28	2.73	30	12
1996	176	3.32	3.98	3	2
1997	**178**	**3.45**	**4.13**	**2**	**1**
1998	175	2.37	2.85	24	10
1999	179	3.15	3.77	4	3
2000	180	2.24	2.68	33	13
2001	**179**	**1.03**	**1.24**	**100**	**30**
2002	184	2.37	2.85	25	11
2003	188	2.13	2.56	44	14
2004	**190**	**2.12**	**2.54**	**46**	**15**
2005	187	1.47	1.76	85	25
2006	197	2.81	3.37	10	5
2007	194	2.43	2.91	20	9
2008	187	2.62	3.14	16	8

USGS daily streamflow data for water-years 1900-2005 were used to estimate average runoff (streamflow per unit area) for the state. For each streamgage, the average daily flow for each water-year was computed and then divided by the streamgage drainage basin area to calculate average runoff for the water-year. Average annual runoff for the Willamette River may differ from the state-wide average because annual precipitation and runoff vary considerably from relatively wet coastal drainage basins to relatively dry basins east of the Cascade Range. The Willamette River Basin lies somewhere in the middle of the spectrum and it is believed to be reasonable to use the state-wide average to generally characterize year-types of the Willamette Basin.

Based on **Table 1**, 2001 was selected as the dry year because it ranked last in runoff and it occurred relatively recently (data is more likely to be available). Water year 2004 was selected as the typical year because runoff during this year ranked 15th, approximately the median over the 30-year period. Water year 1997 was selected as the wet year; it ranked first in runoff over the past 30 years and second over the previous 100 years.

For the dry (2001), typical (2004), and wet (1997) water years, hourly stage data for the Willamette River at Morrison Bridge were obtained from the USGS (USGS 2009b). The Morrison Bridge is approximately three river miles downstream of the project site; however, there is no significant gradient between these locations. River stages for these years are shown in **Figure 8**. During 2001 stages vary between approximately 3 to 10 feet COP. In 2004, levels vary from approximately 3 to 14 feet COP. In 1997 the wet year, levels were much higher; they ranged from 4 to 26 feet COP. In 1997 there were significant periods of time, particularly in January and again from May to June, when river stages were above normal wet-period stages of 10 to 14 feet COP.

The hourly Willamette River stage data were input into the HEC-RAS model as the downstream boundary condition. Simulations for each of these years were run from November to June, the selected juvenile salmonid rearing season. Culvert velocity results were analyzed, and frequency distributions of velocity magnitudes (absolute value) were created. The frequency distributions (November to June rearing season only) for the dry (2001), typical (2004), and wet (1997) water years are shown in **Figure 9**. These figures show velocities at the upstream face of the culvert, though they were in generally similar and slightly higher than at the downstream face of the culvert.

In **Figure 9**, the curve for each water-year period slopes down and to the right, indicating that velocities near zero occur for a relatively high percent of the time, and velocities above 2 fps are exceeded a low percent of the time. There is also an apparent discontinuity particularly during 2001 and 2004, the dry and typical years, respectively. The curves show a drop in percent exceedance at a velocity of approximately 0.4 ft/s. This discontinuity is more apparent in the dry year, which also shows higher velocities at a given percent exceedance than in the typical year. At first glance, this result is unexpected, since the wet year shows the highest stages and corresponding highest velocities. The expected trend would be for the typical year to have the next highest velocities, and the dry year to show the lowest velocities.

The explanation for the trend reversal and the sudden drop in percent exceedance is that during the dry year, the Willamette river stage is below the culvert invert the highest percent of the time. When the river stage is below the culvert invert, the flow in the culvert experiences normal depth hydraulics, i.e., it is not controlled by the river stage at the downstream end of the culvert. Rather, it is controlled by the flow upstream, and the geometry, slope and roughness of the culvert. The culvert velocity during normal depth conditions is slightly higher than it typically is when the culvert is connected to the river (i.e., when culvert hydraulics are controlled by the rising/falling river stage); thus the velocity exceedance distribution is higher (to the right in **Figure 9**) during the dry year. The discontinuity occurs at approximately 0.4 ft/s because this is the velocity during normal depth flow conditions in the culvert, and the upstream flow boundary in the model was set to be constant at 0.2 cfs.

The water-year conditions showing the occurrence of highest velocities is the wet year, 1997. During this period, culvert velocities range from 0 to 2 ft/s. The 95%, 50% (median), 5% exceedance values from this curve are 0.05 ft/s, 0.3 ft/s, and 1.1 ft/s, respectively. During extreme (wet) periods, culvert velocities are less than 1.1 ft/s 95% of the time. This is within the fish passage criteria for velocity which allows for 2 ft/s up to 95% of the time. Thus, the design parameter of culvert span or width, along with the selected culvert invert elevation of 5.5 feet COP, meets fish passage requirements for flow velocities. It should be noted that peak velocities occur for brief periods during a rising tide, before and after which there are periods of slack water when velocity in the culvert goes to zero.

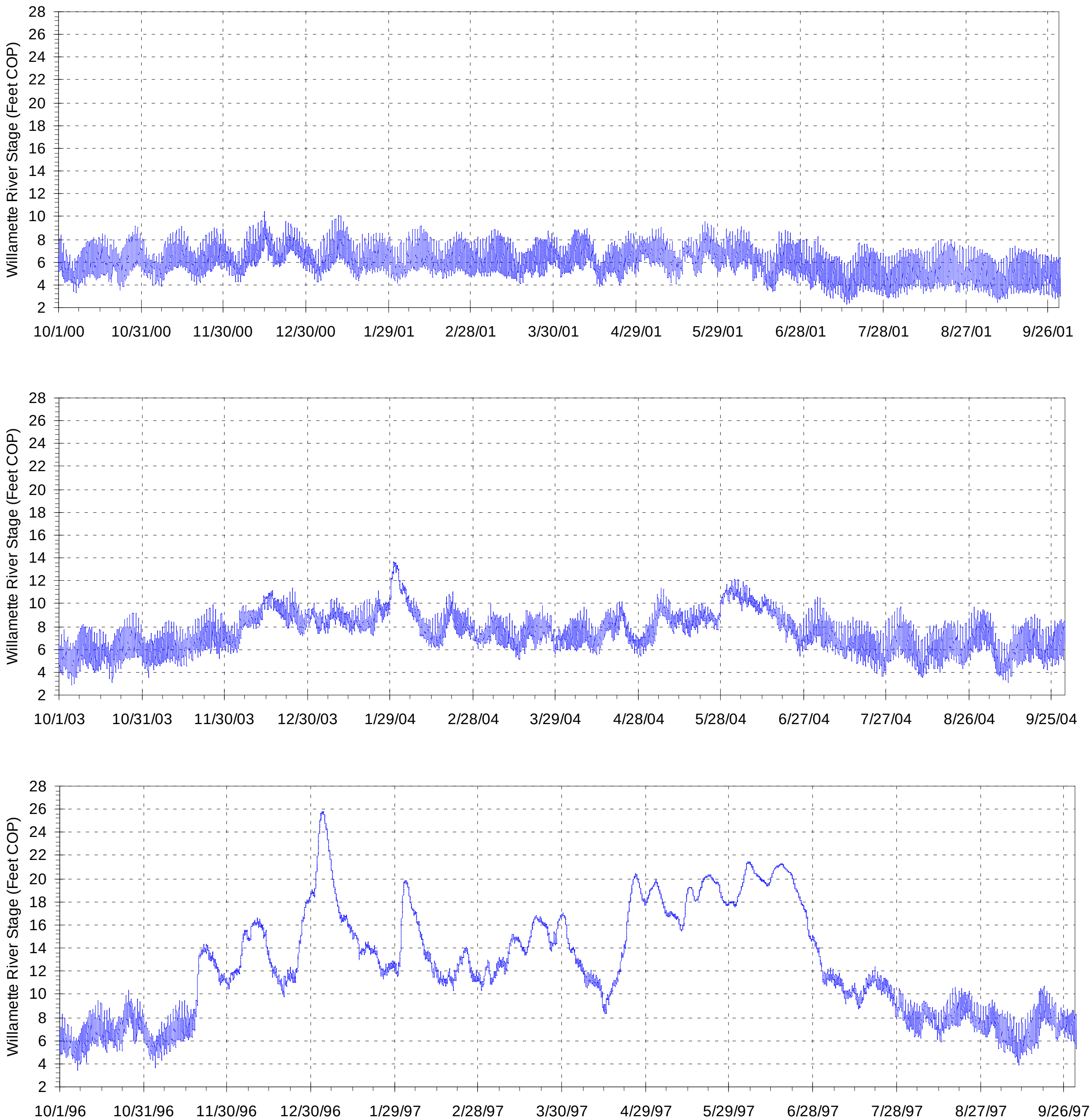

Figure 8. Hourly Stage of the Willamette River for 2001 (Dry Year – Top), 2004 (Typical Year – Middle), and 1997 (Wet Year – Bottom).

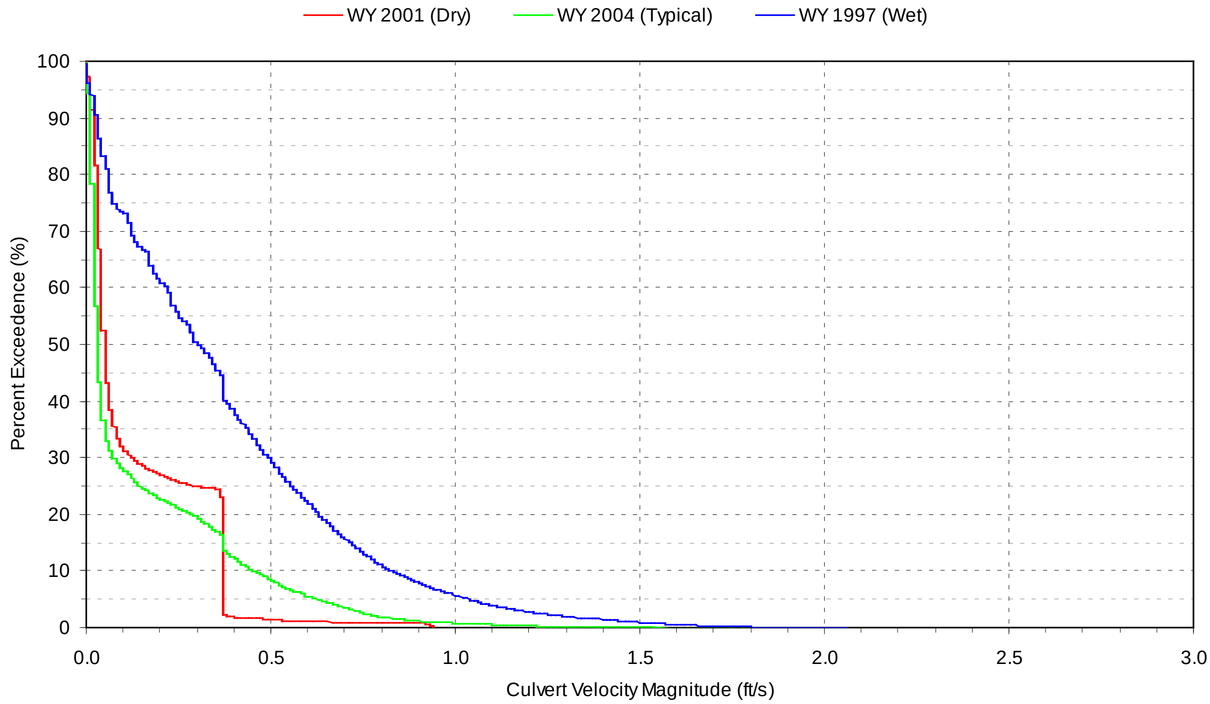

Figure 9. Frequency Distribution of Culvert Velocity for the Selected Dry, Typical and Wet Years (Nov. Through June Rearing Season Only)

2.2 GRADE CONTROL RIFFLES AND MINIMUM RESERVOIR SIZE

A primary purpose of the grade control riffles along the main tidal slough channel that connects the culvert to the reservoir is to ensure a desired minimum open-water area in the reservoir. The City of Portland conducted reservoir and channel bathymetric surveys in 2009 to supplement the existing ground elevations, particularly within the channel and reservoir. These bathymetric survey data were combined with topographic information (based on LiDAR survey data) to develop a combined topographic/bathymetric characterization of the project site. This data provides a better estimate of the required ground elevation, controlled by the riffles, to achieve the desired reservoir size.

One result of the recent survey effort was an improved stage versus reservoir area (storage or surface area) curve. This curve plots surface area of the reservoir in acres as a function of water surface elevation (WSE in feet COP) of the reservoir and is shown in **Figure 10**. This figure includes surface area curves for the south pond (reservoir), the north wetland area, and a curve that combines these two areas. At low stages, the reservoir and the combined curve overlap because the reservoir area is very large relative to the north wetland area.

At low WSEs the area curves are relatively flat, indicating that small changes in WSE result in large changes in reservoir size. The size of the reservoir is sensitive to WSEs approximately from 9 feet COP to 11 feet COP, before the blue and red curves begin to show a greater slope. In addition, from the combined curve (blue curve that overlaps the red reservoir curve), a WSE of approximately 9.5 feet COP results in a reservoir surface area of approximately 4-6 acres. At a WSE of 10 feet COP, the reservoir size increases considerably to just over 20 acres. Guidance from the project team has indicated that a minimum reservoir pool size of approximately 4-5 acres is desired. Thus a control elevation of 9.5 feet COP was selected as the elevation of the upstream-most riffle to help maintain minimum reservoir size when river stages drop below this level.

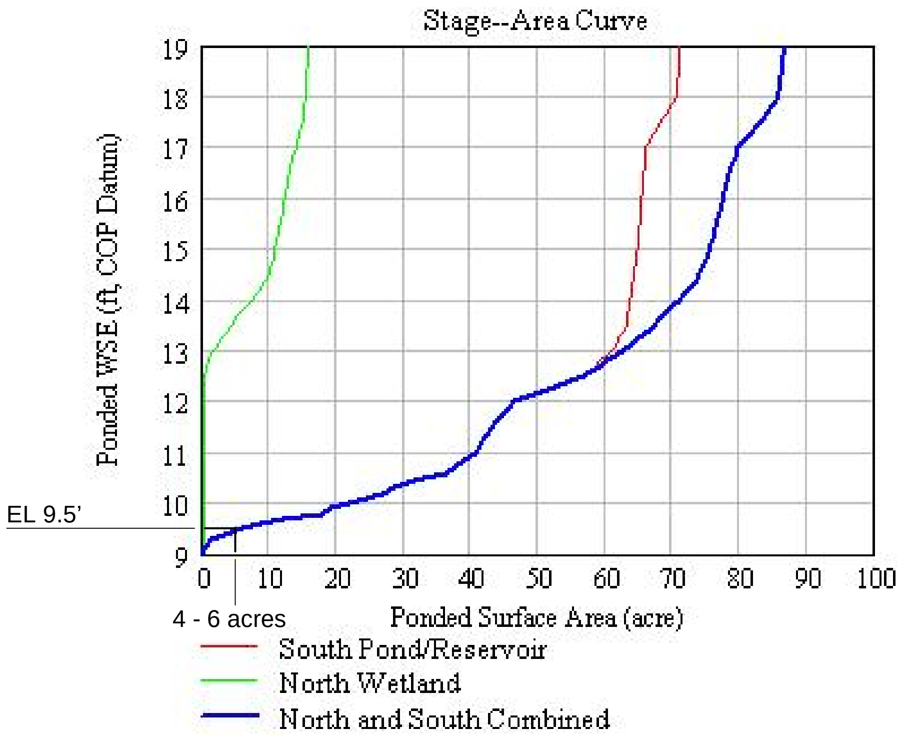

Figure 10. Revised Reservoir Stage versus Storage Area Curve

2.3 RECENT SEDIMENT QUALITY SAMPLING AND ANALYSIS

The City of Portland most recently conducted sediment sampling along the tidal slough channel and in the reservoir to help further refine the areas of potential contamination and provide results for a risk assessment to demonstrate to the agencies the likely effects that could occur to fish and wildlife species (see **Figure 11** for sampling locations and exceedances).

Similar to the results from previous sampling (see summary in 30% Design Report, Tetra Tech 2009), the primary pollutants detected above screening levels in the sediment samples were pesticides. Pesticides 4,4'DDD, 4,4'DDE, and 4,4'DDT were found above screening levels in several locations in the reservoir.

Coordination is on-going with the agencies to develop a sediment management plan to ensure that there are no unacceptable risks for fish and wildlife populations. Because the reservoir is currently contaminated above screening levels, fish and wildlife species present in the project area are already exposed to the contaminants.

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Figure 11. Sediment Sampling Locations from City Sampling in 2009.

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2.4 GEOTECHNICAL INVESTIGATION

Northwest Geotech conducted a geotechnical investigation in October 2009. The Draft Geotechnical Report is included as Appendix A. The results are briefly summarized here.

A ground-penetrating radar survey was conducted along the railroad berm to identify if a buried trestle was present below the ground. The results of this survey indicate that there are timbers and pilings underneath the soil of the embankment. Thus, it is highly likely that there is a buried trestle structure present. This buried trestle will likely be encountered during excavation of the embankment.

Two borings were completed from the top of the railroad embankment to a depth of 120 feet below ground surface. The embankment soils are primarily comprised of silty, gravelly sands of varying compaction. The side slopes of the existing embankment are steeper than would be recommended for slope stability and erosion is evident in several locations. Beneath the embankment, soils consist of plastic, clayey silts, underlain by more granular alluvium including silty sands and silty sandy gravels.

The embankment and underlying soils would be subject to liquefaction under seismic conditions. It is likely that the embankment and its associated structures would be damaged due to liquefaction, landsliding, and settlement during a significant seismic event. The proposed culvert would be present in the same conditions and could be damaged under seismic conditions. However, due to the depth of embedment of the culvert, there is lower risk of damage.

During construction, the underlying soils should be removed and replaced with suitable granular base material to support the footings and culvert. The existing embankment material is suitable for backfill over the culvert. Two to one slopes are recommended for slope stability. Geotextile reinforcement is recommended. Other geotechnical recommendations are documented in the report attached as Appendix A.

Based on the current culvert design, additional geotechnical recommendations include more clarifications on the need to sufficiently dewater the site during construction to ensure the soils do not heave while placing the footings, and minor updates to show the proposed culvert dimensions. These additions will be incorporated into a Final Geotechnical Report to be provided for the 100% design.

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3.0 DESIGN CRITERIA

In order to develop and evaluate the project alternatives, design criteria were developed for the key objectives and elements of the project including fish passage, fish habitat and use, wildlife passage, hydrology, structural design, and the desired future conditions criteria developed by Portland Parks and Recreation. Additionally, because of the presence of the Springwater Trail and railroad tracks on the top of embankment, it is presumed that the design should facilitate a short construction period to minimize disruption to the users of the trail and railroad.

3.1 FISH PASSAGE CRITERIA

Oregon Department of Fish and Wildlife Oregon Administrative Rules (Division 412) describe state fish passage regulations. Within Division 412, OAR 635-412-0035 (4) and (5) specify fish passage criteria for **estuaries**, **floodplains** and **wetlands**. The most relevant portions of the regulations to the design are highlighted in blue below.

(4) Requirements for fish passage at artificial obstructions in estuaries, and <u>above which a stream is present</u>, are:

(a) Fish passage shall be provided at all current and historic channels;

(b) Fish passage structures shall meet the criteria of OAR 635-412-0035(2) or (3)[1]*, except fish passage structures shall be sized according to the cumulative flows or active channel widths, respectively, of all streams entering the estuary above the artificial obstruction;*

(c) Tide gates and associated fish passage structures shall be a minimum of 4 feet wide and shall meet the requirements of OAR 635-412-0035(2) within the design streamflow range and for an average of at least 51% of tidal cycles, excluding periods when the channel is not passable under natural conditions.

(5) Requirements for fish passage at artificial obstructions in estuaries, floodplains, and wetlands, and above which <u>no stream is present</u>, are:

(a) Downstream Fish Passage:

(A) Downstream fish passage shall be provided after inflow which may contain native migratory fish;

(B) Downstream fish passage shall be provided until water has drained from the estuary, floodplain, or wetland, or through the period determined by the Department which shall be based on one, or a combination of, the following:

- *(i) A specific date*
- *(ii) Water temperature, as measured at a location or locations determined by the Department;*
- *(iii) Ground surface elevation;*
- *(iv) Water surface elevation; and/or*
- *(v) Some other reasonable measure.*

[1] OAR 635-412-0035(2) and (3) describe fish passage requirements for fish passage at dams and road-stream crossing structures such as bridges and culverts, respectively.

(C) Egress delays may be approved by the Department based on expected inflow frequency if there is suitable habitat and as long as passage is provided by the time the conditions in OAR 635-412-0035(5)(a)(B) occur;

(D) A minimum egress flow of 0.25 cubic feet per second (cfs) at one point of egress shall be provided;

(E) Egress flow of 0.5 cfs per 10 surface acres, for at least the first 100 surface acres of impounded water, shall be provided;

(F) All plunging egress flows shall meet the requirements of OAR 635-412-0035(2)(1)(B);

(G) If egress flow is provided by a pump, it shall be appropriately screened;

(H) The minimum water depth and width through or across the point of egress shall be 4 inches;

(I) The ground surface above the artificial obstruction shall be sloped toward the point(s) of egress to eliminate isolated pools; and

(J) An uninterrupted, open connection with a minimum water depth of 4 inches shall be present from the point of egress to the downstream waters of this state, unless another connection is provided as per OAR 635-412-0035(2)(1)(A).

(b) Upstream Fish Passage: a fishway or road-stream crossing structure with or without a tide gate shall be provided during the period determined by the Department if there is current or historic native migratory fish spawning or rearing habitat within the estuary, floodplain, or wetland area impounded by the artificial obstruction.

The historic channels and sloughs that exist upstream of the culvert are fed by intermittent and perennial springs and seeps coming from the bluffs, by stormwater, and by surface water from the Willamette River. The 1852 GLO map shows an outflow channel from a pond in much the same location as the existing channel. However, there is not a stream, by traditional definition, that flows through the culvert. Thus, the project site does not neatly fit into one of the categories listed above, and the design will focus on providing fish passage to comply with the requirements for artificial obstructions above which there is no stream present. The elements highlighted in blue will be utilized as the primary design criteria, along with other reasonable measures to achieve the project goals.

The culvert invert and downstream passage design was guided by identifying elevation 5.5 feet (CPO datum) as an appropriate water surface elevation that provides a minimum of 6 inches of water depth at the upstream end of the culvert at a 95% exceedance frequency during the primary rearing season for juvenile salmonids in the Lower Willamette River. The rearing season of interest for juvenile salmonid rearing and refuge is winter and spring during their outmigration as fry or smolts into the Columbia. We have selected November 1 thru June 30 to generally encompass when flows increase on the Willamette through the peak of the outmigration. Note, the definition of rearing season excludes the summer and early fall months when the channel would not be accessible under natural conditions – also there is no expectation (or desire) to have the channel accessible during the summer when water temperatures are high and predators are present.

For fish habitat, an approximate 18-inch water depth at the culvert will optimize fish passage into Oaks Bottom and provide functional rearing habitat moving upstream from the culvert back into the historic and proposed channel sloughs. Note, the deepest water depths will be at the culvert – with the water depth becoming shallower from the culvert moving upstream into the channels/sloughs.

3.2 FISH HABITAT AND USE CRITERIA

The fish species of primary interest for using the Oaks Bottom Wildlife Refuge are salmonids including Upper Willamette stocks of Chinook salmon and steelhead trout, which are both listed as threatened under the Endangered Species Act. In addition, Lower Columbia stocks of Chinook, coho, and steelhead include fish that utilize the Lower Willamette and its tributaries and are also all listed as threatened species. Salmonids utilize off-channel and floodplain habitats during winter seasons and their outmigration towards the ocean for both rearing and refuge from high flows, and lower tidal rivers and estuaries are particularly utilized by Chinook fry and juveniles (Healey 1991). Winter rearing habitats typically exhibit low velocities are off-channel habitats are utilized. Studies of juvenile salmonids in the Lower Willamette River indicates they utilize slow velocity sloughs and channels ranging from 0.2 to 0.8 m/s velocities (0.7 – 2.6 f/s) (Friesen, *et al.* 2004). Other habitat factors include dense cover, overhanging vegetation, inundated floodplains, logs, and boulders.

Other native fish species such as white sturgeon and lamprey may also utilize tidal floodplain habitats.

3.3 WILDLIFE PASSAGE CRITERIA

Wildlife passage criteria have been developed based upon recommendations in METRO's wildlife crossings guide (METRO 2009) and lists of species of interest from the City of Portland TEES workgroup. Wildlife of interest for passage between Oaks Bottom Wildlife Refuge and the Willamette River include raccoon, coyote, bobcat, beaver, deer, otter, snakes, turtles, and amphibians. METRO suggests that for large mammal crossings, the minimum size for box culverts should be at least 8 feet high and 16 feet wide (typical height/width for arch culverts). However, they also cite that urban adapted wildlife have been observed using smaller structures (i.e. 8x8 foot structures). They further recommend that a wildlife walkway be constructed that is a minimum of 18 inches wide and 12 inches high to allow dry passage for terrestrial wildlife adjacent to stream flows. Amphibians and reptiles will utilize moist and/or sandy substrates for passage through culverts. Additionally, it is beneficial to provide cover such as overhanging vegetation, logs, or boulders at the inlet and outlets of culverts to provide cover for the various species as they enter or exit the culvert.

3.4 STRUCTURAL DESIGN CRITERIA

The vertical loads for the railroad replacement structure will be based on Cooper E80 loading, which is standard for freight-carrying tracks. Horizontal (or lateral) loads will incorporate seismic effects and will be based on the current edition of the Oregon Structural Specialty Code (OSSC). The temporary railroad structure will be designed in accordance with following loads, codes and standards:

- Vertical Loads – "Cooper" Class E-80
  - Wheel load per track = 80,000 lbs
- Seismic Loads – ground accelerations
  - 1-second duration = 1.0g
  - 0.2-second duration = 0.35g
  - Site Class D
  - Importance = 1.0
- Oregon Structural Specialty Code
- American Railway Engineering and Maintenance-of-way Association (AREMA)
- Oregon Department of Transportation (ODOT), Rail Division

3.5 PARKS DESIRED FUTURE CONDITION CRITERIA

Portland Parks and Recreation has developed a number of criteria related to the habitat types they would like to enhance and preserve within Oaks Bottom Wildlife Refuge as well as for the long-term operation and maintenance of the park.

- Maintain a minimum of 4 acres of open water habitat year-round for waterfowl, wading and shore bird use.
- Restore natural hydrologic conditions to the greatest extent possible, by allowing winter high water levels and summer low water levels, as dictated by the level of the Willamette River.
- Allow for the maintenance and establishment of open water, mudflat, emergent marsh, scrub-shrub wetland, and surrounding riparian forest in the reservoir area.
- Minimize operation and maintenance requirements at culvert and any grade control structures or other structures associated with the tidal channels/sloughs.
- Do not dewater existing wetlands, particularly *Polygonum* sp. wetland (except per desired future condition for reservoir area).
- Minimize or preclude boater access into the park via either culvert or bridge opening.
- Minimize construction impacts and closures on the Springwater Trail.
- Include interpretive features along the Springwater Trail as part of the project.

4.0 RESTORATION PLAN AND DESIGN ELEMENTS

The recommended restoration plan as evaluated and derived from the project design criteria, supplemental technical studies, and project team review is presented in this section by key design element.

4.1 CULVERT REPLACEMENT

The proposed replacement culvert is a precast, reinforced 16-foot span by 13-foot rise (including 3-foot stem wall) concrete three-sided culvert. The culvert is to be furnished by a culvert manufacturer/vendor according to design criteria specified in the final version of this report and the plans and specifications. The proposed culvert is 90 feet long and would be placed horizontally (with no slope) to facilitate construction. The inside of the culvert is to be back-filled with two feet of streambed material including a mixed gradation of gravel and cobbles with boulders placed throughout. The slope and grade of the streambed inside the culvert is to match that of the continuous tidal channel on the upstream and downstream ends.

The Springwater Trail and Oregon Pacific Railroad berm is to be reconstructed with a top of berm elevation and slopes (sideslopes) similar to those of the existing berm in order to match grades and slopes on either side of the construction limits. The existing and proposed top of berm elevation at the proposed culvert crossing is at an elevation of approximately 34 feet COP and the existing and proposed slope along the trail and railroad alignment is flat (zero slope). The proposed berm sideslopes on the downstream (west) and upstream (east) sides are 2 horizontal to 1 vertical (1.5H:1V) to conform to permanent fill slope recommendations in the geotechnical report (see Appendices).

4.1.1 Structural Design

Culvert

Several options have been reviewed for the proposed culvert system, consisting of the following:

- Steel plate rectangular three-sided arch (with an open bottom) set on precast footings
- Precast concrete box culvert
- Precast concrete arch culvert (shown on the drawings in Appendix B)
- Precast concrete clamshell (two 3-sided boxes)
- Corrugated metal arch culvert

In all cases, a criterion of selection is the ease and speed of installation. A cast-in-place option was considered less desirable because it requires a longer construction period (to allow the concrete to cure), whereas the other options do not require curing in-place. Most of the potential options offer the desired width of channel (12 foot minimum, 16 foot for improved wildlife passage) and overhead clearances (8 to 10 feet measured at the center). Box-shape culverts are generally difficult to find in spans greater than 12. The advantage of the square box and rectangular 3-sided culverts is a uniform vertical ceiling in the culvert section. However, these sections are not preferred by some agencies due to a history of cracking in the corners and the resulting maintenance issues.

There is also a difference in costs between the precast concrete and the corrugated metal arch options. The metal culvert is approximately 30% of the cost of the precast concrete arch option.

In all of the potential options, the design criteria include earth-loading, train loads from the railroad tracks, and pedestrian/vehicle loads from the Springwater Trail. The anticipated structural design criteria are listed in Section3.4.

Temporary Railroad Bridge

A temporary railroad bridge is being considered to allow the Oregon Pacific Railroad to have once per week operations. Oregon Pacific Railroad will construct the bridge and install it on additional steel piling that would be installed behind the sheet piling for the shoring support system. Five HP 14X73 will be required on each side of the cut to support the temporary railroad bridge; total of 10 pilings.

The width of the excavation will determine the bridge span. Currently, an approximately 30-foot wide trench supported by steel sheet piling is identified and an estimated 40-foot span bridge would be required. The vertical sheet piling may be braced across the trench by strategically placed walers and braces, or tie-backs may be used. Currently, it is assumed that 23 sheet pile sections (4 foot lengths) will be needed on each side of the cut for a total of 46 sections to shore the cut. The contractor may propose an alternate method of shoring that would provide equivalent safety and accommodate the bridge crossing.

4.2 TIDAL SLOUGH CHANNELS AND GRADE CONTROL RIFFLES

Proposed tidal slough channels (channels) are to be excavated. Channel A will connect the culvert to the reservoir, and Channel B splits from Channel A and extends north for approximately 300 feet (see Plans, Sheet C01). Both channel alignments are to follow the existing wetland channels. Channel A is to include grade control structures (riffles) to provide positive drainage from the reservoir to the culvert, while Channel B will have a constant slope without grade control structures. Channel A will have a bottom width of 12 feet for continuity with the channel through the proposed culvert. Channel B will be regraded for positive drainage to Channel A, and thus will require excavation from its intersection with Channel A to the end of the channel at approximately elevation 10 feet COP. The channels and their design features are described in more detail in the following sections.

4.2.1 Channel to Reservoir – Channel A

Channel A begins downstream of the proposed culvert at Station 10+84.49 where it intersects the existing ground, extends through the culvert, and ends slightly upstream of Station 27+00, where its elevation is set at 9.5 feet COP (see Plans, Sheet C01). The downstream control elevation is at the upstream face of the culvert (Station 12+28.55), where the elevation is set at 5.5 feet COP to meet fish access requirements. The resulting slope between these locations is 0.003 feet per feet (0.3%).

Grade Control Riffles

Grade control riffles constructed of rock are proposed along Channel A to control the grade to ensure positive drainage out of the culvert as the water level recedes and to prevent headcutting of the channel in order to preserve the 4-7 acre reservoir. The rock riffles are designed so that the maximum vertical drop between adjacent riffles is approximately 0.5 feet (see Plans, Sheet C07). The tops of the riffles are to be constructed flush with the finish grade of the channel so that the structure is in line with the overall channel slope of 0.003 ft/ft. The drop may be exposed if the channel incises over time. The elevation of the rock riffles are set to limit changes in channel bed elevation to approximately 0.5 feet or less.

The actual locations and vertical drops of the riffles along the Channel A alignment were designed to

(1) approximately match the 0.5 feet elevation drop target, and
(2) be correctly located in planform from a geomorphological perspective.

Riffles are located at inflection points of adjacent curves along the alignment because this is typically where grade control points occur in natural channels. Placement of riffles at inflection points also reduces the risk of scour along the outside of a meander bend where hydraulic shear forces are greatest. In order to meet these objectives, in some cases it was necessary to space adjacent riffles slightly farther apart such that the vertical drop would be greater than 0.5 feet (yet still not greater than 0.6 feet). A list of the riffle numbers and the Channel A stationing and elevations is given in **Table 2**. The maximum potential drop between adjacent riffles is 0.54 feet (6.5 inches), and the minimum drop is 0.41 feet (5.0 inches).

The riffle structure is comprised of a well graded mix of 8-inch minus cobbles and gravels to resist scour. Boulders are to be placed throughout the riffle as shown on the Plans. Boulders are to continue up the sideslopes and provide a key-in to the bank to prevent scour around the structure.

Over time, sediment will likely deposit on some of the riffles so that they are not visible. At locations that may become slightly scoured, portions of the riffle may be visible.

Table 2. Grade Control Riffle Locations along Channel A.

Overall Slope:		0.003			
Riffle No.	Station (Ft)	Elev. (Ft PDX Datum)	Spacing (Ft)	Grade Rise (Ft)	Notes
(Culvert)	12+28.55	5.5			U/S face
1	14+00.00	5.97	171.45	0.47	
2	15+50.00	6.37	150.00	0.41	
	15+67.25	*6.42*			*Elevation at Channel B Split*
3	17+20.00	6.84	170.00	0.46	
4	19+10.00	7.35	190.00	0.52	
5	21+10.00	7.90	200.00	0.54	Inflection of small radius-curves (fixed pt.)
6	23+10.00	8.44	200.00	0.54	
7	25+10.00	8.98	200.00	0.54	
8	27+00.00	9.50	190.00	0.52	

4.2.2 Channel to the North – Channel B

The primary purpose of Channel B is to reconnect the south pond (duck donut) and regrade for positive drainage towards the culvert to minimize fish stranding as well as reducing habitat suitability for nutria. Excavation will be required in Channel B to connect to Channel A at the location where they intersect; however, the extent of excavation in the channel is minimized to reduce impacts to wetland areas north of Channel B.

Channel B begins at station 15+67.25 of Channel A, and continues upstream approximately 300 feet, from Station 2+00 to Station 4+92.79 of Channel B (see Plans, Sheet C01). This channel is 12-feet wide for continuity with Channel A, and it has a constant slope of 0.012 ft/ft (1.2%). Channel B begins at an elevation of 6.77 feet COP, and ends where it intersects the existing ground at an elevation of 10.0 feet COP and Station 4+92.79.

Channel B construction will also include re-grading the 'duck donut' region to the west of Channel B near Stations 3+00 to 4+50. The existing channel at this location will be excavated to match the proposed invert elevation of Channel A for continuity in slope. The high islands within the duck donut will be excavated to create a lower wetland area that will be revegetated with willows.

4.2.3 Vegetative Berms – Margins of Channel A

As part of construction of Channel A, vegetated margins at the tops of the left and right bank of the channel will be constructed to reduce the risk of flanking or avulsion of the channel during high river stage events. Vegetated margins will include the placement of prevegetated mat strips, approximately 5-feet wide, of relatively dense emergent vegetation seeded and grown into a coir fabric mat with the specific purpose to resist erosion at the tops of bank of the channel. Channel avulsion and the potential for formation of other drainage channels outside of the designed riffles might cause headcutting and the drainage of the reservoir, potential stranding issues, and other problems. The earthen berms that were previously considered to prevent channel flanking are not necessary because they would not be significantly more effective than vegetated margins, and would be significantly more difficult to construct and have higher impacts to the existing wetland.

The vegetated margins would be constructed approximately six inches above existing grade and would include stripping off the reed canary grass rootmat, placement of prevegetated coir mats (with the wetland seed mix pregrown to minimum 2 inch height). Willow and cottonwood cuttings would also be installed along the channel slopes. The margins would parallel the proposed channel top of bank for approximately 275 feet of Channel A on the left bank (looking downstream) and for approximately 400 feet along the right bank. Downstream of the sections where the prevegetated mats would be installed, the channel banks would be revegetated with seeding of native grasses and sedges and willow cuttings.

4.2.4 Large Wood and Boulders within the Channels

Large woody debris (LWD) and boulders will be placed within the wetland channel as habitat features to enhance stream complexity. Wood will be either imported or from salvage. Trees removed and salvaged during grading activities that meet specified requirements and approved by the City of Portland construction manager will be reused as LWD. These trees will have rootwads intact, and will be either Douglas fir or Oregon ash. The number and arrangement of logs will be varied throughout the channel to mimic naturally occurring woody debris. Current plans show one to three logs per cluster. Logs will be substantially buried into the channel bank and ballasted with boulders (referred to as Ballast Boulders on the Plans) to prevent movement when inundated. Mechanical anchoring of the logs is not necessary in the relatively low-energy channel system.

Boulders will also be placed adjacent to and across-channel from the LWD clusters to promote varying areas of scour (pools) and deposition within the channel. These boulders are referred to as Habitat Boulders on the Plans. These boulders will vary in size from approximately two to five feet in diameter. Boulders salvaged during channel and embankment excavation may be used at the construction manager’s discretion for habitat boulders.

4.2.5 Boulders for Boater Exclusion

In order to deter boaters from entering the culvert, several large boulders (Boater Exclusion Boulders) and a few pieces of large wood will be placed at the mouth of the culvert along the bank of the river. Several boulders (same size as Habitat Boulders) and boulder clusters will be placed in a natural orientation and also somewhat offset relative to adjacent boulders over a width of 20 feet. The spacing will be such that canoe, kayaks and similar small watercraft will have difficulty navigating through the field of boulders. The appearance and layout of the boulders will be as natural as possible. The existing large boulders currently at the culvert mouth will be reused if possible.

4.3 REMOVAL OF INVASIVES AND REVEGETATION

The overall revegetation plan for the reservoir will be prepared by the City of Portland staff (including both Parks and Recreation ecologists and BES revegetation staff). Included in this design for contract will be revegetation of all areas disturbed during construction. In general, an approximately 100-foot wide zone along the proposed Channels A & B will be cleared of reed canary grass during the channel excavation activities and then replanted with native species to achieve an appropriate native plant community for the ground elevation and flooding frequency. The channel margins will be seeded with a native grass and sedge mix and then willow and cottonwood cuttings will be installed along the channel slopes and tops of banks. At the area of the access ramp off of the embankment, the ramp will be removed and restored to the original contours and then replanted with a native grass seed mix and native Pacific willow and black cottonwood woodland plant communities. The willow community could include Oregon ash, Pacific willow, Scouler's willow, Columbia River willow, red osier dogwood, and ninebark. The cottonwood community could include Oregon ash, Douglas' hawthorn, red osier dogwood, elderberry, and peafruit rose. The railroad embankment area disturbed during construction will be protected with jute matting and seeded with a native upland grass mix following completion of grading.

It has not yet been determined the extent of invasive species control and/or revegetation that will occur around the reservoir. The Parks Desired Future Condition (DFC) plan for the area calls for the re-establishment of three plant communities: willow and cottonwood woodlands and emergent marsh. Overall, the proposed revegetation budget for the project is $300,000. More details on revegetation, including a site plan and species list, will be provided by the City at the next design submittal.

4.4 INTERPRETIVE FEATURES AND SPRINGWATER TRAIL

Viewing platforms and interpretive features are proposed at two locations within the project. One location is immediately south of the proposed culvert, at the southwest edge of the Springwater Trail as shown on the Plans. A second platform and interpretive station is proposed immediately north of the trail ramp from Oaks Amusement Park. Construction access to both platforms will be the same as that for the culvert construction. Current plans have the viewing platforms at 30 feet in length by 8 feet in width with an ADA accessible ramp up to the elevated platform, approximately 40 feet in length. They will include railings and the City will design and install interpretive signage and information.

The Springwater Trail will need to be repaved along the entire access route to the culvert following construction to repair damages associated with truck traffic. Repairs are also expected to be required along the Oaks Park access roadway.

4.5 UTILITIES

Various known utilities are present in the project vicinity. These include a power transmission tower located at the eastern toe of the embankment, just south of the proposed culvert. The tower supports overhead transmission lines that run parallel to the embankment. The lines are likely high enough that they will not impact crane operation during construction, but staging and access will need to be designed to avoid impacts to the tower and lines.

There is also an abandoned gas main pipeline to be demolished and capped. The gas main is a steel pipe, approximately 18 inches in diameter. The pipe is exposed on the east side of the embankment, located above the existing culvert. Roughly 100 feet of this line will be demolished, and the opposing ends will be capped and remain in place.

4.6 RISK MANAGEMENT

Management of the risks associated with the project is considered in this section. The risks are grouped into two categories: those pertaining to design, and those pertaining to construction. The various design and construction risks are identified, and mitigation and management measures are described.

Design-Based Risk Considerations

Important design-related risks involve natural/physical processes acting on and within features of the project. These include evolution of the tidal channel connecting the culvert to the reservoir. The geometry of this channel will likely change in response to the increase in connectivity (tidal prism) with the Willamette River. There is some risk that the channel will avulse and bypass the sequence of riffles within the designed channel. The result could be a channel that develops distinct drop(s) with greater height than that is appropriate for juvenile fish passage, or the channel could headcut into the reservoir thus reducing the open water area of the reservoir. Highly vegetated channel banks will be utilized to mitigate the risk of channel avulsion by making it difficult for a new channel to be cut through the proposed channel.

Culvert scour is another risk associated with natural processes that is mitigated through design measures. The risk of scour of the culvert and wingwall foundations will be mitigated by use of properly designed rock channel protection. The channel protection has been designed according to expected scour velocities predicted from the hydraulic model, and common and accepted design methodologies.

Another related risk is that of stranding of fish that utilize the newly constructed habitat. Stranding could occur if fish are unable to exit the reservoir and channel before the river stage recedes. Rock riffles are designed to control the grade of the channel so that the channel drains as the river stage recedes.

Construction-Based Risk Considerations

Construction-related risks are those occurring during construction of the project. Some construction risks involve the placement (installation) and use of the temporary railroad bridge, shoring of the excavation, removal of the existing culvert and placement of the proposed culvert units by crane from the top of the embankment, as well as risks associated with the difficulties in construction vehicle and equipment access to the site (ingress and egress). There may also be risks associated with dewatering and hauling excavated materials, requiring special methods of dewatering or disposal.

The temporary bridge involves construction challenges because it is located on top of a large earthen and potentially unstable embankment. The railroad owner has indicated that they would install and remove the temporary bridge to facilitate rail line use on weekends. Delays in the installation and removal of this bridge each week could create delays in the construction process.

Shoring to reduce excavation and backfill quantities will also be challenging because of the height of the embankment and excavation depths required. Approximately 35 vertical feet of embankment will require shoring or stabilization for construction of the culvert. This will pose risks and challenges to the contractor. Risks related to shoring will be mitigated through allowing contractors to implement methods with which they are familiar and requiring them to demonstrate experience in similar projects.

The excavation of the embankment material for the culvert replacement will remove a minimum of 2,000 CY of existing material. Much of this material is suitable for reuse in backfilling the embankment after placement of the new culvert. However, some excess material may need to be hauled away. Various methods may be viable including truck haul along the Springwater Trail or removal by barge. Because the trail and railroad will have an open cut during construction of the culvert, removal of the material will need to be facilitated to the south of the culvert (shortest haul distance) for the truck haul scenario, or be stockpiled on site until the cut is backfilled.

5.0 PERMITS

A number of permits and supporting documentation are required for this project. If Corps funding is utilized for this project, the Corps will fund or facilitate completion of all requirements related to Federal permits and approvals.

5.1 SECTION 404 DREDGE AND FILL PERMIT (CORPS)

Upon review of the permit application, the Corps will make the determination as to whether this will be covered by a Nationwide permit or an individual permit. Even though this is a habitat restoration project, it may require an individual permit. The Corps will request Section 7 consultation with NMFS-USFWS necessitating submittal of a Biological Assessment and possibly the response of a Biological Opinion prior to obtaining the permit.

Review Period: 6-12 months; permit submittal in July 2010.

5.2 SECTION 7 CONSULTATION (NOAA, USFWS)

An informal consultation or Biological Opinion (BO) will be required from USFWS and/or NMFS regarding potential effects to listed salmonid species and wildlife (i.e. Chinook, coho, and steelhead). Typically the in-water work window for the Lower Willamette River is July 1 through October 31. If the work area behind the berm is isolated from the river, it may be possible to extend the window.

Review Period: 60-180 days; permit submittal in July 2010.

5.3 SECTION 401 WATER QUALITY CERTIFICATION (ODEQ)

This permit will be issued by ODEQ and depends on the volume of excavation proposed and potential effects on water quality. It is expected that the construction will require isolation of the work area via coffer dams or similar to ensure no release of sediment or other pollutants into the Lower Willamette River.

Review Period: 30-180 days; permit submittal in July 2010.

5.4 REMOVAL/FILL PERMIT (ODSL)

This permit will be required for any excavation or fill within wetlands or other waterbodies.

Review Period: 30-90 days; permit submittal in July 2010.

5.5 OTHER PERMITS AND DOCUMENTS

A number of City of Portland approvals will be required including Greenway Approval, Non Park Use Permit, Development Review, Environmental Review, and Floodplain Review.

Review Period: 30-120 days; permit to be submitted in August 2010.

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6.0 COST ESTIMATE

Total project costs were estimated to reflect the current 90% design level of detail and are summarized below in **Table 3**.

The total project cost is estimated to be $4,871,000 (rounded-up). This includes site preparation (mobilization/demobilization, traffic control, fencing, BMPs, temporary trail access ramps, etc.), culvert replacement, temporary railroad bridge, channel construction, riparian restoration and revegetation, design contingency, real estate investigations and negotiations, engineering and inspection/administration during construction, and post-construction effectiveness monitoring. Operation and maintenance over an assumed 50-year life, although not reflected in the total cost, are detailed in the Appendix D and are shown for informational purposes.

Table 3. Total Cost Summary.

Feature		Cost
Site Preparation	$	690,844
Culvert Replacement	$	1,791,001
Channel Construction & Riparian Restoration	$	970,436
Direct Construction Subtotal	*$*	*3,452,281*
Contingency	$	863,070
Real Estate	$	10,000
Engineering During Construction	$	69,046
Construction Inspection & Administration	$	276,182
Post Construction Effectiveness Monitoring	$	200,000
Operation & Maintenance (Not Incl. in Total)		$354,257
TOTAL COST (rounded-up)	**$**	**4,871,000**

The estimates are based primarily on recent information obtained from local and regional construction contractors and vendors. These included large general contractors who could be the prime contractor, various land-based excavation construction firms, marine-based construction firms with crane barges and other equipment for driving piles and excavating, and smaller construction firms who specialize in one or more specific aspects of the work such as shoring, crane operation, etc.

General assumptions of the estimates include:

- Costs do not reflect complete designs and are commensurate with the current level of design of the project which is 90%.
- Unit costs include equipment, labor, material, and contractor overhead, profit and other markups.
- Real estate acquisition costs are not included at this time. Only general right-of-way and other real estate investigation costs are included.
- Costs do not account for phased construction involving multiple mobilizations,
- Costs are in 2010 dollars and escalation factors are required dependent on the anticipated period of construction,
- Excavation and disposal costs assume most (75%) of berm and channel material will require disposal costs for contaminated material.
- Operation and maintenance costs are not included in the total project costs.
- Design contingency of 25% of direct construction costs.

7.0 REAL ESTATE & EASEMENT REQUIREMENTS

This section describes real estate, easement, and adjacent property owner requirements and agreements that will affect the project. At this stage of design, a lot of information is yet to be obtained regarding requirements and the nature of agreements with adjacent property owners; however, anticipated construction access requirements are described primarily to assist development of these negotiations and agreements.

Property owners adjacent to the project include the Oregon Pacific Railroad (OPRR), METRO – the owner of the embankment on top of which the Springwater Trail and railroad run, Oaks Amusement Park and the Oregon Yacht Club. An agreement with OPRR will be required for construction access and to temporarily close the track. Construction vehicles will also need to cross the tracks at Tacoma and Nehalem Streets to access the roadway along Oaks Amusement park and the Springwater Trail.

Construction access looks most feasible from near the northern boundary of Oaks Amusement Park or from the property immediately to the north, which is owned by the Oregon Yacht Club. The Oregon Yacht Club property is primarily a grassy field used as a dry-dock for boats and equipment. Access from these locations will reduce damage and subsequent repair costs to the trail which will likely incur more damage from dump trucks and heavy machinery than the road along the Amusement Park. The largest potential staging areas are also at Oaks Park or the Yacht Club. Thus, easements or agreements for access and leasing of property (space) would facilitate construction.

A temporary construction easement or access agreement may be required from METRO, the owner of the embankment, but this is likely to be a no-cost agreement.

Portland Parks and Recreation owns the Oaks Bottom Wildlife Refuge and the Bureau of Environmental Services will need to obtain a Non Parks Use Permit for use of the Springwater Trail and Wildlife Refuge. It will also need to be determined which department within the City will be responsible for the long-term operation and maintenance of the culvert.

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8.0 DESIGN AND CONSTRUCTION SCHEDULE

The current estimated schedule for the remaining design tasks, bid phase, and construction is listed below in **Table 4**.

Table 4. Design and Construction Schedule.

Task	Duration	Start Date	End Date	Predecessor
30% Design Phase	***209 days***	***3/23/2009***	***1/7/2010***	
Geotechnical Investigation	90 days	9/7/2009	1/8/2010	
Design Phase	***264 days***	***1/8/2010***	***1/12/2011***	
60% Design Phase	98 days	1/8/2010	5/25/2010	
Permit Applications	***122 days***	***3/8/2010***	***8/24/2010***	***5***
Archaeological Investigation	60 days	4/30/2010	7/22/2010	
SHPO Response Letter	23 days	7/23/2010	8/24/2010	7
Draft Biological Assessment	70 days	3/8/2010	6/11/2010	5
Prepare Application Forms	50 days	4/19/2010	6/25/2010	5
City/Corps Review	20 days	6/28/2010	7/23/2010	10
Submit Permit Applications	5 days	7/26/2010	7/30/2010	11
Permit Processing/Receipt	118 days	8/2/2010	1/12/2011	12
Review for Completeness	15 days	8/2/2010	8/20/2010	13
Internal Agency Review	20 days	8/23/2010	9/17/2010	14
Public Notice	23 days	9/20/2010	10/20/2010	15
Applicants Responds to Comments	5 days	10/21/2010	10/27/2010	16
NOAA Review BA	30 days	8/2/2010	9/10/2010	17
NOAA Prepare BO	65 days	9/13/2010	12/10/2010	18
Corps Writes EA	21 days	12/13/2010	1/10/2011	19
Corps Issues Permit	2 days	1/11/2011	1/12/2011	20
90% Design	61 days	5/26/2010	8/18/2010	5
Review/assimilate 60% Comments	3 days	5/26/2010	5/28/2010	22
Prepare 90% plans, specs, costs	35 days	5/31/2010	7/16/2010	23
Technical Review	3 days	7/19/2010	7/21/2010	24
Submit 90% plans, specs, costs	5 days	7/22/2010	7/28/2010	25
90% Review Meeting	10 days	7/29/2010	8/11/2010	26
Final Public Meeting	5 days	8/12/2010	8/18/2010	27
100% Design	***97 days***	***8/19/2010***	***12/31/2010***	***28***
Review/assimilate 90% Comments	3 days	8/19/2010	8/23/2010	28
Complete 100% Plans, Specs, Cost	20 days	10/28/2010	11/24/2010	30,17
Bidability/constructability Review	6 days	11/25/2010	12/2/2010	31
Submit 100% Plans	5 days	12/13/2010	12/17/2010	32
100% Review Meeting	10 days	12/20/2010	12/31/2010	33
Final Design Phase	21 days	1/13/2011	2/10/2011	34
Review/assimilate 100% Comments	3 days	1/13/2011	1/17/2011	35

Task	Duration	Start Date	End Date	Predecessor
Prepare Final Designs/Bid Set	10 days	1/18/2011	1/31/2011	36
Bid Book/Final Design Report	5 days	2/1/2011	2/7/2011	37
Bid Book QA/QC Check	3 days	2/8/2011	2/10/2011	38
Bid Phase	***92 days***	***2/11/2011***	***6/20/2011***	***39***
Bid Book Routing/Printing	7 days	2/11/2011	2/21/2011	40
Advertise	2 days	2/22/2011	2/23/2011	41
Bid Opening	20 days	2/24/2011	3/23/2011	42
Purchasing Constructs Bid Tabulation	1 day	3/24/2011	3/24/2011	43
Purchasing Prepares Letter with Bid Tab/Proposal	1 day	3/24/2011	3/24/2011	44
PM Reviews Bid Tab/Proposal	1 day	3/25/2011	3/25/2011	45
Purchasing Prepares /Files Council Report.	3 days	3/28/2011	3/30/2011	46
Ordinance Review/Council Agenda	10 days	3/31/2011	4/13/2011	47
First Reading to Approve Funds	3 days	4/14/2011	4/18/2011	48
Return to Council Agenda	4 days	4/19/2011	4/22/2011	49
Second Reading	1 day	4/25/2011	4/25/2011	50
Ordinance Becomes Enacted	23 days	4/26/2011	5/26/2011	51
Documents Returned to Purchasing	1 day	5/27/2011	5/27/2011	52
Purchasing Writes Contract	3 days	5/30/2011	6/1/2011	53
Contractor Executes Contract	3 days	6/2/2011	6/6/2011	54
City Attorney Review/Signature	3 days	6/7/2011	6/9/2011	55
Purchasing Collects Insurance/Performance Bond	1 day	6/10/2011	6/10/2011	56
Commissioner Signs Contract	3 days	6/13/2011	6/15/2011	57
Auditor Assigns Contract Number	1 day	6/16/2011	6/16/2011	58
Auditor's Office Distributes Contract	1 day	6/17/2011	6/17/2011	59
Contract Finalized/Awarded	1 day	6/20/2011	6/20/2011	60
Construction Phase	***97 days***	***6/21/2011***	***11/2/2011***	***61***
NTP	1 day	6/21/2011	6/21/2011	61
Schedule Pre-Construction Meeting	3 days	6/22/2011	6/24/2011	63
Submittal Review/Approval	10 days	6/27/2011	7/8/2011	64
Mobilization/Start of Work	3 days	7/11/2011	7/13/2011	65
Construction Activities	80 days	7/14/2011	11/2/2011	66

9.0 REFERENCES

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Attachment B
Oaks Bottom Hydrologic and Hydraulic Background Information Technical Memorandum (City of Portland)

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CITY OF PORTLAND
ENVIRONMENTAL SERVICES
Systems Analysis
Spatial Analysis and Modeling

Memorandum

To:	Sean Bistoff
From:	Gregory Savage, P.E.
Date:	April 1, 2010
Project:	Oaks Bottom Wildlife Refuge Enhancement Project
Subject:	Hydrologic and Hydraulic Background Information [DRAFT]

1. Introduction

As part of the Wildlife Refuge Enhancement Project, Systems Analysis was asked to provide project support in the form in the form of hydrologic and hydraulic analysis and characterization. This report is based upon the working document titled "Oaks Bottom Hydrology Summary" that was used to provide background information throughout the pre-design and early design phases of this project, and represents the original report's finalization.

This memorandum provides valuable surface and groundwater information, in terms of both data and interpretation, and is divided up into sections that will cover general hydrology, surface water hydrology, and groundwater hydrology.

2. General Hydrology

The Oaks Bottom Wildlife Refuge is a nature park located a relatively short distance up from the Willamette River's confluence with the Columbia River between River Mile (RM) 15 and 16, adjacent to Ross, Hardtack and East Islands (see Figure 1). The actual project site located on a floodplain terrace, on the right overbank (east side) of the Willamette River and is situated below the bluff on the western edge of the Westmoreland neighborhood of SE Portland. On its west side, the site is bounded by a railroad embankment that forms a berm between it and the river.

The first step in providing a characterization of the project site was developed a Digital Elevation Model (DEM) of the project site. The DEM in Figure 2 shows the terrain as a color-coded shaded relief map and was developed by the merging of land survey data (2007) with LIDAR data (2005) taken above the water surface along with the City's 2-foot photogametric topographic data (c.1993) and bathymetry data (2009). The 2007 survey was limited to the areas of the site that include the railroad embankment near the culvert, the Water Control Structure (WCS) just upstream of the culvert, and the north wetlands; and did not include the main channel above the WCS or the south reservoir/pond. The LIDAR data covers the whole site except for the areas below water. At the time the LIDAR data was collected, the pond's WSE was at a high stage so the bathymetry of the South Reservoir/Pond had to be surveyed at a later date.

Also shown in Figure 2 are the locations of the existing culvert that passes through the railroad berm and creates the hydraulic connection between the South Reservoir/Pond (inlet side) and the Willamette River (outlet side), and the existing WCS (located in the main channel about 30-

feet upstream of the culvert's inlet). The Willamette River's surveyed Ordinary High Water mark (OHW) is also shown in Figure 2. This DEM formed the basis of much of the surface- and ground-water hydrologic and hydraulic analysis in this report.

The City of Portland has relatively mild, maritime climate and receives about 38" of rainfall per year. Figure 3 shows the summary of monthly NOAA meteorological data collected at the Portland Airport (period of record: 1940 to present). The plots in Figure 3 show normal daily air temperatures with normal daily minimums and maximums, absolute minimums and maximums for nearly 60-yr+ period of record, monthly average precipitation, number of clear/partially cloudy/cloudy days per month, and average humidity by month. Information can be used for temperature modeling of South Pond/Reservoir which can act as a heat sink.

The lower Willamette River, where the site is located, is a tidal estuary with diurnal fluctuations that are typically on the order of 2-ft. The tidally influenced portion of the Willamette extends up to Willamette Falls located in Oregon City and West Linn at RM 27. The water surface elevation in the lower Willamette is influenced by not only the river flows from approximately 11,100 mi^2 of drainage are but also by the flow and tidal conditions in the lower Columbia River. Figure 4 shows the Daily Average Stream Flows for the Willamette River (Morrison Bridge gage, USGS 14211720, at RM 12.80) by scatter plot data lumped together by month with the average of the daily average as a line. The flows are highest in the months of November through February and steadily decrease from March through July but the river's stage, or water surface elevation (WSE), does not perfectly correspond to its declining flow (see Figure 6). The months with the lowest flows are July through October.

Figure 5 shows the river's stage, or water surface elevation (WSE), in terms of daily minimum, maximum and mean level; as well the difference between the daily high and low tide. The figure also shows the daily mean and median (50^{th} percentile) values for the full period of record, and the median WSE for the periods of record that fall within the November through June "Fish Rearing Season". The median values are more indicative of central tendency or typical conditions because the peak events are so high that they skew the mean. The mean and median values for the rearing season are on the order of 1-ft greater than the corresponding values with the full-year's data.

Figure 6 is a floating bar graph of the Willamette River's WSE shown in Figure 5 summarized by month. The plot has a pair of lines, bold and hairline, that respectively show the median and mean WSE's by month. After February, the stream flows begin to go down, however, as shown on the plot that WSE goes up. The reason for this is that spring freshets in the Columbia River basin increase flows in the Columbia and cause a higher stage in the Willamette. The flows in both the Willamette and Columbia systems are also influenced by dam operations. The floating green bars show the range of the daily mean WSE's by month for the period of record. The thin black bars mark the extent of the absolute daily minimum and maximum WSE's recorded for each month. Longer black bars extending from the top and bottom of the green bars indicate greater differences between the daily mean values and the daily extremes which tend to be greater at lower river stages. Another way of looking at this is that daily tidal fluctuations are more pronounced at lower river levels. The graph shows that the stage regime is very different for the "summer" period of Jul-Aug-Sep-Oct than it is for the rest of the year which corresponds to the "fish rearing season". Also see Figure 7.

§

Figure 1, Site Map

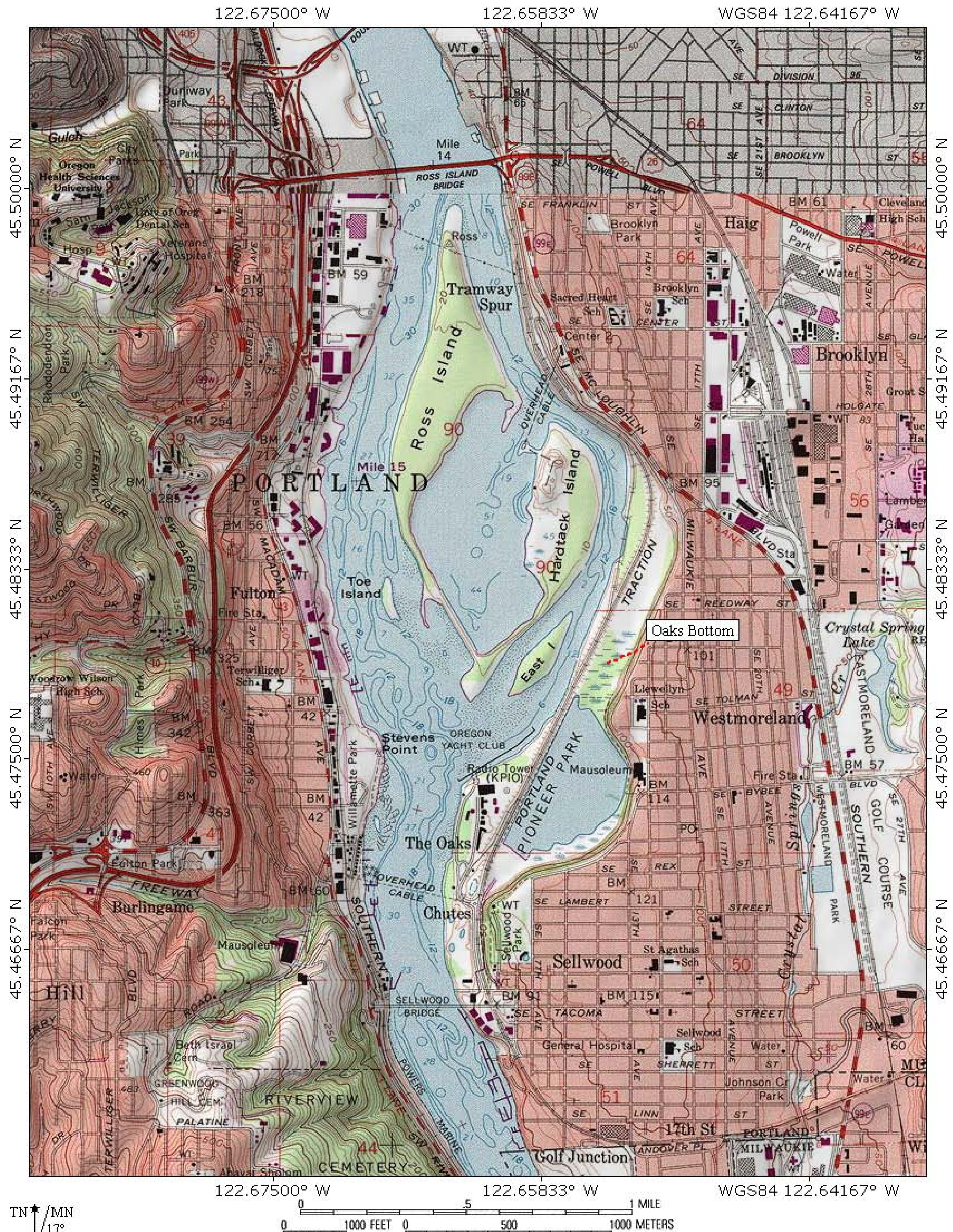

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Figure 2, DEM of Project Site

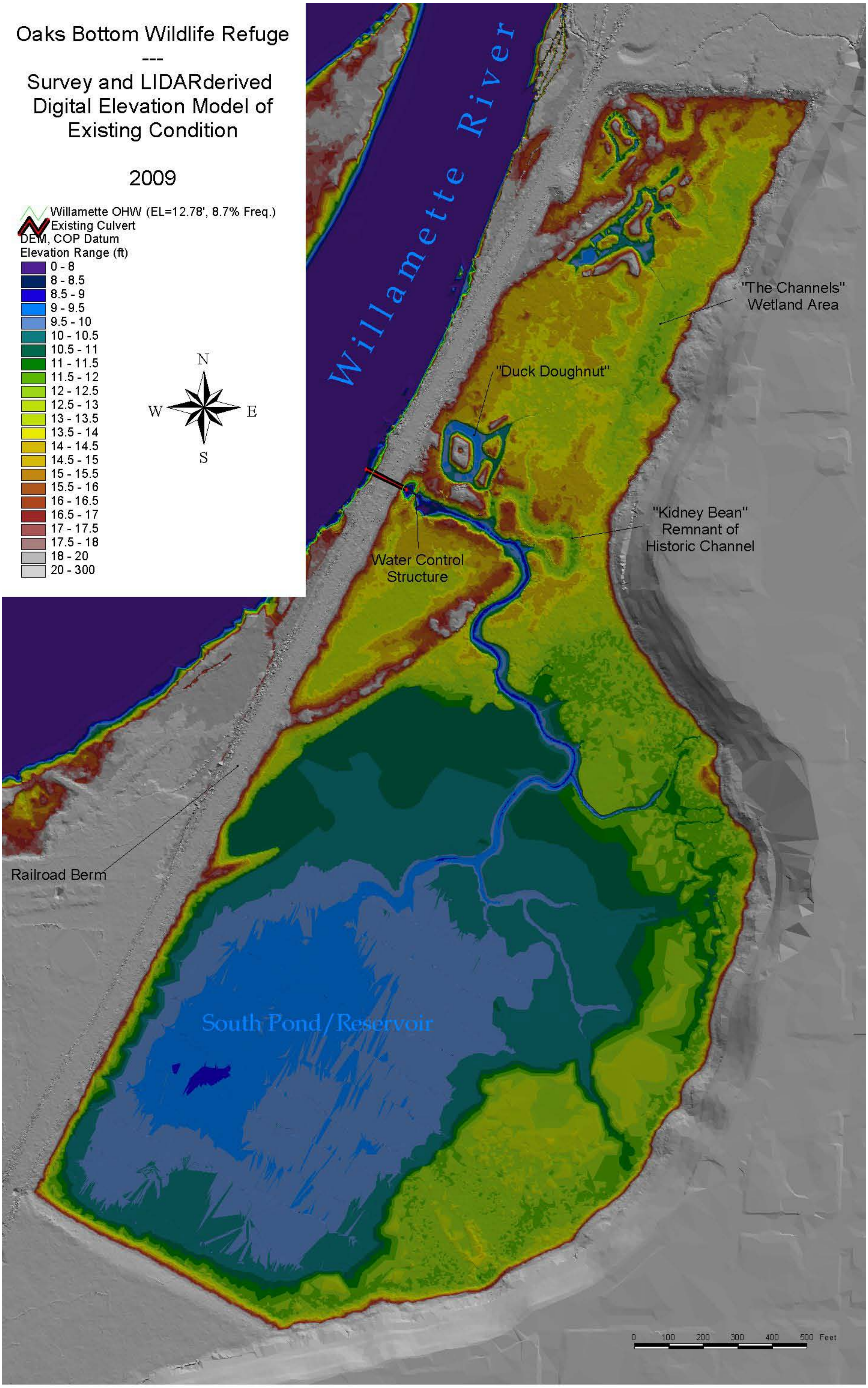


Figure 3, Summary of Monthly Weather Data for Portland, OR

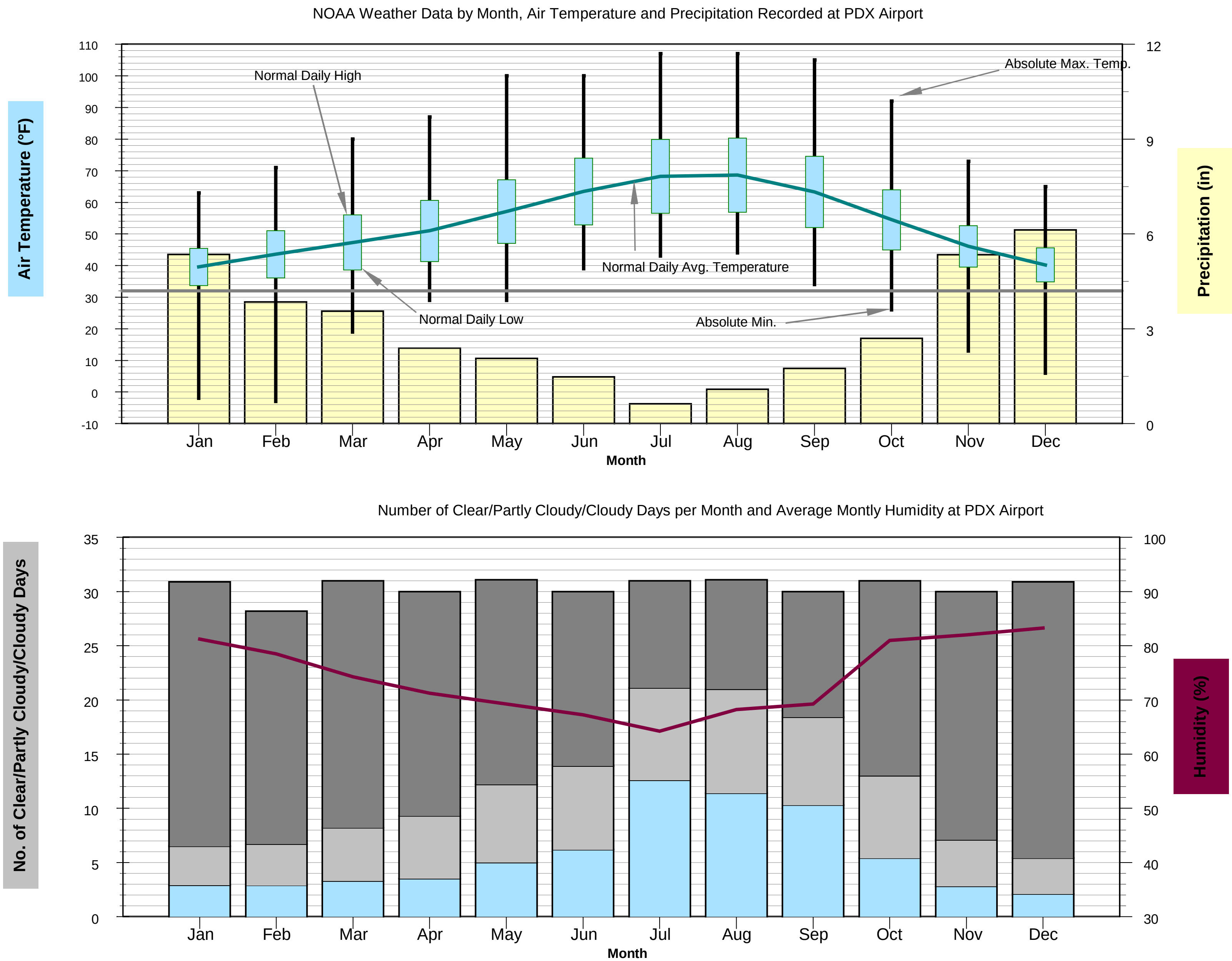


Figure 4, Summary of Daily Average Willamette River Flow Data by Month

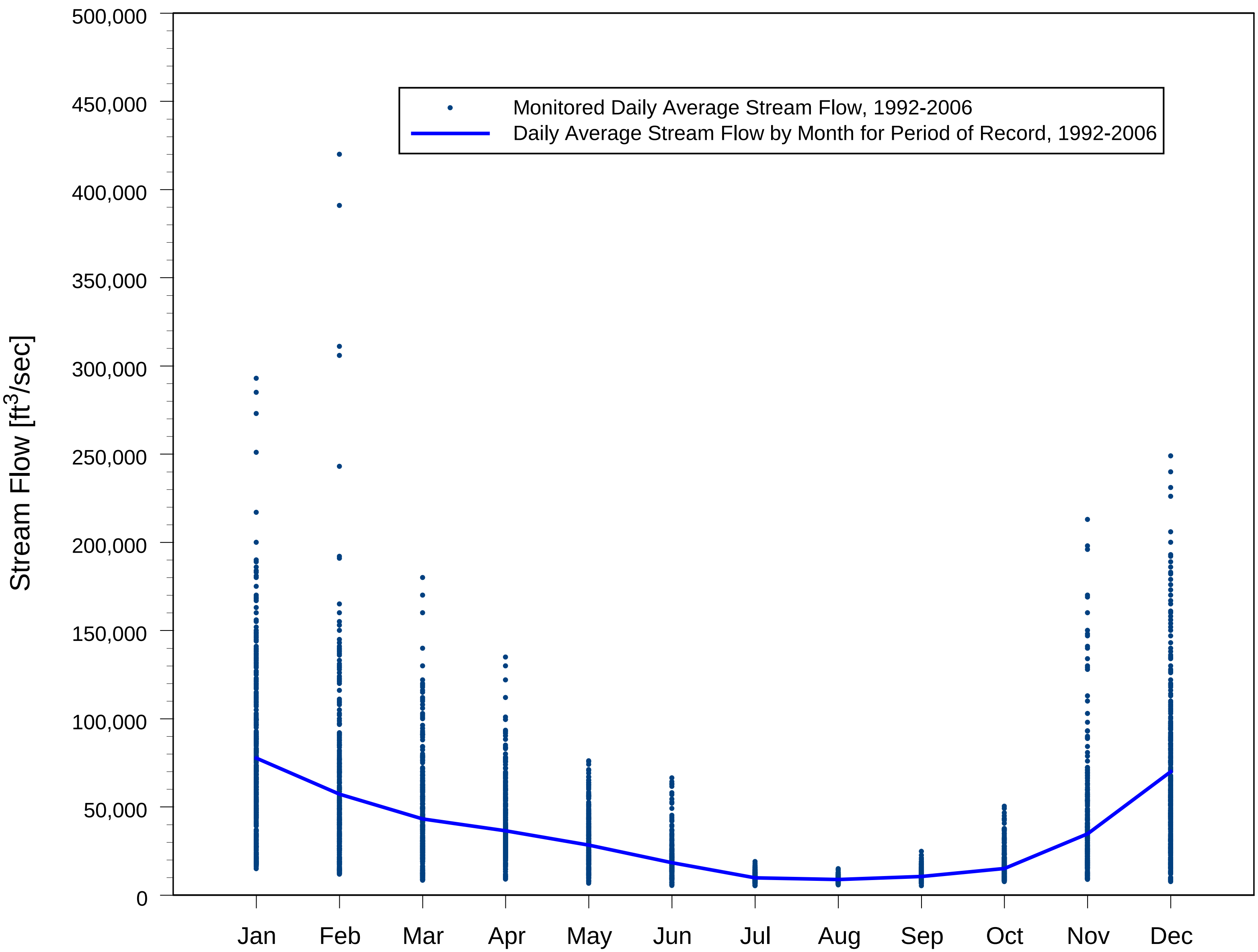


Figure 5, Daily Willamette River WSE Data

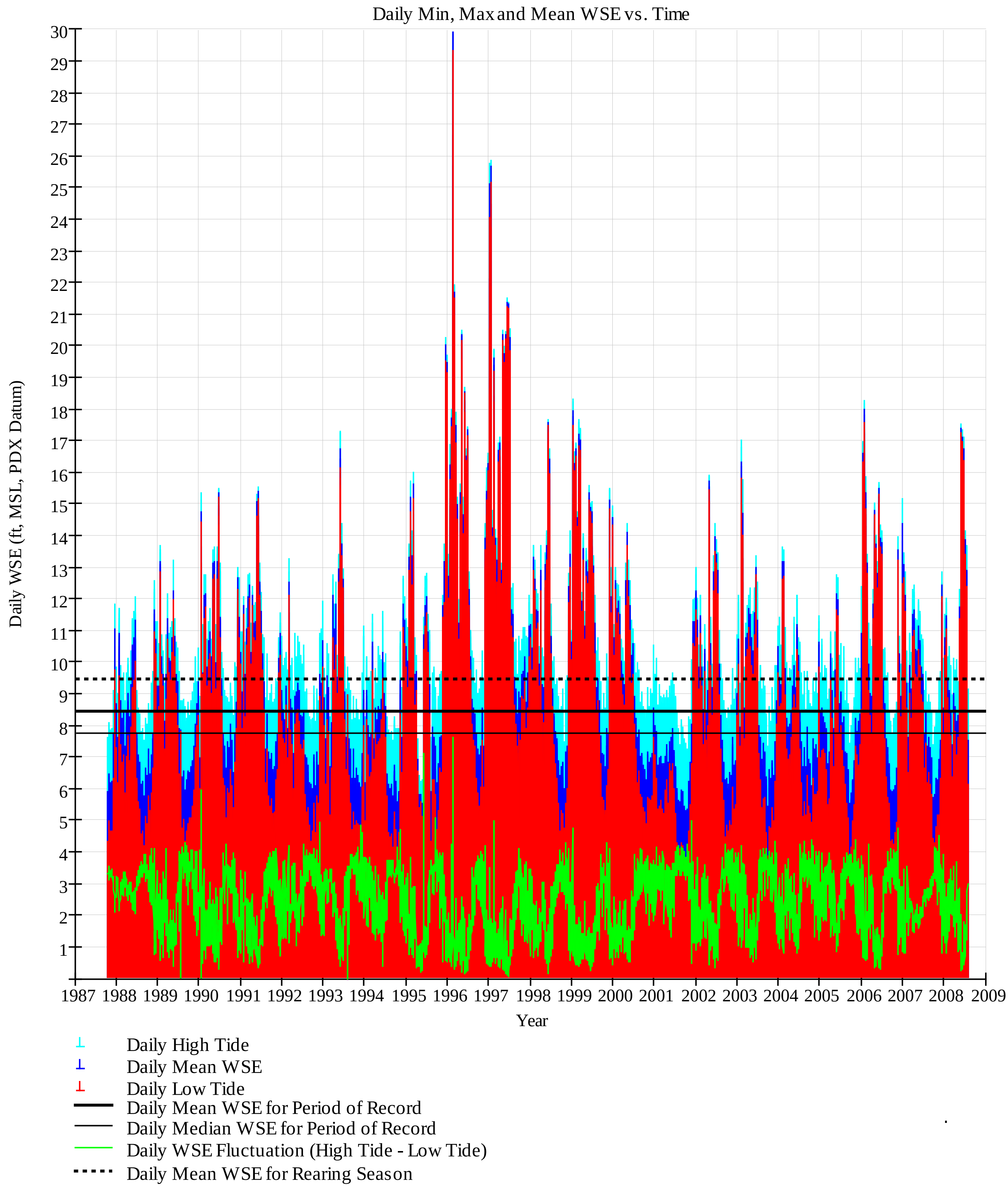


Figure 6, Willamette WSE Data Summary by Month

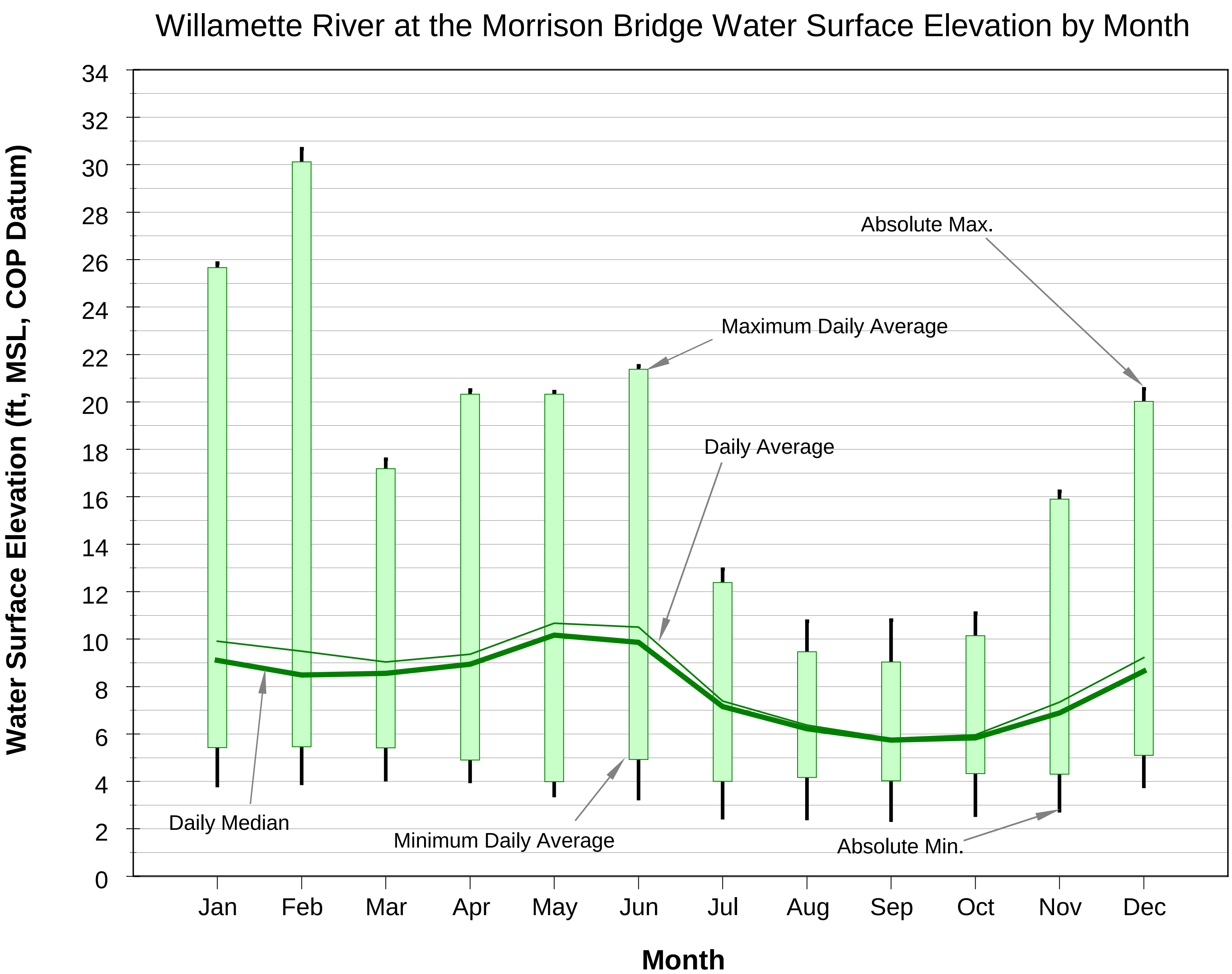
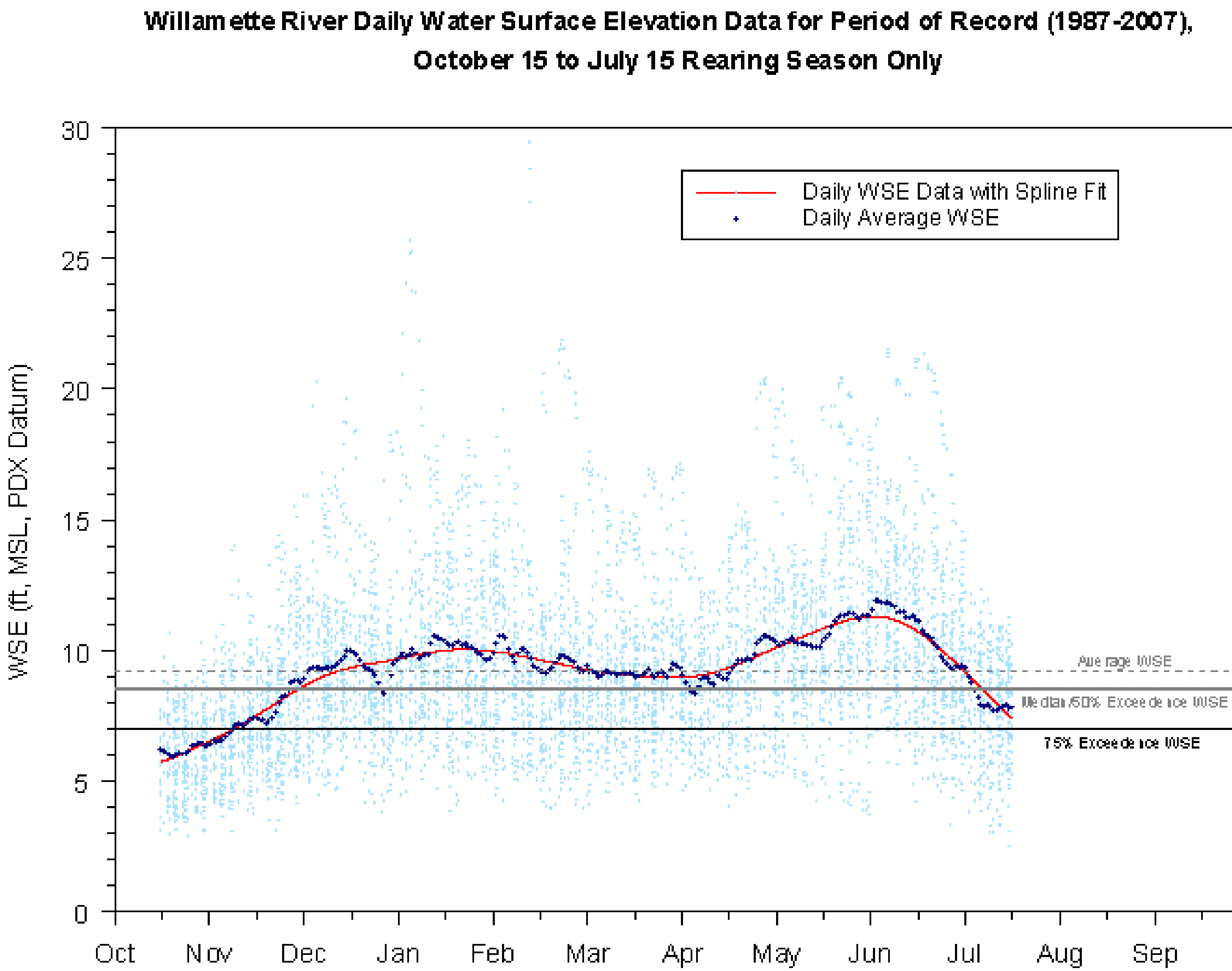


Figure 7 is a plot of daily average WSE for the whole period of record plotted by the day of year but considering only the data for the initially defined fish rearing season (light blue points), and includes the computed averages of the daily average for each day of the year (dark blue points) along with a smoothed line (red line) of the averaged data. Also shown on the plot are the exceedance levels for the 75th and 50th (median) percentile WSE's and the daily average WSE. The 75th percentile WSE is right at about 7' which is just below the existing culvert's inlet IE of 7.22', the median (50th percentile), or typical WSE is about 8.5'. The typical WSE are still relatively low until after the first week of November and steadily decline after the beginning of June right after the year's highest levels are reached.

In a similar manner that a flow duration curve is generated from stream flow data, a set of Water Surface Elevation Duration Curves were developed for this project. Mathematically identical to a flow duration curve (computed using the daily WSE data adjusted to the COP datum), Figures 8a and 8b show the frequency at which a given WSE is met or exceeded for certain time frames. The plot in figure 8a is comprised of a "family" of 6 curves: daily average, low tide and high tide WSE's for the full period of record (solid lines); and daily average, low tide and high tide for the November-June fish rearing season only (dashed lines). The respective curves show the frequency at which a given WSE is met or exceeded and the 50th percentile value is the same as the median. The plot also shows summary statistic tables for both the full period of record and the fish rearing season only. The daily tidal variation, the difference the respective high- and low-tide curves, is typically on the order of 2'-2.5'.The plot also shows the OHW mark derived from field indicators as well as the existing culvert's inlet IE for reference. The curves for the February through September growing season are nearly identical to the full period of record because the growing season includes both the high water conditions from the spring freshets as well as the low river conditions of late summer.

When looking at Figures 4 and 6 together, one can notice three different flow-stage regimes on the Willamette River that correspond to different "seasons" of the year. The time periods for the months Nov-Dec-Jan-Feb corresponds to the time of the year when the river's flow and stage are both high, Mar-Apr-May-Jun is when the flows in the river are declining but the stage is high because of the backwater conditions created by the Columbia River freshets, and the Jul-Aug-Sep-Oct period is when both the river's flow and stage are both low. Figure 8b shows a set of WSE Duration Curves developed in the same manner as those in Figure 8a except that the periods of analysis are confined to the periods of the different flow-stage regimes. The duration curves show all the daily average WSE, daily high tide and daily low tide for their respective periods. The low summer period is significantly different than the other two periods of the year in terms the rivers overall stage (low), the low level of seasonal variation but high level of daily tidal variation. The plots also show the OHW mark derived from field indicators as well as the existing culvert's inlet IE and invert of the existing WCS are also shown for reference. The elevation contour of the Willamette River's OHWM which corresponds with a level of inundation that occurs with a frequency of 8.7%.

Figure 7,



Willamette River Daily Water Surface Elevation Data for Period of Record (1987-2007),
October 15 to July 15 Rearing Season Only
Daily WSE Data with Spline Fit
Daily Average WSE
Average WSE
Median/50% Exceedence WSE
75% Exceedence WSE
WSE (ft, MSL, PDX Datum)
30
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Figure 8a,

Summary Statistics (Period of Record)

	Daily WSE (ft, MSL, PDX Datum)		
	Daily Avg.	Low Tide	High Tide
Min.	3.99	2.37	4.51
Max.	30.12	29.35	30.67
Mean	8.46	7.38	9.75
Median	7.73	6.61	9.18

Summary Statistics (Rearing Season Only)

	Daily WSE (ft, MSL, PDX Datum)		
	Daily Avg.	Low Tide	High Tide
Min.	3.99	2.67	4.51
Max.	30.12	29.35	30.67
Mean	9.47	8.55	10.53
Median	8.77	7.82	9.91

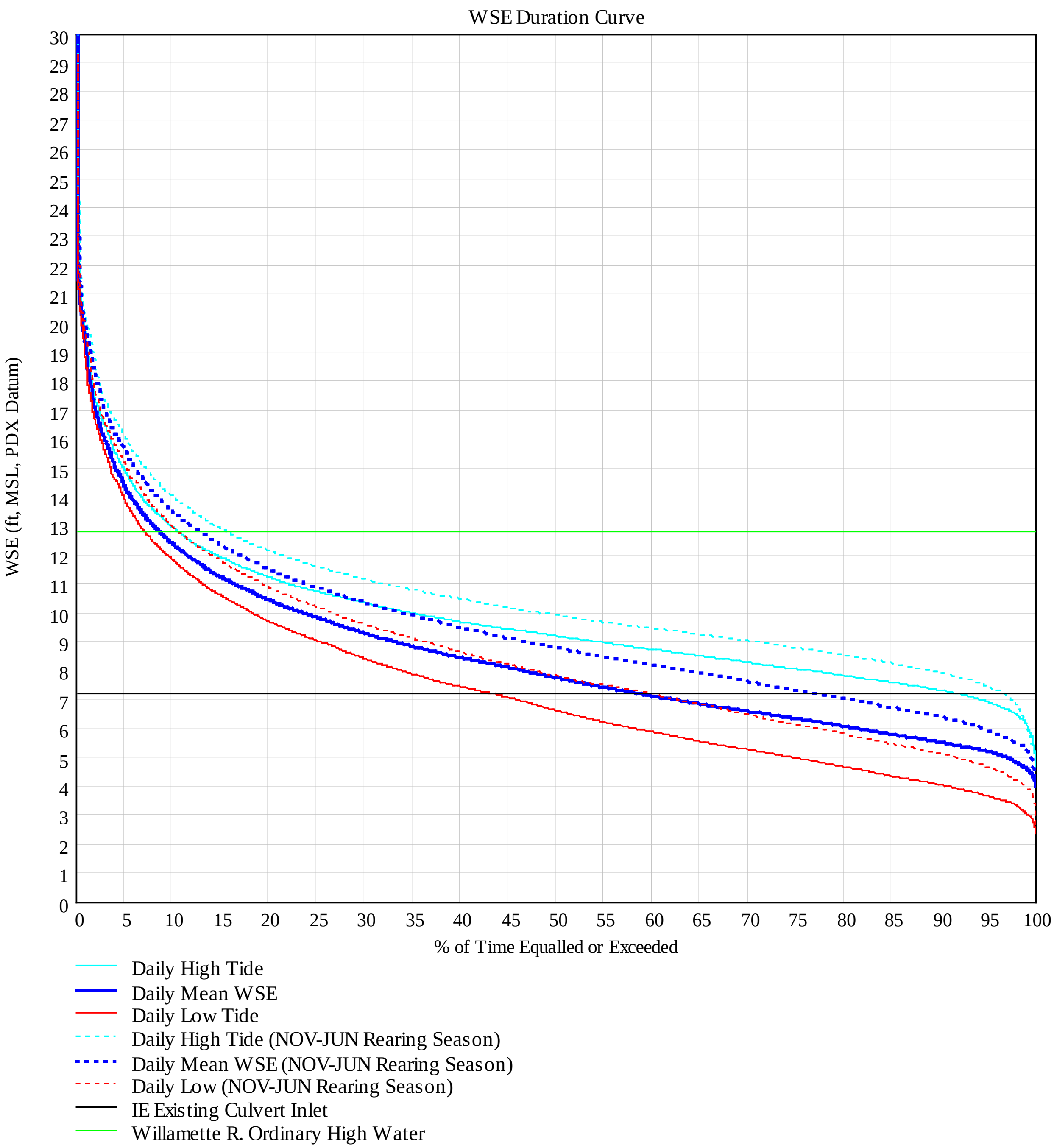


Figure 8b, WSE Duration Curves for Selected Periods of the Year

Summary Statistics (Nov-Dec-Jan-Feb)

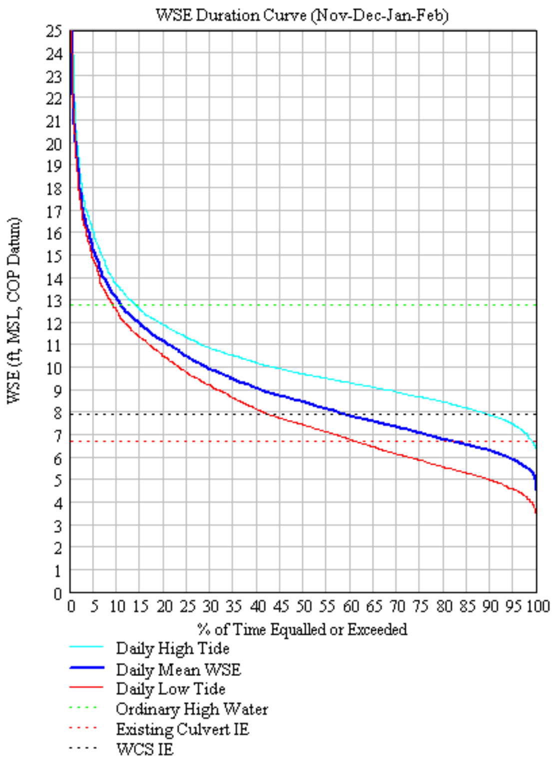
	Daily WSE (ft, MSL, COP Datum)		
	Daily Avg.	Low Tide	High Tide
Min.	4.51	2.76	5.95
Max.	30.11	29.35	30.67
Mean	9.19	8.22	10.39
Median	8.44	7.42	9.69

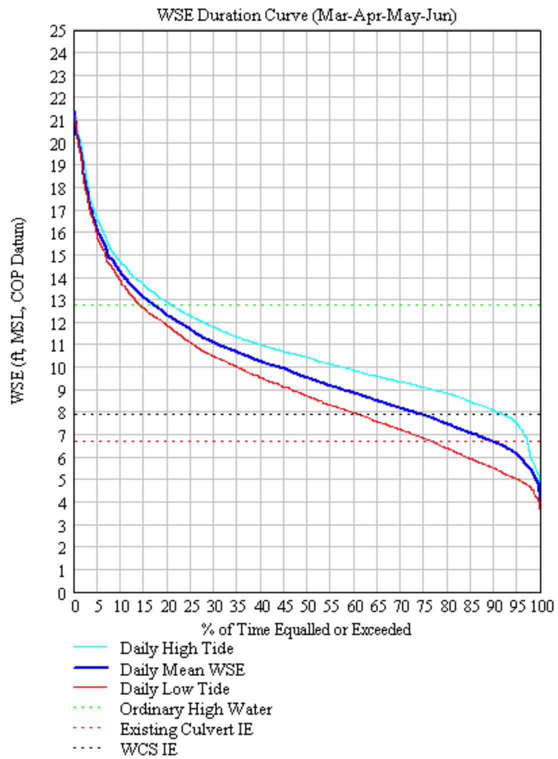
Summary Statistics (Mar-Apr-May-Jun)

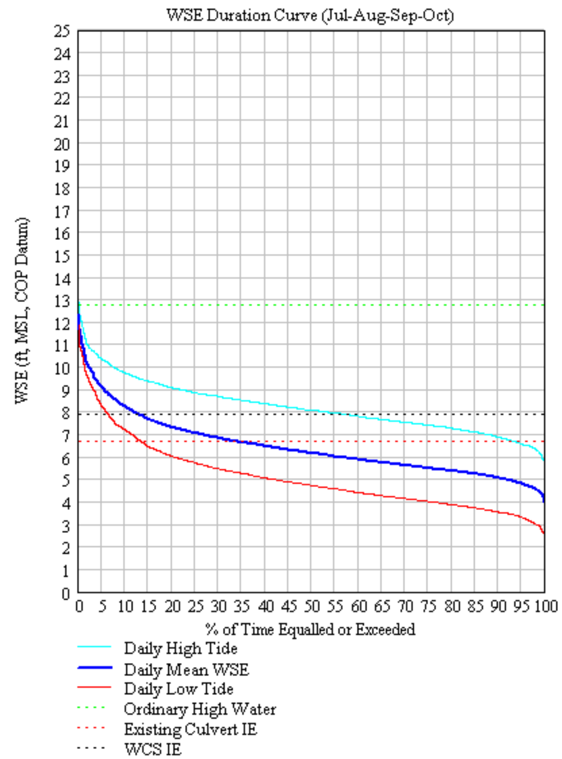
	Daily WSE (ft, MSL, COP Datum)		
	Daily Avg.	Low Tide	High Tide
Min.	3.99	3.28	4.51
Max.	21.38	21.23	21.51
Mean	10.06	9.27	10.93
Median	9.52	8.71	10.44

Summary Statistics (Jul-Aug-Sep-Oct)

	Daily WSE (ft, MSL, COP Datum)		
	Daily Avg.	Low Tide	High Tide
Min.	4.00	2.37	5.71
Max.	12.38	11.93	12.94
Mean	6.45	5.08	8.22
Median	6.18	4.73	8.08







The DEM of the Oaks Bottom site shown in Figure 9 is the same as the one in Figure 2 except that it is color-coded by the frequency at which the different areas of the site are inundated from the Willamette River. The color breaks at various elevations are associated with incremental frequencies taken from the WSE Duration plot for Daily Average WSE for the full year in Figure 8a. The assumed inundation is based on the assumption that there is a free-flowing connection between the river and the site with no stop-logs in the water WCS. With a free connection, the figure shows that the inundation of the pond is actually controlled by the river less than 10-15% of the time. Currently, the South Reservoir/Pond is inundated to some level nearly all the time due to the near-continuous flux of groundwater to the site from the base of the bluff and the presence of the WCS, which, if it does not have stop logs placed in it is typically partially blocked by small woody debris and/or beaver damming. The blockage at the water control structure backs water up the main channel up to the pond to typically a WSE of about 10- to 12-ft (COP datum).

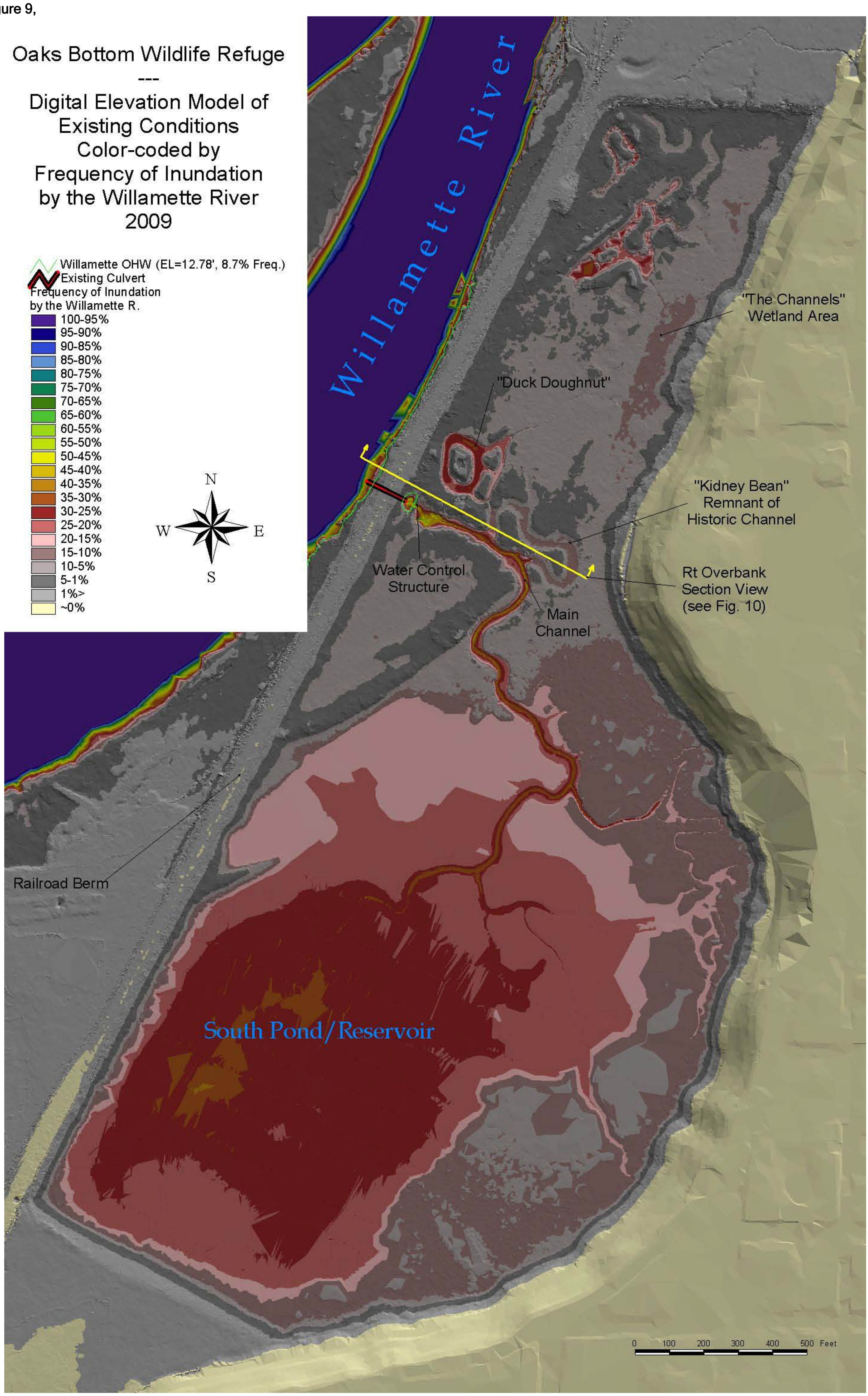
Figure 10 shows a longitudinal profile plot of the main channel centerline (CL) with the existing culvert and includes a section profile of the ground surface along the left overbank (north side of channel) where there are shallow channels that provide a hydraulic connection to the north portion of the site. The figure also depicts the typical (median) river stage conditions (daily average, high- and low-tides). The lateral channel connections to the north wetland areas include a couple of remnant portions of the meandering main channel along with a connection to a constructed "duck doughnut" . Inundation of these areas from the river only occurs when the river's stage gets above about 13'.

Looking at the typical (median or 50th percentile) WSE, it can be seen that under low tide conditions, the river does not back up at all into the culvert and that flows in the culvert are only positive, meaning that the flows are draining only out of the pond, down the main channel and through the WCS. As the tide rises, the river can backwater into the culvert causing a temporary flow reversal; and depending on the level of the river's rise and the configuration of the WCS's stop logs, the flows can backwater up the channel past the WCS. Most of the time, the water flowing in the channel above the WCS is seepage draining from the base of the bluff and passing through the south pond, and is not water backing up from the river and draining out during low tide.

Figure 11 shows a set of Pond Stage-Storage, Stage-Area and Stage-Average Depth Curves for the site. The curves were created by using the DEM data in GIS to incrementally measure the inundation area of both the south and north area at various stages; this information was then used to calculate the storage volumes and average depths of the inundated areas at various stages. These graphs can be used to determine what elevation is needed to be maintained by the WCS or other possible grade control to create a desired pond condition, especially based upon area of inundation or average depth. Also, a stage-volume relationship is needed for any unsteady-state hydraulic modeling of the culvert that includes tidal fluctuations and reverse flows into and back out of the wetland. The stage-volume relationship was also used to estimate the residence time, or detention time (td), of the pond, as shown in Figure 12.

The family of curves in Figure 12 shows the td value for an assumed range of constant in-flows, which actually vary with time, that equal the outflow (i.e., no change in the elevation or storage of the pond). Water seeping into the pond at a given rate will be detained for an average length of time before draining out through culvert and to the river based the WSE and corresponding volume of the pond. The importance of knowing td is that it could help make management decisions in terms of deciding what is/are the optimal WSE(s) with the shortest possible td to provide the best water quality and habitat values.

Figure 9,



Oaks Bottom Wildlife Refuge

Digital Elevation Model of
Existing Conditions
Color-coded by
Frequency of Inundation
by the Willamette River
2009
Willamette OHW (EL=12.78', 8.7% Freq.)
Existing Culvert
Frequency of Inundation
by the Willamette R.
100-95%
95-90%
90-85%
85-80%
80-75%
75-70%
70-65%
65-60%
60-55%
55-50%
50-45%
45-40%
40-35%
35-30%
30-25%
25-20%
20-15%
15-10%
10-5%
5-1%
1%>
~0%
N
W
E
S
Willamette River
"The Channels"
Wetland Area
"Duck Doughnut"
"Kidney Bean"
Remnant of
Historic Channel
Water Control
Structure
Rt Overbank
Section View
(see Fig. 10)
Main
Channel
Railroad Berm
South Pond/Reservoir
0 100 200 300 400 500 Feet

Figure 10,

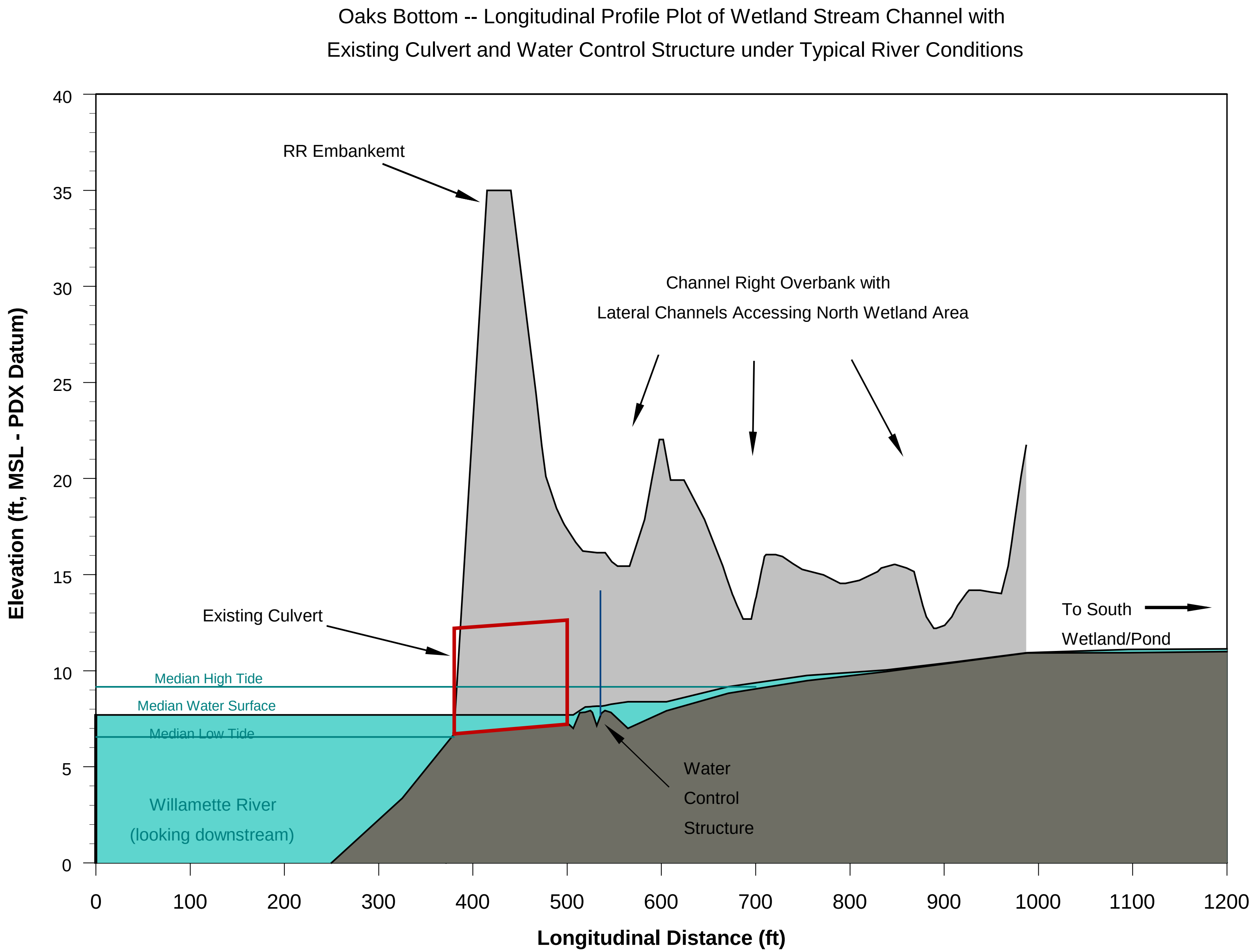
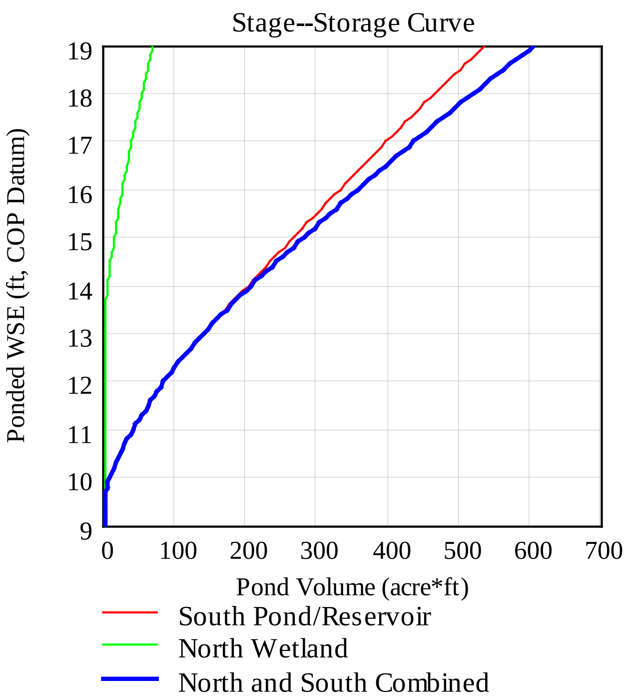
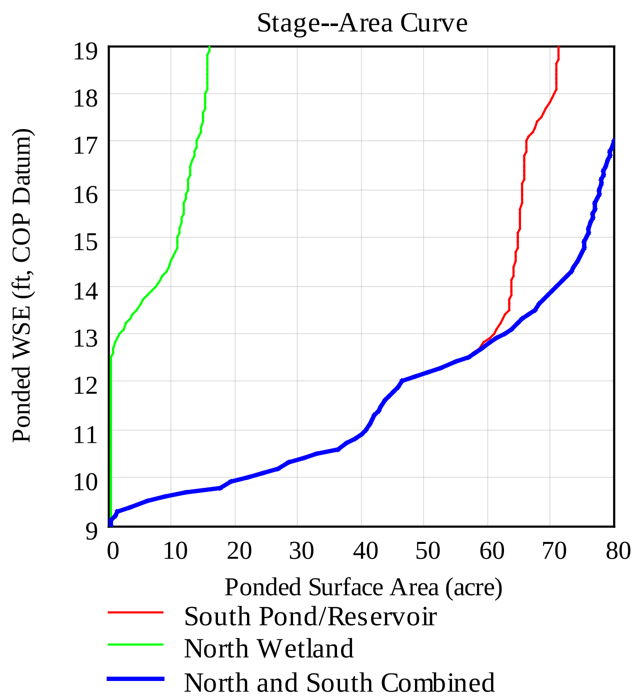

Oaks Bottom -- Longitudinal Profile Plot of Wetland Stream Channel with
Existing Culvert and Water Control Structure under Typical River Conditions
RR Embankemt
Channel Right Overbank with
Lateral Channels Accessing North Wetland Area
Existing Culvert
To South
Wetland/Pond
Median High Tide
Median Water Surface
Median Low Tide
Willamette River
(looking downstream)
Water
Control
Structure
Elevation (ft, MSL - PDX Datum)
Longitudinal Distance (ft)
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
700
800
900
1000
1100
1200

Figure 11, Stage- -Storage, -Area and -Average Depth Curves





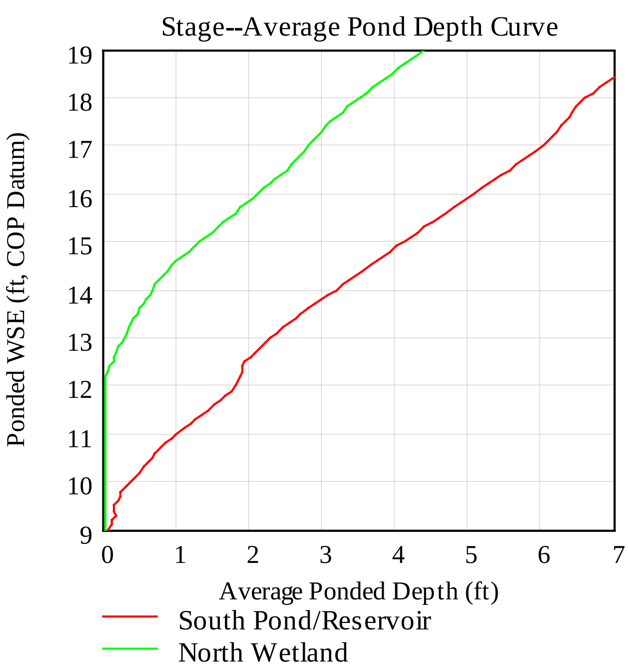


Figure 12, South Pond Detention Time vs. WSE

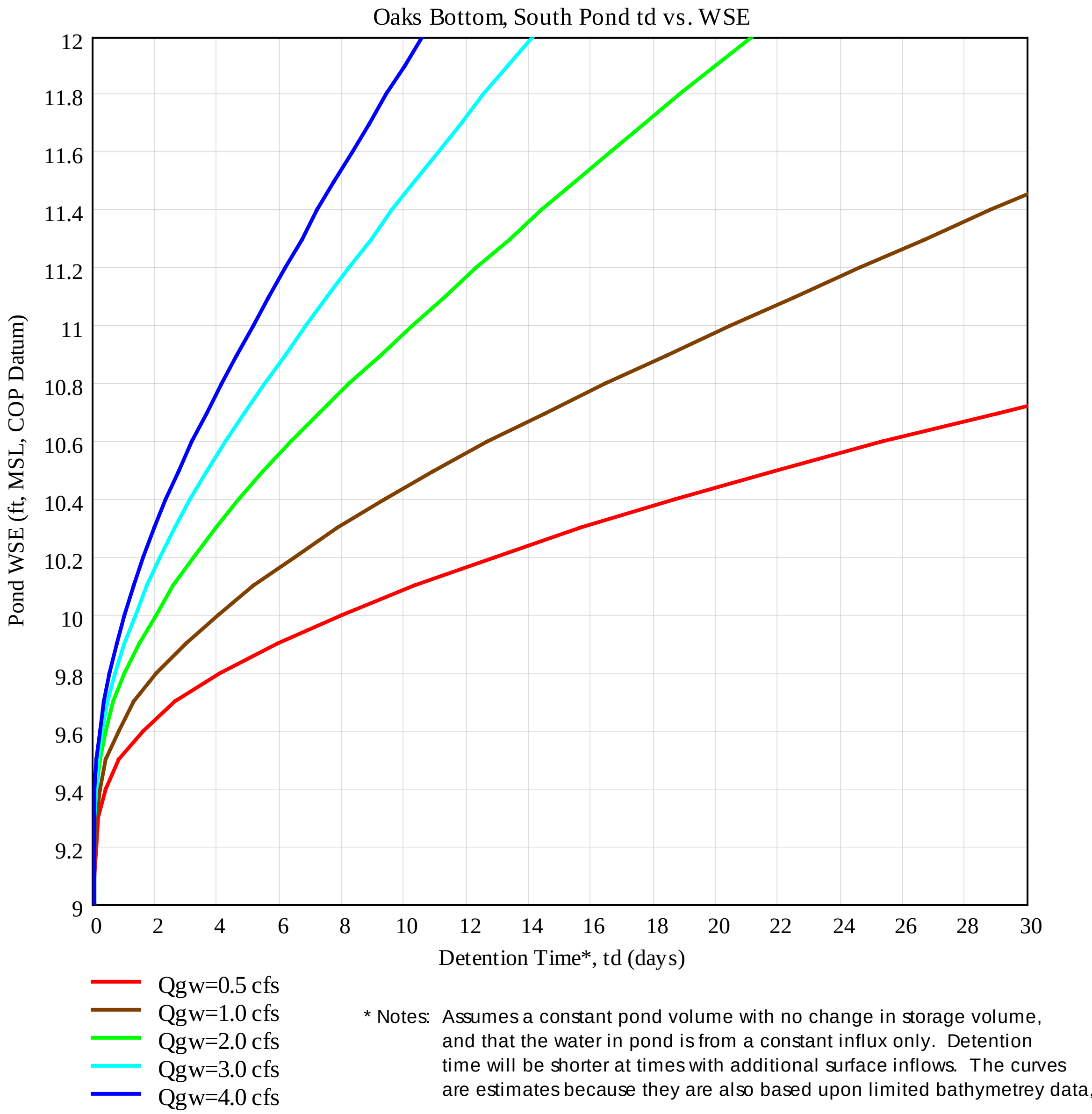
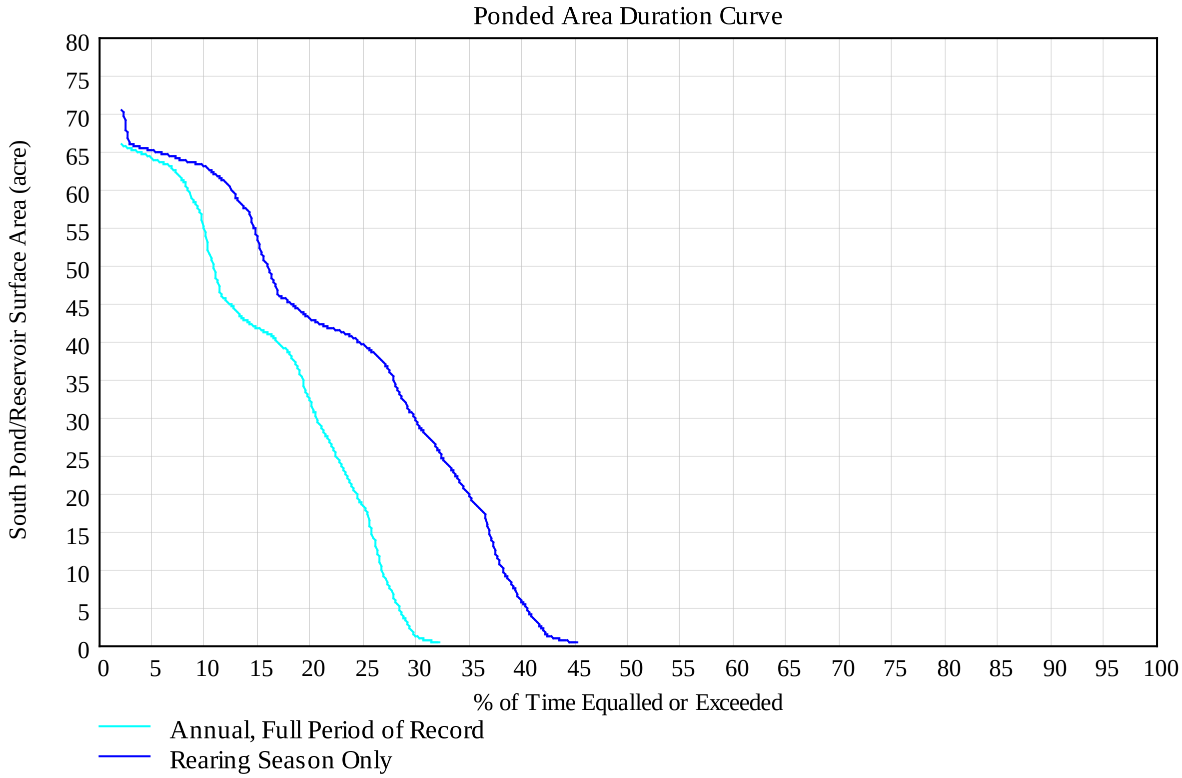


Figure 13 shows Ponded Area Duration Curve for the South Pond/Reservoir which was derived by merging the Stage-Frequency relationships (daily average WSE data of the full year and just rearing season) of the WSE Duration Curves shown in Figure 8a with the stage-area relationship shown in Figure 11. The two derived curves show the frequencies at which a range of the site's ponded area occur for the two time periods of interest. These curves assume that there are no stop logs in the water control structure and that the pond size is governed by the stage of the Willamette River through a direct connection. The graph shows that the river backs up to the pond less than 34% of the time. Once the river drops to a WSE of around 10', the river has no direct influence on the pond's stage and area of inundation. The curve does not consider ponding from surface water runoff or groundwater seepage - only by direct connection to the Willamette.

Figure 13, Ponded Area Duration Curve for the South Pond/Reservoir



Note: Curve assumes no water control structure or other grade controls and water sources, and that the area is solely based upon backwatering from the Willamette River

This project has included some extensive water temperature monitoring of the groundwater, the South Pond/Reservoir, at the WCS and the culvert; as well as monitoring the flows passing through the culvert. These data were collected from remote sensing devices and provided by BES's Field Operations group and also included an array of piezometers. Figure 14 shows graphs of the monitoring data. The two graphs, in addition to showing the temperatures at the identified locations, also show the WSE, flow and flow velocity at the inlet of the culvert as well as the Willamette's WSE. There are some gaps in the culvert's flow and velocity data because of problems with the instruments. A plot of the average groundwater temperature taken from the five piezometers is also provided.

Over the entire period of record, the measured groundwater temperatures only varied within a range of 10°C to 13°C and showed no daily fluctuation whereas the surface water temperatures varied widely and showed a great deal of daily fluctuation. Being a shallow and open water body, the pond naturally heats up and its temperatures were on average about 4°C higher than those at the culvert suggesting that a relatively steady flux of cooler groundwater is surfacing between the pond and culvert, and contributing to the culvert's total flow (the flow passing out of the culvert was not all feeding from the pond).

Figure 15 shows the high, low and average temperatures for the pond and culvert by month for the monitoring period. Also shown for reference are the preferred temperature ranges for salmonids and the lethal temperature limits. The data show the months of year that average temperatures go above the fish-preferred ranges which is outside the fish rearing season.

Figure 14, Monitoring Data

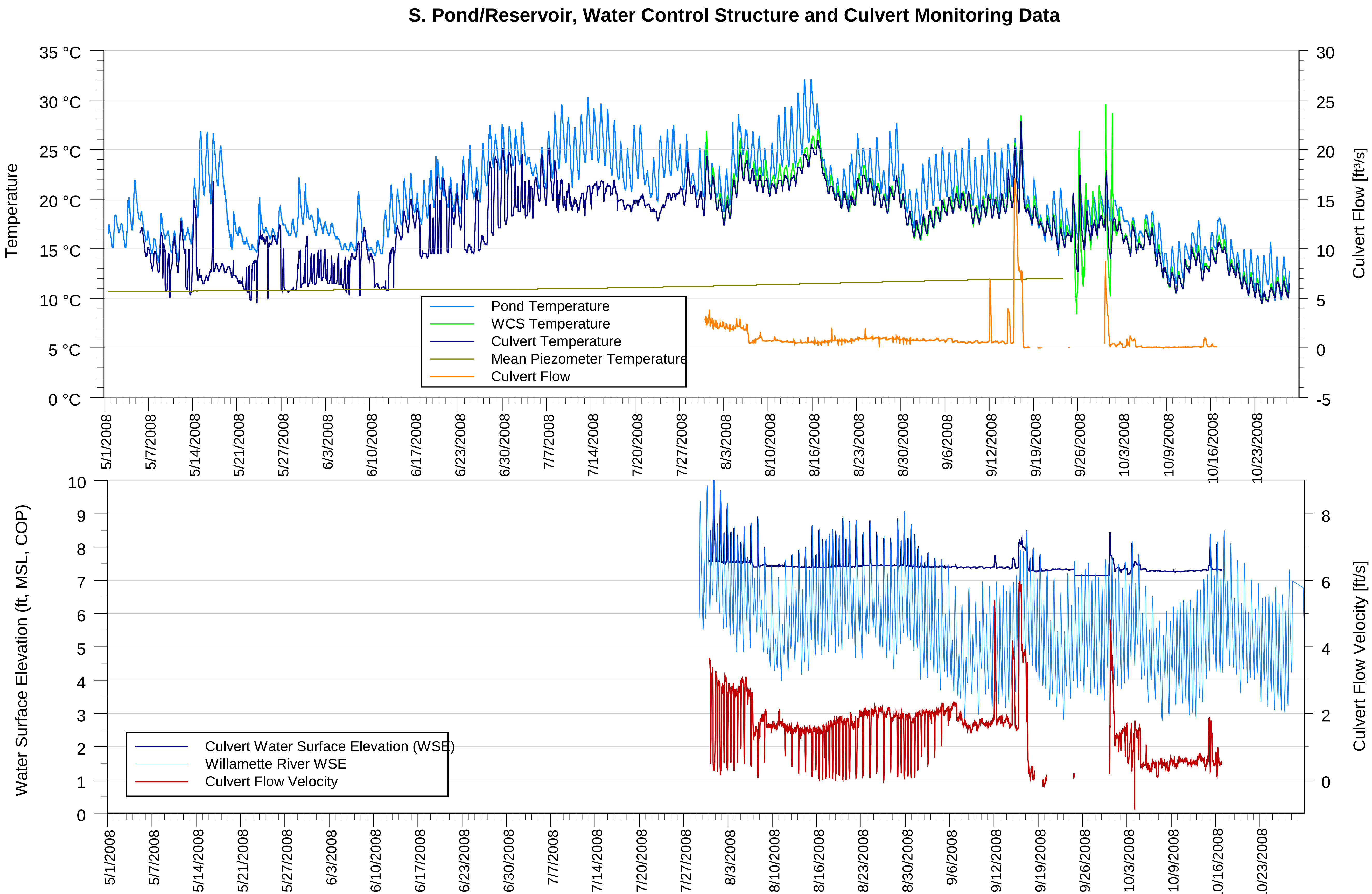
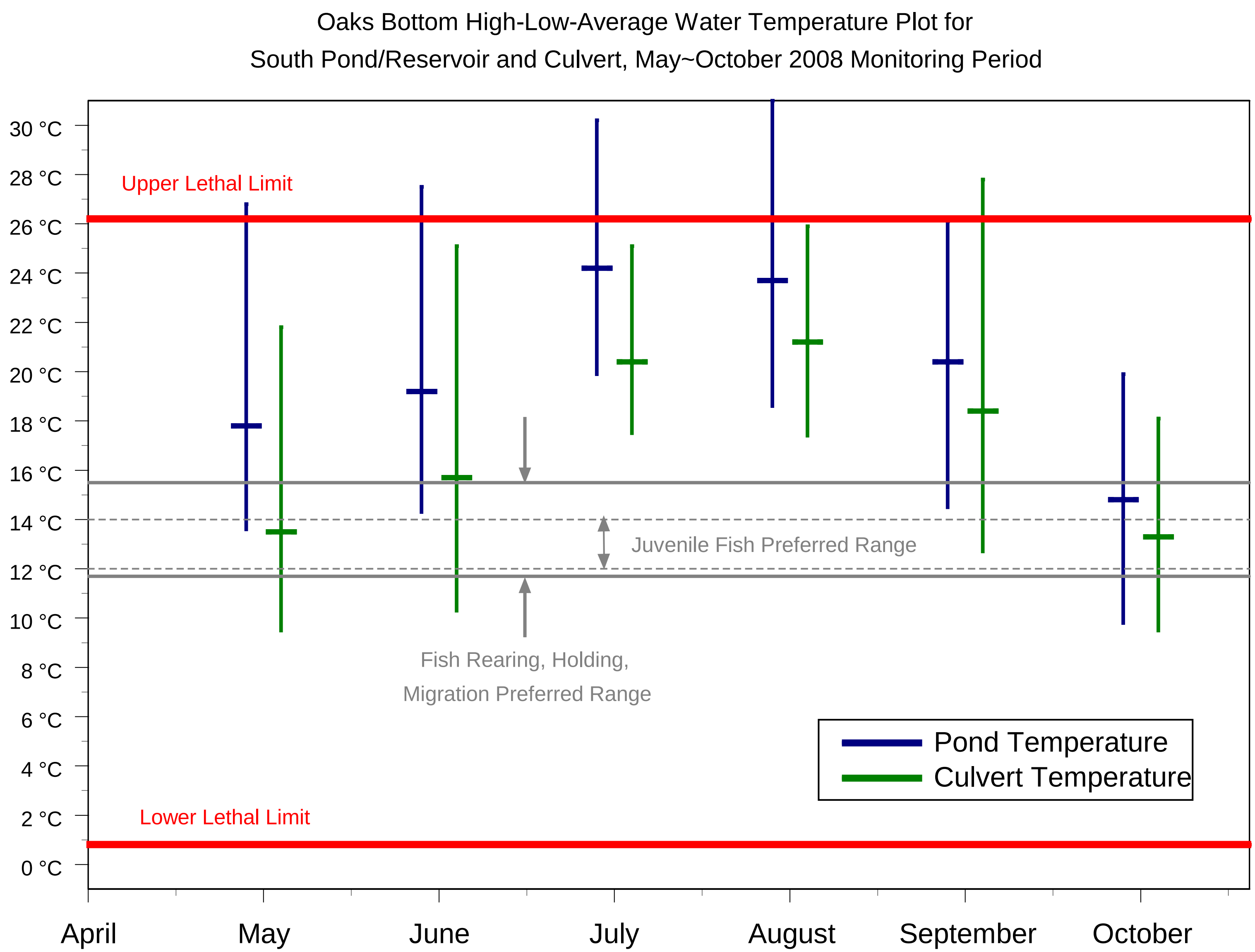


Figure 15, South Pond/Reservoir Temperature Monitoring Data



The locations of the groundwater monitoring wells (piezometers) are shown in Figure 16, on the DEM base map. Also shown is the location of the existing culvert and the Willamette River's 12.78' OHW level. The ground surface elevations (GSE) at the piezometers are shown as well as the elevation ranges within selected colored bands (in yellow type).

Figure 17 is a graph showing time series plots of the river stage, piezometers and rainfall data. The river stage data is from the USGS's Morrison Bridge site; the piezometer data is from the piezometers that were installed for this project at the locations shown in Figure 16, and rainfall data was downloaded from the City of Portland rainfall data collection system. All the data was normalized and tabulated in the same time domain at the same 15-minute time step. The time-series were also data-smoothed using a kernel-smoothing algorithm in order to take out some of the instrument noise. The smoothing parameters for the river WSE data were further adjusted to take out the diurnal tidal fluctuation of the river stage. Since groundwater responses are on a very different time-scale than rainfall events and surface water flows, and there is a desire to determine groundwater responses to rainfall in this analysis, the rainfall depths were summed up over various time windows in order to come up with moving, cumulative volumes over a longer window of time.

The WSE data collected by the Morrison Bridge gage is relative to an independent datum that is 1.55 feet above the NGVD datum, which is 1.375 feet above the City of Portland datum (COP). All Morrison Bridge data that was collected and analyzed for this report were converted to the COP datum by adding a total of 2.925 feet to account for the two datum conversions. The elevations of the piezometers were directly tied into the COP datum when they were installed.

Once time-series data are normalized with the same domain and increment, it is then possible to perform a correlation analysis. Unlike a straight correlation where the correlation between different time-series variables are computed at the same times step, a time-lagged correlation accounts for responses (correlations) between variables with phase shifts or time lags introduced, usually yielding a substantial increase in correlation values. For example, rainfall is the ultimate source of surface and ground water flow, however, the response of surface water flow to rainfall is almost immediate compared to the response of groundwater flow which has a greater lag. Table 1 shows the Time-lagged Correlation with Lag Times of the variables in Figure 17.

This analysis has been re-run following subsequent data retrieval periods roughly every six weeks and it had been found that the absolute numbers have drifted a bit over time; however, the observed trends have remained the same. The piezometers were placed in the site in October of 2007 during low river conditions and have been continuously monitored through a very wet winter and spring period. It was found that the correlation values seasonally vary a little bit but the observed trends for the period of record include the direct response to rainfall is fairly low but the correlation increases substantially with cumulative rainfall volume over time, especially on the order of several days to weeks. The analysis also shows that the piezometers are highly correlated to each other in terms of head (H) and rate of head change relative to each other (dH/dt), but they also have a high correlation to the river stage especially with the diurnal fluctuations smoothed out. Piezometers P1 and P2 are most correlated to P4, and P4 and P5 are most correlated to P2. P3 is most correlated to the river but still has a very high correlation to the other piezometers. P3 is the only piezometer that appears to have a direct response to the hourly tidal fluctuations. The piezometer data was collected at 30-minute intervals and all the time-series analysis was performed at this resolution.

Figure 16, Piezometer Locations

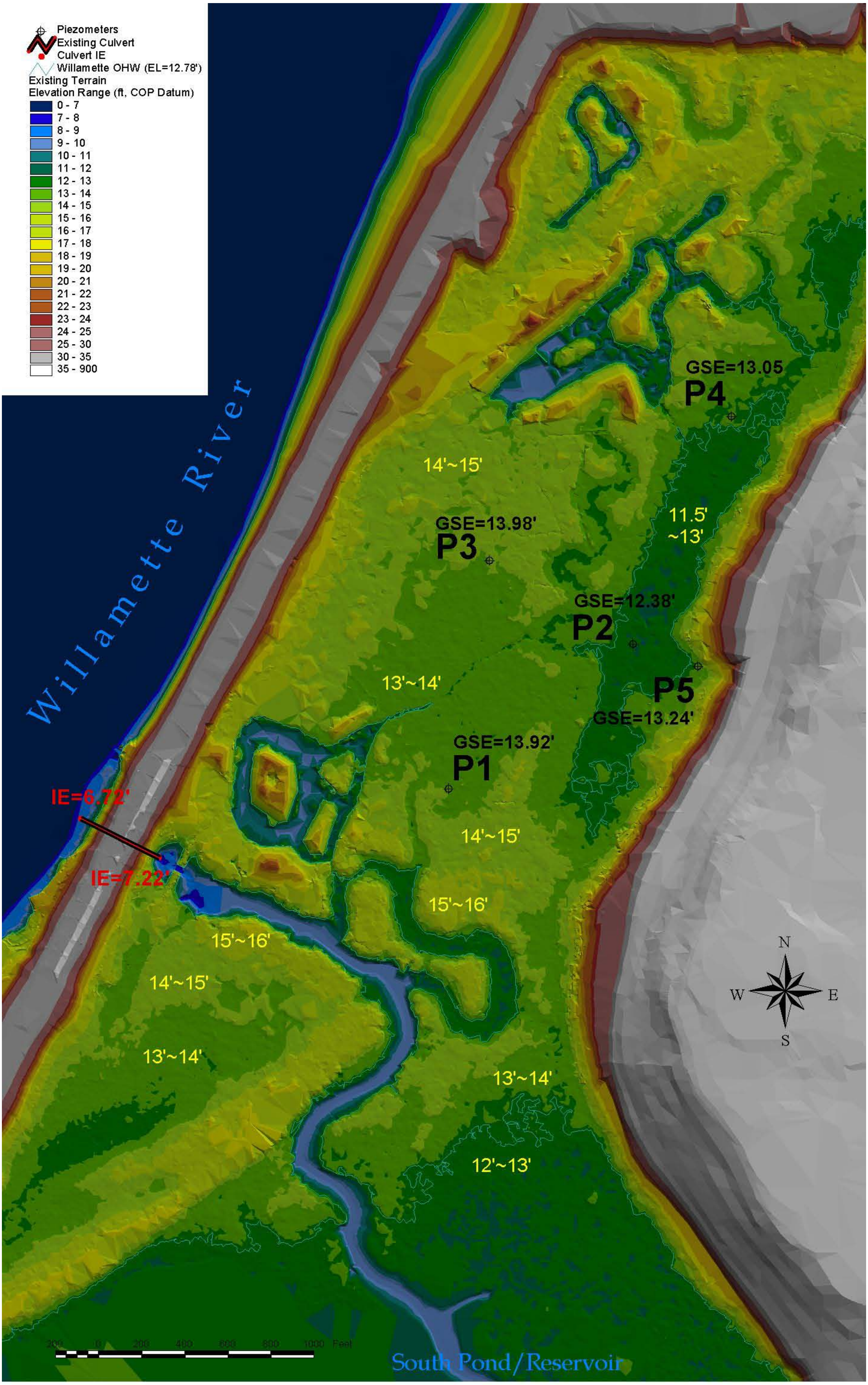


Figure 17,

Oaks Bottom - River Stage, Piezometer and Rainfall Data (Oct 2007 - Sep 2008)

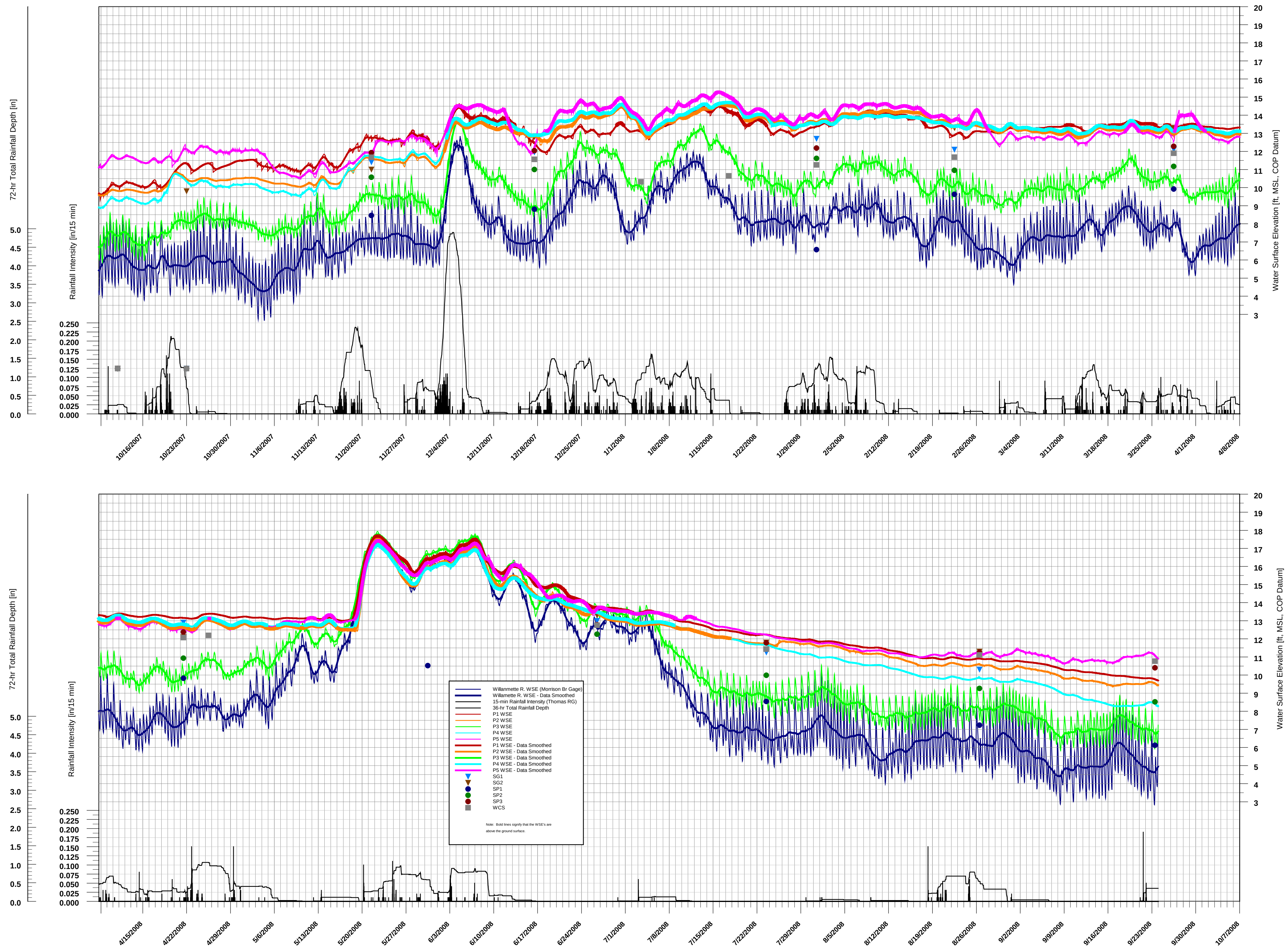


Table 1, Time-lagged Correlation Analysis of Monitoring Data Time Series

Legend

Variable	Description
Rain	15 minute rainfall depth (inches) taken from the City's Thomas PS Raingage near Oaks Bottom
Rain.12	The running 12-hr total depth of rainfall at the Thomas RG
Rain.24	The running 24-hr total depth of rainfall at the Thomas RG
Rain.36	The running 36-hr total depth of rainfall at the Thomas RG
Rain.48	The running 48-hr total depth of rainfall at the Thomas RG
Rain.60	The running 60-hr total depth of rainfall at the Thomas RG
WSE	Willamette River Water Surface Elevation at the Morrison Bridge
WSE.s	Data Smoothed WSE to remove diurnal tidal pattern
P1, P2...	Piezometers #1, #2... respectively
EL.s	Piezometer WSE, Data Smoothed piezometer WSE to remove instrument data noise
dHdt	The rate of the change of the smoothed piezometer WSE with respect to time.

Time-lagged Correlation (Read: "Variable in column 'n' is correlated to the variable in row 'm' with a lag of time 'k'")

										P1		P2		P3		P4		P5	
		Rain	Rain.12	Rain.24	Rain.36	Rain.48	Rain.60	WSE	WSE.s	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt
	Rain	-	0.64	0.58	0.53	0.49	0.46	0.21	0.22	0.12	0.32	0.10	0.36	0.19	0.38	0.11	0.37	0.15	0.27
	Rain.12	0.52	-	0.94	0.87	0.82	0.76	0.34	0.36	0.20	0.51	0.17	0.58	0.32	0.62	0.18	0.60	0.24	0.44
	Rain.24	0.42	0.88	-	0.96	0.91	0.86	0.39	0.41	0.24	0.55	0.19	0.62	0.36	0.65	0.20	0.64	0.28	0.47
	Rain.36	0.36	0.75	0.93	-	0.98	0.93	0.43	0.45	0.26	0.56	0.22	0.61	0.40	0.64	0.23	0.60	0.31	0.47
	Rain.48	0.31	0.66	0.83	0.95	-	0.98	0.45	0.48	0.28	0.54	0.23	0.56	0.42	0.61	0.25	0.54	0.33	0.45
	Rain.60	0.28	0.58	0.75	0.87	0.96	-	0.48	0.51	0.31	0.50	0.25	0.50	0.45	0.57	0.27	0.47	0.36	0.44
	WSE	NA	NA	NA	NA	NA	NA	-	0.92	0.74	0.12	0.75	0.17	0.88	0.11	0.76	0.13	0.78	0.20
	WSE.s	NA	NA	NA	NA	NA	NA	NA	-	0.80	0.11	0.82	0.17	0.96	0.10	0.83	0.13	0.86	0.19
P1	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	-	0.12	0.94	0.12	0.91	0.11	0.95	0.12	0.90	0.10
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0.08	-	0.08	0.83	0.16	0.69	0.07	0.83	0.08	0.72
P2	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0.94	0.11	-	0.11	0.90	0.10	0.99	0.11	0.96	0.09
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0.10	0.83	0.06	-	0.23	0.69	0.07	0.94	0.09	0.73
P3	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0.91	0.10	0.90	0.09	-	0.11	0.91	0.10	0.92	0.10
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0.07	0.72	0.05	0.70	0.21	-	0.06	0.69	0.11	0.69
P4	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0.95	0.12	0.99	0.11	0.91	0.10	-	0.12	0.95	0.09
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0.08	0.83	0.07	0.94	0.18	0.68	0.07	-	0.08	0.73
P5	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0.90	0.11	0.96	0.10	0.91	0.09	0.95	0.10	-	0.09
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0.10	0.72	0.06	0.73	0.21	0.64	0.06	0.73	0.15	-

Time Lag, k (hours)

										P1		P2		P3		P4		P5	
		Rain	Rain.12	Rain.24	Rain.36	Rain.48	Rain.60	WSE	WSE.s	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt	EL.s	dHdt
	Rain	-	5.75	11	18	22.75	27.5	56.75	64	0	12.75	0	12.25	68.5	12.75	0	10.75	0	17.25
	Rain.12	0	-	6	12	18	23.75	55.5	57.75	0	7	0	6.25	62.75	7	0	4.75	0	11.75
	Rain.24	0	0	-	6	12	18	53	51.5	0	2.5	0	1	57	1.5	0	0	0	6.25
	Rain.36	0	0	0	-	5.75	11.75	47	45	0	0	0	0	51	0	0	0	0	1
	Rain.48	0	0	0	0	-	6	38.5	38.75	0	0	0	0	45.75	0	0	0	0	0
	Rain.60	0	0	0	0	0	-	30.25	32.25	0	0	0	0	41.25	0	0	0	0	0
	WSE	NA	NA	NA	NA	NA	NA	-	0	20	0	35.75	0	5.5	0	24.75	0	35	0
	WSE.s	NA	NA	NA	NA	NA	NA	NA	-	20.5	0	36.25	0	8	0	26	0	38	0
P1	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	-	0	0	0	0	0	0	0	0	0
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0	-	0	0	37	0	0	0	0	0.25
P2	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0	0	-	0	0	0	0	0	0	0
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	39.5	0.25	0	-	37.75	0	0	0	57.75	0.25
P3	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	2.25	0	9	0	-	0	2.75	0	11	0
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0	4.25	0	2.75	52.75	-	0	2.75	0	6
P4	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	-	0	0	0
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0	1.5	0	0.5	46	0	0	-	0	0.25
P5	EL.s	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	-	0
	dHdt	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	47.5	0	0	0	0	-

3. Groundwater Modeling

It is recognized that groundwater is a major hydrologic feature of the Oaks Bottom site and has been studied throughout this project. The groundwater analysis performed for this project includes a study of the piezometer data, the development an estimated water budget, and groundwater modeling of a number of design alternatives under different hydrologic scenarios.

In order to illustrate the general surface- and groundwater trend, the average values for the Willamette WSE and the data from all the piezometers, for the period where piezometer data are available, were averaged and used to create a 3-D isocontour plot of the groundwater shown in Figure 18. This figure is a 3-D representation view looking NE from the SW, at an oblique angle; it shows that the general direction of groundwater flow is from below the bluff on the right towards the river on the left. The exact conditions change seasonally but the trend remains constant. The locations of the piezometers are shown as dark triangles.

Figure 18, Groundwater Isocontour Plot with Ground Surface Mesh Overlay

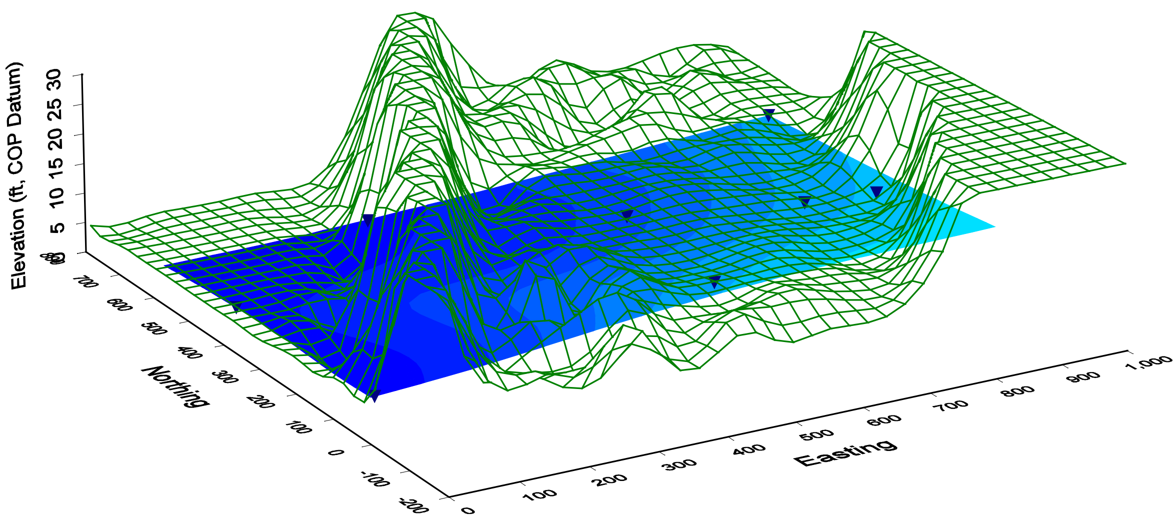
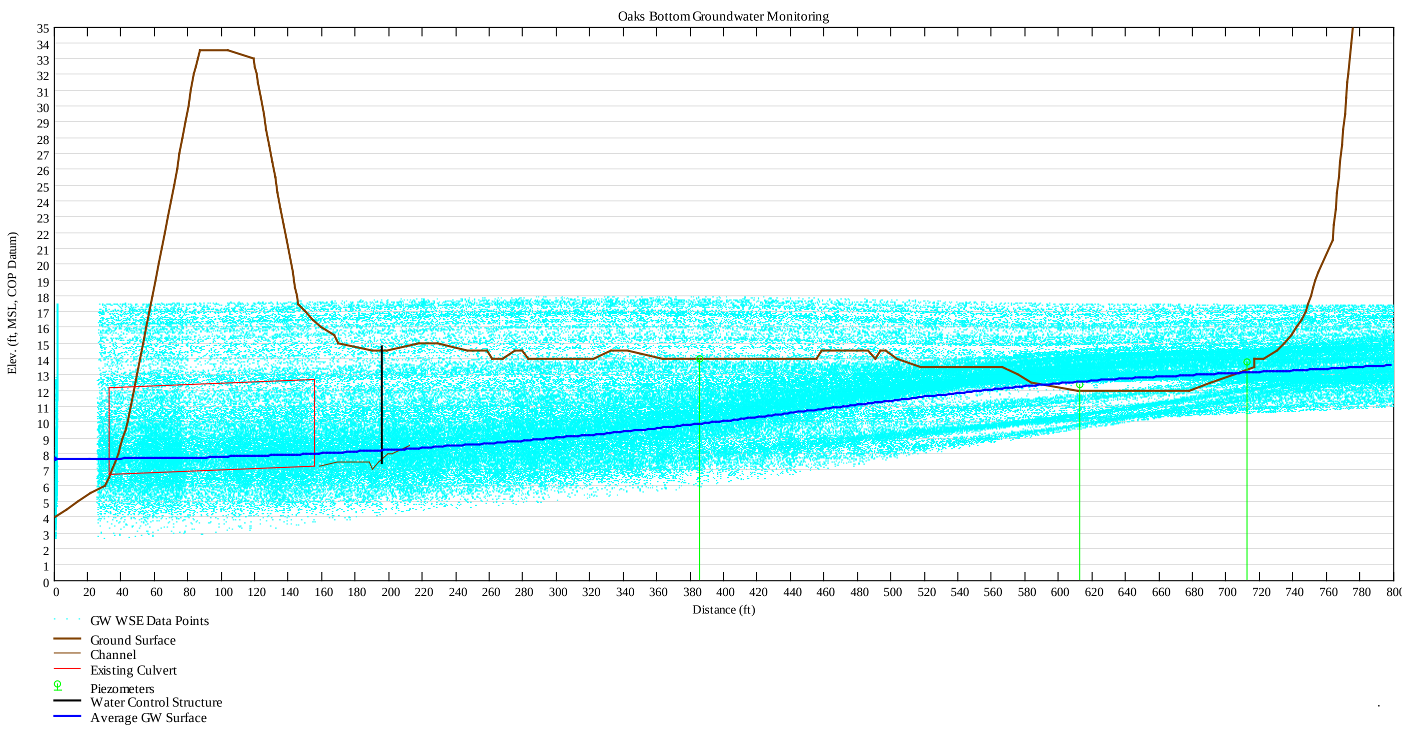


Figure 19 is a profile plot of the groundwater data from the October 2007 to September 2008 monitoring period. The profile that depicts the ground surface was taken along a straight line that intercepts the locations of the river, the railroad embankment, and piezometers P3 (closest to the river), P2 (in the middle) and P5 (closest to the bluff). The plot is a cross-sectional view of the site looking north with the river to the left and the bluff to the right; and the locations of the culvert, WCS and the piezometers are also shown on the plot. The railroad berm and the culvert are towards the left. The groundwater data is shown as a cloud of points taken along a spline fit of the piezometer data points taken at different times during the monitoring period; the dark blue line is the median WSE for the period of record. A direct connection between the groundwater and the river is assumed. The high Columbia River spring freshets of 2008 produced very high backwater conditions (above 13') that inundated the site from the near the middle of May to after the beginning of July.

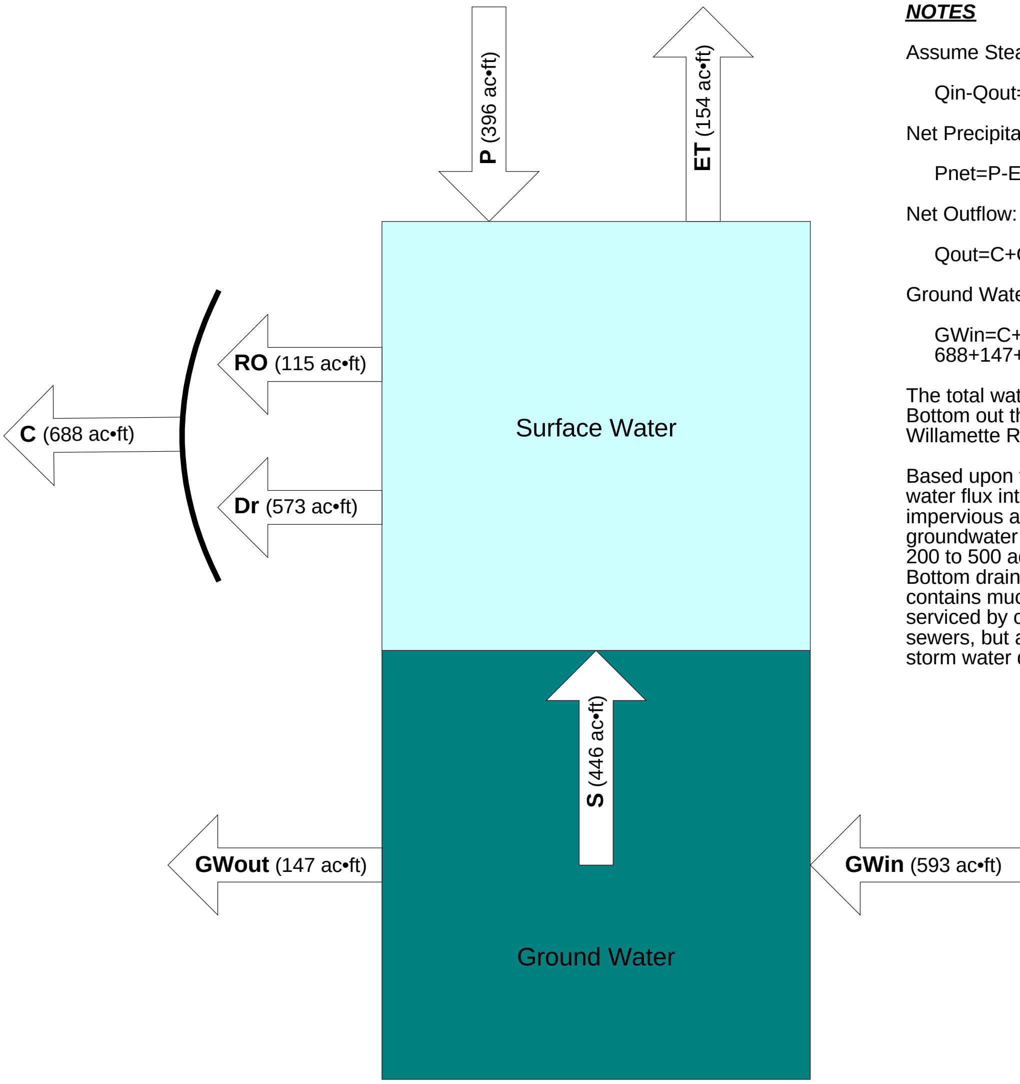
Figure 19, Profile Plot of Groundwater Data, October 2007 to September 2008



Because of concerns regarding effects on the wetlands to the north of the channel, it was desired to further study the ground- and surface-water interactions by developing an annual water budget for the site. Using several data and modeling sources that include: precipitation gages, culvert flow monitoring, DHI MIKE-SHE hydrologic modeling and IGW groundwater modeling, the annual water budget (mass balance) for Oaks Bottom was estimated. The notes in Figure 20 detail the assumptions used in this water budget analysis. In summary, the greatest source of water to the site is from groundwater influx and a larger percentage of it surfaces and leaves the site via surface water drainage.

Figure 20

Estimated Annual Water Budget for Oaks Bottom: Preliminary Analysis



NOTES

Assume Steady-state Conditions:

Qin-Qout=dVol/dt=0

Net Precipitation:

Pnet=P-ET ==> 396-154=242 ac•ft

Net Outflow:

Qout=C+GWout ==> 688+147=835 ac•ft

Ground Water Influx:

GWin=C+GWout+ET-P ==> 688+147+154-396=593 ac•ft

The total watershed area draining to Oaks Bottom out through the culvert and to the Willamette River is about 125 acres.

Based upon the computed value for the ground water flux into the site (assuming a mapped impervious area of about 35%), the groundwater recharge area is an approximate 200 to 500 additional acres outside of the Oaks Bottom drainage. The presumed recharge area contains much of the Sellwood district which is serviced by combined sanitary and storm sewers, but also has a significant number of storm water drywells/sumps (a.k.a., UIC's).

Variable	Description	Data Source	Annual Volume (ac•ft)	Average Flow/Flux (ft^3/s)
P	Total Precipitation	Rainfall Record	396	0.55
ET	Evapotranspiration	City MIKE-SHE Modeling	154	0.21
RO	Direct Rainfall Runoff	City MIKE-SHE Modeling	115	0.16
C	Culvert Out Flow	Monitoring Data	688	0.95
Dr	Drainage	Computed (Dr=C-RO)	573	0.79
S	Seepage	Computed (S=GWin-GWout)	446	0.62
GWin	Ground Water Influx	Computed (See Notes)	593	0.82
GWout	Ground Water Outflux	IGW Modeling	147	0.20

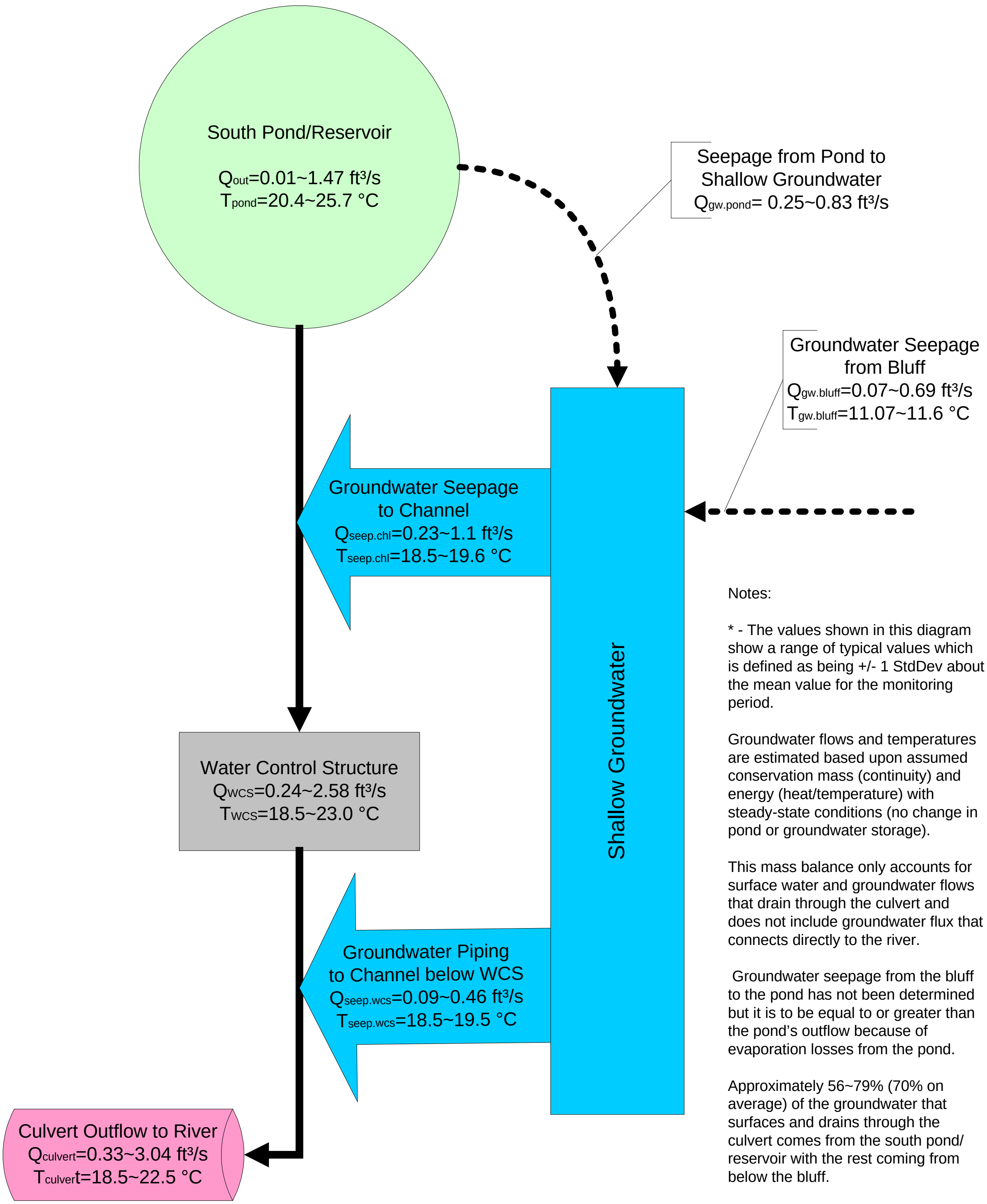
For the dry-season during the period of record, nearly all the water that drained through the culvert ultimately came from groundwater that seeped into the site from the area below the bluff. On average, about 26% of the water exiting the site through the culvert drained directly out of the south pond and the remaining 74% came from groundwater seepage and piping from shallow groundwater. Based on the available temperature data (pond, channel and piezometer), it was found that about 70% of the shallow groundwater that seeps into the open channel above the culvert comes from the south pond with the remaining 30% coming from deeper (and colder) groundwater seeping out below the bluff. The photograph below (Figure 21) shows a point near the WCS and the culvert where piping groundwater flow is surfacing.

Figure 21, Groundwater Piping and Day-lighting near WCS

The average ground and surface water flow conditions for the water draining through the culvert during the August through October 2008 Monitoring Period were analyzed because it was noted that the pond temperatures were consistently higher than the temperature of the water draining from the site through the WCS and culvert. All surface water temperature measurements were significantly higher than the groundwater temperatures. Using the temperature data collected in the pond, WCS and culvert, along with the flow data collected at the culvert, the flows at location of interest were estimated. The points where flow data was not available were computed assuming mass (flow) continuity, where $Q3=Q1+Q2$; and conservation of heat (or temperature) where, $T3=(T1*Q1+T2*Q2)/(Q1+Q2)$. Temperature data from the piezometers was also used in this analysis. Also refer to the "Notes" in the diagram (Figure 22) on the following page.

Figure 22

Average* Ground and Surface Water Flow Conditions for Water Draining through the Culvert -- August ~ October 2008 Monitoring Period:



Notes:

* - The values shown in this diagram show a range of typical values which is defined as being +/- 1 StdDev about the mean value for the monitoring period.

Groundwater flows and temperatures are estimated based upon assumed conservation mass (continuity) and energy (heat/temperature) with steady-state conditions (no change in pond or groundwater storage).

This mass balance only accounts for surface water and groundwater flows that drain through the culvert and does not include groundwater flux that connects directly to the river.

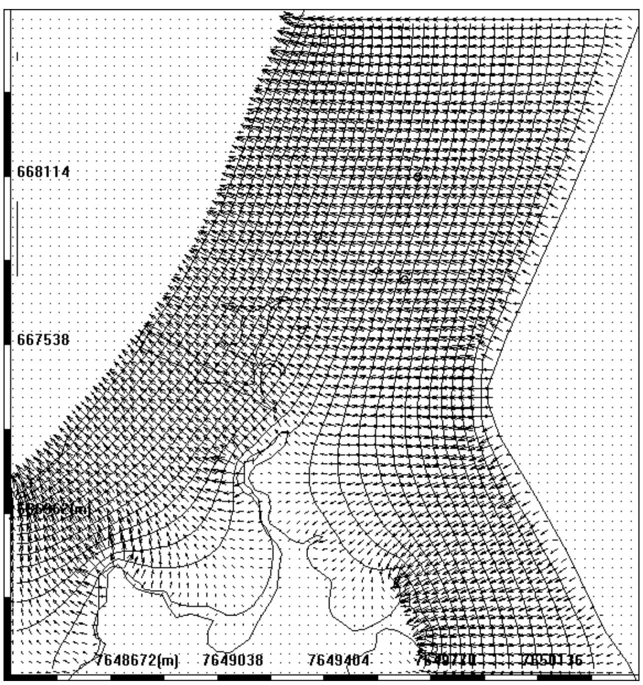
Groundwater seepage from the bluff to the pond has not been determined but it is to be equal to or greater than the pond's outflow because of evaporation losses from the pond.

Approximately 56~79% (70% on average) of the groundwater that surfaces and drains through the culvert comes from the south pond/ reservoir with the rest coming from below the bluff.

One of the first proposed design alternatives evaluated with the groundwater model consisted of excavation of the main channel so there is a direct surface water connection from the river to the duck-doughnut north of the main channel and continuing on to the north duck-doughnut. One of the concerns with this proposed design was that the excavated channel could potentially create enough drawdown in the water table to adversely affect "Wetland A". The plots shown in Figure 23 show the results from a 2-D groundwater model which was run assuming steady state conditions. For both the existing and proposed conditions, the model's fixed head boundary conditions (BC's) for the groundwater source (area below bluff) and sink (river) were developed from the monitoring data.

The isocontour lines in Figure 23 show the groundwater surface elevations. The flow field is comprised of the flow vector arrows which show the direction and magnitude of the flow – pointing in the direction of the flow (down gradient), and the longer arrows (and closer iso-contour lines) indicate higher effective flow velocities. In the northern portion of the site, the groundwater seeps out from base of the bluff and flows towards the river; in the southern portion, water first seeps out into the pond at points along its eastern edge and then back out to the river along its western edge. In the figure, the river is the open white area in the upper left hand corner of the plot, the South Pond/Reservoir is the irregularly shaped area at the bottom, and the area with water seeping out from the below the bluff is along the right edge.

Figure 23, Existing and an Early Proposed Design Alternative Groundwater Modeling Results



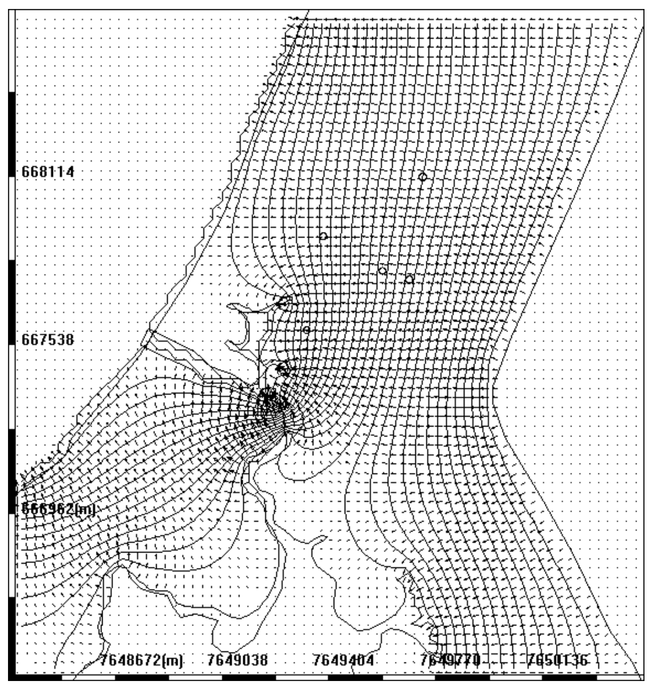
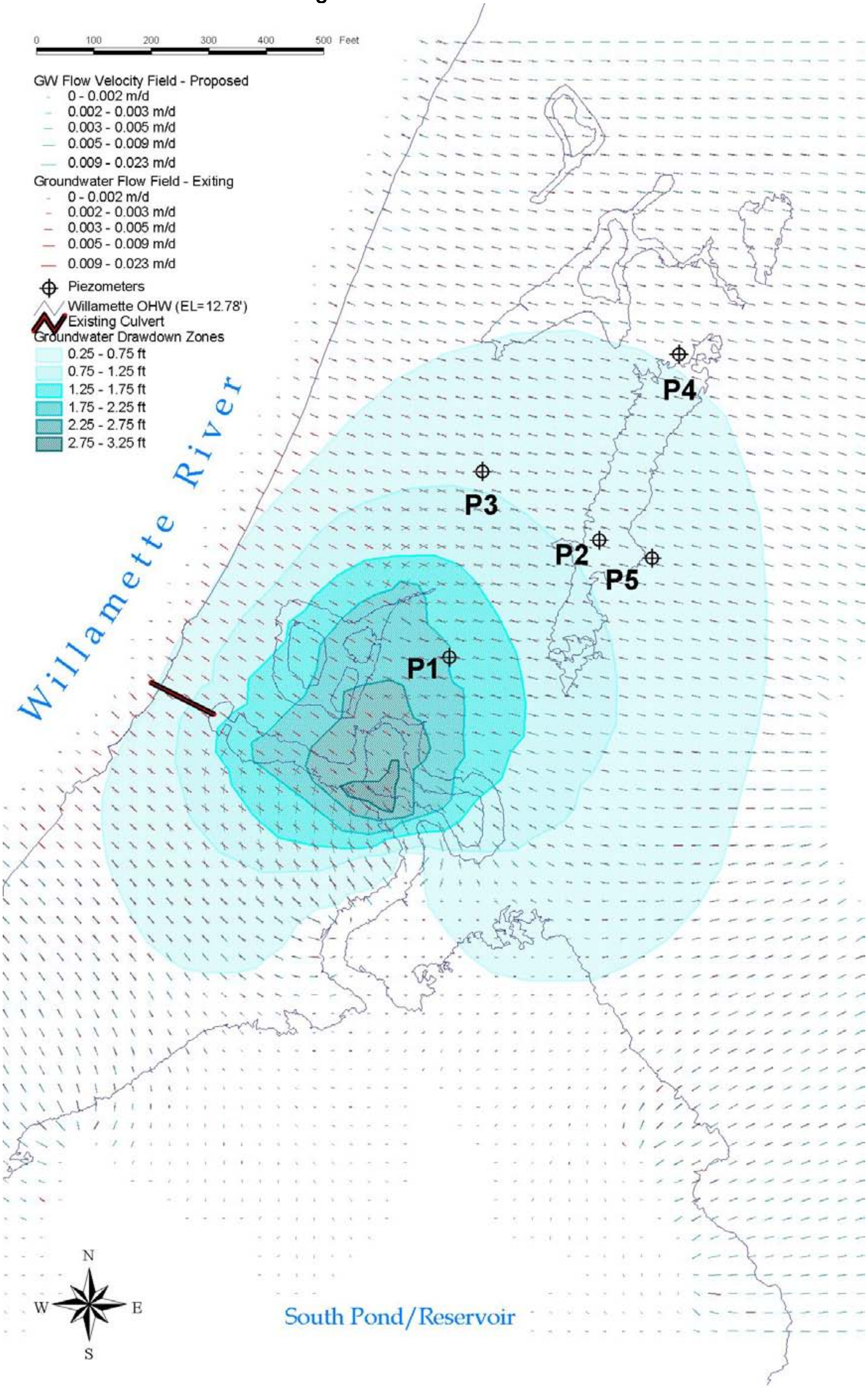


Figure 24 below was generated by taking the groundwater modeling results shown in Figure 23 and subtracting the proposed condition results from the existing condition results, resulting in the estimated water table drawdown with the areas impacted, and to what degree. The result shown is only for the boundary conditions modeled, the actual conditions will vary with the seasonal changes in groundwater and river conditions; but, the general characteristic of there being some dewatering of the site still remains.

Figure 24, Groundwater Drawdown Modeling Results



Several additional alternatives and scenarios were modeled using the groundwater model. Table 2, and Figures 25a through 25e and Figure 26 summarize the inputs and show the outputs from the 9 different scenarios. The model runs presented here are the results of a subsequent round of expanded groundwater models similar to those shown in Figure 23 with the main difference being that the spatial domain of the model was enlarged to include a greater portion of the site and several alternative design scenarios were developed. The modeled scenarios are summarized in the table and the results for each are shown in the figures.

The process for creating the models was identical to the one in Figure 23 with the only difference being the enlarged domain and that 6 different boundary conditions were modeled (Scenarios 1 through 5a) to simulate different time periods of interest under existing conditions. These existing conditions scenarios were run for the purpose of helping to better characterize the site. Three different design scenarios (Scenarios 5b through 5d) were modeled for the purpose of comparing the relative impacts of the possible design alternatives.

For all the modeled scenarios, the boundary conditions (BC) for the river were established using the historic river stage data and the collected piezometer data. The boundary conditions representing the source groundwater aquifer below the bluff were estimated by extrapolating from the data in Piezometers 3, 2 and 5 whose locations are shown in Figure 16 above. All the surface water BC's are assumed to be freely connected to the groundwater zone. Besides the stated fixed-head, steady-state BC's for each scenario, all the model runs use the same inputs in terms of soil layer thickness, assumed soil homogeneity and hydraulic conductivity, and spatial domain. This was done to help identify the probable impacts of specific seasonal or physical changes. Figures 25a through 25e show the groundwater modeling results for all the scenarios defined in Table 2. The results are shown as isocontours depicting the computed groundwater surface elevations.

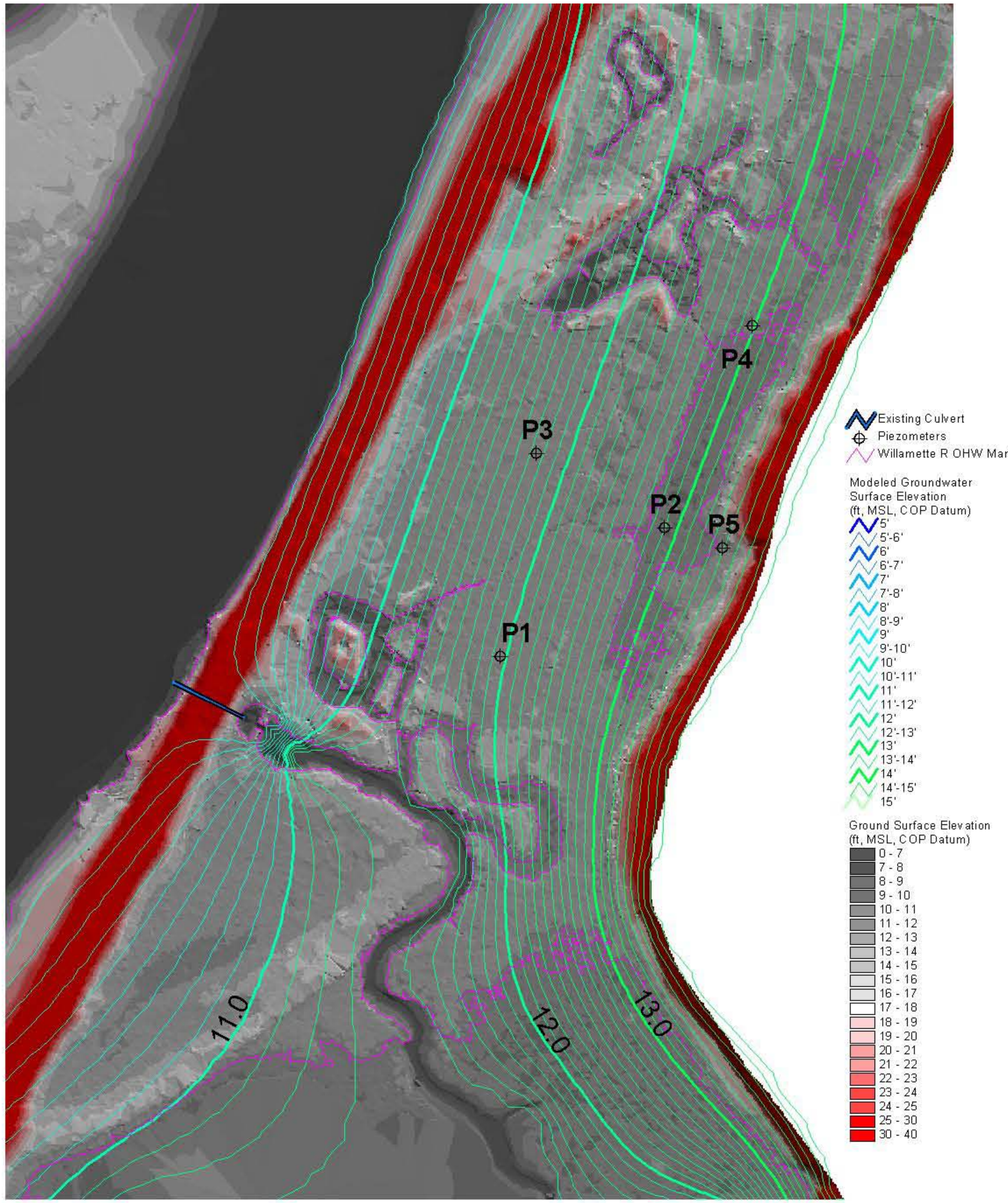
Figure 26 depicts the depth to groundwater under typical conditions. This was created by taking the GW modeling results from Scenario 3a shown in Figure 25b and subtracting the resultant water surface elevations from the ground surface elevations, yielding a conceptual surface that depicts the typical (median) expected depth to the groundwater. The shallowest groundwater is located at the base of the bluff, including where Wetland A is.

Table 2, Summary of Groundwater Model Scenarios with Inputs (Elevations are in feet, MSL, COP Datum)

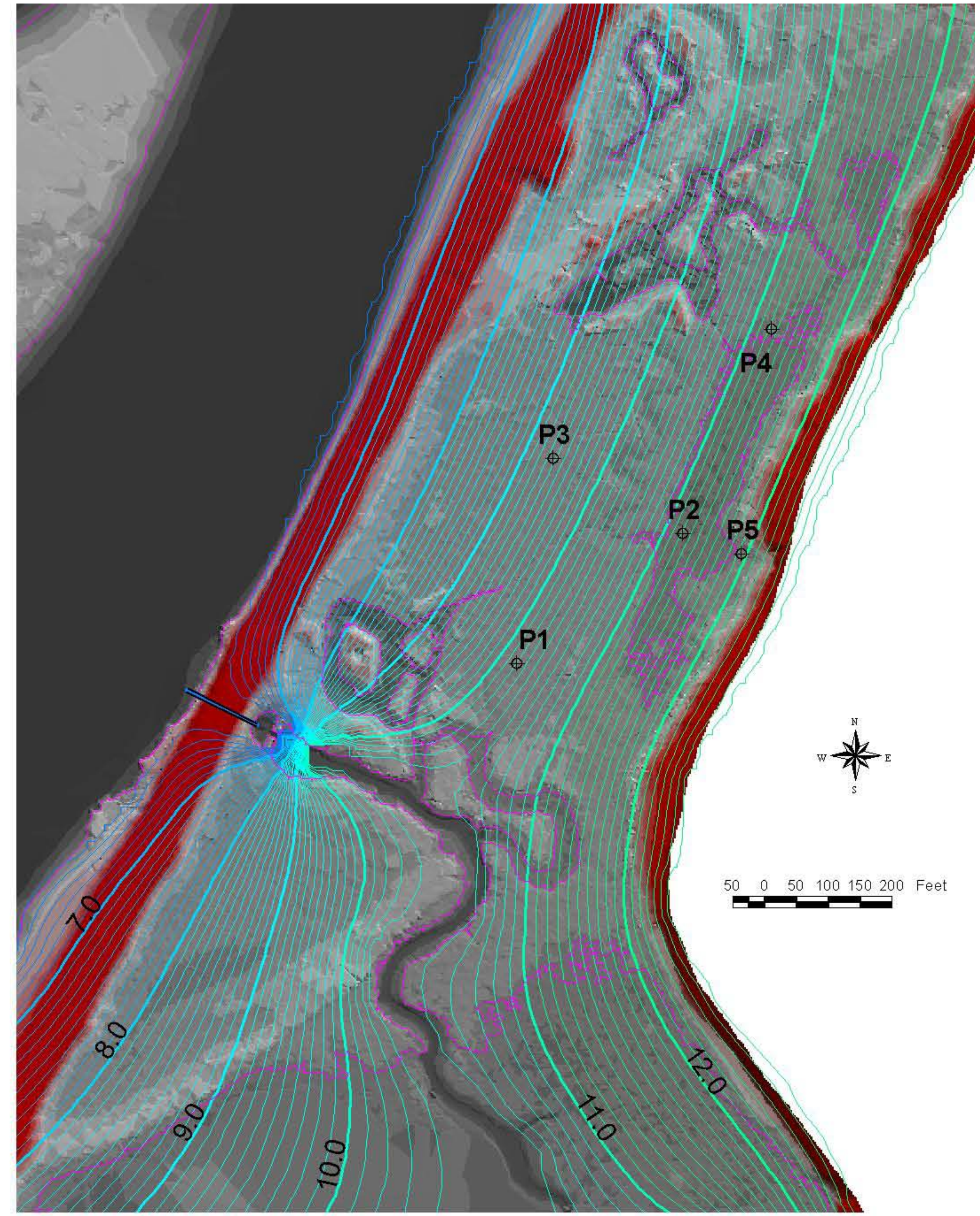
Scenario	Short Name	Description	Constant Head (WSE) Boundary Conditions			
			River WSE (ft)	**Pond WSE (ft)**	**Aquifer below Bluff WSE (ft)**	**Other BC (ft)**
Scenario 1	High	High river conditions for the MAR-APR-MAY-JUN period. Existing WSC location	10.0	11.4	14.5	-
Scenario 2	Low	Low river conditions for the JUL-AUG-SEP-OCT period. Existing WSC location	6.3	10.5	12.7	-
Scenario 3	Rainy	High river conditions for the NOV-DEC-JAN-FEB period. Existing WSC location	8.5	12.0	15.0	-
Scenario 3b	Rainy w/ Ponding	High river conditions for the NOV-DEC-JAN-FEB period. Existing WSC location. Same as Scenario 3 but with Ponded water in wetland A and the in the duck doughnuts	8.5	12.0	15.0	Wetland "A" at 13.5
Scenario 4	Drought	Simulation of very dry conditions with no ponding in the Wetland "A".	5.0	10.0	11.0	-
Scenario 5a	Growing Season, Existing	Simulation of the FEB-->OCT "growing season" with the WCS at its existing location.	7.4	11.4	14.4	Wetland "A" at 12.8 and South Doughnut at 12
Scenario 5b	Growing Season, Proposed Clear and Grub	Simulation of the FEB-->OCT "growing season" with the WCS moved closer to the south pond (reservoir), and with clearing and grubbing to connect Wetland A with South Doughnut.	7.4	11.4	14.4	Wetland "A" at 12.8
Scenario 5c	Growing Season, Connection to North Doughnut	Simulation of the FEB-->OCT "growing season" with an excavated channel running to the north, parallel to the RR embankment, connecting main channel to North Doughnut.	7.4	11.4	14.4	Wetland "A" at 13.3 and North Doughnut at 11
Scenario 5d	Growing Season, Connection to South Reservoir/Pond	Simulation of the FEB-->OCT "growing season" with excavation only in the main channel and stepped to connect to South reservoir/pond	7.4	11.4	14.4	Wetland "A" and North Doughnut at 13.3 , and South Doughnut at 12.0

Figure 25a, Groundwater Modeling Results for Scenarios 1 and 2 Respectively Covering the High and Low River Conditions of the MAR-JUN and JUL-OCT Periods

Notes: The closer the contours are, the higher the groundwater gradient is; which means the greater the groundwater flows are - note the high seepage at the location around the WCS.



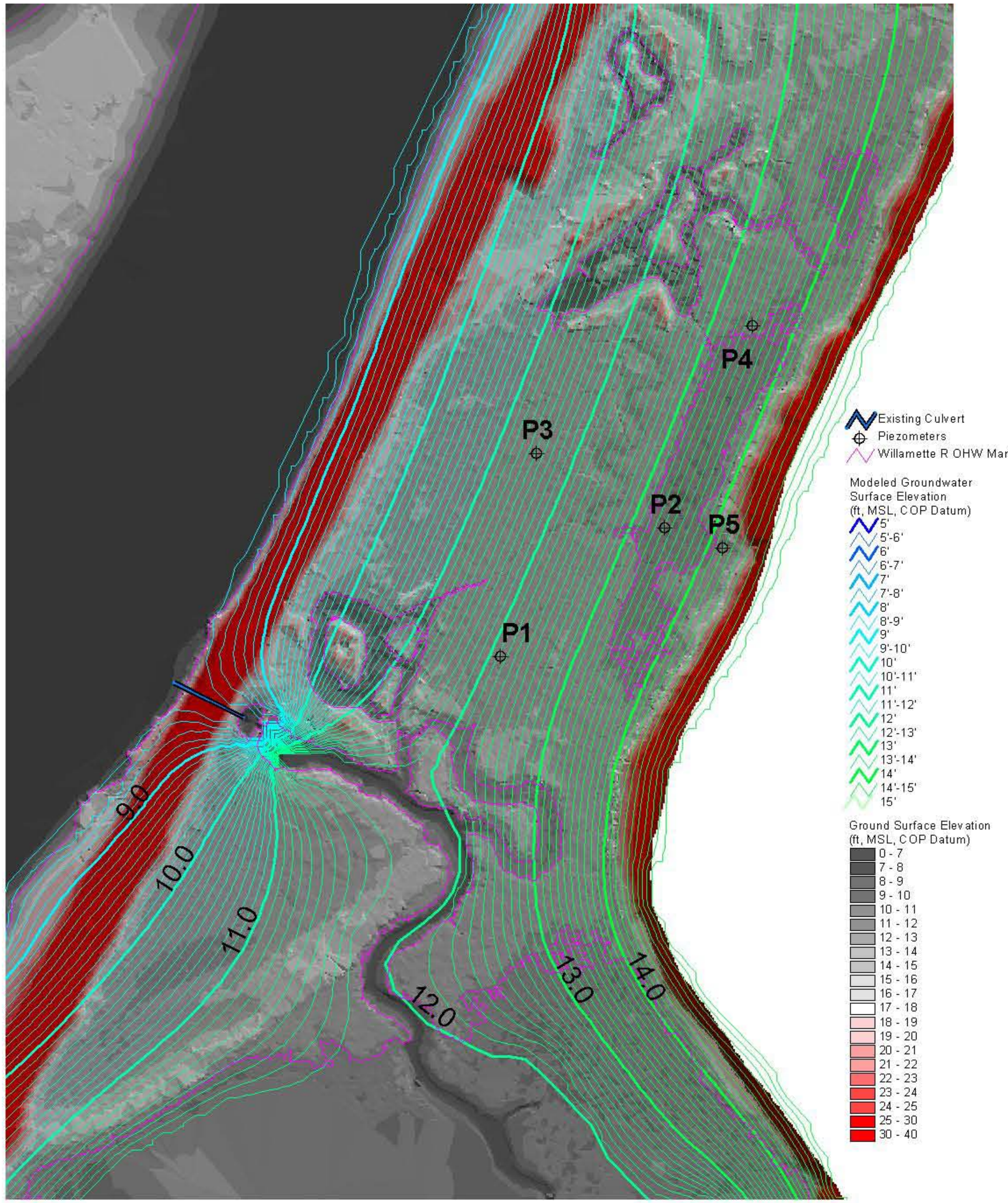
Scenario 1, High River Conditions, MAR-APR-MAY-JUN Period
Surface Water/Ground Water Elevations: River 10.0', South Reservoir 11.4', Bluff 14.5'



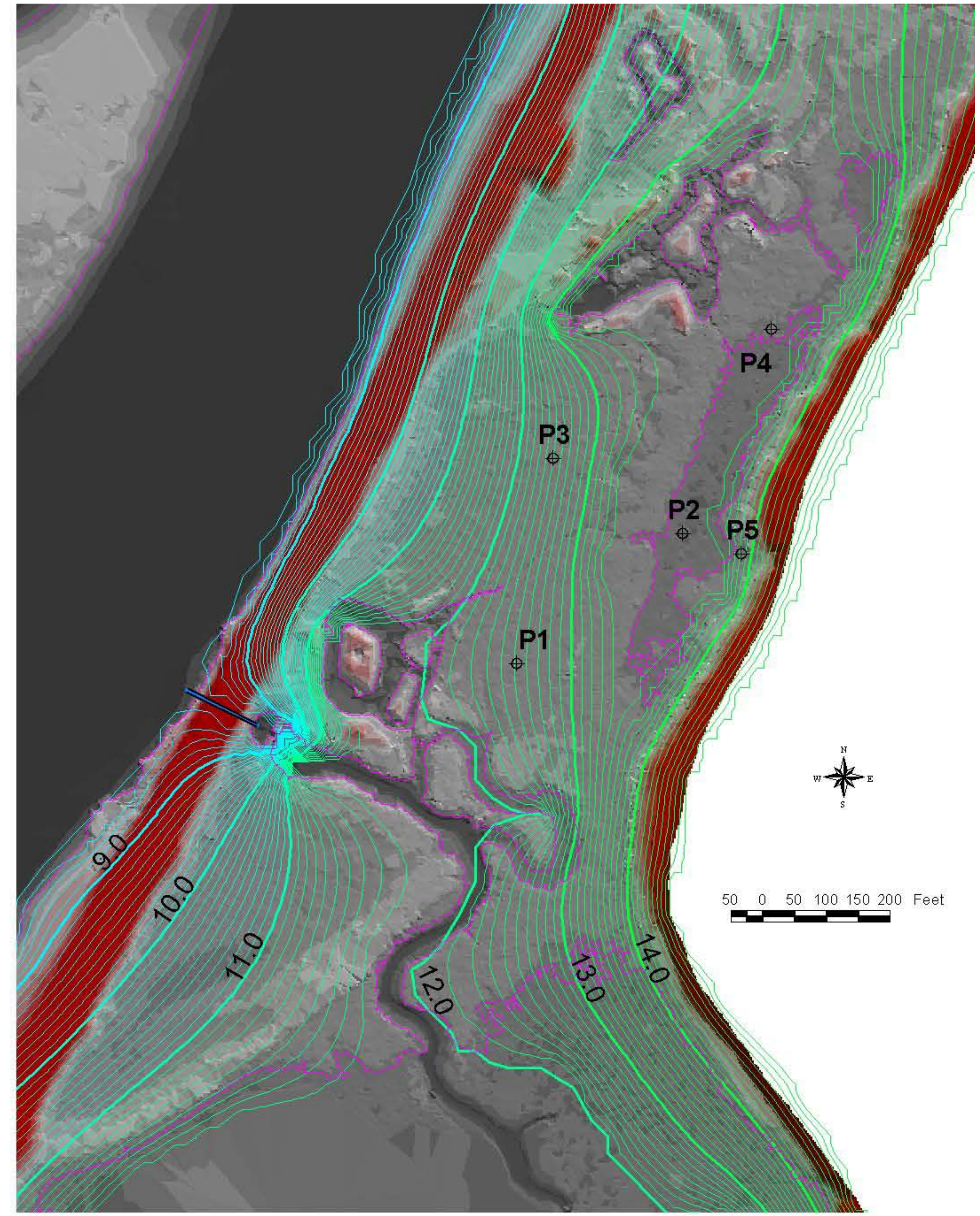
Scenario 2, Low River Conditions, JUL-AUG-SEP-OCT Period
Surface Water/Ground Water Elevations: River 6.3', South Reservoir 10.5', Bluff 12.7'

Figure 25b, Groundwater Modeling Results for Scenarios 3a and 3b That Cover the NOV-FEB Rainy Season, with and without Ponding in the Channels Wetland (Wetland A)

Notes: Ponding in *Wetland A* does influence the groundwater conditions in the north portion of the site based upon the modeled assumptions.



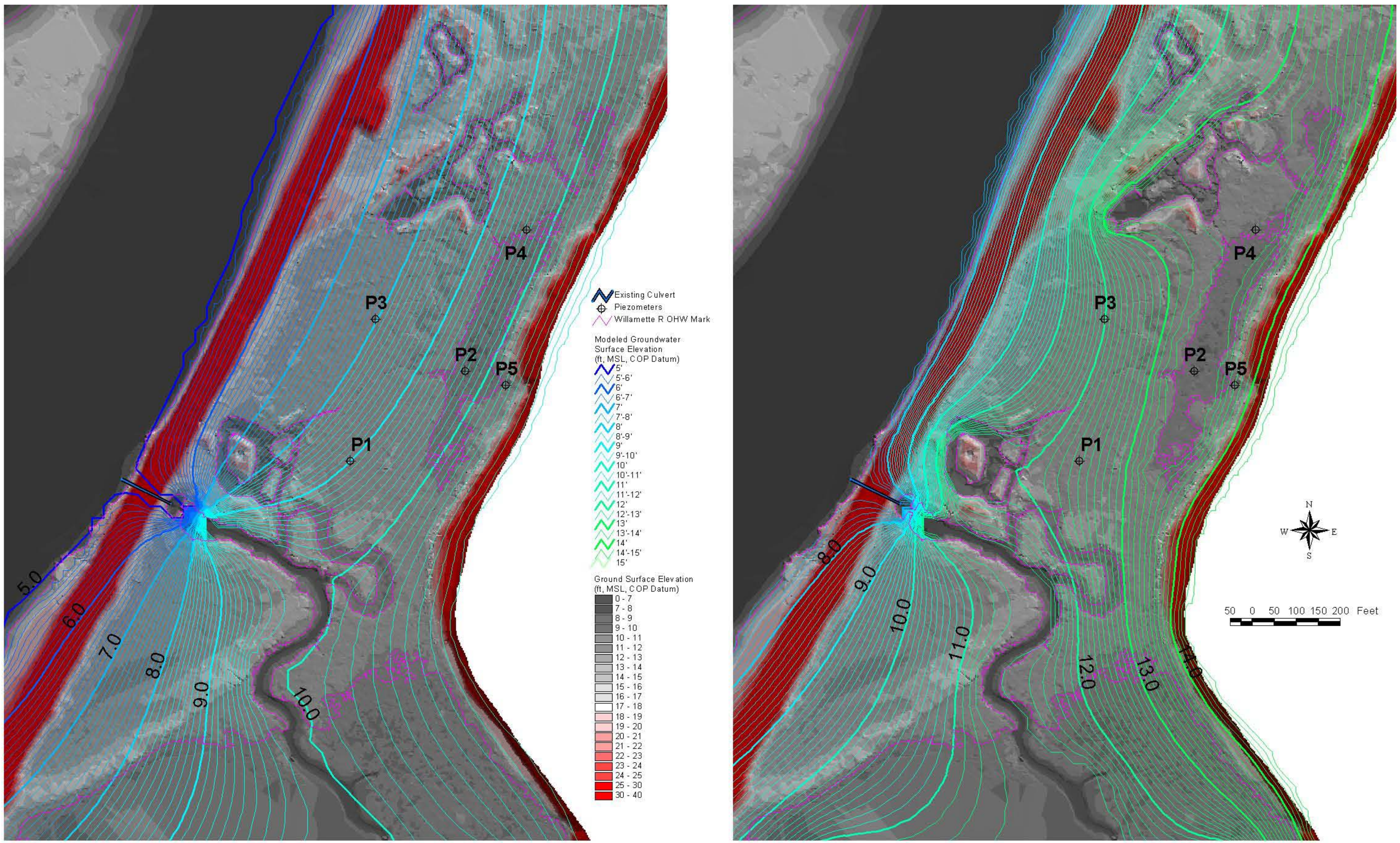
Scenario 3a, Rainy Season with High River, NOV-DEC-JAN-FEB Period
Surface Water/Ground Water Elevations: River 8.5', South Reservoir 12.0', Bluff 15.0'



Scenario 3b, Rainy Season with Ponding in North Wetland, NOV-DEC-JAN-FEB Period
Surface Water/Ground Water Elevations: River 8.5', South Reservoir 12.0', Bluff 15.0'

Figure 25c, Groundwater Modeling Results for Scenarios 4 and 5a Showing Low Groundwater under "drought" and "growing season" Conditions Respectively

Notes: The "growing season" model assumes surface water ponding in *Wetland A*. Scenario 5a is the existing base condition for comparing the three modeled design alternatives (Scenarios 5b... 5d).

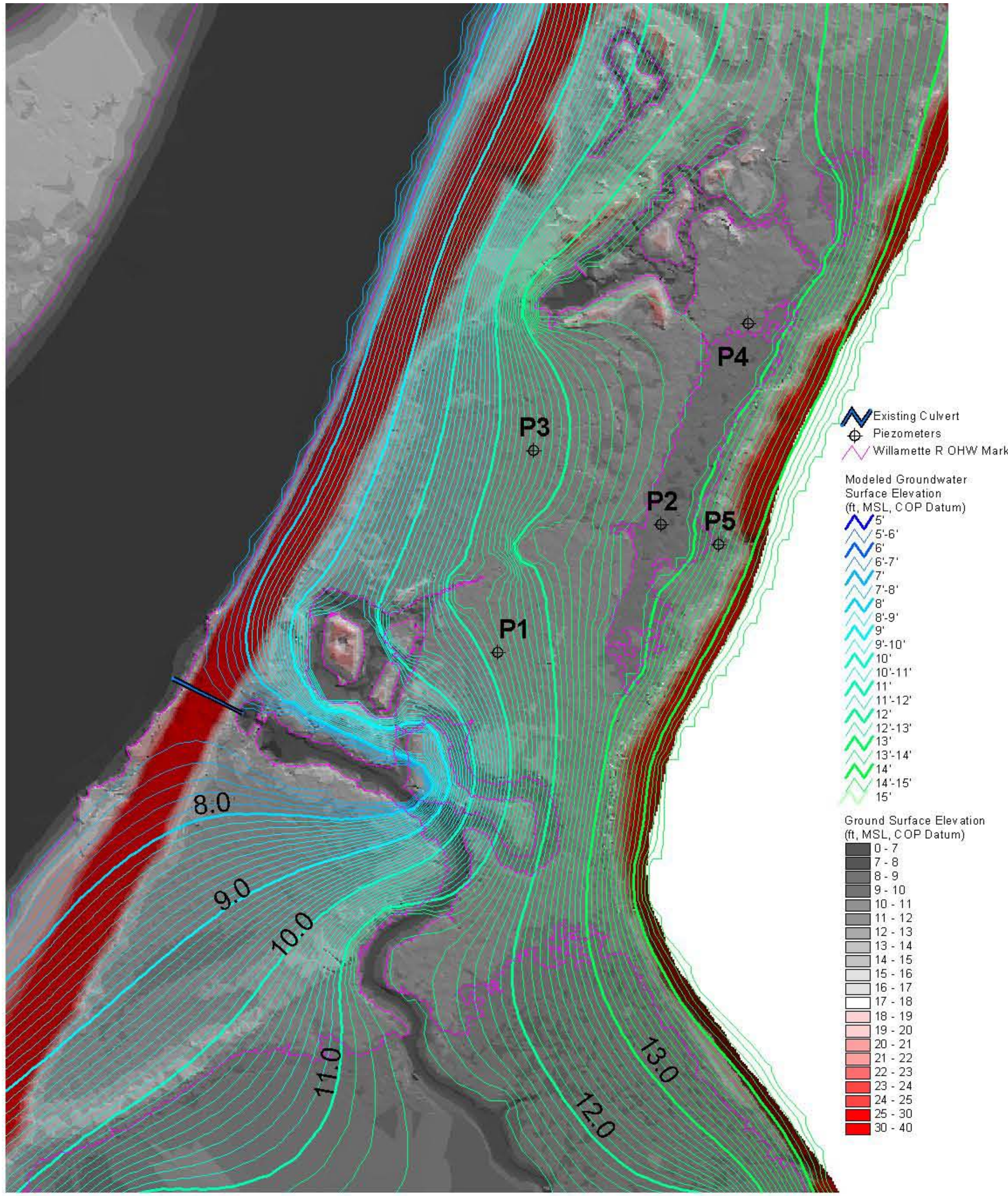


Scenario 4, Dought Conditions
Surface Water/Ground Water Elevations: River 5.0', South Reservoir 10.0', Bluff 11.0'

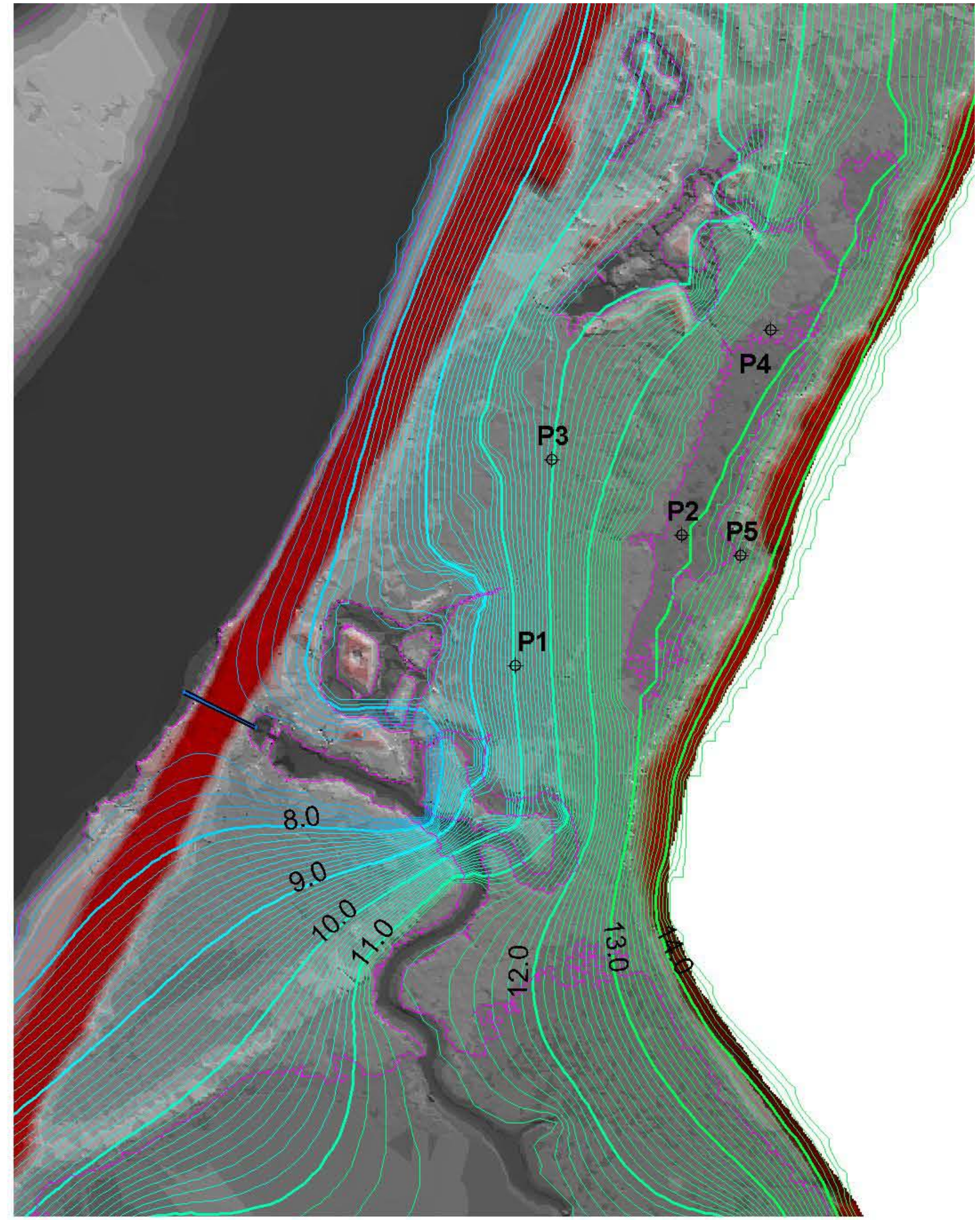
Scenario 5a, Median FEB-OCT Growing Season Conditions with Existing WCS
Surface Water/Ground Water Elevations: River 7.4', South Reservoir 11.4', Bluff 14.4'

Figure 25d, Groundwater Modeling Results for Scenarios 5b and 5c

Notes: 5c shows a slightly greater impact on *Wetland A* because of the connection it has to the north duck doughnut, through which it could drain.



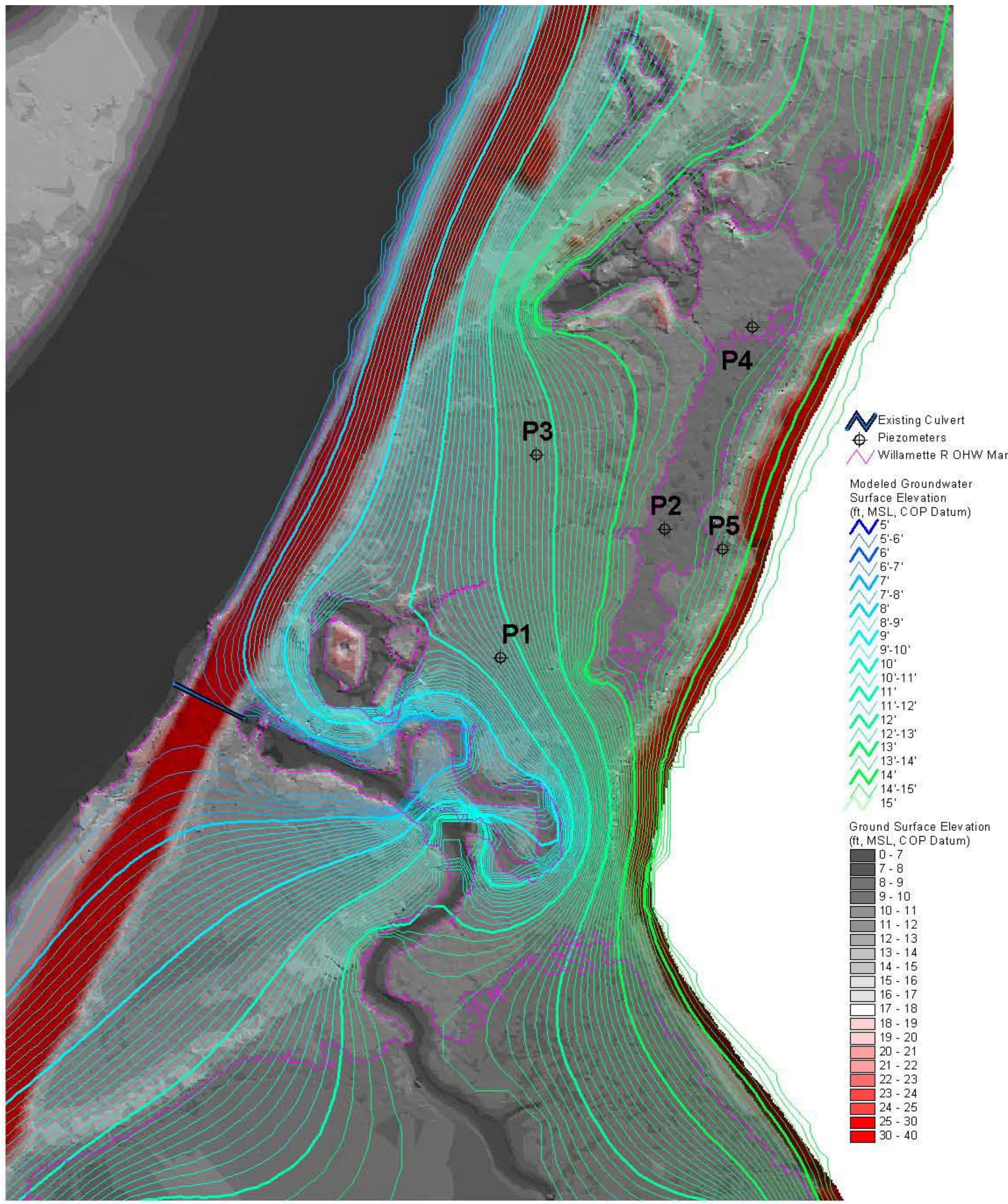
Scenario 5b, Median FEB-OCT Growing Season Conditions under Proposed Conditions
Surface Water/Ground Water Elevations: River 7.4', South Reservoir 11.4', Bluff 14.4'

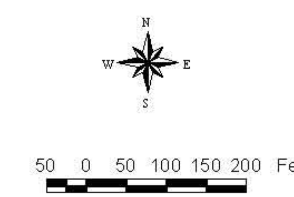


Scenario 5c, Median FEB-OCT Growing Season Conditions under Revised Proposed Conditions
Surface Water/Ground Water Elevations: River 7.4', South Reservoir 11.4', Bluff 14.4'

Figure 25e, Groundwater Modeling Results for Scenario 5d

Notes: This modeled option has the least effect on *Wetland A.*





Scenario 5d Median FEB-OCT Growing Season Conditrions with Excavation in Existing Channel Only
Surface Water/ Ground Water Elevations: River 7.4', South Reservoir 11.4' Bluff 14.4'

Figure 26, Depth to Groundwater Map for FEB-OCT Growing Season