January 2014

FOREST GROVE WASTEWATER TREATMENT FACILITY

South Wetlands Basis of Design Report

FERNHILL
DESIGNTEAM

Project Lead:

Clean Water Services

FERNHILL DESIGNTEAM

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Tables and Figures

Acronyms and Abbreviations

7ADAM	7-Day Average Daily Maximum
AWTF	Advanced Wastewater Treatment Facility
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BGS	Below ground surface
CEC	Contaminants of Emerging Concern
CFS	Cubic feet per second
DEQ	Department of Environmental Quality (Oregon)
DO	Dissolved oxygen
DOGAMI	Department of Geology and Mineral Industries (Oregon)
DSL	Department of State Lands (Oregon)
FEMA	Federal Emergency Management Agency
FOFW	Friends of Fernhill Wetlands
FWS	Free Water Surface
GPD	Gallons per day
HLR	Hydraulic Loading Rates
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HRT	Hydraulic retention time
MBR	Membrane Bioreactor
MGD	Million gallons per day
NGVD	National Geodetic Vertical Datum
NLR	Nutrient Loading Rates
NREL	National Renewable Energy Laboratory
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NTS	Natural Treatment System
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rules
OBIC	Oregon Biodiversity Information Center
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife
ODSL	Oregon Department of State Lands
ORS	Oregon Revised Statute
OSUES	Oregon State University Extension Service
PPCP	Pharmaceuticals and Personal Care Products
RO	Reverse Osmosis
RTE	Rare, Threatened, and Endangered Species
SHPO	State Historic Preservation Office
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorous
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture

USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAC	Washington County
WCD	Washington County Datum
WSE	Water surface elevation
WWTF	Wastewater Treatment Facility

Executive Summary

Clean Water Services (the "District") is converting three existing sewage lagoons into a Natural Treatment System (NTS). The NTS will include a series of emergent wetland cells and an open water pond. The configuration of the design will allow for flexibility in management intended to achieve multiple goals. Foremost among these goals is the reduction of water temperatures and increase in dissolved oxygen before discharge to the Tualatin River. Additional treatment benefits include the potential of removal of metals and nutrients. The design will create complex and diverse habitats, including open water, mudflat, emergent marsh, scrub-shrub, and upland areas, that will support wildlife, provide recreational functions, and create educational opportunities. The key elements of the Basis of Design that is presented in this report are summarized in Table ES-1.

Table ES-1 Summary of basis of design evaluation results.

Evaluation	Results
Wetlands Temperature Modeling	The model predicts significant cooling across the treatment wetlands during most time periods. Average monthly cooling in the wetlands for a 6.3 MGD flow may be as much as 1 ^{o}C in July and 6.0 ^{o}C in November.
Dissolved Oxygen	It is predicted that the wetlands and constructed cascades will maintain dissolved oxygen concentrations of at least 6.0 mg/L in the discharge to the Tualatin River.
Water Quality: Nutrients	Due to the low levels of nitrogen and phosphorus entering the South Wetlands, the potential for nutrient reduction is minimal.
Water Quality: Metals	There is modest potential of reduction of metals in the wetland complex.
Habitat	The layout of the proposed design will replace the relatively homogenous open water conditions with a complex configuration of diverse habitat types, including wetlands, mudflats, open water, and uplands. These habitats are expected to support wildlife, including amphibians, reptiles, birds, and mammals. Observation from nearby reference marshes have been reviewed to identify a planting palette of native species adapted to similar conditions.
100-Year No Net Rise Analysis	The proposed grading plan for the South Wetlands does not alter the elevations of the existing berms located within the mapped 100-year floodplain. In addition, all three sewage lagoons are identified as Ineffective Flow Areas within the FEMA Effective Model. Consequently the proposed grading will result in No Net Rise.
Trails Plan	The proposed design includes improvements to enhance recreational and educational opportunities for visitors focused along the northern edge of the site and includes maintenance trails.
Hyporheic Discharge	Results from soil borings suggest that the soil types are not highly favorable for the hyporheic discharge. As a result, this element will not be included with ongoing design.

The estimated program cost of design and construction work proposed at the South Wetlands is approximately $5.7 million. As design continues, it is anticipated that there will be some additional decision-making and trade-offs between the many design components. This could include, for example, adjusting some design elevations to further reduce the import of fill and the configuration of associated targeted habitats.

1 Overview

1.1 Background and Purpose

This report describes the basis of design for the South Wetlands component of the Fernhill Natural Treatment System (NTS), which is an expansion project of the Forest Grove Wastewater Treatment Facility (WWTF). The Forest Grove WWTF and Fernhill NTS are located on the approximately 750 acre Fernhill site, depicted in Figure 1-1. The report includes a physical characterization of the site, the project goals, and a preliminary site and wetland plan. The preliminary plan was developed from the review of precedents, alternatives, and preliminary engineering reports by others and those produced as part of the present design effort.

Clean Water Services (the "District") has initiated a planning process to convert three former sewage lagoons surrounded by earthen berms to a functional wetland system. By converting the lagoons to a wetland complex, the District seeks to enhance the aquatic and terrestrial habitat while improving water quality, primarily by reducing water temperature before its discharge to the Tualatin River.

The Forest Grove WWTF is one of the four wastewater treatment facilities owned and operated by the District in the Tualatin River basin. The four District facilities include the Forest Grove WWTF, the Hillsboro WWTF, the Rock Creek Advanced Wastewater Treatment Facility (AWTF), and the Durham AWTF. The project would treat wastewater at the Forest Grove and Hillsboro WWTFs, direct it through the proposed 90-acre natural treatment system at Forest Grove, and discharge the treated wastewater to the Tualatin River. Under the planned system, the Forest Grove and Hillsboro WWTFs will be capable of providing advanced secondary treatment, which will include seasonally dependent nitrification and biological phosphorus removal. The effluent from the Forest Grove and Hillsboro WWTFs would then receive additional treatment (including nitrification and denitrification) at the Fernhill NTS prior to discharge to the Tualatin River through the existing Forest Grove WWTF outfall structure.

Once operational, discharges from the Forest Grove and Hillsboro (summertime only) WWTFs are expected to be 5 million gallons per day (MGD) annually. Expected dry weather flows are summarized in Table 1-1.

Table 1-1 Current and projected flows at the Forest Grove WWTF

Flow Rate (MGD)	Condition
4.0	Flow rate used in temperature model calibration
5.0	Current annual baseline flow
6.3	Projected 2025 baseline flow
9.0	Phase 1 expansion future potential flow
18.0	Phase 2 expansion future potential flow

In addition, discharges of treated water into the wetland system may vary diurnally in response to variations in the rate of delivery to WWTF. As a result, the hydrology of the NTS will differ from natural seasonal variations that are typical of local streams and wetlands. The design seeks to incorporate ecological components, such as an adaptable planting palette, that will be consistent and ultimately successful given these underlying physical conditions.

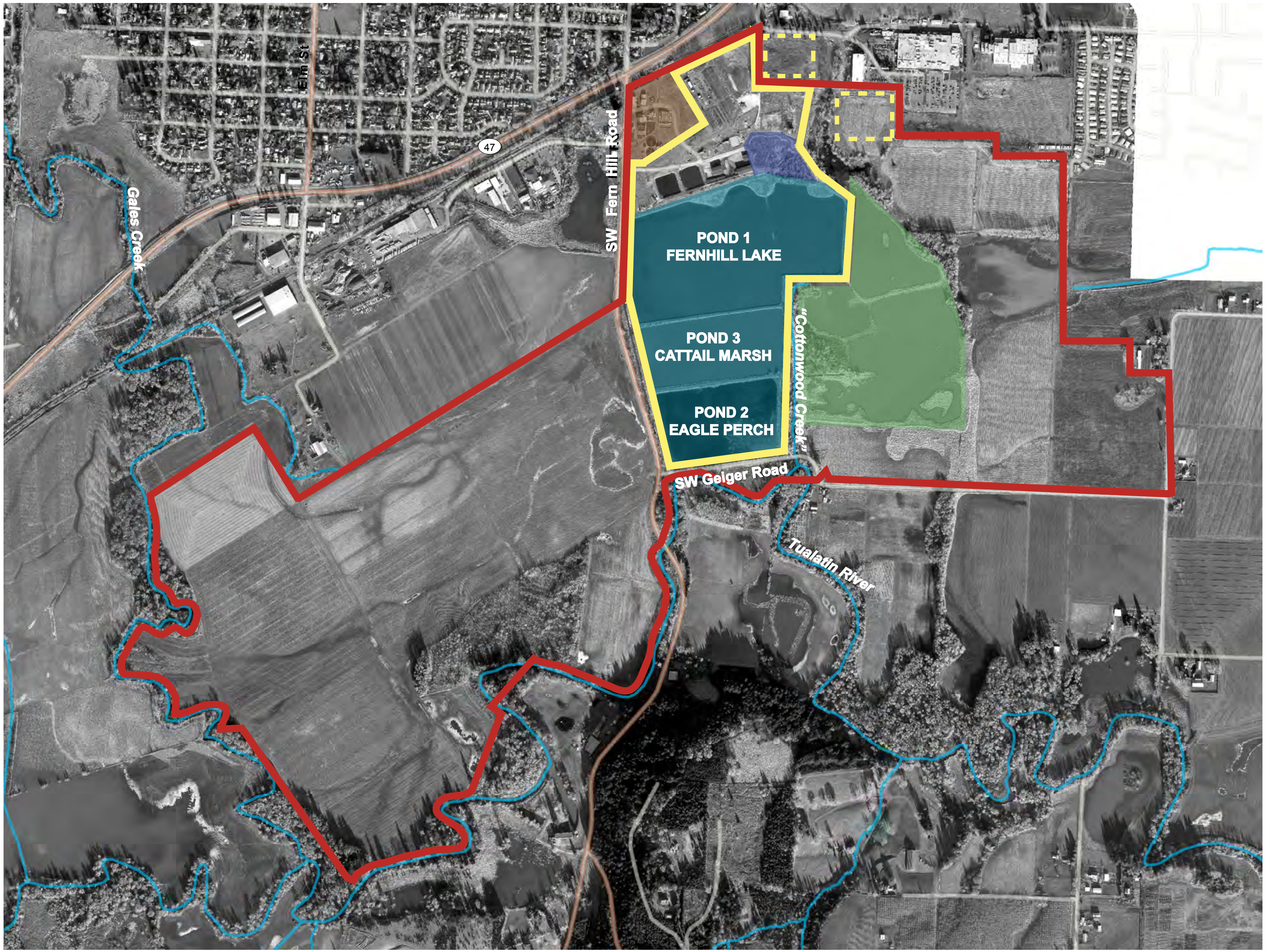

Figure 1-1
Basis of Design
Fernhill Site

South Wetlands
Forest Grove, OR

Legend

- Major Roads
- Streets
- Streams
- Fernhill Site
- Fernhill NTS
- Potential Fernhill NTS
- South Wetlands
- Phase 1A (Existing Lower Treatment Wetland, Restorative Water Garden)
- Barney Mitigation Wetlands
- Forest Grove WWTF

N

0 500 1,000 2,000 Feet

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The Forest Grove WWTF is part of the broader Fernhill Site (Figure 1-1). The Fernhill Site includes agricultural lands to the west and east of the Forest Grove WWTF, the Barney Mitigation Wetlands immediately east of South Wetlands, and riparian forest along the Tualatin River. The Fernhill NTS is comprised of the North Wetlands (with Upper, West, and Lower Treatment Wetland components) and South Wetlands (the focus of this report).

During the earlier stages of design conceptualization, CH2M HILL produced a series of documents summarizing the project goals for the NTS and the basis of design. Since the development of CH2M HILL's concept plans, the project goals emphasize temperature reduction, aeration, habitat creation and passive recreation. The primary goal of the restoration is to convert the sewage lagoons to a mosaic of wetland and deep-water habitats that serve to lower water temperatures of wastewater effluent before they enter the receiving waters while providing a diversity of native habitats for aquatic, terrestrial and avian wildlife. To achieve this, the design includes recontouring within the existing lagoons and reconnecting graded areas with the existing earthen berms.

The Fernhill Wetlands Design Team and other project partners refined project goals during several workshops. Goals for design development and site management include:

- Achieve water quality standards and water quality based effluent limits
- Mimic geomorphic & hydrologic patterns/processes
- Integrate the project with the Tualatin River watershed context
- Identify and restore habitats for species groups
- Create a resilient system (considering flood, dry periods, seasonal inputs, diurnal changes)
- Manage flows while maximizing flexibility, control and habitat creation
- Provide a balanced system for water health
- Integrate the site into the community and regional trail systems and accommodate passive recreation
- Develop passive recreation, educational opportunities and visitor experience
- Develop a future adaptive management plan/program to help ensure long-term success

1.2 Site Location and General Description

The existing Fernhill South Wetlands site lies directly west of Portland, Oregon, in the Tualatin River floodplain, a productive ecosystem with great conservation value to migratory and resident birds and other wetland-dependent species. The project area is entirely within an approximately 750 acre tract of land held by the District, much of it within the 100-year floodplain of the Tualatin River.

The South Wetlands site has undergone a series of modifications due to a wide range of historical anthropogenic uses, including tilling, diking for crops, and pig farming. This historical legacy has acted together with the current management practices and ongoing ecological processes to produce the site characteristics we observe today.

The South Wetlands are bounded by Southwest Fern Hill Road and the adjacent drainage ditch to the west, the treatment plant and landscaped gardens to the north, an unnamed creek, referred to in this report as "Cottonwood Creek", and Barney Mitigation Wetlands to the east, and Southwest Geiger Road and the Tualatin River to the south. The South Wetlands are comprised of three historic sewage lagoons that together represent approximately 90 acres of open water. Class A recycled water produced at the District's Rock Creek Advanced Water Treatment Facility currently can be introduced to the wetland system from the northeast corner of the South Wetlands project site through an existing restorative water garden and waterfall feature (Figure 1-1).

1.3 Intended Audience

This basis of design report was written for:

- DEQ regulatory staff for review, as a source of information for permitting.
- Managers and staff of the District and design team to provide reference for design.

As documented in the Clean Water Services NPDES permitting report for the project submitted to DEQ in 2013 (Clean Water Services, 2013a), the project is being initially permitted for flows up to those expected in 2025. Flows in excess of that are presented in this document for design purposes and potential future use beyond 2025.

2 Regulatory Context

The District's four wastewater treatment facilities (Durham, Rock Creek, Hillsboro, and Forest Grove) and its municipal stormwater program are covered under a watershed-based NPDES permit. The District's watershed-based NPDES permit was issued in 2005 and expired in 2009; the District submitted an application to renew its watershed-based NPDES permit in 2008 and continues to operate under the terms and conditions of the 2005 watershed-based NDPES permit until such time as DEQ renews the permit.

The current watershed-based NPDES permit does not authorize dry season discharge from the Hillsboro and Forest Grove WWTFs. The District is pursuing renewal of the NPDES permit that will allow for dry season discharges from the Forest Grove and Hillsboro WWTFs (Clean Water Services, 2013a). As part of that effort, the District is enhancing the treatment capabilities at the Forest Grove WWTF and the nearby Hillsboro WWTF as part of a larger West Basin management strategy that is establishing facilities plans for the integrated operation of the Rock Creek, Forest Grove, and Hillsboro WWTFs. Currently the Forest Grove and Hillsboro WWTFs treat wastewater and discharge to the Tualatin River during the wet season and transfer the wastewater to the Rock Creek AWTF for treatment and discharge during the dry season. The District is proposing to treat wastewater at the Forest Grove and Hillsboro WWTFs, provide additional treatment through a 95-acre natural treatment system (NTS) at Forest Grove, and discharge treated wastewater to the Tualatin River during the dry season. Under this proposal, the Forest Grove and Hillsboro WWTFs would provide advanced secondary treatment, which would include nitrification and biological phosphorus removal, as needed, during the dry season. The effluent from the Forest Grove and Hillsboro WWTFs would then receive additional treatment at the Fernhill NTS prior to discharge to the Tualatin River through the existing Forest Grove WWTF outfall structure (F001). The Forest Grove and Hillsboro WWTFs will continue to provide conventional secondary treatment and discharge to the Tualatin River through their respective outfalls during the wet season.

The Fernhill NTS is designed to reduce temperature and nutrients, provide wetland habitat and recreational benefits, and improve the overall water quality of the discharge to the Tualatin River. The Fernhill NTS consists of the North Treatment Wetlands and the South Wetlands. The North Treatment Wetlands is an engineered treatment system consisting of surface and subsurface treatment systems and is designed to remove excess nutrients and potentially metals in the effluent from the WWTFs. The South Wetlands consists of surface wetlands and an open water feature and is designed to reduce temperature and meet dissolved oxygen requirements.

2.1 Water Quality Design Criteria

The two primary water quality treatment goals for the South Wetlands project are to reduce temperature and increase dissolved oxygen during the low flow period (i.e. dry season). In addition, it is anticipated that the South Wetlands will improve overall water quality of the discharge by further reducing nutrients, metals, and other trace constituents. For future operations in the year 2025, the average dry season effluent flows to the Tualatin River via the Fernhill NTS are estimated to be 6.1 MGD following natural treatment (6.3 MGD into the South Wetlands prior to treatment).

The discharge limits are determined in part by whether the Tualatin River is in a "low flow period" or "high flow period." These periods are defined in terms of specific river flows (as measured at the Farmington Gage) and the calendar date. Typically, the low flow period is from early to mid-May to October, and the high flow period is from November to April/early May.

In addition to WWTF effluent compliance monitoring, monitoring of the NTS will be conducted to validate the anticipated additional treatment for selected pollutants made in the design of the treatment system. The District anticipates monitoring the effluent from the NTS for nutrients, metals, dissolved oxygen and temperature to demonstrate the effectiveness and functionality of the natural treatment system in meeting applicable water quality standards and TMDL allocations. Anticipated dry season effluent concentrations for key water quality parameters are presented in Table 2-1.

Table 2-1 Summary of South Wetlands water quality parameters

	Temp	DO (mg/L)	$NH_{3-})N$ (mg/L)	NO_{3-} (mg/L)	TP (mg/L)	Cu (mg/L)
Dry Weather Influent Quality to South Wetlands	varies	varies	0.2	2.0	0.5	0.0074
Target Effluent Parameters	≤ CE-QUAL-W2 Input[1]	6.0	n/a	n/a	n/a	0.006
Expected Effluent Quality[2]	≤ CE-QUAL-W2 Input[3]	≥ 6.0	n/a	n/a	n/a	<0.006

n/a = not applicable
[1] USGS modified version of the CE-QUAL-W2 model (Version 3.12) by CH2M HILL, 2012a.
[2] Based Projected 2025 baseline – 6.3 MGD is moving through the emergent wetlands (not the Lake).
[3] See Temperature Modeling in Section 5.7.

2.1.1 TEMPERATURE REDUCTION

Previous studies have modeled the temperature reduction that is expected in the NTS at the South Wetlands (CH2M HILL, 2012a). Those temperature reduction results were used as inputs to the USGS modified version of the CE-QUAL-W2 model (Version 3.12) which determined the mixed temperature of the NTS effluent and Tualatin River. Results from this modeling effort meet the “rearing and migration” criteria of 18 degrees C and do not contribute to increased temperature in the section of the Tualatin River below Farmington where the river currently exceeds temperature criteria and is water quality limited for temperature. Thus the results were the motivation to move the project forward. The target of this latest effort and update to the Fernhill South Wetlands design is to match or exceed the temperature reduction modeled in the previous basis of design (CH2M HILL, 2012a). Results of updated temperature modeling simulating the current design configuration are detailed in Section 5.7.

2.1.2 DISSOLVED OXYGEN

Similar to temperature criteria, the CE-QUAL-W2 model was used by the District to predict dissolved oxygen levels and water quality effects in the river below the discharge from the Fernhill NTS. Near the discharge, the Tualatin River has high dissolved oxygen levels as a result of the stored water releases from Hagg Lake, including the District’s own stored water releases. Dissolved oxygen levels in the Tualatin River above Forest Grove WWTF discharge are typically around 10 mg/L or higher. The Fernhill NTS target effluent criteria is 6 mg/L, consistent with the requirements specified for the Tualatin Basin in the Oregon Administrative Rules (OAR 340-041-0345). A 6 mg/L discharge would result in a slight decrease in the dissolved oxygen levels; however, the resulting dissolved oxygen levels in the river would still be well above applicable criteria (Clean Water Services, 2013a).

2.2 Additional Water Quality Considerations

2.2.1 NITRATE AND PHOSPHORUS REDUCTION

Nutrient reduction is not a primary goal or criteria of the South Wetlands; however, it is understood that some reduction potential exists. Background levels of nutrients and/or contributions from seasonal flooding and bird migration may negate any realized nutrient reduction. An understanding of the nutrient reduction potential of the NTS may allow the WWTF to optimize high rate treatment processes and achieve a more efficient overall system and/or assist in achieving the bubbled mass load for ammonia and phosphorus. Water quality modeling results for nitrate and phosphorus are summarized in Section 5.9 and detailed in Appendix A.

2.2.2 REDUCTION OF METALS

Metals reduction is not a primary goal or criteria of the South Wetlands; however, it is understood that some reduction potential exists. An understanding of the metals reduction potential of the NTS will allow the District to better protect the environment and be more prepared for future decreases in the permitted Total Maximum Daily Limits (TMDLs). Regulated metals include copper, lead, nickel, and zinc. Results of water quality modeling and existing permitting conditions are summarized in Section 5.9 and detailed in Appendix A.

2.3 Permitting Pathway

Previous reports completed by CH2M HILL (2010 and 2012a) for the NTS identified the potential environmental permitting requirements for the project. These documents cite 10 to 12 potential environmental permits or regulatory approvals at the federal, state, and local levels. All construction work will occur within the footprint of the existing wastewater lagoons and property owned by the District, thus many of the federal and state permits may no longer be relevant.

Additionally, the design for the NTS initially included hyporheic discharge to the Tualatin River; however, preliminary analysis indicated limited potential for hyporheic discharge. This aspect of the design has since been eliminated and thus simplifies the subsequent permitting pathways.

<u>Short-term Permitting Pathway</u>

Analysis of the South Wetlands design predicts no change in water surface elevation for the 100-year event and negligible effects on flood depths, duration and frequency of Fern Hill Road (Sections 5.6). This will limit some of the permitting needs anticipated for the project.

The existing wastewater lagoons and current design footprint are within the city limits of the City of Forest Grove (City of Forest Grove, 2013). Should future work occur east of the top of the east berm (for example in the area between the east berm and Cottonwood Creek), land use permits from the Washington County Land Use and Transportation Department would need to be procured. It is likely that land use permitting will be sought for the entire Fernhill NTS site, with varying certainty in terms of exact final use.

Table 2-2 presents potential permits or regulatory approvals and the associated agency, regulatory authority, and timeline when they are known. Figure 2-1 presents the short-term permitting pathway. The District will be responsible for procuring all required permits for construction of the project. Permits with an asterisk (*) in Table 2-2 are those that may be required if federal or state authorities determine that this project falls under Section 404 of the Clean Water Act or under the Oregon Removal-Fill Law. CH2M HILL's (2010) Appendix A, Environmental Permitting Strategy Technical Memo contains detailed information on many of the regulations cited in the table.

2.3.1 LONG-TERM PERMITTING PATHWAY

The long-term goals for the site include connecting the South Wetlands to the Barney Mitigation Wetlands and to Cottonwood Creek. Either of these projects would involve work in federal waters or waters of the state and would fall under Section 404 of the Clean Water Act and the Oregon Removal-Fill Law. Permits marked with an asterisk in Table 2-2 would need to be pursued at that time.

These long-term projects would also affect the NPDES permit for Forest Grove WWTF. Permitting activities for these projects may take several years. Development of a permit task list and schedule well in advance of pursuing these long-term projects with the NPDES permit renewal application is recommended.

Figure 2-1
Basis of Design

Short Term Permitting Pathway

South Wetlands
Forest Grove, OR

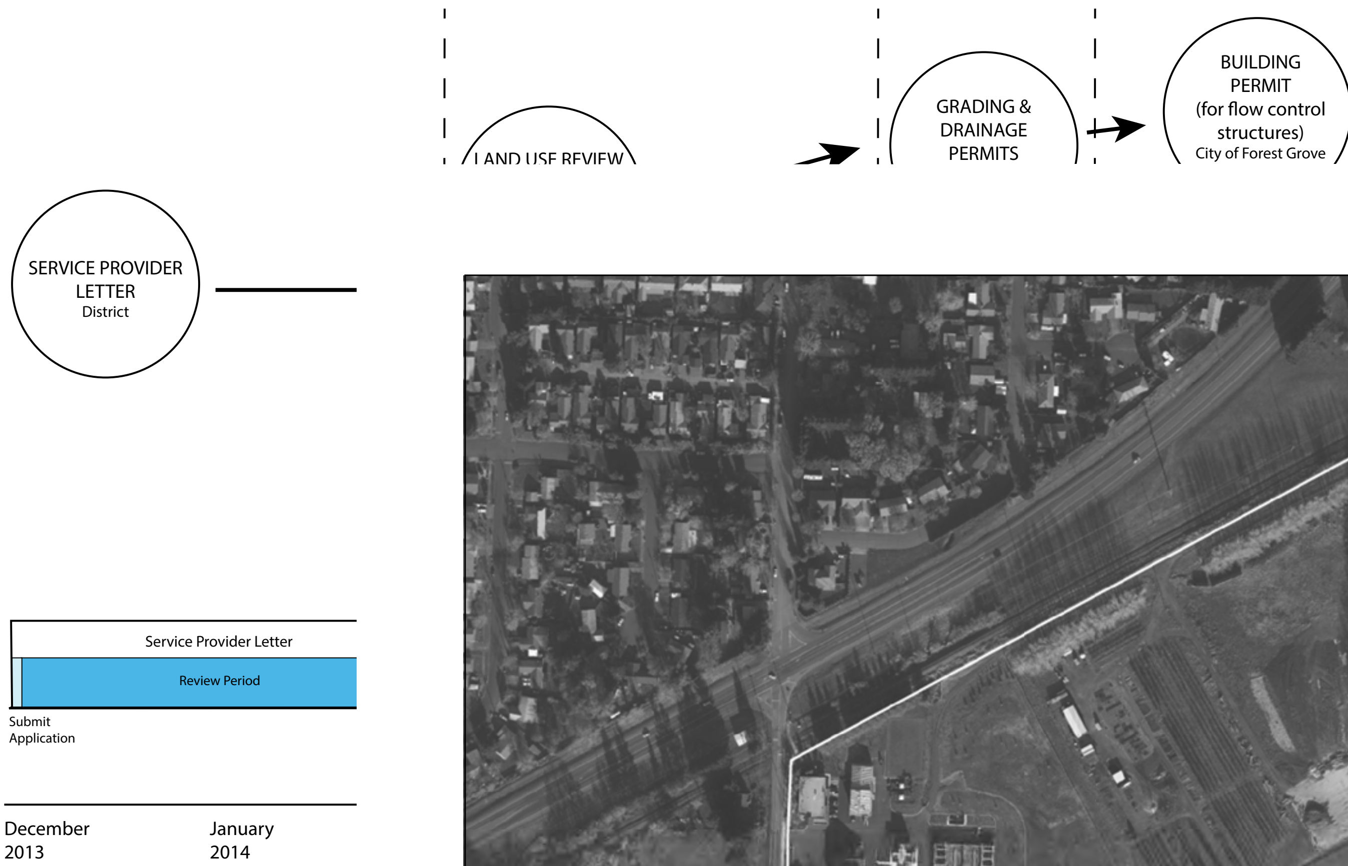

Table 2-2 Short-term permitting pathway.

Permit or Regulatory Approval	Agency	Regulation	Timeline	Other Notes
Section 404 (wetlands) permit*	USACE	Clean Water Act, Section 404	3-4 months to process	All other potential federal permits need to be completed prior to issuance.
Endangered Species Protection*	USFW, NOAA	Federal Endangered Species Act, Public Law 93-205	Incidental take permit: 6-9 months	RTE data received from Oregon Biodiversity Information Center. 11 element occurrence records in 2 mile radius of project.
Fish & Wildlife Coordination*	NOAA, ODFW	Fish and Wildlife Coordination Act of 1934		
Section 401 Water Quality Certification*	DEQ	Clean Water Act, Section 401	60-90 days	
Cultural Resources Review*	SHPO	Section 106, Historic Preservation Act of 1966; Executive Order 11593		2010 BoD recommended survey due to site proximity to Tualatin River. 2012 BoD states all work done on previously disturbed site, so unnecessary.
National Pollutant Discharge Elimination System	DEQ	Clean Water Act, Section 402; OAR 340-045	6-9 months	
Oregon Removal & Fill Permit*	DSL	Oregon Removal-Fill Lay (ORS 196.800-990)	90 days	Fernhill potentially exempt per OAR 141-085-0515(7) as artificially created wetland, but DSL may be interested in work in floodplain and connectivity to waters of the state.
Oregon Endangered	ODFW, ODA	Oregon State Endangered Species Act (ORS 496)		RTE data received from Oregon Biodiversity Information Center. 11 element occurrence records in 2-mile radius of project.
y	DEQ	State Agency Coordination Program (OAR Chapter 340, Division 18)	Concurrent with Land Use Review	Signed by Washington County or City of Forest Grove planner and submitted to District with 1200-C Permit.
vider	District	CWS Design & Construction Standards for Sanitary Sewer and Surface Water Management pursuant to Ordinance 27	2-4 months	
trol nit	District (DEQ)	OAR 340-045-0015 & 0033(5)		District is designated as DEQ Agent. Need LUCS to apply.
eview	City of Forest Grove	Forest Grove Development Code	2-3 months	Type II review.
rainage	City of Forest Grove	Forest Grove Development Code (Section 10)	2-3 months	No rise analysis submitted to City, but reviewed by County.
mit	City of Forest Grove	Forest Grove Building Code (Section 8)		Box culvert or water control structures may require building permits.
t	WA County			County desire for roadside frontage improvements along Fernhill Road.

m Section 3 of CH2M HILL (2010)

3 Landscape Setting

An important element in planning for future site work construction and ecological restoration within the study area is understanding the ecological patterns that have defined this area over time. This includes how the South Wetlands fit into the regional landscape at multiple spatial scales.

To illustrate the important ecological patterns and connections to the South Wetlands, simple graphics were prepared at two spatial scales using available GIS information. The layers used in the evaluation included regional streams, wetlands, outdoor recreation and conservation areas, and land cover. Major roads were included in the figure to provide further context. The following information was collected and compiled for the evaluation:

- Streams information was obtained from the Oregon Department of Geological and Mineral Industries (DOGAMI, 2013).
- Wetlands data were obtained from the 1998 National Wetlands Inventory (DOI, 1998) compiled by the US Fish and Wildlife Service with local updates by Metro. These updates include information from local jurisdictions in Washington, Clackamas, and Multnomah counties, and data collected during Metro's implementation of Title 13 Nature in Neighborhoods program.
- The Outdoor Recreation and Conservation Areas layer is from The Regional Conservation Strategy for the Portland-Vancouver Region (The Intertwine Alliance, 2012b). Outdoor areas are classified by ownership, and include federal, local, non-profits, special districts, state, and private. Private lands include golf courses, cemeteries, and properties owned by Home Owners Associations and were not included in the figure. The District's land is classified as a "Special District" in this GIS layer. Metro and the City of Forest Grove are other major land owners in the region, and are both classified as "Local."
- Land cover data was also obtained from The Regional Conservation Strategy for the Portland-Vancouver Region (The Intertwine Alliance, 2012c). The Regional Conservation Strategy team contracted with Portland State University's Institute for Natural Resources to create a 5 meter pixel resolution land cover map for the greater Portland-Vancouver area. The data set has three levels to choose from, with varying numbers of classes. Land cover level 0, with data grouped into 6 classes, was chosen for this exercise. Most importantly, the herbaceous, low-level vegetation and tree classes are displayed to depict landscape connections.

At the broadest landscape scale, the South Wetlands are located along the Pacific Flyway (Figure 3-1), one of four major avian migration routes in the continental United States. Flyways tend to follow natural geographical features, such as valleys, shorelines, and mountain passes that concentrate migrants and provide navigational guidance. The Pacific Flyway extends along the Pacific Coast from Alaska to Patagonia. Located between the Coast Range and the Cascade Mountains within the Willamette Valley, the South Wetlands fall along the natural migration corridor of the Pacific Flyway. The South Wetlands provide critical wetland and riparian habitat for resting and foraging migratory birds travelling the Pacific Flyway during spring and fall. The flyway serves as an important migratory route for shorebirds, raptors, waterfowl and pelagic birds, as well as butterflies, certain bats and dragonflies.

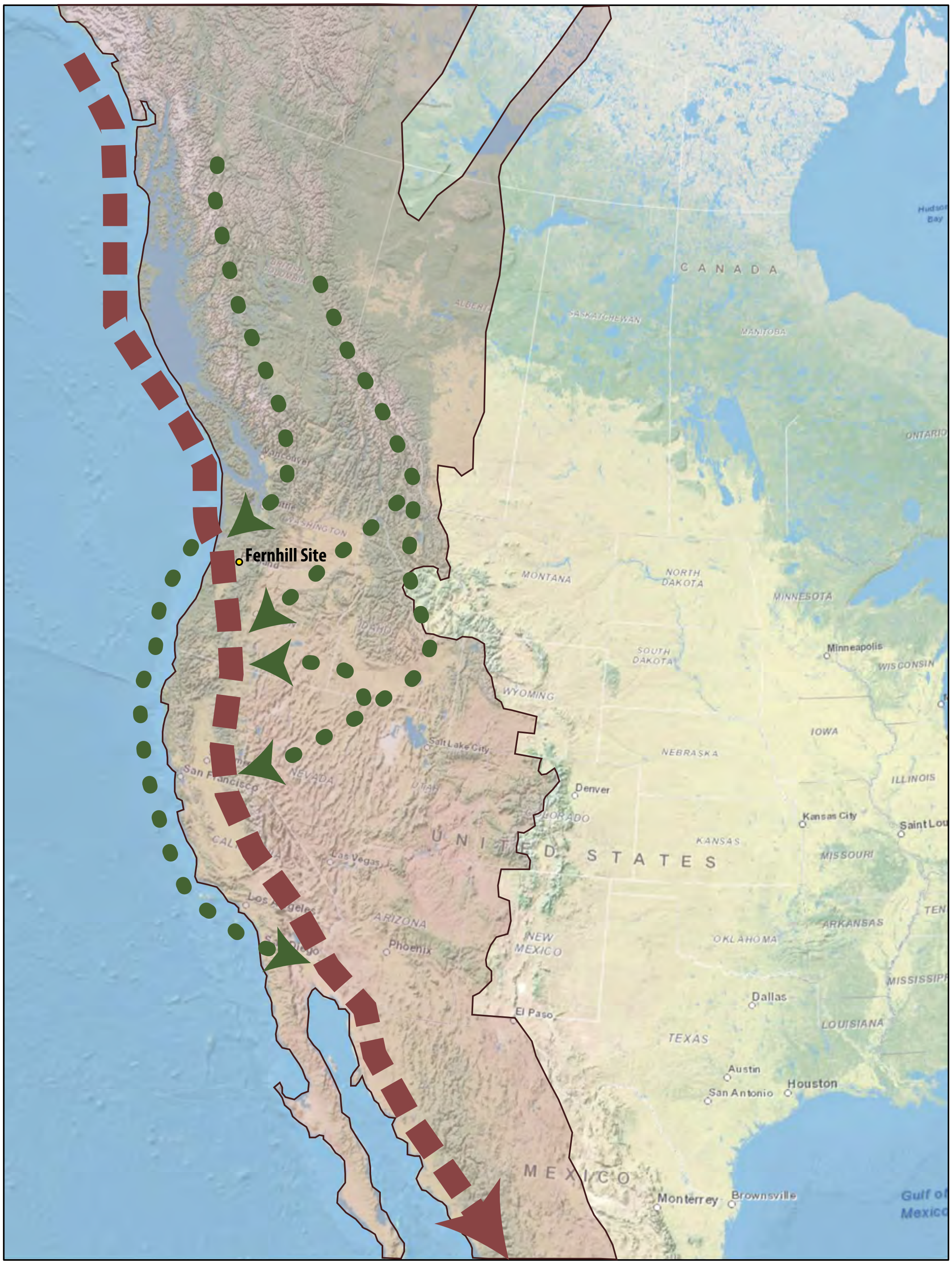

Figure 3-1

Basis of Design

Pacific Flyway with Major, Merging and Principal Routes

South Wetlands
Forest Grove, OR

Legend

MAJOR FLYWAY

PRINCIPLE ROUTE

Source: Pacific Migratory Bird Flyway data are based on an image of the Pacific Flyway presented on the web at http://www.birdnature.com/flyways.html. U.S. Migratory Bird Flyways obtained from U.S. Fish and Wildlife Service, 2003. Migratory Flyways Boundaries data obtained from Ducks Unlimited, 2005.

N

0 50 100 200 300 400 Miles

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At a local to regional scale, the location of the South Wetlands along the Tualatin River bottomlands makes it an important stepping stone and provides habitat patch connectivity in the network of conservation lands and local stream/wetland corridors that sustain resident wildlife and relatively short-distance migrants. The South Wetlands is positioned within a fragmented ecological landscape, with herbaceous and forest cover assuming a checkerboard pattern at multiple scales (Figure 3-2). The promotion of corridors and connectivity between patches of habitat is one conservation strategy to mitigate or abate the effects of habitat fragmentation. Interconnected blocks of habitat are better than isolated blocks, and dispersing individuals travel more easily through habitat resembling that preferred by the species in question. Figure 3-2 illustrates this concept by highlighting some of the important local connections between aquatic features and forest lands that are strengthened by the South Wetlands, including:

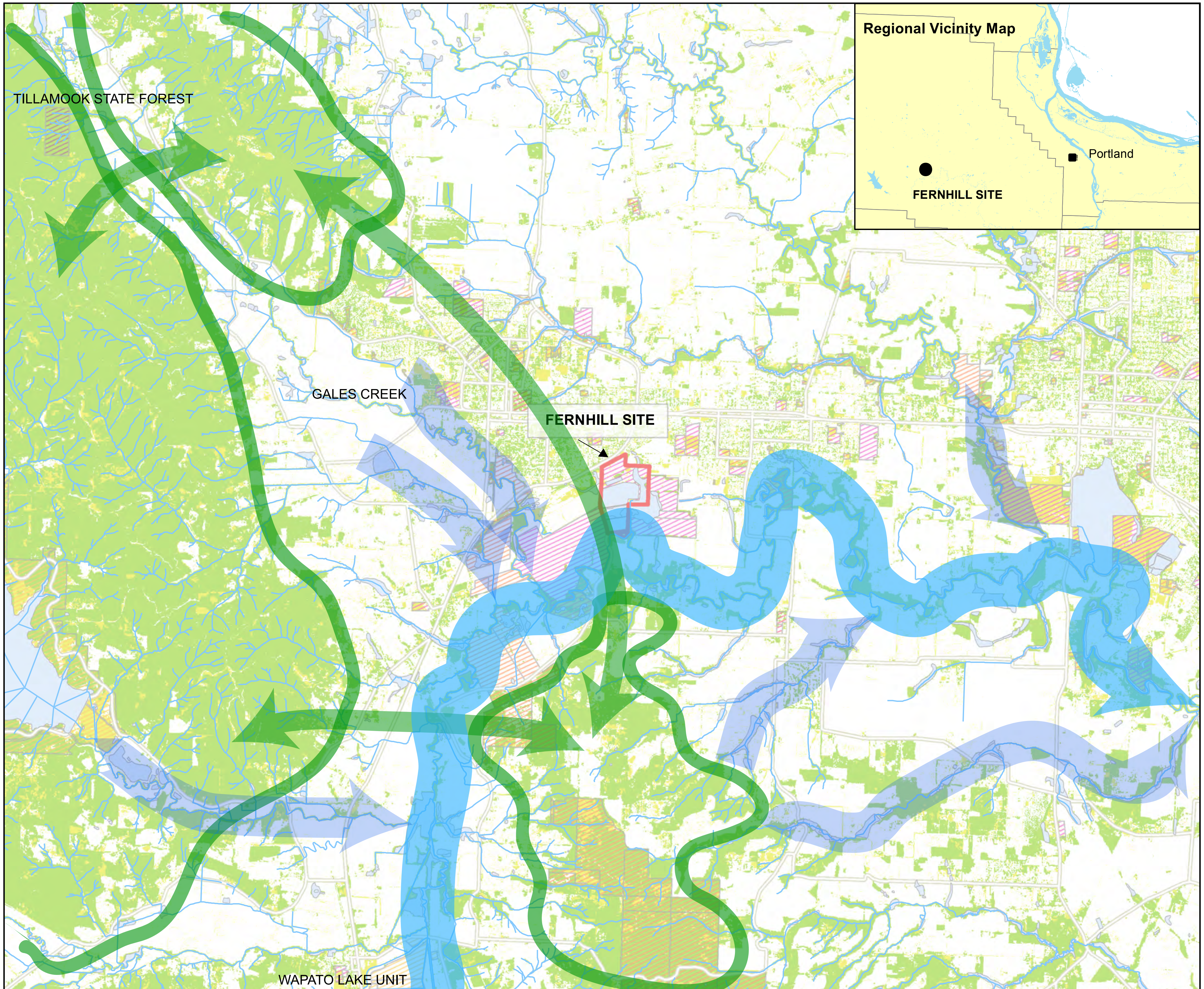
- The confluence between Gales Creek (to the northwest) and the Tualatin River.
- The Wapato Lake Unit of the Tualatin River National Wildlife Refuge (to the south) and Forest Grove.
- Tillamook State Forest (to the west) and numerous smaller parklands surrounding Forest Grove.

The presence of these connections reinforces the importance of maintaining habitats within the South Wetlands that will benefit endemic avian and terrestrial species. These habitats include riparian floodplain wetlands, mudflats, and the open water features that also occur in regional public lands and other natural and open space lands.

Figure 3-2
Basis of Design

Landscape Ecological Connections

South Wetlands
Forest Grove, OR



Legend

- Streams
- Wetlands
- Major Roads
- Fernhill Site

Outdoor Recreation & Conservation Area

- Federal
- Local
- Non-Profits
- Special District
- State

Land Cover

- Herbaceous vegetation
- Conifer & broadleaf trees over 30', large shrubs, small trees

Ecological Connections

- Tualatin River Corridor
- Contributing Stream / Wetland Corridors
- Forest Patch Connections

NOTES:
Datum: NAD 1983 HARN
Projection: Oregon State Plane North
Data Sources: OR DOGAMI, Metro RCS, Metro RLIS

0 0.5 1 2 Miles
N

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CASCADIA BIOREGION

4 Site Characterization and Assessments

To the extent practicable, the existing physical conditions at the South Wetlands were reviewed using past work efforts and available materials, such as relevant reports and mapping. The review was augmented by limited field reconnaissance and directed field inquiries, such as soil borings at specific locations and groundwater monitoring. The results from these efforts were intended to review the site conditions and identify opportunities and constraints to the design.

4.1 Key Existing Features

The three sewage lagoons comprising the South Wetlands are referred from north to south as Pond 1 (Fernhill Lake), Pond 3 (Cattail Marsh), and Pond 2 (Eagle Perch, named for an active nest at the east edge) (Figure 1-1). Each of the sewage lagoons is surrounded by earthen berms that have historically acted as storage reservoirs for treatment of wastewater. The three sewage lagoons have been managed to hold varying levels of water throughout the year. Water flowing through the sewage lagoons starts in Pond 1, flows to the southernmost Pond 2, then back to Pond 3, where it exits and is conveyed via an outfall pipe to the Tualatin River.

The South Wetlands consist of mostly open water habitat, with a fringe of herbaceous vegetation around the berms and some shrubs on berms. The herbaceous vegetation is dominated by the invasive reed canary grass (*Phalaris arundinacea*). Other invasive species present include species like yellow flag iris (*Iris pseudacorus*), Armenian or Himalayan blackberry (*Rubus armeniacus* or *Rubus discolor*), scotch broom (*Cytisus scoparius*), and nutria (*Myocastor coypus*), and are discussed further in Section 4.4.

Each of the three sewage lagoons has unique characteristics. Currently, Pond 1 hosts a large population of common carp (*Cyprinus carpio*) and has little vegetation. Pond 2 hosts more plant diversity and includes a variety of *Polygonum* species and rice cutgrass (*Leersia oryzoides*). A berm separates it from Pond 3, which is mostly open water and the lowest of the three sewage lagoons. Pond 3 also hosts a large population of common carp. The floodway regulated by the Federal Emergency Management Agency (FEMA) passes through Pond 3, so the berms to the east and west are several feet lower than those of the other ponds.

Both Cottonwood Creek and the swale along SW Fern Hill Road are incised and entrenched, and host distinct vegetation communities. Along Cottonwood Creek there is a mature tree canopy with a shrub underlayer. The predominant tree species in the upper canopy is black cottonwood (*Populus balsamifera ssp. trichocarpa*). Cottonwood Creek has been affected by beaver (*Castor canadensis*), and there is recent evidence of dam-building near the SW Geiger Road bridge. The swale on the west side of the South Wetlands is dominated by scrub-shrub vegetation. A few young cottonwoods are located at the southern end of the swale near SW Geiger Road.

The topography of the South Wetlands is of low relief. However, there are some key topographic features that define the site and its internal hydraulic function, and that relate to flooding in the broader landscape. The existing berms extend up to approximately 4 to 9 ft above the bottom of each of the three large rectangular sewage lagoons, and the water surface elevations are managed separately in each. The berms around the northernmost and southernmost sewage lagoons (Ponds 1 and 2) are higher than Pond 3 (located between the others). This low spot in the berms allows floodwaters from the Tualatin River to enter Pond 3, before flooding Ponds 1 and 2.

4.2 Public Access and Use

Currently, there are several on-site amenities that serve to engage the public and provide recreational experiences. A viewing stand is located on the southeast edge of Pond 1, permitting a place of rest for visitors and viewpoint of Barney Mitigation Wetlands to the east, and South Wetlands to the west. Around the edges of the ponds there is a gravel path, which allows access for maintenance and for visitors. A network of trails is available along the northeast side of the site. A parking lot, available to the public, is located on the northwest corner of the site, and provides views of Pond 1.

Although there are many nearby opportunities for forest hiking, Fernhill provides the best chance to visit a wetland, just a mile from the center of town. As the county's population leaves the 500,000 mark further behind, chances to escape into natural landscapes will grow more valuable. Therefore, the Fernhill South Wetlands Project has taken into account the current and projected values of the community.

Currently, the site's rich wetlands and the bird life they host are extremely popular among dedicated birders. The site is well-recognized by the birding community and is becoming increasingly popular for other users, who enjoy the trails and more generalized wildlife viewing. Pacific University and local high schools arrange regular visits to explore the habitats there and, with the assistance of the District, have organized tree plantings and other work days to enhance the natural areas.

Future use of the area to the north of the site owned by the District is planned to include additional natural treatment features. Construction in the Upper and West Wetlands areas is scheduled to take place subsequent to construction of the South Wetlands. Treatment will be the primary focus in those areas and public access will be incorporated into those areas as design progresses. Recognition of the future work has been taken into account as public access and use has been considered for the South Wetlands.

4.3 Soils

Several sources of information were used for the characterization of soils at the South Wetlands, including the NRCS USDA soil survey, as well as targeted soil borings conducted on-site. The NRCS USDA web soil survey (2013) was used to determine soil map units and physical characteristics of the soils underlying the South Wetlands. General results from the web soil survey for Pond 2 were compared to soil borings reported in a technical memorandum to the District (Kennedy/Jenks, 2013). In addition, the 2010 Natural Treatment System Basis of Design (CH2M HILL, 2010) contains a Soils Investigation Technical Memo that focuses on the ability of site soils to retain phosphorus, in addition to a brief description of the NRCS mapping units. An additional round of soil sampling and geotechnical investigation is underway; results will be available by February 2014.

The floodplains and bottomlands adjacent to the Tualatin River include the well-drained McBee-Chehalis soil association and the poorly-drained Wapato-Verboort-Cove soil association, formed in alluvium and old lacustrine material. The South Wetlands is comprised primarily of four soil types: Cove soils, Wapato soils, McBee soils, and Chehalis soils (Green, 1982). Figure 4-1 shows the soil series mapped within the South Wetlands.

Soil Map—Washington County, Oregon
(Fernhill South Wetlands)

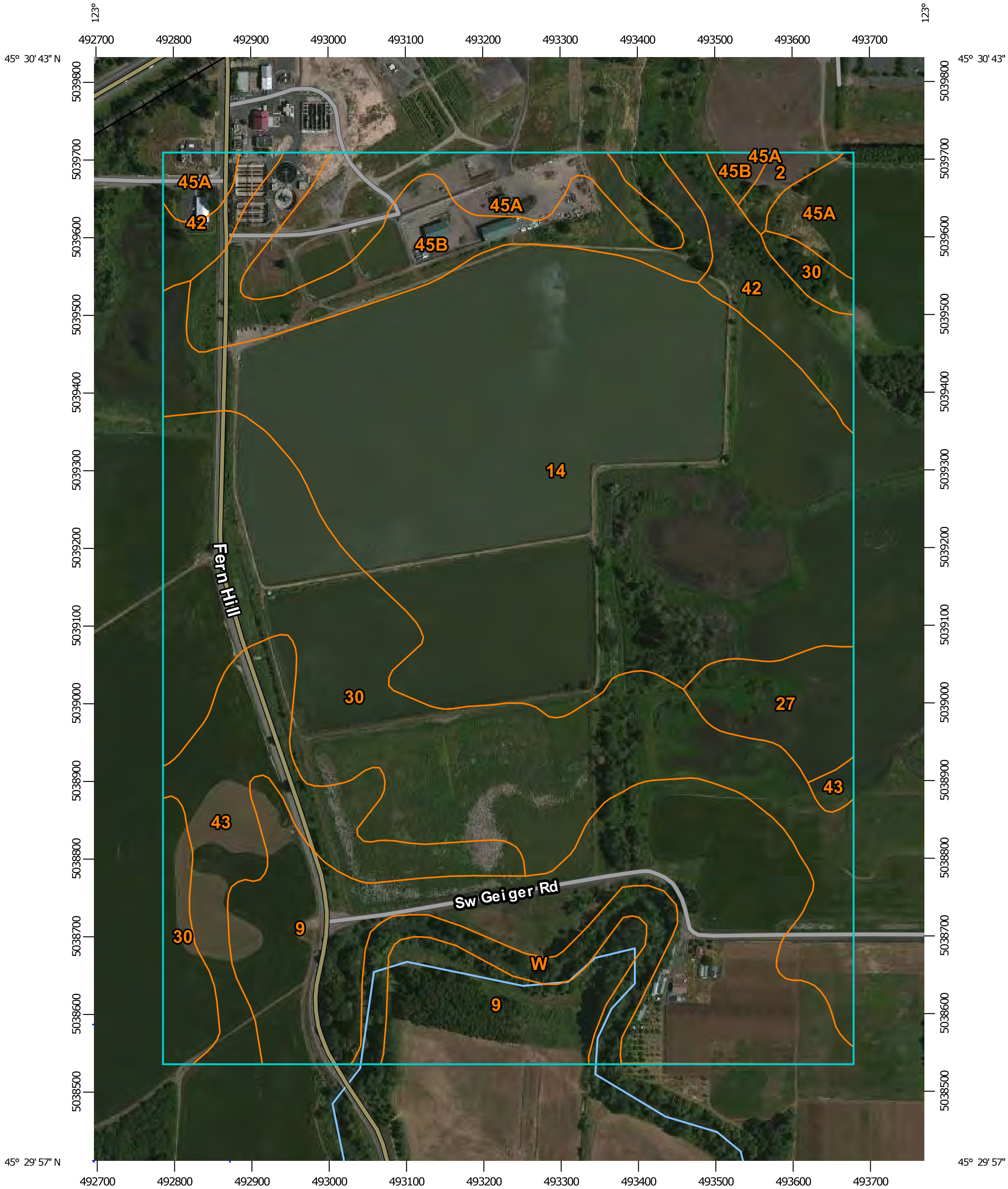

Figure 4-1

Basis of Design

NRCS Soil Map of South Wetlands

South Wetlands
Forest Grove, OR

Legend

MAP UNIT SYMBOL	MAP UNIT NAME	ACRES IN AOI	PERCENT IN AOI
2	Amity silt loam	1.3	0.5%
9	Chehalis silty clay loam, occasional overflow	46.9	18.0%
14	Cove clay	88.3	33.9%
27	Labish mucky clay	6.1	2.4%
30	McBee silty clay loam	54.4	20.9%
42	Verboort silty clay loam	9.0	3.4%
43	Wapato silty clay loam	16.7	6.4%
45A	Woodburn silt loam, 0-3% slopes	14.9	5.7%
45B	Woodburn silt loam, 3-7% slope	16.1	6.2%
W	Water	6.5	2.5%
Totals for Area of Interest		260.1	100.0%

0´ 100´ 200´ N

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The majority of the soil in Ponds 1 and 3 are composed of Cove clay. Cove soils are deep soils found in the floodplain and are typically dark gray to grayish brown in color. A typical pedon has moderate structure to about 40", after which it is massive. The A, B, and C horizons all have distinct yellowish brown or reddish brown mottles, and unless drained, are saturated for 4 to 6 months during the winter and spring. These soils are nearly always moist below the depth of 20 inches.

The southwest area of Pond 2 is composed of Wapato silty clay loam. Wapato soils are also deep soils found in depressions in the floodplain. In the area of the South Wetlands, a typical profile consists of mucky clay to clay to mucky peat. Reddish brown mottles and black masses of manganese accumulation are typically found in the B and C horizons of this soil series. Unless artificially drained, these soils are saturated during the winter months.

McBee silty clay loam makes up the majority of Pond 2, as well as the western edge of Ponds 1 and 3. These soils are found in flat floodplain areas. The upper horizons are dark brown in color changing to grayish brown and gray at lower horizons. The B and C horizons have brown mottles that grow more prominent with depth.

The southern end of Pond 2 leading to the Tualatin River is composed of well-drained Chehalis silty clay loam. The Chehalis soils have a massive, dark yellowish brown C horizon overlain by dark brown A and B horizons with a moderate to strong structure. The soils are in the floodplain and do not typically have distinct mottles.

Table 4-1 summarizes various characteristics of each map unit, including soil texture, drainage class, hydrologic soil group, depth to water table, and saturated hydraulic conductivity (Ksat). The drainage class refers to the frequency and duration of wet periods under natural conditions. The hydrologic soil group is based on estimates of runoff potential with Group A soil having a low runoff potential and Group D soils having a high runoff potential. The Ksat is the capacity of pores in a saturated soil to transmit water, and have been grouped according to standard Ksat class limits. The Ksat values presented in Table 4-1 roughly correspond to rates determined during the hyporheic discharge testing in Pond 2 for the upper layer soils. The NRCS Soil Survey Manual (1993) includes more detailed descriptions of these characteristics.

Table 4-1 NRCS soil series mapped at South Wetlands.

Soil Series	Texture	Drainage Class	Hydrologic Group	Depth to Water Table (in)	Ksat (most limiting layer)
Cove soils	Clay	Poorly drained	D	0-12	0.00 to 0.06 in/hr
McBee soils	Silty clay loam	Moderately well drained	C	24-36	0.20 to 0.57 in/hr
Wapato soils	Silty clay loam	Poorly drained	C/D	0-12	0.20 to 0.57 in/hr
Chehalis soils	Silty clay loam	Well drained	B	80+	0.57 to 1.98 in/hr

Ten soil borings were completed in and adjacent to Pond 2 as part of the hyporheic discharge investigation that was completed in August through September 2013. The borings show that the predominant soil in the first 10 ft below ground surface is silty clay with or without minor iron mottles. The soil is generally a moderate brown color changing to a yellow brown color as it approaches the 10 ft depth. This corresponds to the very coarse level estimates of soil texture presented in the Washington County soil survey.

4.4 Biological Information

4.4.1 SENSITIVE SPECIES POTENTIAL

Sensitive species investigations were conducted for both the 2010 Natural Treatment System Basis of Design (CH2M HILL, 2010) and the 2012 Basis of Design Report for the Natural Treatment System at the Forest Grove WWTF (CH2M HILL, 2012a). The investigation for the 2010 report included a review of state and federal resources and a preliminary evaluation of the site to determine if habitat was present in the project site to support identified sensitive species. The evaluation found that there was potential habitat to support four wildlife sensitive species, three aquatic sensitive species, and four rare plant species that had previously been identified in the vicinity of the project site. In contrast, the 2012 report concluded that there was no habitat present on site to support any sensitive species.

Rare and sensitive species data is constantly changing and is typically valid for not more than one year. The Fernhill Design Team requested updated rare, threatened, and endangered (RTE) species records from the Oregon Biodiversity Information Center (OBIC) for a two-mile radius around the site. This information was collected as background information to assist in determining if federal or state Endangered Species Act requirements would be applicable to the project.

State Heritage Programs, which track and manage information on RTE species, refer to RTE plants, animals, and natural communities collectively as “elements.” Each occurrence of these elements is referred to as an “element occurrence” for tracking purposes in Heritage databases. OBIC follows this naming convention and defines an element occurrence as “an area of land or water where the species is or was known to occur and has a conservation value.”

The data inquiry found 11 element occurrences of nine RTE species, including two wildlife sensitive species, three aquatic sensitive species, and four rare plant species. Table 4-2 summarizes the findings of the OBIC. Other data sources that track wildlife and plant sightings, such as eBird, were not consulted for this exercise.

The 2010 Basis of Design Report (CH2M HILL, 2010) determined that potential habitat was present on or adjacent to the Fernhill NTS project site for six additional RTE species, although it is unclear from the text if each of these species was actually sighted at the site. Different methods and data sources were utilized to form the 2010 list, in addition to a site visit evaluation in 2008. The absence of these species from Table 4-2 is not an indication that they were removed from Federal or State lists, just that their presence in a 2-mile radius of the South Wetlands has not been reported to OBIC. The following is a list of species included in the 2010 report:

- Great blue heron (*Ardea herodias)*: protected under the Federal Migratory Bird Act
- Yellow billed cuckoo (*Coccyzyz americanus*): Proposed threatened
- Oregon spotted frog (*Rana pretiosa*): Proposed threatened
- Bradshaw’s lomatium (*Lomatium bradshawii*): Endangered
- Water howellia (*Howellia aquatilis*): Listed threatened
- Willamette daisy (*Erigeron decumbens*): Endangered

Table 4-2 Rare, threatened, and endangered species recorded near site.

Scientific Name	Common Name	Federal Status	State Status	Last Observation
WILDLIFE SPECIES				
Branta hutchinsii leucopareia[1,2]	Aleutian Canada goose	Delisted	Not listed	1995
Haliaeetus leucocephalus[1]	Bald eagle	Delisted	Sensitive vulnerable	2006
AQUATIC SPECIES				
Actinemys marmorata[1]	Western pond turtle	Species of concern	Sensitive critical	2000
Margaritifera falcate	Western pearlshell (mussel)	Not listed	Watch list (currently stable)	2004
Oncorhynchus mykiss[1,2]	Winter steelhead	Listed threatened	Sensitive vulnerable	2009
PLANT SPECIES				
Horkelia congesta ssp. Congesta	Shaggy horkelia	Species of concern	Candidate	1878
Lupinus oreganus	Kincaid's lupine	Listed threatened	Listed threatened	1941
Sidalcea nelsoniana[1]	Nelson's checkermallow	Listed threatened	Listed threatened	1997
Zizia aptera	Golden alexanders	Not listed	Review needed	NA

[1] *Denotes species included in 2010 Basis of Design Report.*
[2] *Denotes species has multiple element occurrences.*

Spatial data were also obtained from the OBIC, and are presented in Figure 4-2. A source feature is created for each element occurrence, and is spatially represented by a point, line, or polygon. The type of spatial feature developed is based on the likely location and extent of the observation. Each feature also includes an observation uncertainty distance in one or more dimensions, based on factors surrounding the reliability of the data source. Therefore, the spatial distribution of a species represented by a larger diameter circle (e.g., *Horkelia congesta*) represents one discrete observation that could actually be located anywhere within the circle. The spatial distribution of a species represented by a smaller diameter circle (e.g., *Haliaeetus leucocephalus*) is also one discrete observation, with the actual location more accurately known.

4.4.2 VEGETATION

To generally characterize existing vegetation regionally and on-site, several sources of information were consulted, including the Biodiversity Guide for the Greater Portland-Vancouver Region (The Intertwine Alliance, 2012a) and the Fernhill Wetlands Project Conceptual Design Report (CH2M HILL, 2012b). No additional vegetation surveys were conducted for this project.

The Forest Grove WWTF is located in the Tualatin Subbasin. Historically, this area was approximately 51% coniferous forest, 20% oak forest, 12% burned forest, and 12% prairie or savanna (The Intertwine Alliance, 2012a). Over the years, the subbasin has been increasingly converted to urban and agricultural areas, which is reflected by mapping of land cover in the vicinity of Fernhill (Figure 4-3).

Figure 4-2
Basis of Design

Rare, Threatened, and Endangered Species

South Wetlands
Forest Grove, OR

Legend

- Fernhill Site
- Wetlands
- Streams
- Major Roads

RTE Species

- Branta hutchinsii leucopareia (Aleutian Canada goose)
- Haliaeetus leucocephalus (Bald eagle)
- Actinemys marmorata (Western pond turtle)
- Margaritifera falcata (Western pearlshell)
- Oncorhynchus mykiss pop. 33 (Winter steelhead)
- Horkelia congesta (Shaggy horkelia)
- Lupinus oreganus (Kincaid's lupine)
- Sidalcea nelsoniana (Nelson's checkermallow)
- Zizia aptera (Golden alexanders)

NOTES:
Datum: NAD 1983 HARN
Projection: Oregon State Plane North
Data Sources: National Agriculture Imagery Program, OR DOGAMI, ORBIC, Metro RLIS

Species boundaries for RTE data include an uncertainity distance based on factors surrounding the data collection. ORBIC sets the uncertainity distance while processing received data.

N

0 0.5 1 2 Miles

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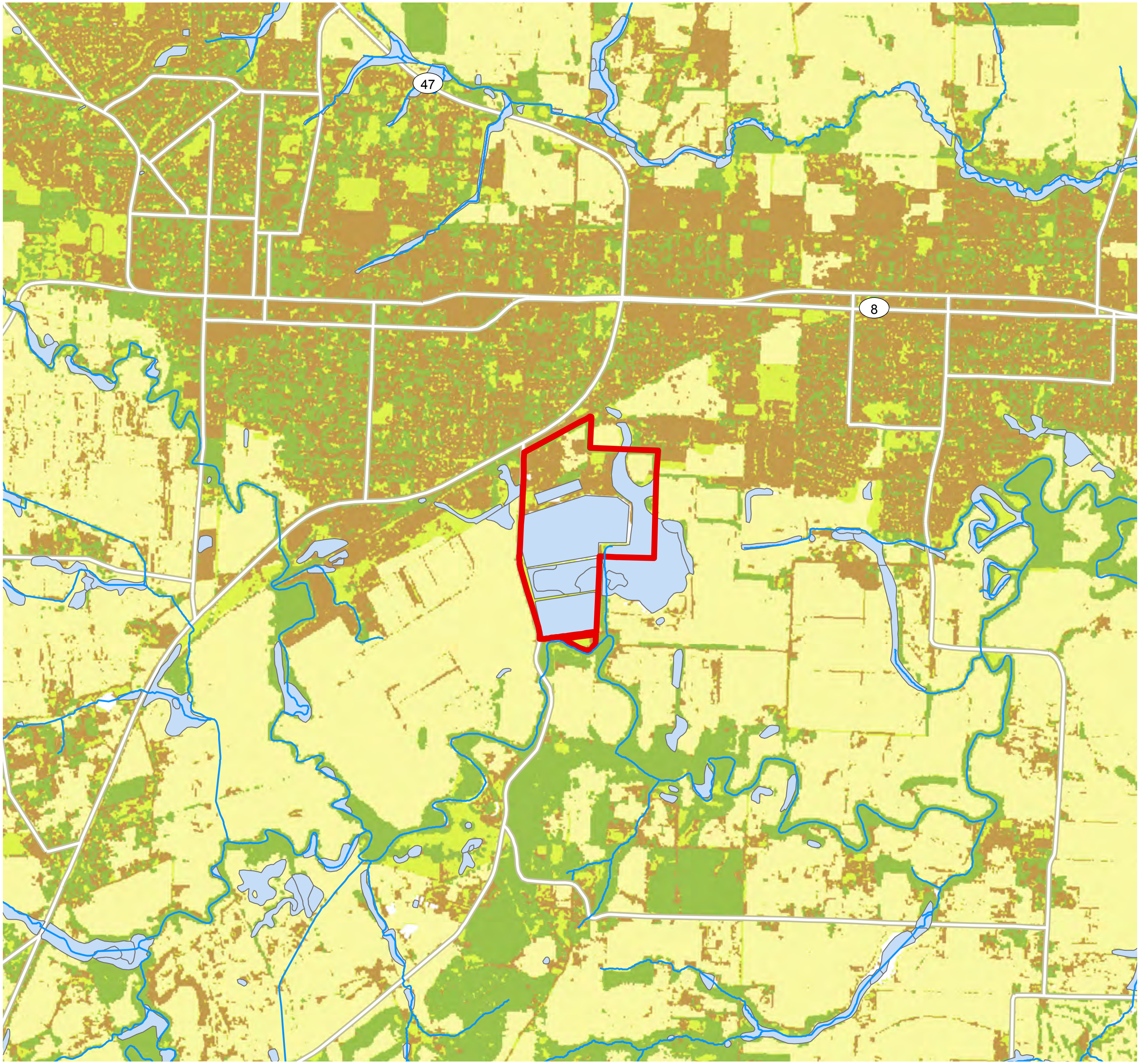
Figure 4-3
Basis of Design

Land Cover in Vicinity of South Wetlands

South Wetlands
Forest Grove, OR



Legend

- Fernhill Site
- Wetlands
- Streams

Land Cover

- Agriculture
- Developed
- Low vegetation
- Tree cover

NOTES:
Datum: NAD 1983 HARN
Projection: Oregon State Plane North
Data Sources: OR DOGAMI, Metro RCS, Metro RLIS

0 0.125 0.25 0.5 Miles

N

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Appendix A of the Fernhill Wetlands Project Conceptual Design Report (CH2M HILL, 2012b) was compiled by Clean Water Services staff and briefly describes existing conditions at the South Wetlands. The following is a summary of conditions cited in that memo in addition to observations made during design team site visits.

The dominant vegetation throughout all three sewage lagoons are reed canary grass (*Phalaris arundinacea*), common teasel (*Dipsacus fullonum*), and birdsfoot trefoil (*Lotus corniculatus*). Ponds 1 (Fernhill Lake) and 3 (Cattail Marsh) are both predominately open water with sparse vegetation growing along the edges. There is also a fair amount of Himalayan blackberry (*Rubus discolor*) growing along the berm on the north edge of Pond 3. Rice cutgrass (*Leersia oryzoides*) and a variety of *Polygonum* species, including marshpepper smart weed *(Polygonum hydropiper*), are present in Pond 2 in addition to the species listed above.

Of the plants listed above, rice cutgrass is the only native species. Reed canary grass and Himalayan blackberry are both considered invasive. The District has been working to control reed canary grass on site, although flooding of Pond 2 potentially brings a new seed bank from upstream. A control plan is in place to try to limit the spread of this invasive species, through water level control, tilling, and targeted herbicide spraying.

4.4.3 REPTILES, AMPHIBIANS, AND MAMMALS

The Tualatin subbasin contains habitat for sensitive amphibians and reptiles, including the northern red-legged frog (*Rana aurora*), western painted turtle (*Chrysemys picta bellii*), and western pond turtle (*Actinemys marmorata*). Western toad (*Anaxyrus boreas*), Oregon spotted frog (*Rana pretiosa*), and salamanders (eg. *Ambystoma macrodactylum*) thrive in wetland habitat, and may be present around the site. The proximity of the South Wetlands to the Tualatin River and the floodplain also provides important hiding and overwintering habitat for stream-dwelling amphibians in the Forest Grove region (The Intertwine Alliance, 2012a).

Elk (*Cervus canadensis*), deer (*Odocoileus sp.*), common muskrat (*Ondatra zibethicusl*), and northern river otters (*Lontra canadensis*) are some of the mammals present in the Tualatin subbasin. Coyotes (*Canis latrans*) and weasels (*Mustela sp.*) are commonly found in mudflat habitat, feeding on larger prey species that may be feeding on invertebrates (The Intertwine Alliance, 2012a). Dabblers Marsh and Barney Mitigation currently have populations of beaver and nutria (*Myocastor coypus*). While beaver are seen as “ecological engineers” by some, they also present a management issue when trying to establish newly planted vegetation. The District currently has a contract with Oregon Wildlife Services for trapping and removal of nutria, and this will continue to be a management issue as the natural treatment system comes online (CH2M HILL, 2012b).

Tables E-2 through E-5 in Appendix E of the Intertwine Alliance’s Biodiversity Guide for the Greater Portland-Vancouver Region (2012a) list species that occur regionally by habitat type. Examples of habitat types listed in these tables include wetlands, shorelines, mudflats, and open water.

The habitat types in the region available for supporting wildlife can be a key driver in defining applicable vegetation communities and planting zones to promote native biodiversity and species conservation. Additionally, understanding wildlife use potential is of interest to regulatory agencies in evaluating potential wildlife habitat impacts including the ecological improvements offered by the restoration project.

4.4.4 FISH AND AQUATIC INVERTEBRATES

Pond 1 was sampled for fish diversity in 2012 with the following species being identified:

- Common carp (*Cyprinus carpio*)
- Fathead minnow (*Pimephales promelas*)
- Yellow bullhead catfish *(Ameiurus natalis*)
- Bluegill sunfish (*Lepomis macrochirus*)
- Warmouth sunfish (*Lepomis gulosus*)
- Pumpkinseed sunfish (*Lepomis gibbosus*)

The common carp is considered a nuisance species, and can be very destructive to aquatic habitats as they scavenge the bottom substrate and sediments for food. The Tualatin River, adjacent to the site, is habitat to native cold-water fish populations including cutthroat trout and winter steelhead (The Intertwine Alliance, 2012a). It is unlikely that migratory fish species would enter through the outlet structure and make use of the South Wetlands under typical summer flow regimes. The South Wetlands are part of the broader river ecosystem and contribute to eco-regional and watershed-scale habitat conservation and protection beneficial to these species. During flooding events there is potential for fish to seek refuge in the South Wetlands. As floodwaters recede the fish likely will return to the Tualatin River as they do in other flooded areas along the river.

4.4.5 BIRDS

Artificial wetlands and wastewater treatment lagoons are increasingly important bird habitat, especially along migratory corridors such as the Pacific Flyway (Murray and Hamilton, 2010). The South Wetlands are a popular birding destination and provide habitat to a broad range of avian species throughout the year. Waterfowl populations frequently are observed in the thousands from November through March. Shorebirds (at least 17 recorded species thus far) occur in numbers frequently exceeding 100 birds in spring, fall, and sometimes winter (Audubon Society of Portland, 2013). Pond 3 and the Barney Mitigation Wetlands to the east have been known to support nesting or summering species that have been observed irregularly in this part of Oregon (Evanich, 1990).

The following steps were taken to evaluate avian usage and ultimately provide context to design development:

- Collection and review of readily available avian usage records for the site (e.g., using eBird).
- Identification of seasonal habitat use (based upon eBird records).
- Determination of sensitive avian species identified during RTE review and consideration of specific habitat needs.

The “Fernhill Wetlands” (which includes the South Wetlands and the adjacent Barney Mitigation Wetlands) are classified as an Important Bird Area by the Audubon Society and a hotspot on eBird. Launched in 2002 by Cornell Lab of Ornithology & National Audubon Society, eBird is a real-time, online checklist program that records observed bird species and collects observations from birders through portals managed and maintained by local partner conservation organizations. The records provide an unusual and invaluable resource, both in the site-specific and temporally comprehensive nature of the records. One must consider that observations in the eBird database at the South Wetlands cannot be differentiated from those from the Barney Mitigation Wetlands or Dabbler's Marsh to the east. In addition, eBird reports only the frequency with which species are observed (not abundance). Frequency is a measure of the percentage of submitted checklists that record a given species—whether there is one individual or hundreds observed.

Records from eBird were queried for the last 10 years, and reviewed to summarize available avian usage information. Results from this query are presented in Appendix B. eBird lists over 220 avian species observed at the Fernhill Wetlands (221 species with over 25 other taxa). Records reflect the broad range of resident and migratory species. Migratory species include short- and long-distance migrants traveling numerous pathways. Timing of migration varies considerably between species. Regionally, fall migration tends to stretch between late August to mid-November, and spring migration lasts from mid-March to early June. Bird species use the habitats within the Fernhill Wetlands for a variety of foraging, resting and nesting behaviors. The mosaic of open water and wetlands host thousands of migrant and resident bird species throughout the year.

Available bird usage records were reviewed in order to identify a representative "bird guilds." The concept of bird guilds has been a concept in avian ecology first used to identify a "group of species that exploit the same class of environmental resources the same way" (Root, 1967). Within the literature base, scientists have defined the units of guilds in a wide range of ways, and there are no overarching guidelines. Most have defined guilds by foraging behavior, sometimes using detailed statistical analyses to cluster and differentiate suites of species. Verner (1984) suggests that guilds can be a helpful tool to indicate the capability of habitats zones (and foraging areas within these habitats) to support avian needs, and that most management purposes can addressed in this framework, even when faced with a complex dataset.

For our practical purposes, guilds are used in a management context to identify groups of similar birds that depend on the same environmental resources, i.e. habitats, and for certain life requisites and behaviors (e.g., foraging method). The intent is not single ("focal") species management, but rather considering habitat needs that contribute to the broader goal of restoring a diverse, functioning and productive wetland system.

As an initial step in defining the bird guild, a subset of the 200+ species was identified and characteristics of these species were reviewed, and then reduced further to 22 representative species. Implicit in the exercise was the selection of species that are neither extremely commonplace nor rare, but that instead represent the foraging and habitat usage currently present on-site and targeted for enhancement or restoration.

Habitat categories used include open water (shallow to deep), mudflat, wetland (emergent, scrub-shrub), and upland (forest, grassland). Characteristics of these species using these habitats were reviewed, including seasonality of usage, migratory context, primary and secondary habitats usage, and general nesting preferences.

While there is much complexity to the many species and their timing and habitat uses, there are some general patterns that are useful to note. Figure 4-4 provides a selective representation of general habitat use by the representative species (and relates habitat usage to managed water surface elevations as described in Section 6.14). The selected species utilize habitat types for significant parts of their breeding and foraging needs. Together, Appendix B and Figure 4-4 highlight some key themes regarding season habitat needs:

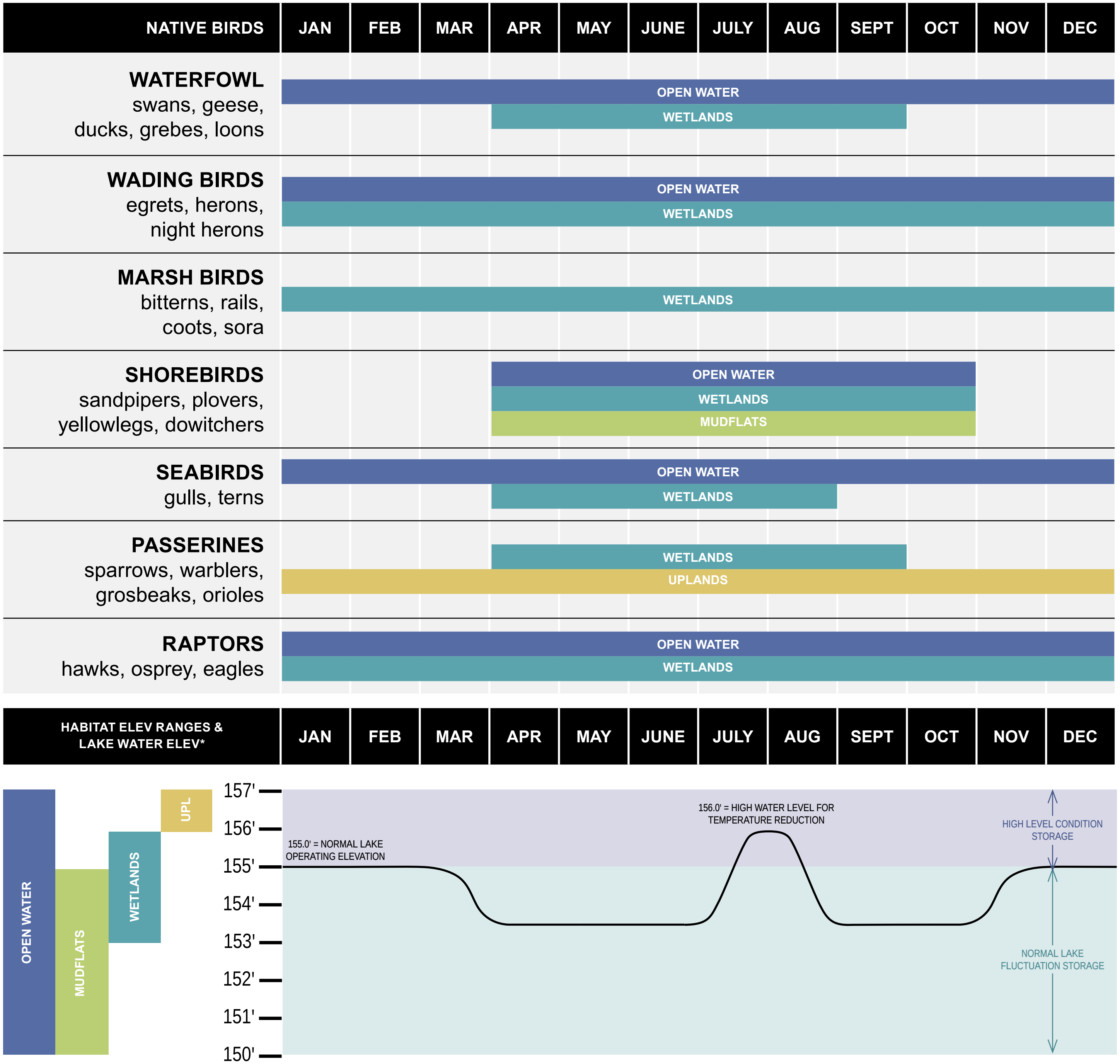
- Collectively, all four habitats are important in supporting the representative bird groups. Among the bird groups, species rely more strongly on wetland and open water habitats.
- Fall and winter bring relatively greater use of open water habitats that support foraging seabirds and waterfowl (including grebes, swans and geese, and dabbling and diving ducks).
- Shorebirds rely on mudflats during critical spring through fall months.
- Spring and winter months are associated with relatively greater use of wetlands supporting foraging and nesting shorebirds, waterfowl, seabirds, and passerines.
- Marsh birds, wading birds, and raptors tend to use wetland areas year-round.
- Passerines make use of adjacent transitional and upland marginal areas (i.e. trees and shrubs along the perimeter of the sewage lagoons) year-round.

Figure 4-4

Basis of Design

General Monthly Habitat Use by Representative Species and Lake Level Operating Scenario

South Wetlands
Forest Grove, OR



*Example of one lake level operating scenario, actual lake level scenario may vary each year

5 Basis of Design

The conceptual design presented in this Basis of Design report was developed through an extended and iterative design process. This section summarizes the key components, methods, and decision points that provide the foundation of the current conceptual design.

The general project goals and guiding principles identified in Section 1.1 were used by the design team in the earliest stages of refining the conceptual design of South Wetlands. Initial design development was fueled by collaborative discussions in workshops with staff from the District and the consultant design team and preliminary computations, as briefly summarized in Section 5.1. These early efforts culminated in the presentation of a conceptual design (Biohabitats, 2013) that updated and revised the concept of CH2M HILL (2012b).

Since that time, additional specific design objectives were identified for the project (including those described in Section 2.1), and are presented in Section 5.2 below. Data gaps were addressed by collecting additional data and conducting further analyses. Design iterations have integrated the many supporting analyses (Sections 5.4 - 5.12), to produce the latest concept plan, which is introduced and depicted in Section 5.3.

5.1 Preliminary Design Considerations

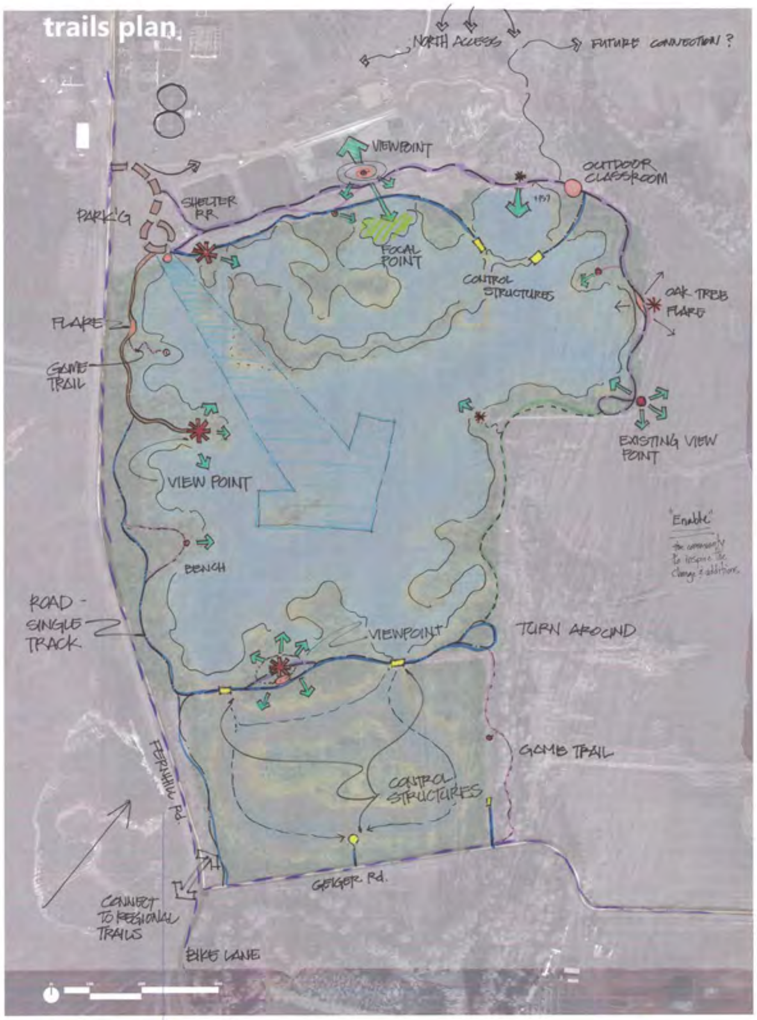
The Lower (South) Wetlands Conceptual Master Plan (CH2M HILL, 2012b) and this Basis of Design evolved through a series of workshops and conversations among the Biohabitats design team, relevant District personnel and CH2M HILL staff. Through them, the design team became acquainted with the South Wetlands and nearby reference sites, identified additional design considerations, and discussed the design approach. The group explored possibilities at both the conceptual and computational levels and evaluated ideas so that it could be improved or discarded. This process set the design considerations, parameterized many of the variables, and established a shared set of expectations for how information would be gathered and brought to bear on the evolving design.

The team met for three workshops in May and June of 2013. The first provided a project overview, site tour and orientation. Local experts led discussions on the management of the site, its meaning to the community, and the historical and regional context. The second workshop reviewed the potential reference sites, established an approach for their study, and discussed how the information would bear on the final design. At the third workshop a few weeks later, the group drafted the design considerations, which culminated in the goals presented in Section 1.1 of this report. Following the three workshops, the design process continued through several iterations of modifying, reviewing and incorporating comments. Figure 5-1 shows a few of the earlier design sketches.

Wetland / Lake Concept

Wetland / Lake Concept

Trail Typology



Trail Concept

Trail Typology

Flood Flow

Figure 5-1
Basis of Design

Design Workshop Sketches

South Wetlands
Forest Grove, OR

NOT TO SCALE

N

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Biohabitats
CASCADIA BIOREGION

5.2 Design Objectives, Supporting Principles, and Challenges

Based on ongoing input from the District and the results from early design workshops and analyses, the conceptual design was further focused to address specific objectives. These objectives were supported by design principles, as shown below:

- Achieve water temperature reductions in effluent to Tualatin River to meet applicable temperature requirements
  - Create open water and emergent wetland areas that promote the storage and slow movement of water
  - Create a large “footprint” of wetland to maximize the area of treatment (rather than volume) and maximize temperature reduction via shading by shallow emergent vegetation
  - Promote vegetation cover that provides shade in emergent wetlands for maximum temperature reduction (e.g., shallow water depths)
  - Avoid large open areas with minimal vegetation and little water movement that would absorb rather than dissipate heat
- Promote internal system stability
  - Establish stable inlet flow distribution and outlet flow collection
  - Accommodate discharge flows from the wastewater facility (e.g., up to 18 MGD)
  - Prevent flow concentration and incision by collecting and spreading effluent flows across a broad, uniform flow path within and between wetland cells
  - Maintain low velocities through open water and wetland cells during normal operational flows
  - Provide physical conditions conducive to wetland plant growth
  - Accommodate flows that transverse the site during flooding of the Tualatin River
- Provide flexibility in operations
  - Utilize control structures at point of effluent to distribute flows between open water and emergent flows
  - In the emergent wetlands, provide multiple cells in a series along two parallel tracks that can be managed separately
  - Allow for possible later connection points with adjacent features, such as Barney Mitigation Wetlands and Cottonwood Creek
- Increase dissolved oxygen levels to 6.0 mg/L (to be consistent with the requirements in Oregon Administrative Rules and reduce potential of the formation of methyl mercury) at outlet from South Wetlands
  - Integrate drop structure(s) with height needed to meet dissolved oxygen requirements
  - Provide flexibility for type(s) of structure(s) to accommodate drop within grading plan
- Provide potential for nutrient reduction
  - Manage hydraulic loading rates (HLR) and nutrient loading rates (NLR) to maintain and to promote targeted water quality levels and promote botanical diversity
  - Reduction of phosphorus levels by increasing contact with vegetation. Vegetation will remove phosphorus in water column via microbial action, plant production, and sorption.
- Cost control
  - Where consistent with other objectives, utilize existing contours and topography to minimize earth disturbance

    - Limit excess cut/fill (i.e. <100,000 CY)
    - Provide for flexible but passive controls
- Promote establishment and growth of diverse native wetland vegetation
    - Integrate variable water depths (via macro- and microtopography along wetland surfaces) to maintain the diversity in wetland plant species long-term
    - Inhibit the growth of invasive, non-native species via management of water levels
    - Limit erosive velocities during normal operational flow conditions
- Provide a diversity of habitats to support biological communities
    - Create a mosaic of wetland-dominated habitats that will include open water, mudflat, wetland, scrub-shrub, and upland areas.
- Evaluate potential for hyporheic discharge
    - Evaluate utility of a hyporheic discharge component to the wetland system
    - If beneficial, incorporate hyporheic discharge into design
- Improve visitor experience
    - Provide recreational and educational opportunities through trails and site amenities focused on the northern edge of the South Wetlands
    - Promote public uses consistent with other ecological objectives

There is inherent conflict between some of the design principles above, which requires some give and take between design parameters. For example, the design of wetlands for temperature reduction is, in some ways, in conflict with maximizing the habitat value of the wetlands. To maintain a uniform hydraulic loading, rectangular channels of uniform width and depth are ideal. However, these kinds of sections are not natural looking and lack microtopography associated with complex habitat. Instead, we attempt to ameliorate this rigid geometry by providing irregular planting surfaces (recessed laterally from the hydraulic flow lines) that allow for a more diverse plant community while still maintaining broad areas that promote hydraulic loading and the reduction of temperature. Additionally, there are limits to the types of plants that will grow in various water depths, with the diversity of species diminishing at depths exceeding 2 feet. The Basis of Design attempts to incorporate the many design principles, but the design cannot optimize for each one or achieve a precise balance between them all. The design instead seeks to achieve all of the major design principles, but emphasizes the important water quality goals. Adjustments to the design are expected as analyses continue through the design phase.

5.3 Site Design

5.3.1 SITE LAYOUT

The overall site layout of the wetlands is designed to account for the principles outlined in Section 52. Figures 5-2 and 5-3 present the layout of the design in planform with “cell” numbers identified. The generalized grading plan includes illustrative contours (irregular contour intervals) that outline the design elevations and surfaces. Figure 5-2 depicts those areas that would be inundated with either shallow or deep water under normal operating conditions.

As depicted in Figure 5-3, the design includes two distinctive areas: 1) a large, deep open water area in the northwest quadrant, and 2) wetlands to the east and south (Cells 1-6). The open water body (“Lake”) is positioned as the centerpiece, viewable from the existing parking lot, and intended to immediately engage the visitor. The Lake is configured as one cell with an irregular perimeter. It is possible to walk to the emergent wetlands from the parking lot via a series of trail connections.

Figure 5-2
Basis of Design

Normal Operating Water Level

South Wetlands
Forest Grove, OR

Habitat Zones

	ACRES	%
Upland	15	17%
All Wetlands	49	54%
Mudflat	2	2%
Open Water	24	27%
TOTAL	90	100%

Legend

- Water Surface
- Deep Water
- Flood Flow Crossover
- Wetland Cell Boundary
- Berm
- Control Weir
- Control Structure
- Control Valve
- Cascade
- Flow Path
- Piped Flow
- Flood Condition Flows

* Depth of Cells 1-6 = 12"

0' 300'

N

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Biohabitats

Figure 5-3
Basis of Design
South Wetlands Design

South Wetlands
Forest Grove, OR

Habitat Zones

	ACRES	%
Upland	15	17%
All Wetlands	49	54%
Mudflat	2	2%
Open Water	24	27%
TOTAL	90	100%

Legend

- Upland Woodland
- Upland Berms
- Scrub/Shrub and Emergent Wetland
- Mudflats
- Deep Water
- Water Surface
- Wetland Cell Boundary
- Control Weir
- Control Structure
- Control Valve
- Cascade
- Flow Path
- Piped Flow
- Flood Flow Crossover
- Flood Condition Flows

0' 300'
N

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Biohabitats

The irregular contours within the grading plan, such as those along the open water areas and locally along edges of the emergent wetland, create heterogeneity. These areas are not intended to be part of the "effective" flow path. Instead, these areas will provide the complex habitats that support diverse biological communities. For example, the design provides recessed areas of mudflat along the east side of the open water feature. It is also anticipated that additional microtopography will be superimposed upon this macro-scale grading plan to increase the habitat complexity of the project area.

Flow quantities, rates and durations will be managed through various hydraulic control structures and related flow paths, providing multiple ways to produce water surface elevations higher or lower than those depicted in Figure 5-2. Hydraulic control structures (described below in Section 5.5) will be placed throughout the wetlands 1) to introduce and divide flow into the project area, 2) to moderate flow between separate wetland cells, 3) to capture water from the Lake, 4) to create turbulence and increase dissolved oxygen concentrations while dropping water into the last wetland cell (Cell 6), and 5) to collect and discharge water at the end of the wetland cells for outfall discharge to the Tualatin River. Collectively these structures provide the flexibility to manage water levels as needed to drawdown for maintenance, to store water volumes, and/or to manage water levels for various aquatic and wetland habitats, including the control of invasive species. Specific details regarding each structure will be developed as design progresses, but preliminary design information is included in Section 5.5.

Flows from the WWTF will enter the South Wetlands through a waterfall feature and enter an Upper Pool (Figure 5-2) near northeast corner of Pond 1. All flow entering this Upper Pool can be split into three different flow paths: either of two pathways through emergent wetlands (Cells 1A and 1B) or into the Lake. During the dry season, most water will flow through the emergent wetlands for temperature reduction. The wet season will tend to have more flow moving through the Lake to reduce the HRT.

Flow through the emergent wetland are initially directed through two parallel alignments (Cells 1A versus 1B), allowing flexibility in flow path. Flow is then combined in Cell 2 and continues to flow through Cell 3, 4 and 5. Within each wetland cell, the grading plan depicts broad, shallow areas under normal flow conditions (e.g., 12" depth). Within each cell, slightly deeper elongated pools (e.g., 4' depth or greater) are shown perpendicular to the predominant flow path. These occur across the width of each cell at the inlets and outlets, and at one or more of the internal locations, depending on the length of the cell. The intended function of these features is to broadly collect flow within locations along the flow path through the emergent wetlands and then re-spread exiting flow to maintain the same broad, uniform flow across the emergent wetland cells. At locations where flow will be making a fairly sharp turn (as through Cells 3 through 5), these deep cells are particularly important to "even out" flow and prevent its concentration along the outer portions of the bend.

5.3.2 EARTHWORKS

The primary earthwork goal is to limit the amount of fill imported to the site. This will be accomplished by balancing the cut/fill between Ponds 2 and 3, and utilizing approximately 100,000 cubic yards of the existing onsite stocked soils to fill in Pond 1. Any excess required fill in Pond 1 can be derived from deepening the Lake. Surface calculations included site civil cut and fill quantity takeoffs to develop an understanding of the overall net soil balance associated with the proposed improvements. Table 5-1 presents the cut/fill volumes by dividing the South Wetlands into three areas: existing Ponds 1, 2, and 3.

Table 5-1 South Wetlands cut/fill volumes.

Earthwork (CY)			
Area	Cut	Fill	Net
Pond 1	41,300	147,816	106,516
Pond 3	25,573	11,674	-13,899
Pond 2	97,062	1,808	-95,254
Ponds 2 & 3	122,635	13,482	-109,153
Total	163,935	161,298	-2,637

Net earthwork between Ponds 2 and 3 is projected to be 109,153 cubic yards of cut. An attempt to create net balance between the two ponds will be explored during 15% design. In Pond 1, a total of 147,816 cubic yards of fill is needed with 106,516 cubic yards of the total coming from existing onsite soil. The remaining 41,300 cubic yards of fill will come from cut in the Lake.

5.4 Hydraulic Retention Time and Water Storage

In treatment wetlands, the hydraulic retention time (HRT) and water storage volume help determine the amount of sediment and nutrients that will be removed from the water. The HRT was calculated for each of the flow cells included in the design for the following dry weather influent flow rates:

- 4.0 MGD – flow used in the CH2M HILL temperature model
- 5.0 MGD – current baseline flow
- 6.3 MGD – projected 2025 baseline flow
- 9.0 MGD – Phase 1 Potential Future Flows Expansion at Forest Grove WWTF
- 18.0 MGD –Phase 2 Potential Future Flows Expansion at Forest Grove WWTF

Effluent flow generated from the Forest Grove WWTF may vary seasonally. If more than 18 MGD is generated from the WWTF, an additional 2 MGD may bypass the NTS and be directed to the Tualatin River discharge pipe. Flows higher than 20 MGD (the maximum capacity of the Tualatin River discharge pipe) are directed to two 24-inch transfer pipes that convey wastewater effluent to Rock Creek AWTF for discharge. Discharge flow rates through the NTS may vary based on precipitation, evaporation and evapotranspiration. Precipitation and combined loses from evaporation and evapotranspiration may vary widely day to day. A rainfall depth of 0.5 inch over approximately 74 acres of water surface (Lake and wetlands) would add approximately 1,000,000 gallons to the system. The average daily minimum and maximum losses are 140,000 and 397,000 gallons, respectively. However they could be as much as 725,000 gallons per day for an annual daily maximum. In addition to the HRTs, the potential water storage volumes were developed for each of the cells based upon the following storage elevation scenarios:

Lake

- Elevation: 148.00 – 156.00 (Total storage potential)
- Elevation: 152.00 – 156.00 (High gate storage potential)
- Elevation: 148.00 – 152.00 (Bottom gate storage potential)

Emergent Wetlands

- Cell 1A/1B: Elevation 151.00 – 152.00
- Cell 2: Elevation 150.00 – 151.00
- Cell 3: Elevation 149.50 – 151.00

- Cell 4: Elevation 149.00 – 151.00
- Cell 5: Elevation 148.50 – 148.50
- Cell 6: Elevation 148.00 – 148.50

Hydraulic Retention Time

Hydraulic retention times were also calculated using water volumes developed from the proposed plan and total flow rates through the wetlands of 4.0, 5.0, 6.3, 9.0 and 18 MGD. Two different flow paths through the South Wetlands were considered:

1) Emergent marsh flow path (averaged between flow paths A & B)
2) Lake flow path

The two different flow paths at 4.0, 5.0, 6.3, 9.0 and 18 MGD flow rates respectively result in the following HRTs, presented in Table 5-2. The Cell 1 flow split should be further refined during 15% design, possibly incorporating a gated structure to allow more flow to the Lake at low flow conditions.

Table 5-2 South Wetlands flows and HRTs

Total System Flow Rate (MGD)	4.0	5.0	6.3	9.0	18
Flow Path	HRT[1] (days)				
Emergent Wetland	6.8	5.4	4.3	3.0	2.9
Lake	10.3	8.2	6.5	4.6	2.3

[1] HRTs listed are for 100% of the flow moving through each of the flow paths separately.

Storage Capacities

The storage capacity of each wetland cell was calculated. The emergent wetland cells have storage potential from their respective normal operating elevation to a maximum water elevation that is dependent on the surrounding berm elevations. Each emergent wetland pond also has storage potential when water overtops interior berms and is then stored within the exterior berms. This pond storage potential is calculated from their respective normal operating elevation to 1 foot below the exterior berm elevation to allow for freeboard.

The Lake has three different storage potentials that include total storage and storage based on the function of the Lake outlet structure. Lake total storage was calculated from the Lake bottom to one foot below the surrounding berm elevation. High gate storage represents the amount of water the high overflow weir gate can drain with the bottom gate closed. The bottom gate storage represents the amount of water that can be drained by the bottom sluice gate when the high gate has already drained its volume. A further discussion of the Lake outlet structure is described in Section 5.5, Structure 3. All storage volumes are included in Table 5-3.

Hydraulic Grade Line

Figure 5-4 shows the various flow paths in the South Wetlands, and Figure 5-5 presents the hydraulic profile modeling these flow paths. Two water surface elevations are provided, which depict the 5 and 18 MGD flow conditions, both developed using a Tualatin water surface elevation of 144.90 feet. The Tualatin River water elevation used is the 10% exceedance value during the dry season which was developed by the Fernhill Design Team.

The hydraulic profile was modeled to include flow through the South Wetlands, to a maximum of 18 MGD. It also includes a maximum additional 2 MGD through the Forest Grove outfall pipe, which has a maximum capacity of 20 MGD. The profile was also modeled assuming the primary operating condition is that flow through the Lake does not occur when incoming flow is less than 9 MGD and the Lake is only used for storage. This primary operating condition represents the worst case hydraulic scenario due to the Lake, which has negligible head loss, being eliminated from the profile at flows less than 9 MGD.

Head loss through emergent wetland cells was calculated using the Manning formula and roughness coefficients developed for wetlands with the plant coverage anticipated for the South Wetlands. An important variable to head loss and to the health of wetland plants is the velocity flowing through the wetlands cells (Table 5-4). Overall, head loss through the emergent wetlands ranges from approximately two inches at low flows of 4.0 MGD to four inches at high flows of 18 MGD. The specific head loss in each of the cells should be further refined during 15% design based on structure elevations and design plant coverage in the wetland cells.

Table 5-3 South Wetland storage volumes.

Storage Volumes	Elevations (ft)	Volume (MG)	Volume (acre-ft)
Cell 1A	151.00 – 152.00	3.06	9.40
Cell 1B	151.00 – 152.00	3.19	9.78
Cell 2	150.00 – 151.00	2.30	7.05
Cell 3	149.50 – 151.00	2.30	7.05
Cell 4	149.00 – 151.00	3.23	9.92
Cell 5	148.50 – 148.50	0.00	0.00
Cell 6	148.00 – 148.50	0.58	1.78
Pond 1 – Emergent Wetland	Varies – 156.00	33.4	103
Pond 2 – Emergent Wetland	Varies – 156.00	38.5	118
Pond 3 – Emergent Wetland	Varies – 151.00	16.6	51
Emergent Wetland Total	Varies – Varies	88.6	272
Lake – Bottom Gate	148.00 – 152.00	20.2	61.9
Lake	152.00 – 153.00	5.7	17.5
Lake	153.00 – 154.00	6.0	18.4
Lake	154.00 – 155.00	6.6	20.3
Lake	155.00 – 156.00	7.1	21.8
Lake - High Gate	152.00 – 156.00	25.5	78.1
Lake - Total	148.00 – 156.00	45.6	140

Table 5-4 Emergent wetland cell velocities.

Total System Flow (MGD)	Water Velocity (ft/s)					
	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
4.0	0.011	0.016	0.022	0.014	0.012	0.012
5.0	0.014	0.019	0.027	0.018	0.014	0.015
6.3	0.017	0.025	0.035	0.022	0.018	0.019
9.0	0.024	0.035	0.049	0.032	0.026	0.027
18.0	0.049	0.070	0.099	0.063	0.052	0.055

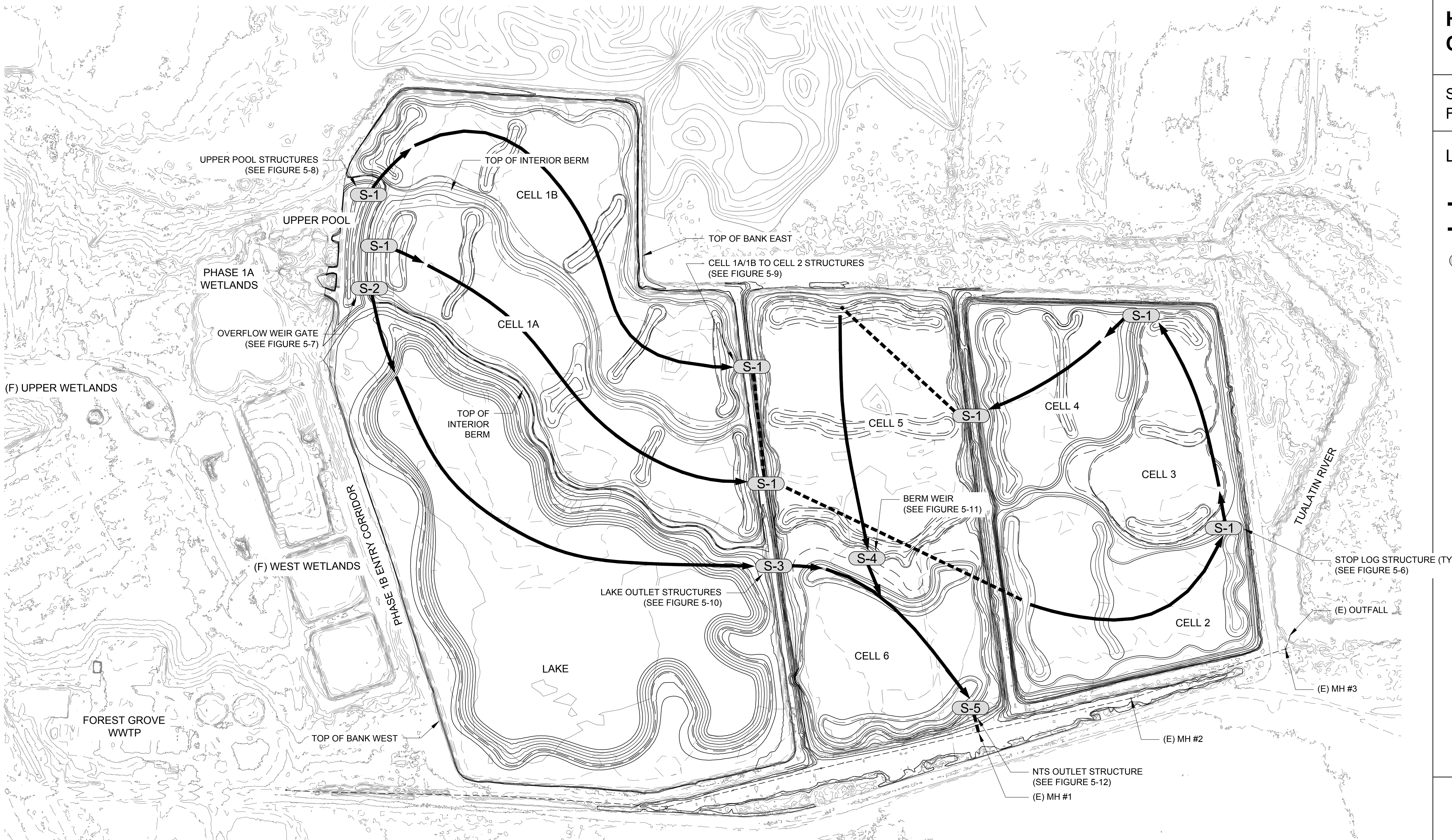
System hydraulics provide a maximum of 2.80 feet and 1.12 feet of free water drop at 5 MGD and 18 MGD, respectively, at the Cell 6 outfall structure when the Tualatin River is at its 10% exceedance elevation of 144.90. The purpose of the free water drop is to add dissolved oxygen back into the effluent before discharge. If necessary, additional aeration could be added using mechanical methods. Table 5-5 lists different free water drops in relationship to the various average dry season flow rates. It should be noted that 90% of the time during the dry season the Tualatin River will be lower than 144.90 increasing the free water drop potential listed in Table 5-5.

Table 5-5 Potential free water drop from Cell 6.

Total System Flow (MGD)	Water Surface Elevation in Cell 6	Water Surface Elevation in Outlet Pipe Manhole	Drop from Cell 6 to Manhole (feet)
4.0	147.80	144.99	2.81
5.0	147.84	145.04	2.80
6.3	147.89	145.12	2.76
9.0	147.98	145.35	2.63
18.0	148.25	146.94	1.31

Figure 5-4
Basis of Design
Hydraulic Structures Concepts Site Plan

South Wetlands
Forest Grove, OR



Legend

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Figure 5-5
Basis of Design

Hydraulic Structures Concepts Hydraulic Profile

South Wetlands
Forest Grove, OR

Legend

Q=18 MGD / Q=5 MGD — WATER SURFACE ELEVATIONS

S-1 — STRUCTURE TYPE DESIGNATION

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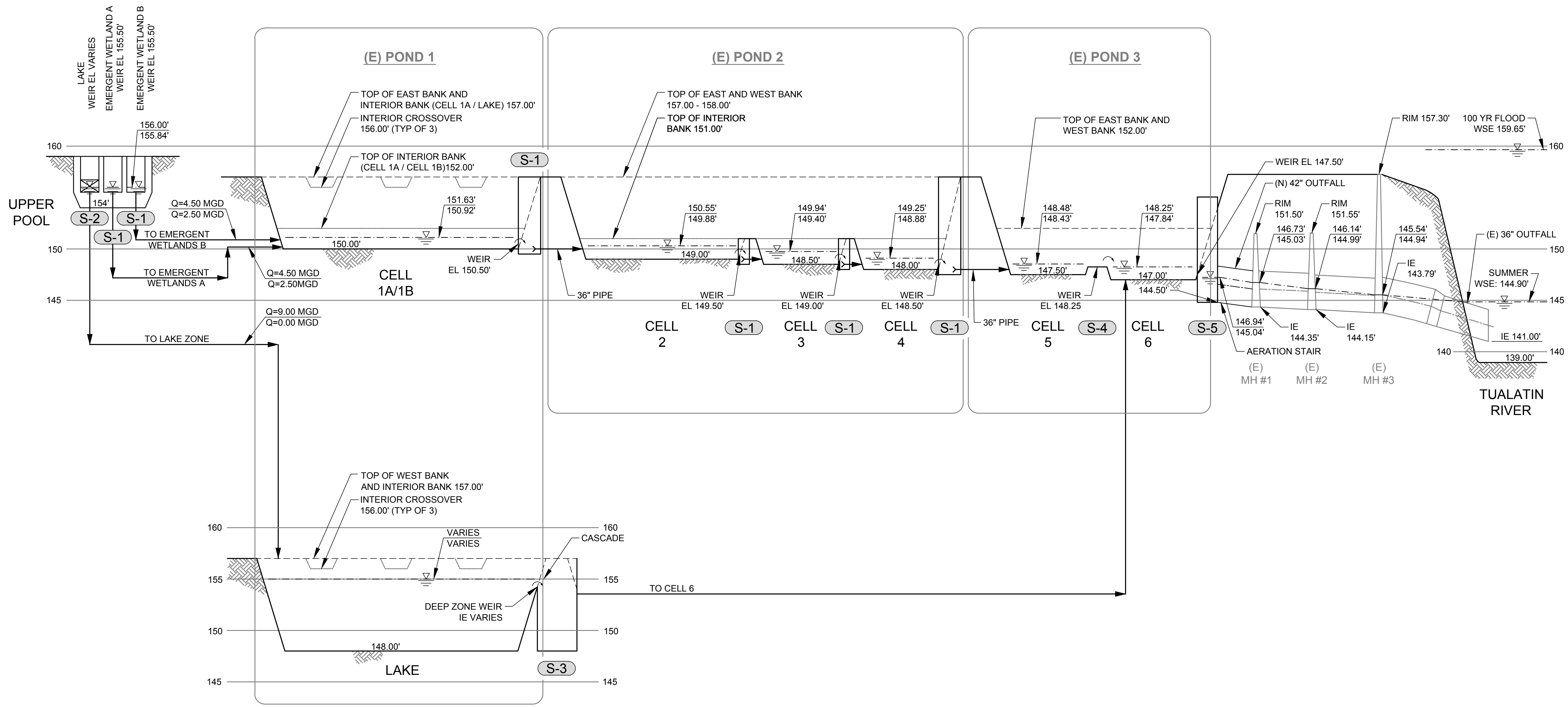

NOTES:

1. HGL SHOWN BASED ON RIVER LEVEL 144.90 (10% DRY SEASON EXCEEDANCE)
2. LAKE WATER LEVEL VARIES DEPENDING ON STORAGE REQUIREMENTS.

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5.5 Hydraulic Control Structures

Hydraulic structures will be placed throughout the South Wetlands to separate each wetland cell, to split flow between the emergent marsh and the Lake, to store water within the Lake, to create turbulence and increase dissolved oxygen concentrations, and to collect water at the end of the wetland for outfall discharge. Four different hydraulic structures were considered in preparation of the hydraulic grade line calculations for separating wetland cells and splitting flow between emergent wetlands and the Lake: broad-crested weirs, rectangular weirs, two stage broad-crested weirs, and compound weirs.

Descriptions of the weir types considered in the design include the following:

- A broad-crested weir is a thick structure that acts as a dam for the water upstream. The key difference between a broad-crested and sharp-crested weir is the weir thickness. For a broad-crested weir, water flows at critical depth over the top of the weir for a measurable distance before developing the nappe. A sharp-crested weir maintains a sharp and thin weir surface, immediately developing the nappe. Head loss over a broad-crested weir is typically greater than a sharp-crested weir due to a less precise flow condition change. Broad-crested weirs were used as the basis of design in the hydraulic profile where stop log structures are used.
- Rectangular weirs are sharp-crested weirs that are commonly constructed as adjustable overflow gates. The sharp edge of the weir allows for the water to break from the structure cleanly forming a nappe which induces aeration. Two sharp-crested weirs as overflow gates are used in the hydraulic profile.
- Two stage broad-crested weirs are two broad-crested weirs that are positioned within the same plane. At low flow conditions, the head loss over the lower weir is such that flow is contained across only the lower weir. As flows increase, the head loss over the weir increases and the higher, overflow weir is crested. Once crested, the overall weir length is the sum of the lower weir length and upper weir length.
- Compound weirs are sharp-crested weirs with notched geometry cut into the crest of the weir. For the purposes of this evaluation, compound V-notched weirs were considered. A V-notch compound weir utilizes a combination of a triangular notch (90° right angle triangle was used for this evaluation) and a rectangular weir. Low flows are passed over the notched section while higher flows increase the head across the weir causing both the notched and rectangular sharp crested sections to be crested.

<u>Structure 1: Stop Log Structure</u>
A number of the wetland cells contain flow transfer structures, conveying flow directly from an upstream cell into a downstream cell. An example of this structure would be between Cell 3 and Cell 4. As shown in Figure 5-6, Structure 1 is an approximately 12 foot by 12 foot rectangular concrete vault that is placed within the wetland with three out of the four sides being surrounded by water. The fourth side is built into the respective berm to allow for easy maintenance and observation access.

The three water facing sides of the vault can have either face-mounted or in-channel stop logs that act as a broad-crested weir. The stop logs can be made out of lumber or fiberglass reinforced plastic (FRP). How the stop logs will be mounted to the vault and their material of construction will be decided during 15% design, but are shown as face-mounted and FRP in Figure 5-6. To provide wetland depth flexibility, the height of each stop log can range from 4 to 6 inches. Each stop log can be fitted with lifting pins to add ease in stop log removal or placement. The maximum stop log length will be approximately 5 feet to allow operators the ability to remove or place the stop logs without the need for mechanical assistance.

Each stop log structure, except the two in the Upper Pool, were designed to have a total stop log weir length of 30 feet to maintain target water surface elevations at 6.3 MGD. With the structure having three water facing sides, this creates three 10 foot stop log sections each divided in two to maintain a maximum stop log length of 5 feet. The two stop log structures in the Upper Pool have a total stop log weir length of 9 feet (3 feet each side) and will have a smaller 5 foot by 5 foot concrete vault.

All weir lengths will be further defined during 15% design. An alternative to having one large structure at the end of each wetland cell is to have multiple smaller structures that directly feed the downstream cell. For example, each individual emergent cell can have three structures each with a total stop log length of 10 feet (3.33 feet each side). Benefits to having multiple smaller structures are:

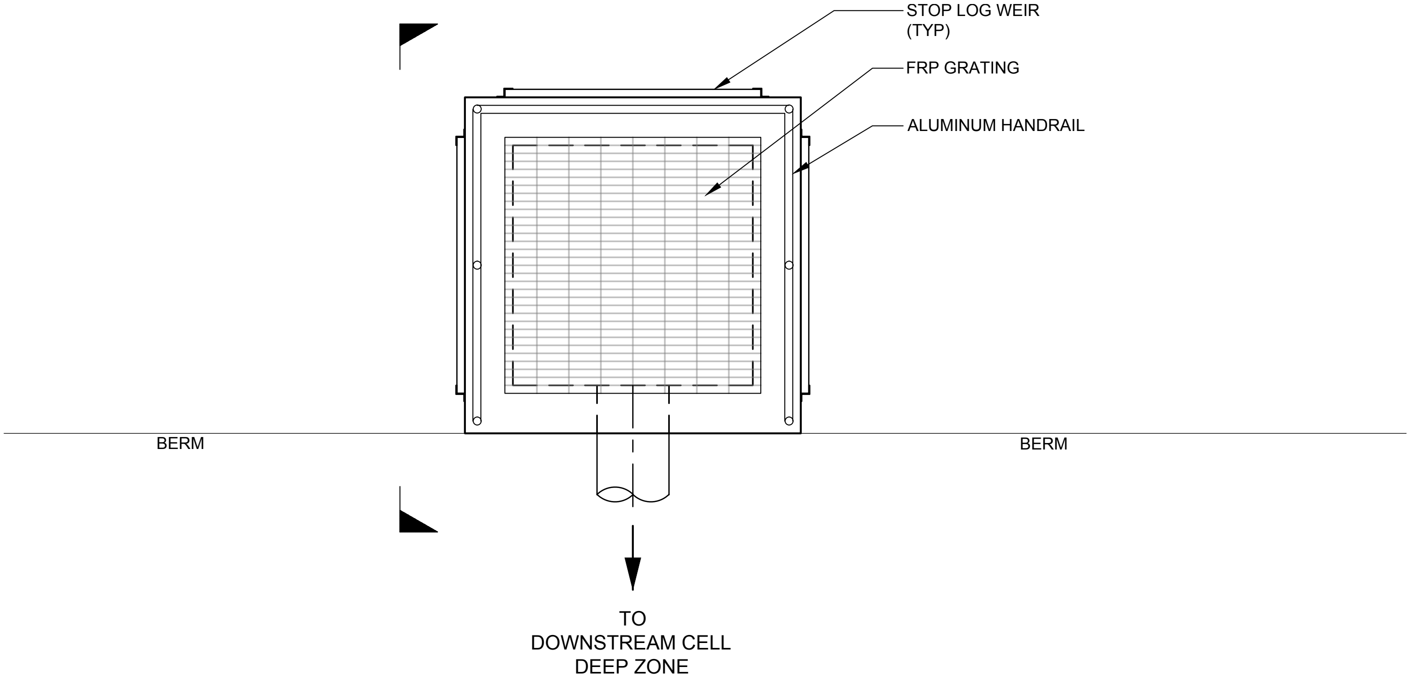
- Individual stop logs are smaller, making them easier to remove and place.
- The structures are less noticeable possibly making the overall natural treatment system more visually appealing.
- Short circuiting could be reduced with the outlet structures and downstream inlet pipes being evenly placed within the cells.

Each structure may include grating and handrails that can serve as a maintenance deck for removing or placing the stop logs. This deck is not a necessity to the hydraulic function of the structure and will increase cost.

Structure 2: Overflow Gate Structure

One overflow gate structure (Figure 5-7) will be used in the South Wetlands and will be located on the berm between the Upper Pool and Lake. The structure will be an approximately 7 foot by 5 foot concrete vault with a face-mounted overflow weir gate modeled as a sharp-crested weir. Similar to the stop log structure, the vault will have an observation deck where the gate's manual hand wheel will be situated. For design of the hydraulic profile, the overflow gate will seal a 5 foot long by 2 foot tall opening that allows flow into the vault. The gate will be set so it can reach elevations between 154.00 and 156.00. Similar to the stop log structure, gate size will be refined during 15% design and could include two smaller gates instead of the one modeled gate.

Instead of using a manual hand wheel to raise and lower the gate, an actuator can be installed to streamline operation. The actuator can run off a level sensor measuring the water surface elevation in the Upper Pool and a position indicator that relays the elevation of the overflow gate.



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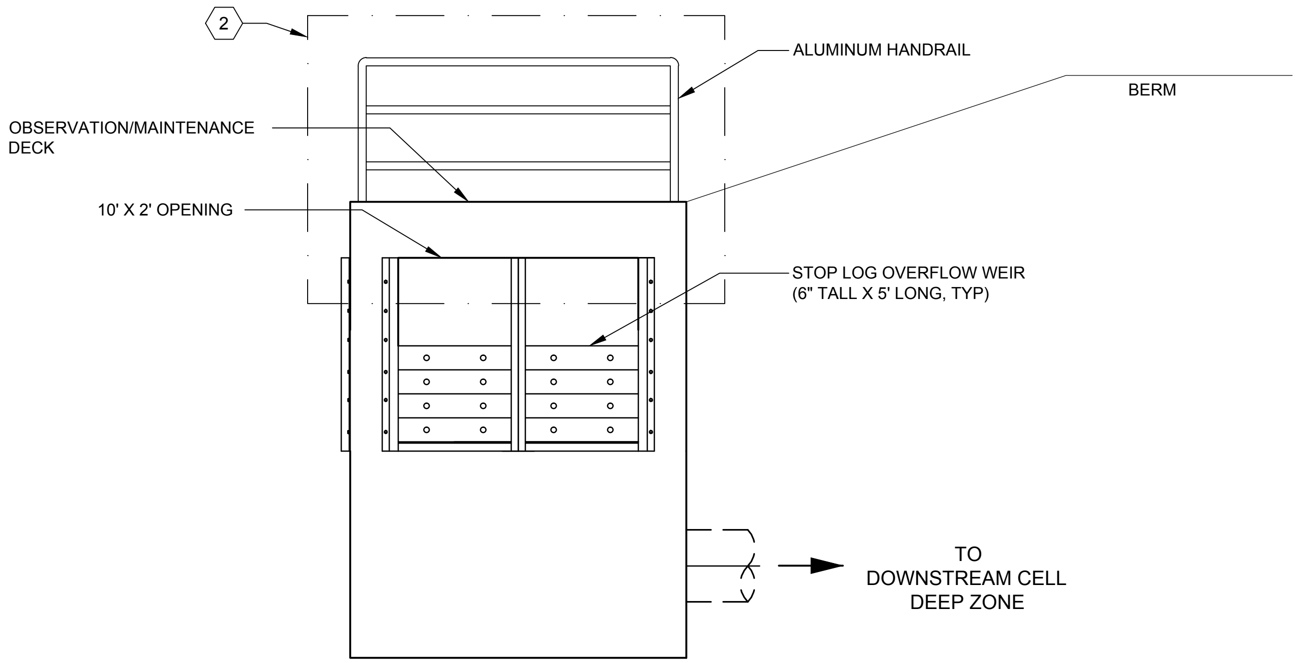

SECTION
NOT TO SCALE

Figure 5-6
Basis of Design

Structure #1
Stop Log
Structure

South Wetlands
Forest Grove, OR

NOTES:

1. STOP LOG LENGTHS WILL BE OPTIMIZED DURING 15% DESIGN AND WERE USED TO DEVELOP HYDRAULIC PROFILE.

(2) OBSERVATION/MAINTENANCE DECK WITH HANDRAILS IS OPTIONAL

NOT TO SCALE

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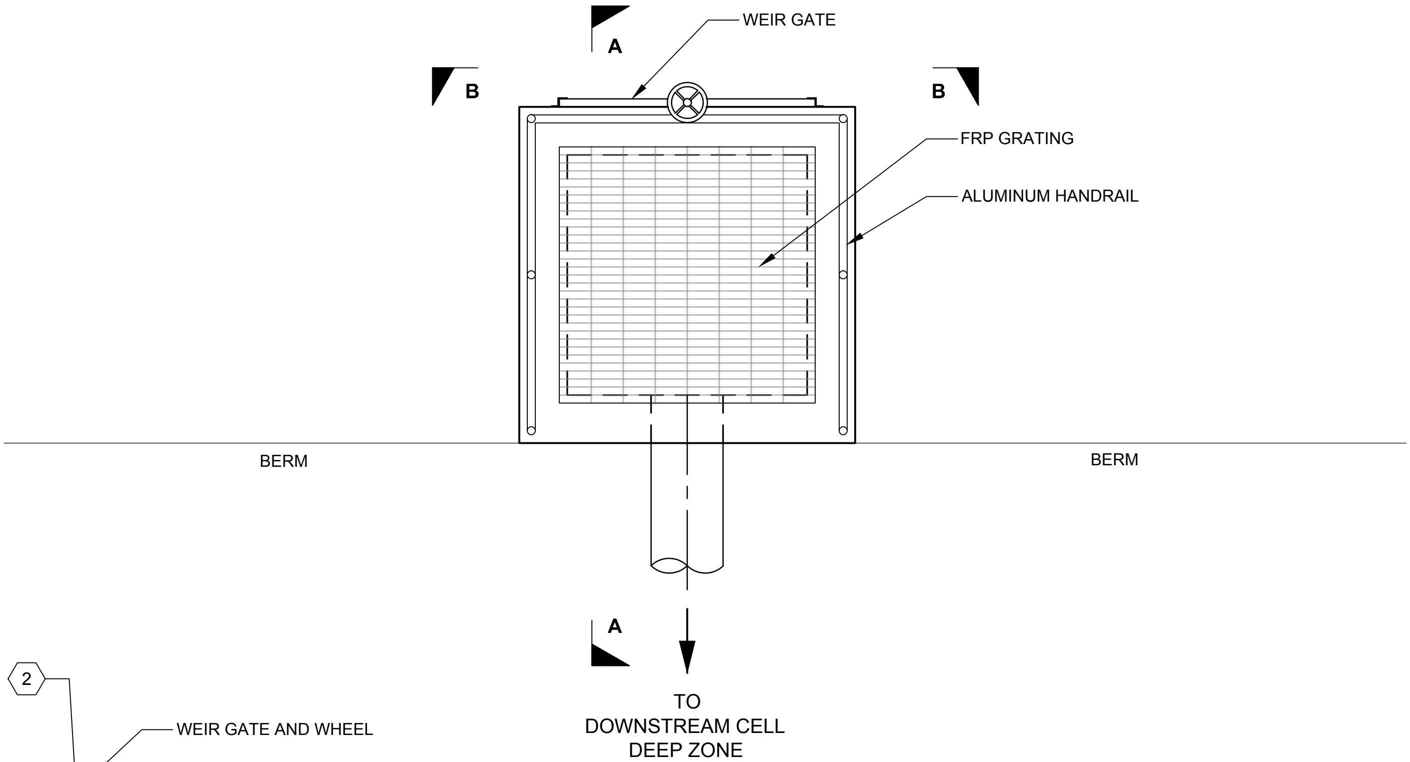

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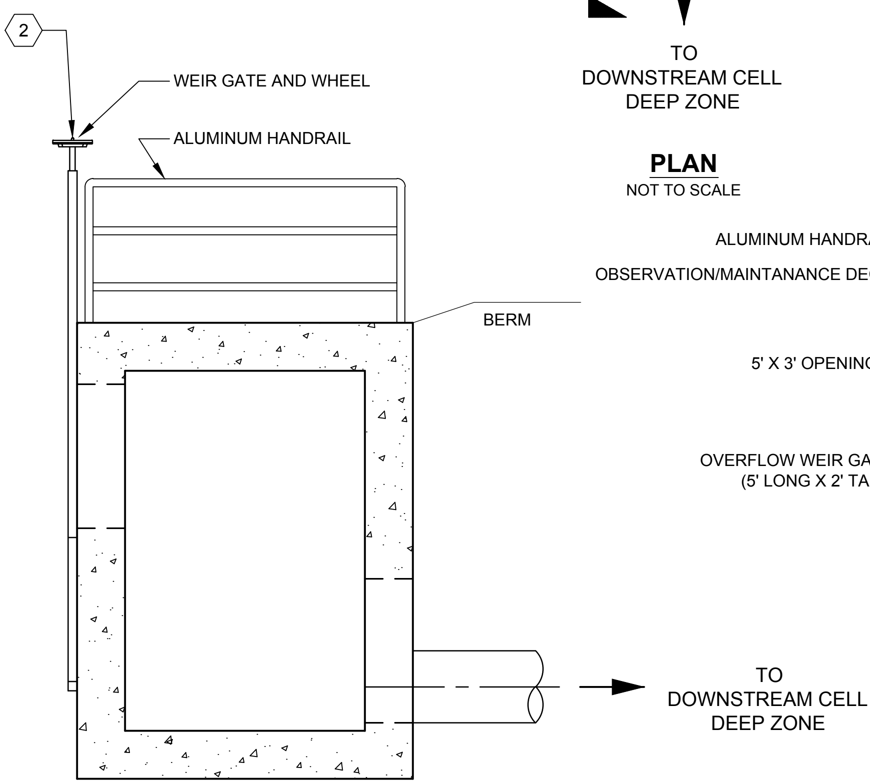

SECTION A
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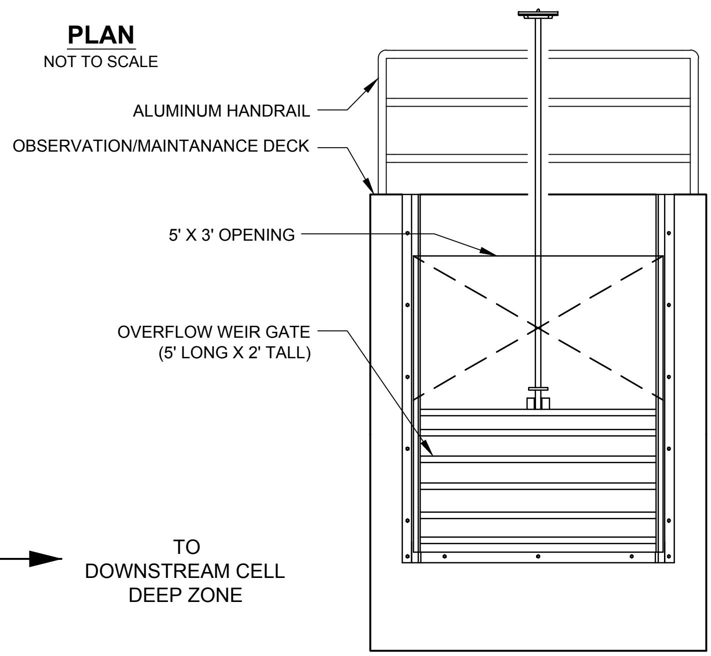

SECTION B
NOT TO SCALE

Figure 5-7
Basis of Design

Structure #2
Overflow Weir Gate

South Wetlands
Forest Grove, OR

NOTES:

1. OVERFLOW GATE LENGTH WILL BE OPTIMIZED DURING 15% DESIGN AND WAS USED TO DEVELOP HYDRAULIC PROFILE.

2. OVERFLOW GATES HAVE THE OPTION TO BE AUTOMATED.

NOT TO SCALE

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Upper Pool Flow Split

All flow passing through the South Wetlands enters the Upper Pool where is it split into three different flow paths: emergent wetlands cells 1A and 1B, and the Lake (Figure 5-8). A number of flow splitting structures and configurations utilizing the weirs described above were investigated. The following goals and operational flow options were used to evaluate the investigated configurations:

Goals:

- Primary flow path is into the Emergent Zones
- Flows into the Emergent Zones are split evenly between emergent trains A and B
- Maximum flow into Emergent Zones is approximately 9 MGD
- Flexibility is needed to divert all flow or no flow to the Emergent Zones

Operational Flow Options:

- No flow through the Lake at flows less than 9 MGD
  - Occurs when effluent does not need additional holding time for treatment purposes.
- Flow through the Lake and Emergent Zones at any flow rate
  - Occurs upon operator discretion. This could occur when Lake water has become stagnant and it needs to be refreshed, or water levels in the Lake need to change to accommodate habitat diversity.
- No flow through the Emergent Zones at any flow rate
  - Occurs when effluent temperature is expected to exceed the heat TMDL and storage of the water is necessary. Storing of the water in the Lake for a length of time will allow air temperatures to decrease and possibly drop the water temperature enough to not exceed the heat TMDL.

The primary configuration that was investigated (Figure 5-8) included broad-crested stop log weirs (Structure 1) into the Emergent Zones and a sharp-crested overflow gate (Structure 2) into the Lake. The emergent wetland split utilizes a length ratio of 1:1 to develop the 50%/50% flow split. In order to standardize the emergent zone weir lengths based on functional weir dimensions and available head loss with the Upper Pool, the emergent zone stop logs were fixed at 9 feet in total length and at an elevation of 155.50. Fixing these weirs along with the overflow gate length at 5 feet, allowed for analysis of flow splitting impacts by evaluating differing Lake gate elevations. This analysis is summarized in Table 5-6.

Table 5-6 Upper pool operational options.

Operational Options	Total Flow (MGD)	Lake Weir Gate Elevation (ft)	Emergent Zones Weir Elevation (ft)
No flow through Lake at flow < 9MGD	0 - 9	156.00 or higher	155.50
	9 - 18	Dependent on Total Flow	155.50
Flow through Lake and Emergent Zones	0 - 18	Dependent on Total Flow	155.50
	18	155.12 or lower	155.50
No flow through Emergent Zones	0 - 18	154.09 or lower	155.50

To achieve no flow through the Lake at flows less than 9 MGD, the Lake gate must be set at an elevation of 156.00 of higher. This forces all flow over the Emergent Zone weirs which are set at 155.50. Once flows exceed 9 MGD, water will start overflowing the Lake gate but will simultaneously flow into the Emergent Zones at flows greater than 9 MGD. To cap the

Emergent Zone flow at 9 MGD, the Lake gate must be lowered to allow more flow into the Lake. The higher the incoming flow, the lower the Lake gate must be due to increased head loss and Upper Pool water surface elevation.

If all flow is needed in the Lake for storage or habitat purposes the Lake gate can be set at or below 154.09 or lower with the Emergent Zone weirs still set at 155.50. The proposed Lake gate minimum elevation of 154.00 can allow up to 20 MGD to flow into the Lake before overtopping the Emergent Zone weirs.

Any Lake gate elevation can push flows through both the Lake and Emergent Zone depending on the total system flow rate. For example, if the Lake gate was set at the same elevation as the Emergent Zone stop logs (155.50) and total system flow was 5 MGD, flow into the Lake would be 1.50 MGD and flow into the Emergent Zone would be 3.50 MGD. However, as described above, the Lake gate must be continuously lowered as flows increase to cap Emergent Zone flow at 9 MGD. The highest Lake gate elevation that can be used at the maximum South Wetlands flow of 18 MGD is 155.12. This evenly splits flow between the Lake and Emergent Zones at 9 MGD each.

Alternative weir lengths and stop log elevations will be explored further in 15% design. It should be noted that the smaller the weir length the more significant head loss changes are making it difficult to replicate in the field. Having all the structures adjustable with gates or stop logs helps with decreasing this sensitivity.

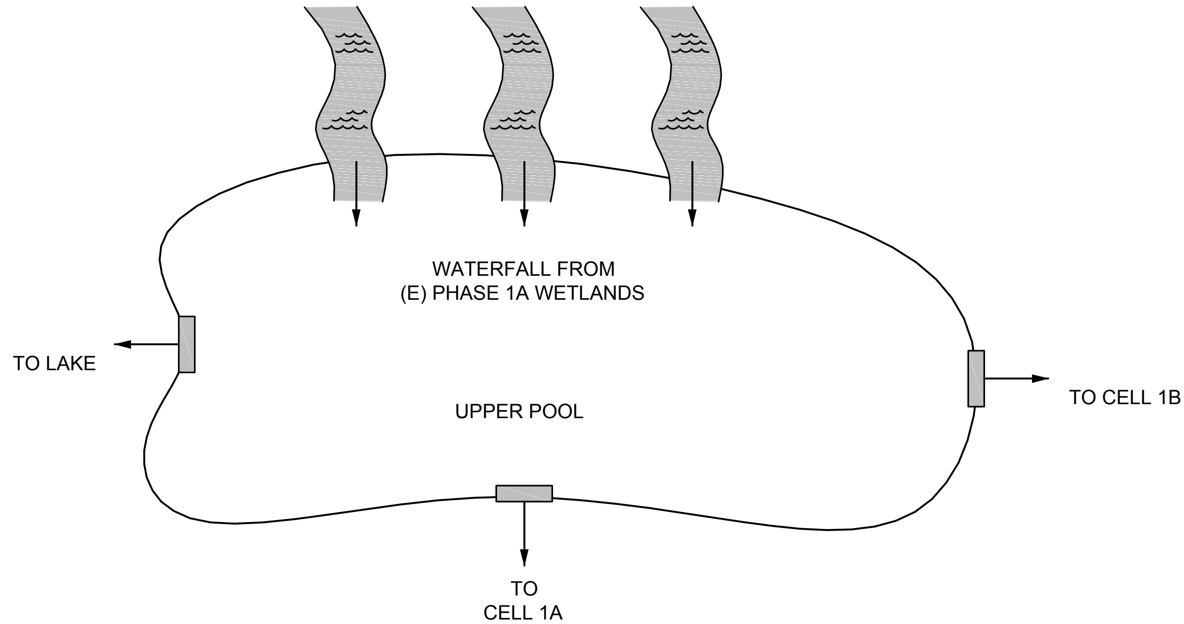
<u>Cell 1A/B to Cell 2 Structures</u>
Two connected stop log structures are presented for transferring flows to Cell 2 from Cells 1A and 1B (Figure 5-9). On the emergent wetland B flow path, flow from Cell 1B overtops the three stop log weirs and flows into a concrete vault. From this vault, flow is piped to the emergent wetland A structure. Both structures are identical to Structure 1 with the exception that the Cell 1A structure has two pipe penetrations: one coming from the Cell 1B structure and one going to Cell 2.

<u>Structure 3: Lake Outlet Structures</u>

The Lake outlet structure consists of two different structures each serving different functions. One structure (Structure 3A in Figure 5-10) will be designed so that the Lake water surface elevations can be adjusted between 152.00 and 156.00. The second structure (Structure 3B in Figure 5-10) will provide the ability to drain the Lake.

Structure 3A will be built within the berm separating Ponds 1 and 3, and be an approximately 6 foot by 6 foot concrete vault. A screened intake pipe will penetrate the vault and sit at the bottom of the Lake to hydraulically connect the Lake with structure. The functions of this gate are to 1) prevent flow from leaving the Lake when storage is needed and 2) control the Lake water elevations between 152.00 and 156.00.

Structure 3B will consist of a standard 48 inch diameter manhole which will house a drainage pipeline and isolation valve connecting the Lake bottom to Cell 6. When the valve is opened, it can completely drain the Lake to the bottom surface elevation of 148.00. The valve will have a stem that can be accessed from the top of the berm to open or close the valve.



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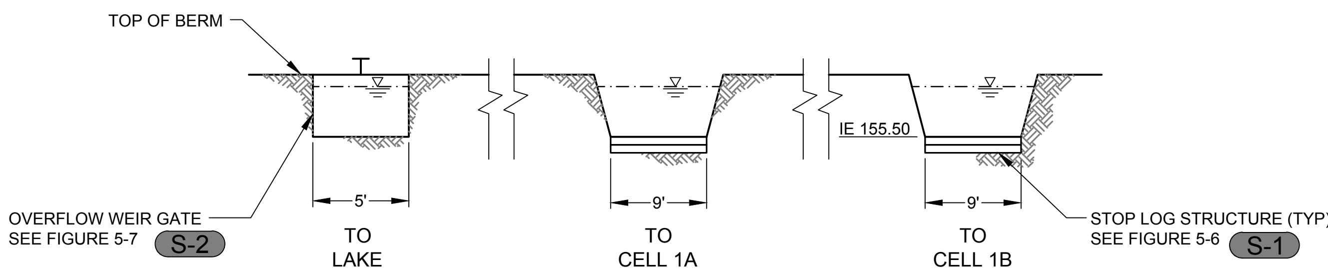

SECTION
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Figure 5-8
Basis of Design

Upper Pool
Flow Split

South Wetlands
Forest Grove, OR

NOTES:

1. WEIR LENGTHS WILL BE OPTIMIZED DURING 15% DESIGN WERE USED TO DEVELOP HYDRAULIC PROFILE.

NOT TO SCALE

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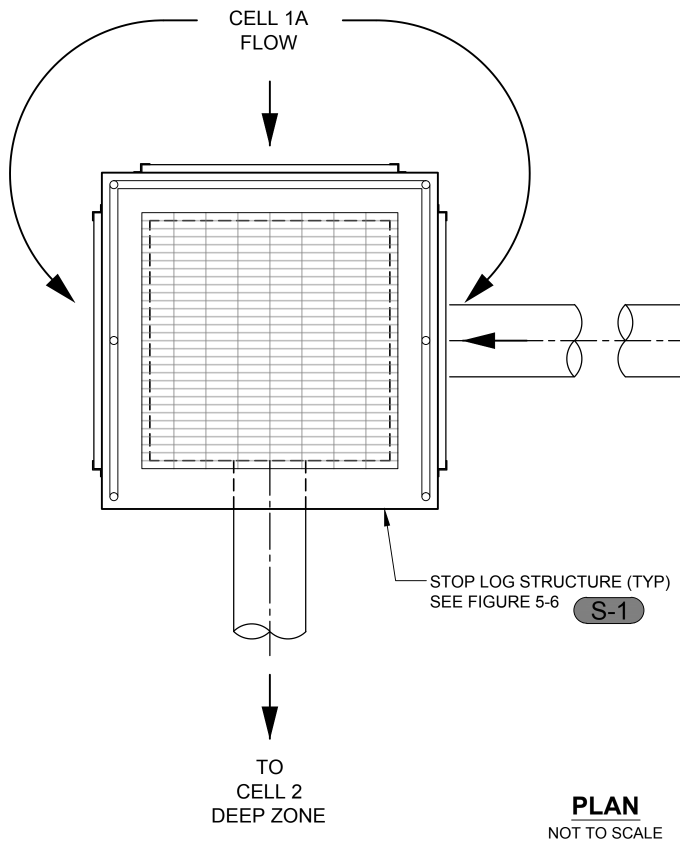

Figure 5-9
Basis of Design

Cell 1A/1B to Cell 2 Structures

South Wetlands
Forest Grove, OR

NOT TO SCALE

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There are a few alternatives to these structures that can be explored during 15% design. One alternative is to have Structure 3B placed in the Lake instead of built within the berm. This option will reduce the amount of concrete as no internal wall is needed to mount the gate. The gate can be mounted on the external wall similar to the overflow Lake gate (Structure 2). An alternative to housing the isolation valve of Structure 3B in a manhole would be to bury it within the berm. However, abrasion from the soil on the 9 foot long stem could cause some maintenance difficulties in the future. A second alternative for Structure 3B is a concrete vault with a sluice gate that can be used to completely drain the Lake.

With all of these alternatives, there are only two places where Structure 3A can be placed; in the Lake or in the berm. Although costs would decrease with Structure 3A placed in the Lake, there are two advantages of having a screened pipe intake at the bottom of the Lake:

- Stratification in the Lake could potentially occur allowing discharge of cooler water than the surface overflow.
- Floating material such as duckweed will not be transported to the downstream cells as it would in an overflow structure.

The advantages of a screened pipe intake along with the list of alternatives need to be further evaluated during 15% design.

Structure 4: Berm Weir Structure

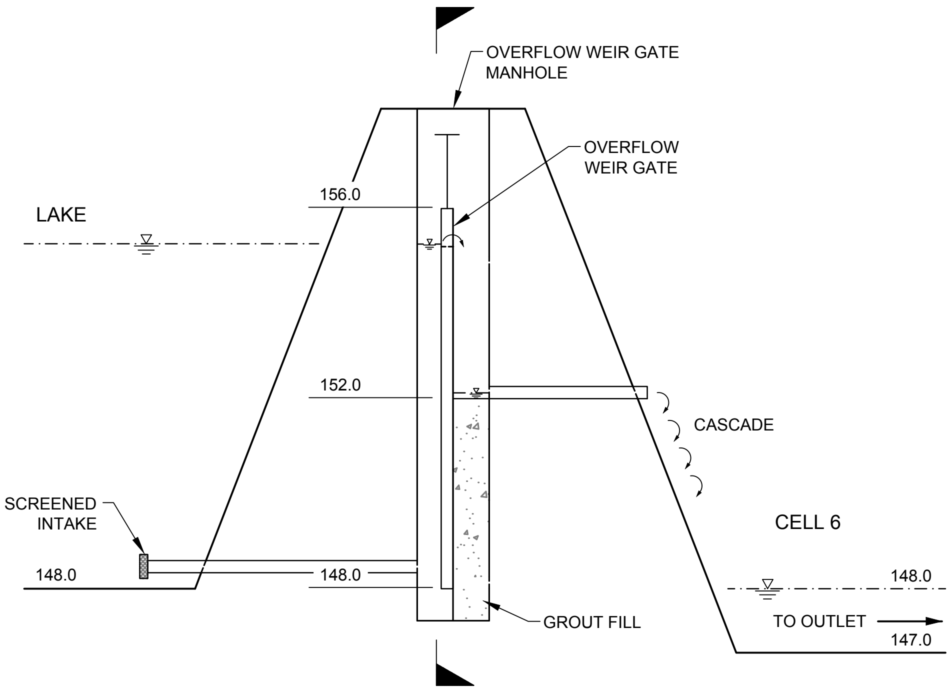
The berm between Cells 5 and 6 will be used as a long broad-crested weir (Figure 5-11). The berm elevation is designed at 148.25 to allow flow from Cell 5 to overflow into Cell 6. Due to the long length of the berm, head loss over the berm will be minimal.

Flood flows typically run through Pond 3 as the existing berm elevations sit lower than the other two ponds. Having the Pond 3 interior berm (berm separating Cells 5 and 6) fortified to not scour and cause destruction of plants is a necessity during flood events. If the berm is already fortified for flood events it will be suitable for continuous overflow during normal wetland operation. It is expected that flood velocities will be greater than normal wetland operation velocities.

Structure 5: NTS Outlet Structure

Effluent flows from Cell 6 will utilize an aerator structure (Figure 5-12). Currently, this is anticipated to include a cascade assembly that utilizes the free fall of water and turbulence to entrain air into solution. These typically consist of a number of concrete stairs over which the water flows. As the water falls off each step, the splashing effect increases the water surface area exposed to atmosphere, allowing oxygen to be diffused into solution.

This structure will also house the effluent quality monitoring station that will monitor flow, temperature and dissolved oxygen. Telemetry control options will be reviewed during 15% design.



STRUCTURE #3A
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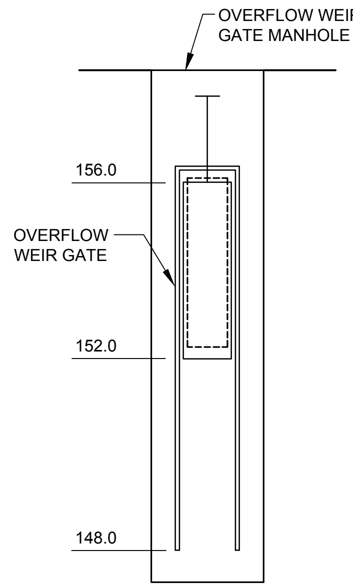

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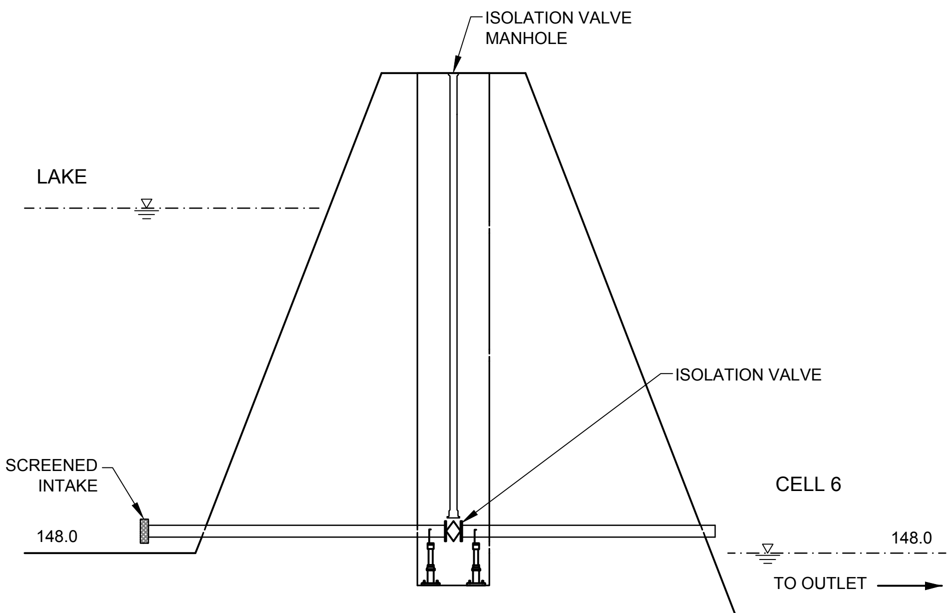

STRUCTURE #3B
NOT TO SCALE

Figure 5-10
Basis of Design

Structure #3 Lake Outlet Structures

South Wetlands
Forest Grove, OR

NOTES:

1. OVERFLOW GATE USED TO MANAGE WATER LEVELS IN THE LAKE.
2. ISOLATION VALVE USED TO DRAIN LAKE.

NOT TO SCALE

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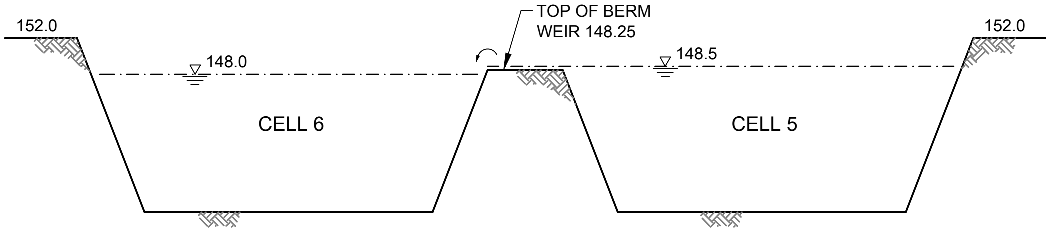

SECTION
NOT TO SCALE

Figure 5-11
Basis of Design
Structure #4

South Wetlands
Forest Grove, OR

NOTES:

1. BERM WILL BE FORTIFIED TO HANDLE FLOOD VELOCITIES.

NOT TO SCALE

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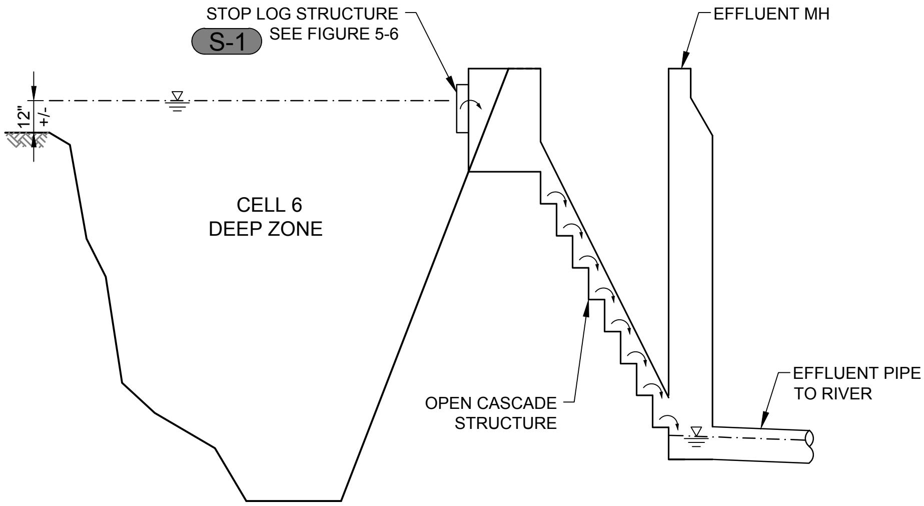

SECTION
NOT TO SCALE

Figure 5-12
Basis of Design

NTS Outfall Structure

South Wetlands
Forest Grove, OR

NOT TO SCALE

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5.6 100-Year No Net Rise Analysis

To ensure that the proposed design does not increase the potential for flood impacts off site, the Design Team evaluated hydraulic conditions with a focus on the potential effect on the Base Flood Elevation, which is the FEMA 100-year water surface elevation.

FEMA has determined that a portion of the project site falls within the "Zone AE Special Flood Hazard Area" and within a "Floodway" (FEMA, 2007). Consequently, any action involving cut and fill of material must be evaluated hydraulically to ensure that there will be no increase in the Base Flood Elevation. In an effort to determine the impact that the proposed grading in the South Wetlands Project Area would have on the FEMA Special Flood Hazard Area and the Floodway, the Current Effective Model was evaluated. The Current Effective Model used in the model were developed by FEMA using the standard Hydrologic Engineering Center Analysis River Analysis System (HEC-RAS [USACE, 2006]).

The Current Effective Model designates the wetland ponds as ineffective flow areas, meaning that areas below the designated ineffective flow elevations do not contribute to conveyance. In the Current Effective Model, the ineffective flow area was set to an elevation of 161 feet, which is higher than the predicted water surface elevation (water surface elevation) of the 100-year high flow event (159.13 feet). Consequently, the limited grading proposed for the South Wetlands will not result in an increase in the water surface elevation for the 100-year storm event. As the design progresses a No-Rise Certification letter will be prepared in support of the permit process with the City of Forest Grove and Washington County. At that time the appropriate level of modeling will be conducted to satisfy requirements set by floodplain managers for the City of Forest Grove and Washington County.

The existing conditions HEC-RAS model was also used by the Design Team to predict flow velocities through South Wetlands, especially through Pond 3 when floodwaters overtop Fernhill Road. Since the existing ponds are being modified to reduce water temperatures of the wastewater effluent by introducing emergent and forested wetland vegetation through site, the ability for these plant communities to resist scour during high flow events is critical.

During low to moderate high flow events, floodwaters from the Tualatin River and Gales Creek overtop their banks upstream of the Fernhill Road Bridge and enter the field west of Fernhill Road. The floodwaters then overtop Fernhill Road, enter the adjacent roadside ditch and overtop the western berm through Pond 3 before flowing across the pond and discharging over the eastern berm into Cottonwood Creek. At flows greater than the 2-year event, backwatering of the floodplain from downstream results in an incremental decrease in energy through the South Wetlands. In addition, more of the floodplain becomes activated through Ponds 1 and 2. Consequently, the focus of this analysis was at flows less than the 2-year event.

Because the 2-year event flow in the Tualatin River behaves differently than the 100-year flood flow, certain parameters and assumptions were altered in the existing conditions model to accurately represent the existing and proposed conditions. They include:

- Ineffective Flow Areas: Ineffective flows areas were reduced through Pond 3 to match the elevation of the eastern berm,
- Roughness Values: Roughness values were reduced to reflect an increase in vegetation. Because the distribution of vegetation was not known and at high flows the

vegetation would likely be in a leaf-off condition or sub-grade in the case of emergent vegetation, the roughness was only increased slightly,

The model was run with these modifications for a range of flows between initiation of flow over Fernhill Road and the 2-year peak flow event. The discharge over Fernhill Road, water depth at Fernhill Road, and velocity through Pond 3 are summarized in Table 5-7.

Table 5-7 Water surface elevations, depths, and velocities at Fernhill Road through Pond 3 at a range of overbank flow conditions.

Discharge[1] (cfs)	Existing Conditions		
	WSE[2] (ft)	Depth (ft)	Velocity (ft/sec)
100	156.27	0.27	0.13
200	156.35	0.35	0.20
400	156.44	0.44	0.30
600	156.53	0.53	0.37
800	156.58	0.58	0.44
1400	156.73	0.73	0.59
Q2 (2116)	156.87	0.87	0.74

[1] Discharge refers to left overbank flow from the Tualatin River. Q2 discharge quantity is an estimate of total left overbank flow for the 2-year peak flow event from the Existing Condition HEC-RAS model.
[2] Elevations are in NGVD29.

5.7 Water Temperature Modeling

In the 2012 Final Basis of Design (CH2M HILL, 2012a) for the Natural Treatment System (NTS) at the Forest Grove Wastewater Treatment Facility, several Heat Source Wetland models were prepared to assess the influence of the NTS on effluent temperatures and thermal loads on the receiving Tualatin River. The models showed substantial cooling across the wetlands, ranging from 0.4 ^{o}C in July to 6.6 ^{o}C in December.

Although the design of the Lower Wetlands (now “South Wetlands”) has changed since 2012, a persistent anticipated benefit associated with the NTS is to provide a means of cooling effluent from the Forest Grove WWTF. The Heat Source Wetland model used for the 2012 Basis of Design is proprietary software owned by the CH2M HILL. To evaluate the results from the 2012 Heat Source Wetlands model and determine whether the anticipated benefits extend to the most recent design iteration of the Lower Wetlands and Lake, a temperature model (referred to as the thermodynamic heat balance model) employing a well documented energy balance methodology (Klemetson and Rogers, 1985; Kadlec and Wallace, 2009) was prepared using an hourly time step (described in further detail below). Revised wetland and lake surface areas, water depths and flows were evaluated under five different flow regimes. The model confirms that effluent from the Forest Grove WWTF may be cooled by the NTS throughout most of the year. The anticipated degree of cooling is a function of numerous factors associated with the design and operations, including flow rate running through the NTS, surface area and volume (depth) of the NTS, and the reduction of solar radiation due to shading by plants.

5.7.1 MODEL METHODOLOGY

As stated, temperature models of previous design concepts of the Lower Wetlands at Fernhill projected significant cooling. CH2M HILL modified the Oregon Department of Environmental Quality's (DEQ) publicly available Heat Source 7 software to model wetlands. Heat Source is a powerful tool for analyzing stream thermodynamics using "spatially continuous data coupled with deterministic modeling of hydrologic and landscape processes" (Boyd and Kasper, 2003). Modifications to Heat Source for modeling the heat and mass transfer in wetlands are the proprietary intellectual property of CH2M HILL (Smesrud, pers. comm.). Therefore, building upon and revising the previous temperature models using the Heat Source Wetlands model for the new concept design was not pursued by the design team.

A thorough literature review of thermal models for wetlands and open waterways was performed. Risley (1997) reported on the methods employed to develop and calibrate two dynamic flow heat transfer models for the Tualatin River to approximate historic temperature patterns and evaluate management scenarios. Wallace and Nivala (2005) used an energy balance to model the thermal response of insulated subsurface flow treatment wetlands in Marine of St. Croix, Minnesota to maintain treatment performance during cold weather. This work contributed to the energy balance methods published in Kadlec and Wallace (2009). Herb et al. (2006a) developed a computational simulation model to quantify the effect of a stormwater pond on the temperature of surface runoff. The model was similar to previous 1-D models and solves equations that describe flow and heat transfer processes in hourly or daily time steps, and incorporates a shade model for predicting the solar radiation reduction of marsh vegetation (Herb et al., 2006b). The literature review provided valuable background and provided a measure of confidence in the thermodynamic heat balance methodology used to predict effluent temperatures for the latest iteration of the NTS design.

The thermodynamic heat balance model we employed, modified from Klemetson and Rogers (1985), is:

$H = He + Hc + Hr - Hs - Ha$

- Where H = net heat loss
- He = heat loss by evapotranspiration (ET)
- Hc = heat loss by convection
- Hr = heat loss by radiation (primarily night sky infrared radiation)
- Hs = heat gain by radiation
- Ha = heat loss to ground

Equations for each of the heat loss and gain variables are from various sources, including Rafferty (1991), Klemetson and Rogers (1985), and ASHRAE (2013). The equations are based on the effects of solar radiation, ET, infrared radiation (IR) return, and convection that were developed for aquaculture ponds.

The model employs basic thermodynamic principles, and therefore produces intuitive results in response to inputs. For example, the water temperature of the lake is greatly affected by the surface area and mass of water (volume) being heated or cooled. Shallow ponds will warm more quickly during the day, and cool more quickly at night. The reverse applies to deeper ponds and lakes. Surface flow wetlands are, in essence, shallow ponds with vegetation that provide a reduction in solar radiation and reduce the cooling (or warming) effects of wind. The mass of the water acts as a capacitor or reservoir of heat, reducing the diurnal and seasonal temperature fluctuations of the air. A flow-through system, such as envisioned for South Wetlands, will therefore be highly dependent on the volume and temperature of the inflow, and the volume of water in the wetlands. The volume of the inflow will determine the hydraulic residence time (HRT = volume of wetlands or lake/influent flow rate): longer residence times cause water temperature to approach the air temperature (the result of local climate conditions, including solar radiation, wind and evapotranspiration), whereas shorter residence times cause the water temperature in the wetlands to approach influent water temperature.

<u>Input Data</u>

Inputs to the Fernhill temperature model include time-dependent variables and fixed variables associated with the surface area and water depths of the proposed wetlands and lake. Time-dependent variables required to run the model include:

- water temperature flowing into NTS
- average daily air temperature
- wind speed
- solar radiation

Data for water temperature, average daily air temperature and wind speed were obtained from previous Heat Source Wetland model runs (2002 data from CH2M HILL, 2012a). Solar radiation data was obtained from the NREL solar radiation database (NREL, 2010).

Additional factors used to check sensitivity and calibrate the model include the percent reduction of solar radiation associated with vegetated cover and the percent reduction of wind speed at the surface relative to the 10 meter standard monitoring height due to drag.

The Fernhill temperature model employs much of the same input data as the previous Heat Source Wetlands models. The input data is from 2002, a year that had low precipitation and high air temperatures. As was reported in the Basis of Design Report for the Natural Treatment System at the Forest Grove Wastewater Treatment Facility (CH2M HILL, 2012a), the climatic conditions of 2002 resulted in low river flows and higher river temperatures. The analysis is therefore conservative in that potential thermal impacts will be more likely than average years.

<u>Model Testing</u>

Although Heat Source is the appropriate tool for modeling thermodynamics over a watershed scale, we believe, due to the relatively small project area, that a less data-intensive method based on well-documented thermodynamic principles is equally effective as a predictive tool. In order to evaluate the performance of the thermodynamic heat balance model, a simulation was conducted to compare and fit the observed data to the model results from the 2012 Concept Design, as reported in CH2M HILL (2012b). As can be seen in Figure 5-13, the Fernhill temperature model compares favorably with the calibrated Heat Source model.

In our particular model, seasonal variability in plant cover reduces solar radiation gain by shading the water. Plant cover also slows wind speed at the boundary of the surface, which may influence ET rates. The effects of vegetation on reducing radiation inputs and influencing ET are greatest in summer. In winter, senescing plants provide less cover and shade.

Morris (1989) modeled light distribution in a *Spartina* marsh plant community and looked at the function of biomass density and solar angle. To estimate the solar radiation reduction at the surface due to shade, we employed a simple model developed by Van Raalte et al. (1976). Light was measured beneath the canopy of a marsh. As density of biomass increased, the percent of light at the surface was reduced as a power function.

To account for vegetation, we assumed 80% of the wetland is vegetated at a density of 400 grams per meter square. This assumption of plant density is based on a recent study of a Typha marsh in winter in California. During the summer, plant density of Typha was found to exceed 2000 grams per meter square (Miller and Fujii, 2010). The assumption of 400 grams per meter represents a conservative estimate of Typha. Based on this density and the shade model developed by Van Raalte et al. (1976), a 60% reduction of solar radiation in summer due to shading is expected and was input into the model. The model also assumed a 25% reduction of solar radiation in the winter due to plant senescence. Finally, wind speed reduction due to drag associated with vegetation was anticipated. The model assumed wind speed reduction of 20% initially.

To test and compare the Fernhill temperature model to the Heat Source Wetland model, we input the surface area, volume and flow rate from the September 2012 Upper Treatment Wetlands. All time-dependent variables were the same, except solar radiation, as reported above. Percent solar and wind speed reduction due to vegetation were adjusted until the output from the two models visually matched.

Several model iterations were run to obtain the best fit to the Heat Source model of the Upper Treatment Wetlands. Adjustments to initial model settings include:

- Summer solar radiation reduction due to shade: 60%
- Winter solar radiation reduction due to shade: 55%
- Reduction of wind speed due to drag: 0%

Although the solar radiation reduction due to shading in summer was the same as predicted by Van Raalte et al. shade model, solar reduction in winter was higher than expected. It is possible reduction of shading by dying vegetation may be offset by the lower solar incidence of the winter sun. It was also observed that observed wind speeds, rather than adjusted due to drag, produced results most consistent with Heat Source model results of the 2012 Upper Treatment Wetlands.

Output from the developed thermodynamic heat balance model was graphed with the Heat Source model for the 2012 Upper Treatment Wetland and is shown in Figure 5-13. As can be seen, thermodynamic heat balance model compares well with a previously calibrated simulation of the 2012 Design Concept. Water temperatures from the output reflect the moving 7-day average daily maximum (7DADM). The near replication of results indicates that we can apply the thermodynamic heat balance model with a satisfactory degree of confidence.

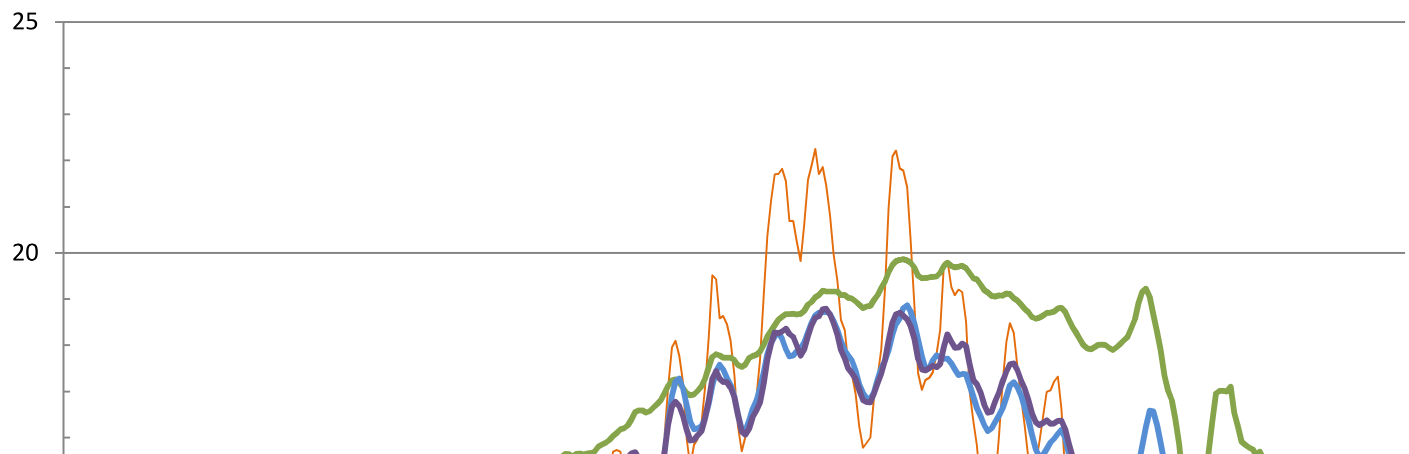
Figure 5-13
Basis of Design

Thermodynamic Heat Balance Model Testing

South Wetlands
Forest Grove, OR

Legend

Average Air
Inflow H2O
Wetland Effluent



2013 Design Models

Temperature simulations of the South Wetland (cells 1 through 5 and the Lake) were prepared for five different flows. Cell 6 was excluded from calculation as it was assumed to be a mixing zone. Surface areas and volumes were calculated from proposed drawings in AutoCAD Civil 3-D 2011. To account for zones where flow is expected to be stagnant due to proposed design topography, an effective flow path was estimated to be 75% for the wetlands and 90% for the Lake. Both volume and area were modeled to be 75% of the total wetland and 90% of the Lake volume and area.

Water surface elevations were assumed to be flat through the wetland cells and lake. The average depths for all flows were assumed to be 12 inches. Simulations were run without mixing scenarios between Lake and wetlands. Finally, solar radiation due to vegetation was adjusted from the model testing simulation described above to reflect 10% open water and 80% of the wetlands being covered with vegetation at 400 grams per meter square. Over the vegetated portion of the wetlands, solar radiation at the surface is predicted to be 25%, while the unvegetated and open water areas will receive 100% of the incoming radiation. The total flows are either through the wetlands or through the lake. Table 5-8 summarizes the differences between each of the simulations, as identified by the flow rate.

Table 5-8 Summary of five temperature simulation inputs of the South Wetlands.

Flow Rate (MGD)	Total Water Volume (cf)	Hydraulic Residence Time (days)[1,2]	Water Surface Area (acres)	Percent Solar Reduction Summer	Percent Solar Reduction Winter
4.0	1.5 E6	2.8	34.5	55%	50%
5.0	1.5 E6	2.2	34.5	55%	50%
6.3	1.5 E6	1.8	34.5	55%	50%
9.0	1.5 E6	1.2	34.5	55%	50%
18.0	1.5 E6	0.6	34.5	55%	50%

[1] HRT calculations do not include the Lake or Cell 6. Section 5.4 includes HRT calculations for these areas.
[2] HRTs are calculated at 12" depth.

5.7.2 RESULTS

Results from the five temperature simulations are shown in Figures 5-14 through 5-16. Figure 5-14 includes the Heat Source predicted temperature of effluent from the 2012 treatment wetlands concept for comparison. At the 4 MGD flow rate, the simulation indicates significant cooling relative to inflow temperature. With an HRT of 2.8 days, effluent temperatures from the wetland trends toward air temperature during the cooler seasons. However, during summer, water is cooled below air temperatures due to losses associated with significant evapotranspiration.

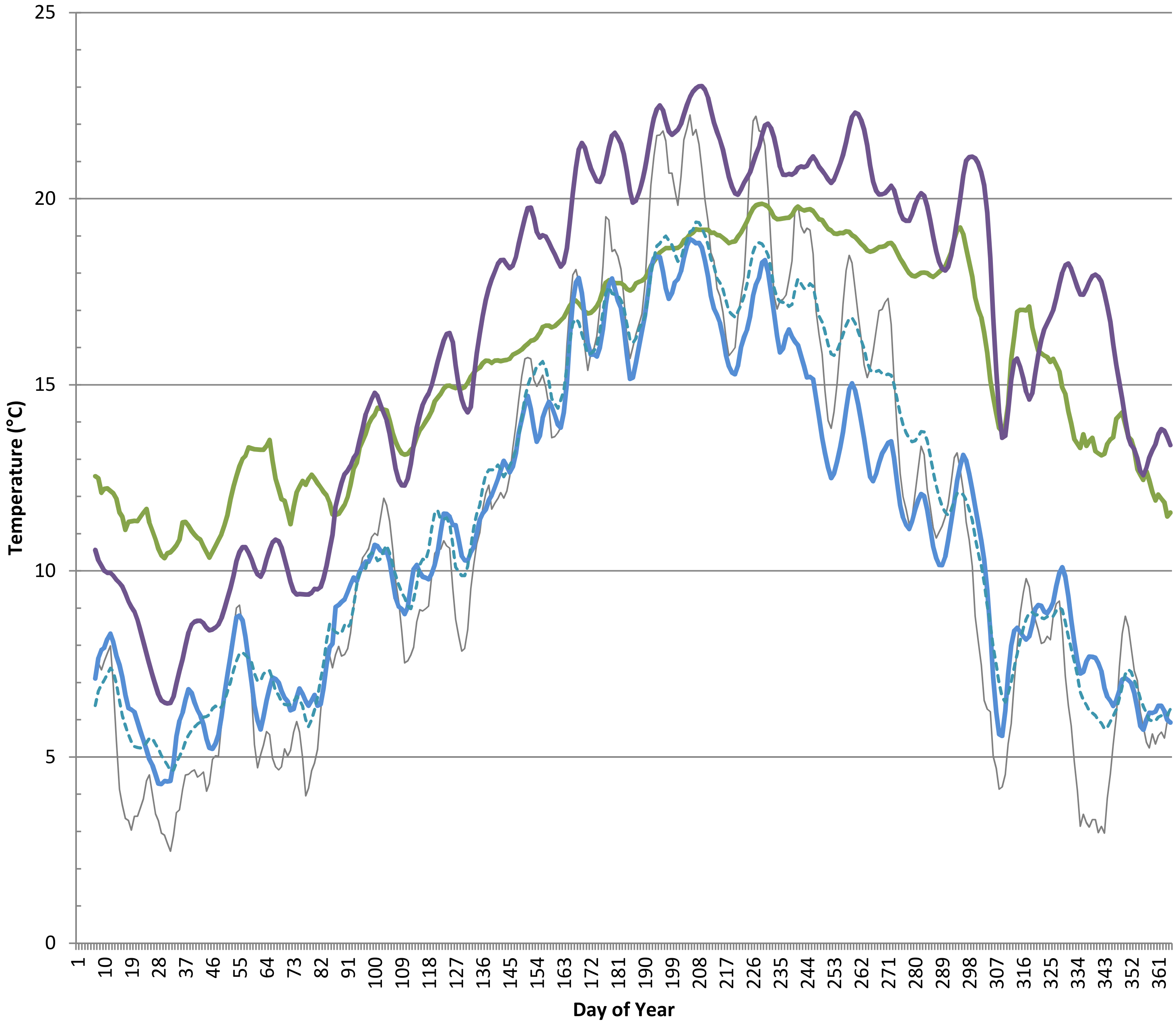
In general, the Lake simulation is cooler than inflow water temperature only during the winter months. By late spring and summer increased solar radiation contributes to warming the Lake whereby temperatures exceed inflow. With a volume of 5.1 E6 cubic feet, the significant thermal mass retains the heat of the summer into autumn and begins to reflect trend of inflowing water temperature. The cooling appears to be driven by both dropping air temperatures and high winds. However, in November, several days of low winds and high solar radiation warm the Lake.

Figure 5-14

Basis of Design

Temperature Simulation at 4 MGD

South Wetlands
Forest Grove, OR



Legend

- Average Air
- Inflow H2O
- Wetland Effluent
- Lake Effluent
- 2012 Concept

NOTE:
Water temperatures from model output reflect the 7 day average daily maximum (DADM).

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Biohabitats CASCADIA BIOREGION

Figure 5-15 shows the temperature results of the 5 MGD, 6.3 MGD, 9 MGD and 18 MGD flows through the wetlands. As can be seen in the figure, the wetlands are predicted to cool water inflowing into the wetland from the WWTF for all flows at all times of the year. There are several days when effluent from the wetland is warmer than the inflow into the wetland around Day of Year 170 (June 18th). Another pattern that can be readily observed from Figure 5-15 is that the lower the flow rate, more cooling is expected relative to the influent temperature, as there is more time to lose heat through evapotranspiration and convection losses. Also, seasonal peaks are about the same for all flow rates and below seasonal peak temperatures without wetland treatment. Average monthly and annual temperature changes for each flow rate simulation are shown in Table 5-9. Maximum temperatures reductions are 6.4^{o}C and 5.9^{o}C in November at 5 and 6.3 MGD, respectively. The least amount of cooling is expected in June and July when solar radiation begins to peak and air temperature rises.

Table 5-9 Summary of average predicted temperature changes in Celsius through wetlands at various flows. Negative numbers imply cooling of water relative to influent.

	Average Predicted Degree Change from Inflow for Four Flow Rates (negative reflects cooling)			
Month	5 MGD	6.3 MGD	9 MGD	18 MGD
Jan	-4.7	-4.3	-3.8	-2.6
Feb	-4.8	-4.5	-4.0	-2.8
Mar	-4.9	-4.5	-4.0	-2.9
Apr	-3.8	-3.6	-3.2	-2.5
May	-3.4	-3.2	-2.8	-2.1
June	-1.4	-1.3	-1.2	-0.9
Jul	-1.0	-1.0	-0.9	-0.7
Aug	-2.8	-2.7	-2.4	-1.8
Sep	-5.0	-4.6	-4.0	-2.8
Oct	-5.8	-5.4	-4.6	-3.1
Nov	-6.4	-5.9	-5.2	-3.6
Dec	-5.7	-5.3	-4.6	-3.2
Annual	-4.1	-3.8	-3.4	-2.4

Figure 5-16 shows the temperature results of the 5 MGD, 6.3 MGD, 9 MGD and 18 MGD flows through the Lake. As can be seen in the figure, the Lake is predicted to warm water inflowing from the WWTF most times of the year. It appears that temperatures may be cooler than influent from January through March. The bump in warmer water in December is thought to be associated with low wind speeds and clear sunny days at the beginning of the month, limiting mixing and contributing heat through solar radiation. Another pattern that can be readily observed is that the higher the flow rate, the lower the heat gain. This is the opposite of the wetlands models. Average monthly and annual temperature changes for each flow rate simulation are shown in Table 5-10.

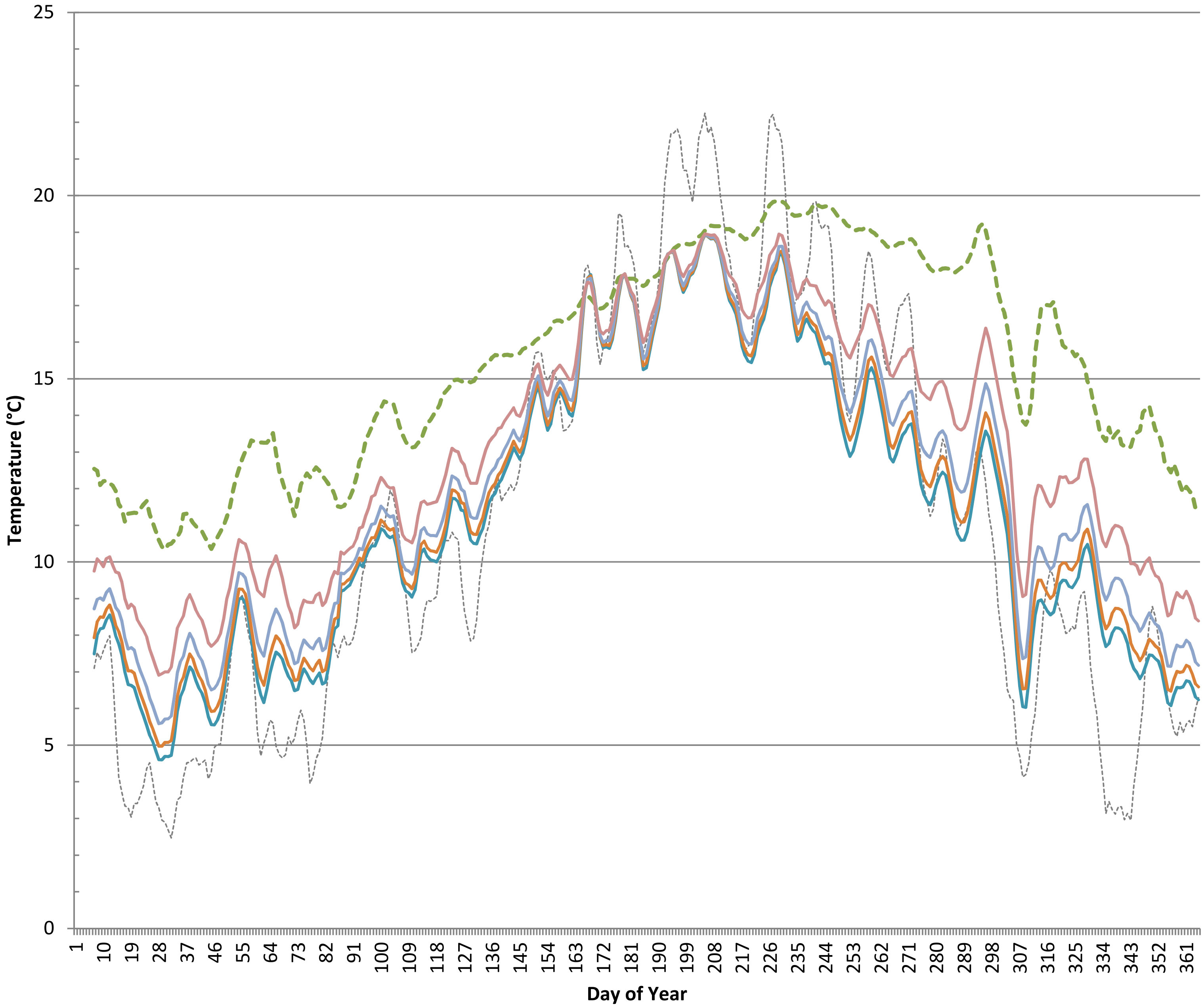

Figure 5-15

Basis of Design

Temperature Simulations at 5 MGD, 6.3 MGD, 9 MGD and 18 MGD through Wetlands

South Wetlands
Forest Grove, OR

Legend

- Average Air
- Inflow H2O
- 5 MGD
- 6.3 MGD
- 9 MGD
- 18 MGD

NOTE:
Water temperatures from model output reflect the 7 day average daily maximum (DADM).

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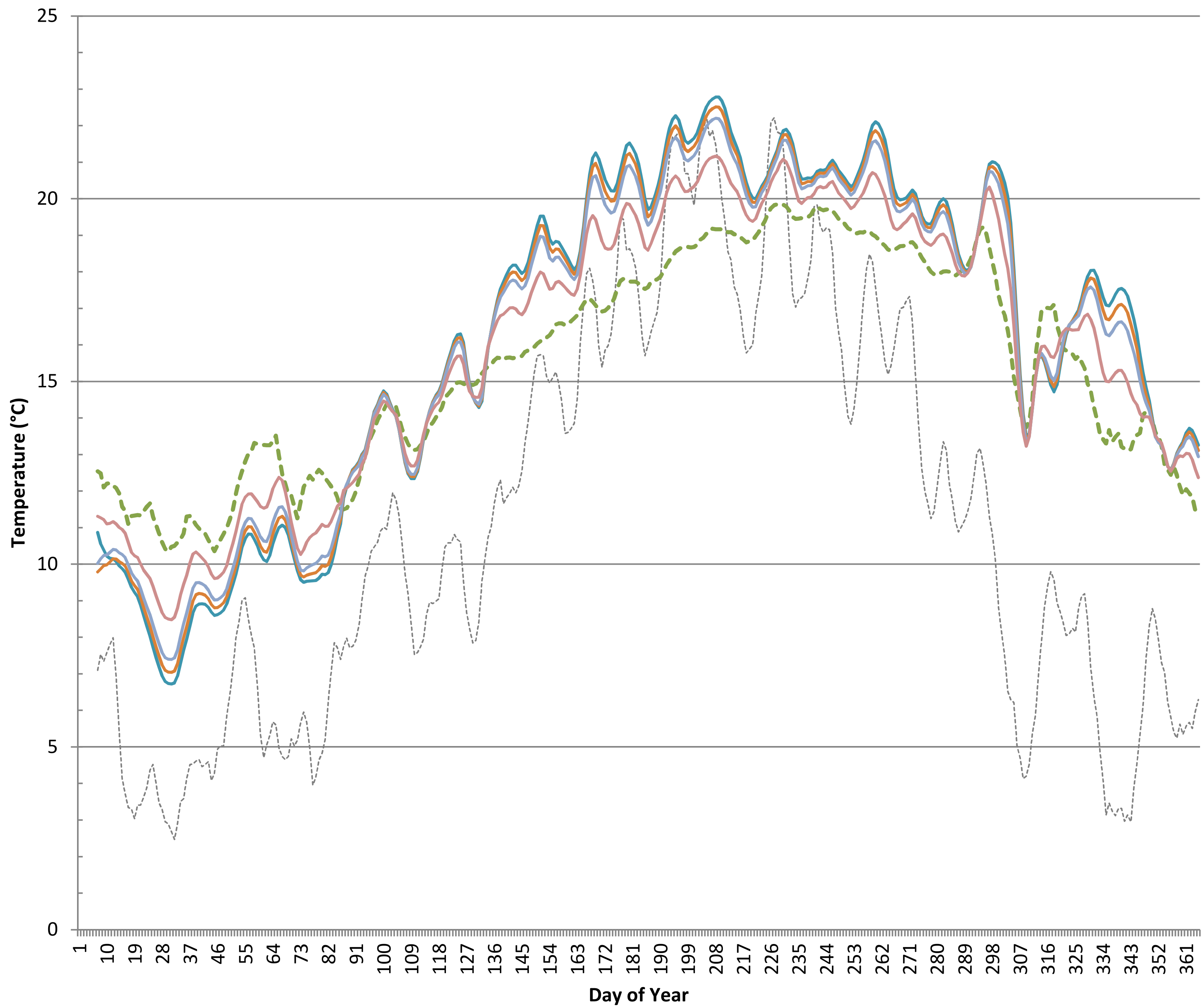

Figure 5-16

Basis of Design

Temperature Simulations at 5 MGD, 6.3 MGD, 9 MGD and 18 MGD through Lake

South Wetlands
Forest Grove, OR

Legend

- Average Air
- Inflow H2O
- 5 MGD
- 6.3 MGD
- 9 MGD
- 18 MGD

NOTE:
Water temperatures from model output reflect the 7 day average daily maximum (DADM).

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CASCADIA BIOREGION

Table 5-10 Summary of average predicted temperature changes in Celsius through Lake at various flows. Negative numbers imply cooling of water relative to influent.

	Average Predicted Degree Change from Inflow for Four Flow Rates (negative reflects cooling)			
Month	5 MGD	6.3 MGD	9 MGD	18 MGD
Jan	-2.4	-2.3	-2.0	-1.2
Feb	-2.7	-2.4	-2.2	-1.4
Mar	-1.7	-1.6	-1.4	-0.8
Apr	-0.2	-0.2	-0.2	-0.2
May	1.3	1.2	1.1	0.7
June	2.7	2.5	2.2	1.4
Jul	3.0	2.7	2.5	1.5
Aug	1.4	1.3	1.2	0.7
Sep	1.9	1.7	1.6	1.0
Oct	1.9	1.8	1.6	1.1
Nov	0.9	0.9	0.8	0.6
Dec	2.0	1.8	1.6	1.0
Annual	0.8	0.7	0.6	0.4

5.8 Dissolved Oxygen

A dissolved oxygen concentration of 6 .0 mg/L is the target effluent concentration for discharge to the Tualatin River. This target is based on the requirements in the Oregon Administrative Rules for the Tualatin Basin (OAR 340-41).

The dissolved oxygen concentrations in natural wetlands are typically much lower than those required by this project (6.0 mg/L). In fact, the background dissolved oxygen levels in natural wetland systems are generally less than 2.0 mg/L in wastewater treatment wetlands (Kadlec and Wallace, 2009). This is the result of the oxygen demand by decaying organic material. Although biological activity can introduce oxygen into wetlands, wind-driven mixing is the primary means of increasing oxygen. The rate of surface diffusion at the air-water interface is therefore limited in the wetlands environment because the emergent plant community reduces the wind velocity. The South Wetlands will have only approximately 10% emergent wetland area as deep, open water zones.

In treatment wetlands, dissolved oxygen can vary significantly, both in terms of input and output concentrations (Kadlec and Wallace, 2009). Treated wastewater enters the South Wetlands from an existing waterfall, which increases dissolved oxygen to near saturation levels. Saturation of dissolved oxygen will vary based on temperature but in general will fluctuate between 8 and11 mg/L. It is expected that dissolved oxygen concentrations will approach a more natural condition (< 2mg/L) as it approaches the South Wetland outfall.

Final dissolved oxygen concentrations at the South Wetlands outfall will depend on flow rate and flow path. In general, the Lake has a longer retention time than the emergent wetlands but has more surface area for wind mixing. Higher flow rates may allow for higher concentrations at the outfall, as water will have less time to use up the available oxygen. Additionally, the presence of submerged aquatic vegetation in the Lake and deep zones of the emergent wetlands will also increase the dissolved oxygen concentrations in the water (Kadlec and Wallace, 2009).

In the event that the South Wetlands do not maintain the dissolved oxygen levels through the system and the concentration must be increased prior to discharge to the Tualatin River, the South Wetlands include a final aeration system comprised of a waterfall structure that saturates the water column with oxygen via rapid mixing. Such waterfalls can increase the dissolved oxygen if they are steep and turbulent. While there is supporting literature in the field of engineering for constructed gravity-flow, stepped chutes and spillways (e.g., Chanson and Toombes, 2002), there is no definitive design methodology to calculate the increase in dissolved oxygen resulting from more natural cascades or step pools. Engineered cascades rely on a thin layer of flow over the step, which entrains air during its fall. Oxygen transfer also occurs to a lesser degree at the air-water interface within each step.

Model Methodology

The engineered cascade formula determines dissolved oxygen concentrations based on water temperature, the background dissolved oxygen concentration, atmospheric pressure, influent water quality and the type of cascade. Shading by wetlands plants has an important effect on the height required to achieve the desired effect. Additionally, colder water requires less height to achieve the same dissolved oxygen goals.

Results

Supporting calculations (Appendix A) are based on a background dissolved oxygen level of 2.0 mg/L and modeled temperature results at varying flow rates. Results of the hydraulic grade line from each flow rate determine the available height of the final structure, an aeration stair at the outfall of Cell 6 to the existing outlet pipe manhole. As flow increases, the backwater effect reduces the effectiveness of the aeration stair due to the backwater flooding. Results in Figures 5-17 and 5-18 illustrate that the 6.0 mg/L target is not always achieved. A mechanical aeration system will be used during times when natural diffusion and the discharge cascade do not achieve the regulated dissolved oxygen levels.

The water flowing into the cascade outlet structure from Cell 6 should maintain a dissolved oxygen level of 2.0 mg/L, since the water from the adjacent cells will be falling through cascades as it enters Cell 6 from either pathway. The temperature model for the wetlands indicates that the shading effects of emergent plants will be able to maintain temperatures that allow for higher DO background levels.

Overall, it is predicted that the wetlands will maintain a water temperature that, in conjunction with the background levels of dissolved oxygen provided by the cascades discharging into Cell 6, will enable a 6.0 ft step cascade to provide the sustained dissolved oxygen level of 6.0 mg/L in the discharge.

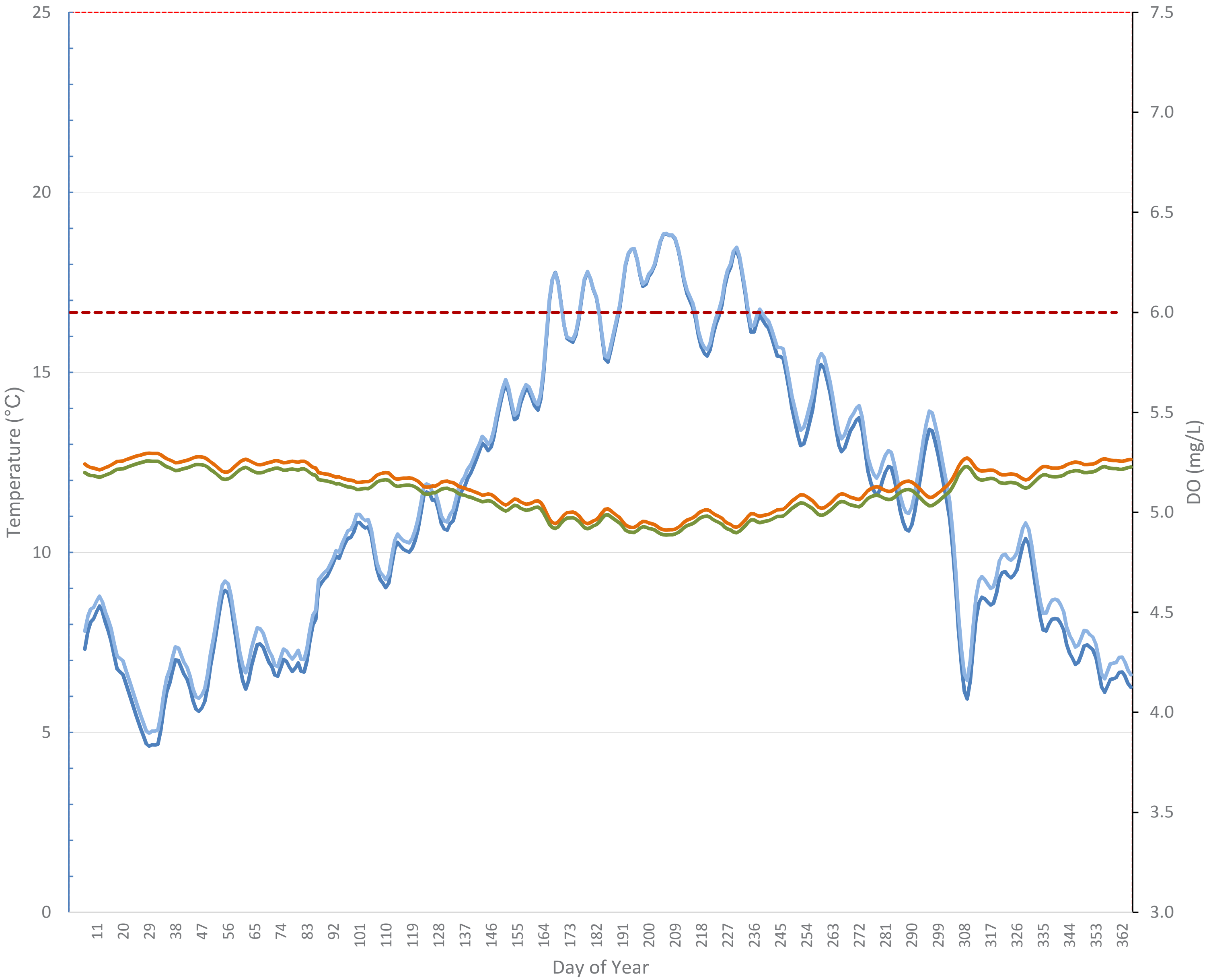

Figure 5-17
Basis of Design

Estimated Dissolved Oxygen at NTS Discharge - 5 MGD and 6.3 MGD

South Wetlands
Forest Grove, OR

Legend

- 7 DADM water temperature @ 5.0 MGD
- 7 DADM water temperature @6.3 MGD
- Dissolved oxygen at discharge @ 5.0 MGD
- Dissolved oxygen at discharge @ 6.3 MGD
- Target DO value (6 mg/L)

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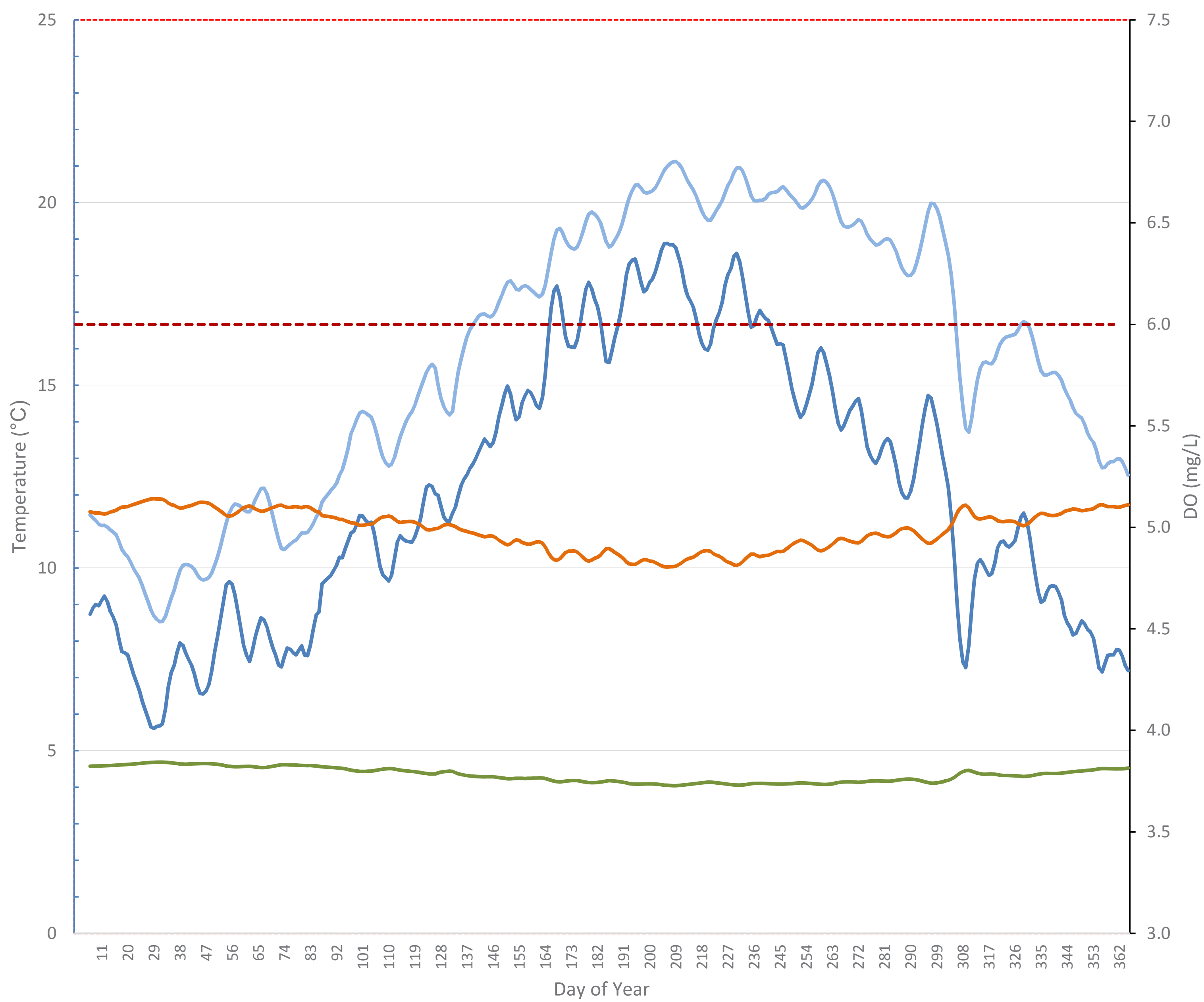

Figure 5-18
Basis of Design

Estimated Dissolved Oxygen at NTS Discharge - 9 MGD and 18 MGD

South Wetlands
Forest Grove, OR

Legend

- 7 DADM water temperature @ 9.0 MGD
- 7 DADM water temperature @18 MGD
- Dissolved oxygen at discharge @ 9.0 MGD
- Dissolved oxygen at discharge @ 18 MGD
- Target DO value (6 mg/L)

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5.9 Additional Water Quality Parameters

Nitrogen

Influent nitrogen concentrations entering the South Wetlands will influence the final effluent nitrogen concentration, although background nitrogen levels and environmental inputs (e.g., seasonal flooding) also need to be considered. When influent nitrogen is within the range of the background levels that can be expected within a typical free water surface (FWS) wetland or surface flow wetland, no net nitrogen removal will be detectable. When influent nitrogen concentrations exceed background levels, nitrates may be removed via denitrification. See Appendix A for further detail.

Phosphorus

Phosphorus has several possible fates in a wetland, including sorption, uptake by biomass, and burial in the wetland sediments. Wetland plants play an important role in phosphorus cycling, with increased phosphorus uptake occurring during spring and fall. Therefore, FWS effluent phosphorus concentration can be expected to vary throughout the year. Kadlec and Wallace (2009) summarized total phosphorus (TP) removal in FWS wetlands, listing an average TP removal of 51% TP removal for nine wetlands receiving influent TP ranges between 0.027-1.404 mg/L. The Forest Grove WWTF and Hillsboro WWTF estimated effluent TP is 0.5 mg/L. Appendix A discusses phosphorus reduction potential.

Metals

Wetlands are natural repositories of heavy metals because the conditions favor the precipitation of these metals as sulfides, sulfates, oxides, hydroxides, carbonates and carbon. Copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) readily precipitate, primarily as metal sulfides in anaerobic conditions and as oxides in aerobic conditions. When sulfates are absent, sorption with carbon compounds is also a significant pathway for reducing concentrations of metals in wastewater treatment wetland effluent in both anaerobic and aerobic conditions. This mechanism will depend on the available carbon, which will be higher in surface flow wetlands (200 $g/m^2/yr$) than subsurface flow wetlands (60 $g/m^2/yr$) (Kadlec and Wallace, 2009). Since the reduction of metals in wastewater treatment wetland effluent is primarily through mechanisms that bind or trap metals in the wetland, they may eventually need to be removed or managed. Advanced secondary treatment at the Forest Grove WWTF and additional treatment provided by the future North and West Wetlands till produce effluent entering the South Wetlands with low metals concentrations meeting applicable water quality criteria. Therefore, there is little potential for significant metals accumulation in the South Wetlands. Appendix A further discusses metals reduction potential.

5.10 Habitat

5.10.1 HABITAT ZONES & VEGETATION

At present, the three existing sewage lagoons at Fernhill provide relatively homogenous open water conditions. The proposed design creates a more complex open water configuration and dramatically increases other wetland habitats.

Figure 5-3 illustrates the general configuration of habitat zones that are targeted within the South Wetlands. The figure combines the freshwater aquatic and other priority habitats into four primary categories: upland (17%), all wetlands (54%), mudflat (2%), and open water (27%). The preliminary design elevations associated with these habitat zones are shown in relation to the normal operating water level. The figure illustrates the variability that could be achieved while still satisfying various management scenarios. At other water depths, the extent of habitats will change. For example, at lower water surface elevations than in Figure 5-3, the area of mudflats would increase relative to open water.

The layout of the proposed wetlands includes a lake that will be important to resident and migratory waterfowl, wading birds, shorebirds, and raptors. This lake is surrounded and protected by a mosaic of emergent, scrub-shrub and forested wetlands. Figure 4-4 illustrates the habitat types that would be available along the Lake relative to one operating scenario. These habitats could be accessed purposefully by manipulating water depths throughout the year in conjunction with other management goals.

Grading in these areas is designed to accommodate a variety of depths, slopes and bottom conditions including exposed mud, submerged aquatic vegetation, and woody habitat structures. The variety of depths and bottom conditions will create a diversity of feeding opportunities and refugia for macroinvertebrates, amphibians and fish, along with waterfowl and wading birds.

As an irregular zone around the deepwater habitat, a series of mudflats extends out from the wetlands and back into recessed areas, providing protected shorebird habitat from spring through fall. Above the mudflats, a mosaic of emergent marsh, along with scrub-shrub and forested wetlands will grade upslope into the upland habitat along the perimeter berms. The irregular perimeter of the lake creates protected coves intermingled with emergent, scrub-shrub and forested wetlands that provide a variety of protected areas for resident and neotropical migratory birds, while also providing cover and forage for larval and juvenile fish, amphibians and reptiles. Several higher elevation refugia areas are strategically placed within the wetlands and on peninsulas to provide protection for amphibians and terrestrial species for nesting and during flood events

Cells 1 through 6 will function predominantly as emergent marshes, covered with shallow aquatic vegetation varying in composition and capable of surviving in water 1-2 ft deep for an extended duration. At the margins of the emergent marshes, conditions will be variable and transition locally to scrub-shrub and upland habitats.

Scrub-shrub vegetation adjacent to emergent marsh will provide overhead cover and perching areas for avian species. Similarly, forested wetlands will occasionally extend down to the water's edge, providing unique habitat for a variety of terrestrial, aquatic and avian species. These edge habitats will also offer low-disturbance areas for nesting and egg-laying shorebirds, marsh birds, wading birds, and waterfowl. As one example, the intermingling of these habitats will benefit wading birds that require a shallow, sparsely vegetated littoral area and perching surfaces adjacent to open water areas.

Upland habitat will be concentrated on the outer perimeter of the site, with portions also along new internal berms and remaining segments of internal levees. Plant communities may include a mix of oak forest and upland prairie selected according to the ability of species to screen and sometimes frame off-site views, buffer noise and provide visual transitions to the wetlands. Within the wetlands and uplands, the specific planting zones will be established to provide habitat for pollinator species. These habitats will provide nectar and pollen sources for native pollinators.

There is also an opportunity to incorporate transplanted vegetation (such as willows and other shrubby vegetation) at specific locations to introduce pockets of more mature vegetation with root masses already intact. Transplantation could be targeted at specific locations where a “jump start” in stability is desired to hold grading elevations and introduce an additional layer of complexity to the initial plantings.

Because plants are crucial to the success of the natural treatment approach and are the ultimate determinants of particular habitat types, the Fernhill Design Team conducted a study in the summer of 2013 of four existing wetlands within and adjacent to the Portland metropolitan region (Appendix C). The purpose of the study was to understand the distribution of particular plant species in relation to the duration and depth of flooding. Although the selected sites are not being used to treat wastewater, developing an understanding of species-specific tolerances to prolonged inundation is important to the South Wetlands design process. The study also provides an opportunity to compile a list of plant species that occur locally and could be propagated for inclusion in the proposed treatment wetlands.

Appendix C includes a description of the four sites, the study approach, and the results. From this study, preliminary plant palettes for specific habitats were developed for use in the South Wetlands (Tables 5-11 through 5-16). Selection of these plants was based on their hydrologic tolerances, ability to provide the desired level of shading at the appropriate time of year, commercial availability, and observed success at other wetland restoration sites in the region.

Further discussions will be required as the design process moves forward to identify the most important criteria for selecting the desired plant communities and species. Results from the reference sites suggest there is a diverse palette of native plant species that can tolerate the water depths anticipated for the site. However, these plants are normally adapted to the annual cycles of wet/dry hydrology typical of a climate with wet winters and warm dry summers. The treatment wetlands will require active management of water surface elevations and wetting and drying cycles to achieve the desired habitat types and species diversity while at the same time supporting other project objectives, such as water temperature reduction.

The plant palettes provided in Tables 5-11 through 5-16, which were developed through both regional knowledge of wetland plants and the data obtained from the reference sites, are meant to provide a starting point for propagation and introduction to the South Wetlands. Ultimately, the distribution of vegetation communities and the success of individual plant species will depend on localized soil conditions, microtopography, successional dynamics, hydroperiod and water depth, and the influence of both native and non-native wildlife. Because construction of the site will likely be staged over several years, there will be opportunities to manipulate some of these variables and observe the response at both the community and species level. For example, the desirability of emergent versus forested wetland species in achieving the desired project objectives can be tested, thereby providing data to adaptively manage the site.

Table 5-11 Preliminary plant palette for riparian habitats.

	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Abies grandis	Grand fir	X	1	bare-root
Acer macrophyllum	Bigleaf maple	X	1	bare-root
Alnus rubra	Red alder	X	2	bare-root
Amelanchier alnifolia	Serviceberry	X	1	bare-root
Bromus vulgaris	Columbia brome	X	1	plug
Carex deweyana	Dewey sedge	X	1	plug
Cornus stolonifera	Red-twig dogwood	X	3	bare-root
Crataegus douglasii	Black hawthorn	X	2	bare-root
Delphinium trollifolium	Columbia larkspur			bulb
Euonymus occidentalis	Western wahoo	X	1	bare-root
Frangula purshiana	Cascara	X	4	bare-root
Fraxinus latifolia	Oregon ash	X	3	bare-root
Heracleum lanatum	Cow parsnip	X	1	plug
Lonicera involucrata	Twinberry	X	1	bare-root
Mahonia aquifolium	Tall Oregon grape	X	1	bare-root
Oemleria cerasiformis	Indian plum	X	3	bare-root
Phacelia nemoralis	Shade phacelia	X	1	plug
Philadelphus lewisii	Mock orange	X	1	bare-root
Physocarpus capitatus	Pacific ninebark	X	1	bare-root
Polystichum munitum	Sword fern	X	1	1-gal
Populus trichocarpa	Black cottonwood	X	2	bare-root
Prunus emarginata	Bitter cherry	X	2	bare-root
Rosa pisocarpa	Swamp rose	X	1	bare-root
Rubus parviflorus	Thimbleberry	X	2	bare-root
Rubus ursinus	Dewberry	X	4	bare-root
Sambucus racemosa	Red elderberry	X	3	bare-root
Solidago canadensis	Canada goldenrod	X	1	plug
Spiraea douglasii	Douglas spiraea	X	3	bare-root
Symphoricarpos albus	Snowberry	X	3	bare-root
Tellima grandiflora	Fringe cup	X	1	plug
Thallictrum polycarpum	Tall Western meadow-rue			plug

Table 5-12 Preliminary plant palette for forested wetland habitats.

Species	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Carex arcta	Nothern cluster sedge	X	1	plug
Carex obnupta	Slough sedge	X	1	plug
Cornus stolonifera	Red-twig dogwood	X	3	bare-root
Crataegus douglasii	Black hawthorn	X	2	bare-root
Fraxinus latifolia	Oregon ash	X	3	bare-root
Glyceria elata	Tall mannagrass	X	1	plug
Leersia oryzoides	Rice cutgrass	X	2	plug
Lycopus uniflorus	Northern bugleweed	X	1	plug
Physocarpus capitatus	Pacific ninebark	X	1	bare-root
Populus trichocarpa	Black cottonwood	X	2	bare-root
Rubus ursinus	Dewberry	X	3	bare-root
Salix lasiandra	Pacific willow	X	3	bare-root
Scutellaria lateriflora	Mad dog skullcap	X	1	plug
Symphoricarpos albus	Snowberry	X	1	bare-root
Torreyochloa pallida	Pale false mannagrass	X	1	plug

Table 5-13 Preliminary plant palette for wet prairie habitats.

Species	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Agrostis exarata	Spike bentgrass			seed
Alisma plantago-aquatica	Water plantain	X	1	seed
Aster subspicatus	Douglas aster	X	1	plug
Bidens cernua	Nodding beggar's tick	X	2	seed
Camassia quamash	Common camas			bulb
Carex aperta	Columbia sedge	X	2	plug
Carex densa	Dense sedge			plug
Carex scoparia	Pointed broom sedge	X	2	plug
Carex stipata	Sawbeak sedge	X	1	plug
Carex unilateralis	One-sided sedge			plug
Carex vesicaria	Inflated sedge	X	1	plug
Carex vulpinoidea	Fox sedge	X	1	plug
Deschampsia caespitosa	Tufted hairgrass			seed
Downingia elegans	Downingia			seed
Eleocharis acicularis	Needle spikerush	X	1	plug
Eleocharis palustris	Common spikerush	X	1	plug
Glyceria elata	Tall mannagrass	X	1	plug
Hordeum brachyantherum	Meadow barley			seed
Juncus acuminatus	Taper-tip rush	X	1	plug
Juncus nevadensis	Sierra rush			plug
Juncus oxymeris	Pointed rush	X	2	plug
Juncus tenuis	Slender rush	X	1	plug
Leersia oryzoides	Rice cutgrass	X	1	plug
Plagiobothrys figuratus	Fragrant popcornflower			seed
Potentilla gracilis	Slender cinquefoil			plug
Prunella vulgaris	Heal-all			seed
Scirpus microcarpus	Small-fruit bulrush	X	1	plug
Solidago canadensis	Canada goldenrod	X	1	plug

Table 5-14 Preliminary plant palette for scrub-shrub habitats.

Species	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Alnus sitchensis	Sitka alder	X	1	bare-root
Cornus stolonifera	Red-twig dogwood	X	3	bare-root
Lonicera involucrata	Twinberry	X	1	bare-root
Physocarpus capitatus	Pacific ninebark	X	1	bare-root
Rosa pisocarpa	Swamp rose	X	3	bare-root
Rubus ursinus	Dewberry	X	1	bare-root
Salix columbiana	Columbia River willow	X	2	bare-root
Salix geyeriana	Geyer willow	X	1	bare-root
Salix piperi	Piper willow	X	3	bare-root
Salix rigida				bare-root
Salix sitchensis	Sitka willow	X	4	bare-root
Spiraea douglasii	Douglas spiraea	X	4	bare-root
Symphoricarpos albus	Snowberry	X	1	bare-root

Table 5-15 Preliminary plant palette for emergent wetland habitats.

Species	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Agrostis exarata	Spike bentgrass	X	1	seed
Alisma plantago-aquatica	Water plantain	X	2	seed
Bidens cernua	Nodding beggar's tick	X	2	seed
Carex aperta	Columbia sedge	X	2	plug
Carex aquatilis	Water sedge			plug
Carex cusickii	Cusick's sedge	X	1	plug
Carex lenticularis	Lakeshore sedge	X	1	plug
Carex rostrata	Beaked sedge			plug
Carex scoparia	Pointed broom sedge	X	1	plug
Carex stipata	Sawbeak sedge	X	1	plug
Carex vesicaria	Inflated sedge	X	3	plug
Eleocharis acicularis	Needle spikerush	X	1	plug
Eleocharis ovata	Ovate spike rush			seed
Eleocharis palustris	Common spikerush	X	4	plug
Glyceria leptostachya	Narrow mannagrass	X	1	plug
Juncus acuminatus	Taper-tip rush	X	1	plug
Juncus effusus var gracilis	Soft rush	X	1	plug
Juncus nevadensis	Sierra rush			plug
Juncus oxymeris	Pointed rush	X	2	plug
Juncus tenuis	Slender rush	X	1	plug
Juncus torreyi	Torrey's rush			plug
Leersia oryzoides	Rice cutgrass	X	2	plug
Lycopus uniflorus	Northern bugleweed	X	1	plug
Polygonum hydropiperoides	Swamp smartweed	X	3	div
Polygonum lapathifolium	Nodding smartweed	X	1	div
Sagittaria latifolia	Wapato	X	2	bulb
Scirpus lacustris	Hard-stem bulrush			plug
Scirpus microcarpus	Small-fruit bulrush	X	2	plug
Scirpus validus	Soft-stem bulrush			plug
Sparganium emersum	Bur-reed	X	4	plug
Torreyochloa pallida	Pale false mannagrass			plug
Typha latifolia	Cattail	X	2	plug

Table 5-16 Preliminary plant palette for aquatic habitats.

Species	Common Name	Found at Reference Sites	Number of Sites Where Observed	Stock Type
Carex cusickii	Cusick's sedge	X	1	plug
Carex lenticularis	Lakeshore sedge	X	1	plug
Ceratophyllum demersum	Hornwort	X	1	div
Elodea canadensis	Common waterweed	X	1	div
Elodea nutallii	Western waterweed	X	1	div
Leersia oryzoides	Rice cutgrass	X	1	plug
Nuphar lutea var. *polysepala*	Yellow pond lily	X	1	bulb
Polygonum amphibium v. emersum	Longroot smartweed	X	1	div
Polygonum hydropiperoides	Swamp smartweed	X	3	div
Potamogeton epihydrus	Ribbon-leaf pondweed	X	1	div
Potamogeton foliosus	Leafy pondweed	X	1	div
Potamogeton natans	Broad-leaved pondweed	X	2	div
Potamogeton nodosus	Long-leaf pondweed	X	2	div
Sparganium emersum	Bur-reed	X	3	plug
Stuckenia pectinata	Sago pondweed	X	1	div

5.10.2 HABITAT ELEMENTS & WILDLIFE USE

The South Wetlands have great potential to enhance and expand habitat for a range of species, including those that are threatened or endangered regionally. In addition to being managed to address water quality, vegetation and water levels can be managed to provide a range of niches for wildlife and support higher species diversity. The existing storage ponds include very limited functional habitat features that provide refuge and support wildlife activities like basking, perching, and nesting. To improve these conditions, a range of elements will be incorporated in the design to enhance and diversify the available habitat.

It is anticipated that many habitat elements incorporated in the design will be comprised of woody material, including coarse and large woody debris. Snags and other woody debris play an important role in wetland systems. Surveys at reference marshes, especially at the Killin and Barney sites, provided examples of how woody material could be effectively integrated into the site. These sites contain large volumes of standing snags and downed wood that provide shade and very complex habitat for frogs, salamanders, birds, and other wetland creatures. Woody debris provides cover and feeding areas for aquatic and amphibian species, roosts and nesting opportunities for birds, as well as haul-outs and sunning platforms for snakes and turtles. Several species of plants root on downed and floating logs. In addition, dead wood casts significant year-round shade on water surfaces, which promotes temperature reduction.

To emulate these types of natural habitats, woody debris can be used in the form of downed logs, standing snags, islands/rafts, mats/piles, and log jams. Even the simplest of log structures, such as a solitary rootwads or standing snags, can be used as perches by birds (e.g., herons, cormorants, hawks and kingfishers). Woody structures will require special treatment or placement to ensure that they do not become buoyant and transported off-site during large flood events. Any wood installed in the South Wetlands may need to be keyed into the banks and/or marsh surface or anchored in with pile logs or other approved methods (e.g., duckbill anchors).

Over the longer term, we recommend managing the South Wetlands for the natural recruitment of snags and downed wood as the most sustainable long-term approach. Successful natural recruitment of dead and downed wood will require growing trees and shrubs that can produce durable wood, thereby allowing natural limb drop, wind throw, beaver girdling, and flooding to turn them into snags and logs. These natural snags will be rooted in the substrate and are likely to persist on site as well or better than installed snags or unsecured logs.

While harder to design for and predict, the food chain that develops on-site over time will be an important factor in sustaining the wildlife on site. The nutrient levels in the water will move through the food chain from detritus to invertebrates and small fish, reptiles, amphibians, and birds. The nutrient levels of inflow waters will provide support to organisms lower on the food chain. The natural recruitment and decay of woody inputs in the long term will return detritus and carbon back to the water and soil, and support invertebrate habitat for a more complex food web. Depending on some of these dynamics, there may be additional opportunities to integrate freshwater mussels into the Lake that will be explored further as design work advances.
The creation of the proposed wetland habitats will be attractive to beaver, and that will be an important consideration as the design advances and for future management activities.

Finally, while less natural in their aesthetic, nest boxes can also be added at strategic locations to encourage use by species such as the wood duck, though such boxes should also be designed to exclude undesirable species such as European starlings.

One potential concern in attracting wildlife is the extent to which wildlife may be disturbed by human activities on-site. Migrating and breeding birds, for example, can experience various degrees of disturbance when they share foraging and breeding space with humans, though the net effect on birds is difficult to understand and quantify (Nesbit, 2000). Many gulls seem impervious or even attracted to human activity, whereas shorebirds may not return to normal behavior for up to 40 minutes after a disturbance (Burger et al., 2004). The disturbance also depends on the activity of the bird. Regular residents and breeders may become habituated to humans more easily than migrating birds that are passing through an area. Most of the negative effects recreation can likely be addressed through sensitive trail design. As discussed further in Section 6.11, the design seeks to integrate human uses while minimizing disturbance to wildlife.

5.11 Trails Plan

5.11.1 HUMAN HABITAT & VISITOR EXPERIENCE

The existing features at the South Wetlands offer an important community recreational resource and destination for the region (Appendix D, Figures D-2 and D-6). As it is developed and people become more aware of its unique qualities, Fernhill has the potential to become a world-class destination.

The Forest Grove WWTF and Fernhill site can provide a diverse set of recreational opportunities for visitors. The site's complex treatment system and expansive natural resources provide an extensive set of landscape typologies for visitors to explore. The site is conceptually and physically separated into the North and South Wetlands by waterfalls and associated topographic step. Both the North and South Wetlands can incorporate carefully designed recreational opportunities within these sensitive ecological areas.

The primary focus for the entire Natural Treatment System area is water quality enhancement. The divide between the South Wetlands and the northern part of the Fernhill NTS also marks a line where goals for each area and the user experience will be distinctly different. The northern part of the site will encourage public access, provide educational opportunities and offer a landscape and amenities that are designed for human interaction. The South Wetlands will be an area that is intentionally natural offering habitat for birds and other animals.

5.11.2 STAKEHOLDER ENGAGEMENT AND PUBLIC VALUES

The lagoons and wetland mitigation sites collectively known as “Fernhill Wetlands” have been designated as in Important Bird Area by the Audubon Society of Portland. Since 1992, when the Fernhill Wetlands Concept Master Plan was published, people have flocked to the area to witness the migratory birds, study wetlands flora and fauna, and enjoy the scenery and solace. The Fernhill Wetlands Council and Friends of Fernhill Wetlands, established in 1992, built and maintained viewing shelters and information kiosks, installed bird boxes, maintained trails, conducted other service projects, and the Council retains funds designated to help build a research/education center.

The Fernhill project has reinvigorated the Fernhill Wetlands Council and the Friends of Fernhill Wetlands. Community interest in Fernhill is so fervent that since the project’s groundbreaking in August of 2012 there have been two Birds and Brew festivals attended by more than 200 visitors. These events rose out of the interest of birders and photographers who were elated by the new diversity of bird species visiting Fernhill due to the changes in the lagoons for construction of the first phase of natural treatment wetlands. The Water Garden, which was constructed to aerate the water, and the accompanying trails and bridges have attracted a great deal of media attention and exponentially increased the number of visitors.

Fernhill has long been an outdoor classroom for Pacific University, Tualatin Academy, Forest Grove Community School, Forest Grove High School Community Alternative Learning Center, and other local schools. As the project continues to improve human and wetlands amenities and advance the science of water treatment, the number of visitors will soar.

Stakeholder engagement is always a priority for Clean Water Services. In fact, its award-winning public involvement program was born out of the District’s early attempts to promote water reuse in the vicinity of Fernhill that went badly because stakeholders were not brought in early to help plan the program. Public outreach for the Fernhill project has and will continue to be intense. Among the many stakeholders groups staff has presented the project plans to and received input from are:

- Joint Water Commission
- City of Forest Grove City Council (televised)
- Fernhill Wetlands Council
- Forest Grove Kiwanis and Rotary clubs
- Forest Grove/Cornelius Chamber of Commerce
- Friends of Fernhill Wetlands
- Pacific University
- City of Hillsboro Water Department

- Citizen Participation Organization 15 (Forest Grove/Fernhill)
- Cooperative Public Agencies of Washington County
- Washington County Public Affairs Forum (televised)
- Forest Grove Town Hall
- Forest Grove Library Association Public Forum

Staff and consultants presented a preconference workshop on the Fernhill project and natural treatment systems at the Pacific Northwest Clean Water Association conference in September of 2013. The unique nature of public involvement for this project was showcased in the presentation titled “Building Trust One Conversation at a Time” at the 2013 conference of the International Association for Public Participation.

This project has been widely publicized, has its own website at fernhillnts.org, and has been the subject of numerous media and trade journal articles. Staff knows the people who care about what happens at Fernhill, involves them in project planning, listens and responds to their concerns, and incorporates their ideas. In all of the outreach, there has been nothing but positive feedback about the potential for water reuse. Some of the very individuals who once strongly opposed water reuse when it was originally proposed near Fernhill in the early 1990s are now vocal supporters of the project. Here, as across the nation, public values about water are evolving; people have a better understanding of the natural and developed water cycles, and are more accepting of the notion that water reuse makes sense.

5.11.3 SITE APPROACH

The beginning of the visitor experience at the South Wetlands starts with the arrival. How one arrives, where, and for what purpose are all factors in shaping the public space and amenities. The parking lot is typically the first point of arrival, and its impact on the visitor’s perception of the place is fundamental in shaping their first impression.

The existing visitor parking lot and trailhead have recently been improved and expanded to improve circulation and wayfinding (Appendix D, Figure D-3). The annual flooding of the previous access driveway periodically prohibited use during the wet months of the year, and the new location now reduces this conflict. Additionally, the improvements fulfill the desire to have a drive-through wildlife safari-type visitor experience of the wetlands without leaving the vehicle and to allow buses and shuttles to move through the parking loop. Accessible parking spaces exist, and provide full access to the existing trail system and our future trails to the south.

Since the majority of visitors arrive by car, the opportunity to decompress and open up to the natural world around them is important. To create a space to allow this transition to occur, the site needs to allow space and to organize the amenities. The cluster of existing public improvements at the South Wetlands consists of parking, a picnic shelter and a restroom. To this cluster, the project proposes to add a trailhead, outdoor classroom-type seating area overlooking the wetlands and a screen along the wetland-oriented parking spaces. The screen will effectively create a car blind to conceal the parked cars from the wetlands.

Visitors arriving by foot or bicycle will start their assimilation into the natural environment as soon as they enter off of Fern Hill Road. Once at the trailhead, signage will be provided to give an overview of the South Wetlands and its tenets. Bicyclists will be informed of the sensitive habitat and directed to use the bike racks provided.

5.11.4 REGIONAL CONNECTIONS

The South Wetlands are at a crossroads of multiple regional and local trail systems (Appendix D, Figures D-1 and D-4). Metro Regional trails connect to Banks, Forest Grove and the Tualatin Valley Scenic Bikeway; all linking to the site at Fernhill Road. The Tualatin River is a part of a regional water trail. Additionally, the wetlands also serve to create social connections by drawing the local community to a central hub in a natural setting. Connections from Forest Grove are made from Fern Hill Road to the west and Poplar Road at the north. Cornelius connections may be made in the future via the Duyck Sump area.

5.11.5 TRAILS

Fernhill NTS is organized into three main areas: Upper, West and South Wetlands. The Upper and West Wetlands are focused on treatment, recreation and education. As such, these areas are more active and require a more refined and available trail system and amenities. The South Wetlands are focused on treatment and habitat creation, with recreation and birdwatching on the north shore.

A recreational system of trails and site amenities are integrated with the new natural treatment system and improved habitat. The proposed site and trails plan incorporates a maintenance corridor within a modest zone of impact, 8’-10’ in width, which additionally serves as pedestrian access.

The primary organizing structure for the trails framework shown in Figure 5-19 is the need for service access. Service routes will no longer feel like roads, aligned with berms and structures. Access routes will be all weather capable and at least 8-feet wide and create the primary trail framework and support defined maintenance practices. These “maintenance trails” should also serve to allow emergency access into the South Wetlands. Service routes should not appear to be service roads, designed to be grassy gravel. Single track trails with minimal service access needs may be only partially mown. Full service roads with wider trail corridors will be better served with full mowing.

As time passes and a more intimate understanding of the site is developed, the District and the users can elect to add side trails, tracks and flares to best serve visitor experience. Over time, access to special view points or more sensitive areas, may develop as single track soil paths or “game trail” paths. The materiality of the trails is determined with respect primarily to flooding risks and long-term maintenance costs.

Service road and trail material will rely primarily on crushed rock and dirt roads, similar to existing trails. Asphalt does not last, concrete is cost prohibitive and bark-natural materials are not able to withstand seasonal flooding. .

5.11.6 TRAILS AND RECREATION MASTER PLAN

Amenities serve human visitors and are organized within the framework of trails in the Trails and Recreation Master Plan (Figure 5-19).Site specific amenities that can be constructed as a part of the wetland improvements, are a combination of existing built elements that are improved or enhanced, new built elements that would be designed and constructed, and simple built features such as interpretive signage or elevated viewing mounds that provide explanation for water treatment strategies, natural wetland features, and habitats that can be viewed on site

(Figure 5-19). Proposed amenities are on the northern edge of the South Wetlands at the interface between the South Wetlands and the northern part of the site.

Outdoor Classroom

Outdoor learning opportunities are indicated at the northern edge of the site. These locations provide possibilities for student groups of a variety of ages to experience the wetland habitat in its actual setting. Rather than constructing permanent seating structures in these areas, semi-permanent furnishings such as logs and boulders are envisioned. This provides seating opportunities with minimal impact, and an aesthetic that speaks to the natural site.

Seating

Benches should reflect the character of their setting and use. Benches along an accessible route should have armrests and a back. Seating options further into the wetlands can take the form of logs, boulders or more organized benches constructed of these materials.

Built Structures

There are two existing viewing structures on site. The eastern viewing structure has recently been rebuilt. It has a strong emotional tie to many in the community and has a good vantage point. It is raised for better views and is universally accessible. It is desirable to maintain this structure in its current location or elsewhere on the site. The western structure does not offer stellar views and is older and less well loved. Viewing structures, or bird blinds, best serve birders as temporary rather than permanent structures. Any new blinds are to be constructed of soft, natural materials and should not face into the morning sun. Woven willow, on-site construction, artistic interventions are all potential options.

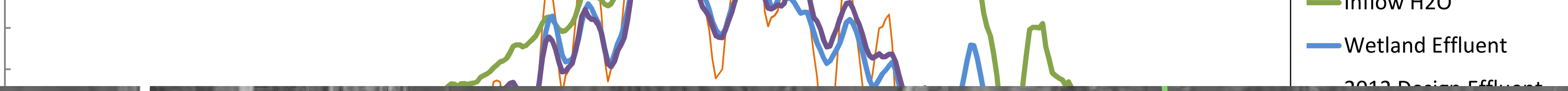

Figure 5-19
Basis of Design

Trails & Recreation Master Plan

South Wetlands
Forest Grove, OR

LEGEND

EXISTING PATH
GRAVEL SERVICE ROAD
SINGLE TRACK TRAIL
BRIDGES
SITE ENTRANCE
PARKING
OUTDOOR LEARNING
ELEVATED VIEWPOINT
VIEWING STRUCTURE
CAR BLIND
SHELTER
GATE
VIEWS

0′ 100′ 200′
N

FERNHILL DESIGN TEAM
PLACE studio

5.12 Hyporheic Discharge

The original concept of the Fernhill NTS included the use of a hyporheic discharge to the Tualatin River for a portion of the NTS flow. The hyporheic discharge system would be a passive connection through shallow groundwater to the hyporheic zone of the Tualatin River. An investigation was conducted from June through August 2013 and included a review of previously completed technical reports, a site visit in June, and the collection of ten soil borings from throughout Pond 2 and from the upland between Pond 2 and the Tualatin River, and a grain-size analysis of the soil borings. A series of ten (10) soil borings were completed in Pond 2 as well as on the south side of Geiger Road to characterize the underlying soils and potential for hyporheic discharge from Pond 2 to the Tualatin River. The soil borings were advanced using direct push drilling equipment (Geoprobe), allowing a continuous soil core to be collected in each boring for lithologic identification and collection of soil samples for grain size analysis.

The soils encountered in Pond 2 generally consist of silts and silty clay in the upper 15 to 30 feet bgs with coarser sands at depths ranging from a depth of approximately 30 to 40 feet, with the exception of one soil boring where sand was encountered at a depth of approximately 15 feet. Grain size distribution analysis indicates the potential hyporheic discharge capacity from Pond 2 utilizing the deeper sands would be approximately 374,000 gallons per day. In addition, the soil boring south of Geiger Road generally indicates the coarser sand layer gets shallow in closer proximity to the river at approximately 15 feet depth.

The major conclusions of the Pond 2 hyporheic discharge investigation are as follows:

- The groundwater flow naturally discharges to the river. Based on the on-site monitoring wells and the water level measurements from the soil borings, the groundwater converges toward the Tualatin River.
- The depth of the groundwater is 10 to 15 feet in the shallow monitoring wells located along the Tualatin River, indicating that this is the depth of the unsaturated zone that would be available to accommodate potential groundwater mounding from a hyporheic discharge in Pond 2.
- The existing water supply wells in the Troutdale Formation are separated from the potential hyporheic discharge operations by Willamette Silt, which likely forms a sufficient hydrologic barrier so that discharge would go to the river rather than to deeper groundwater.
- The shallower depth of the coarse sand layer south of Geiger Road generally indicates hyporheic discharge from sites closer to the river may provide for higher discharge rates.

Following the completion of the soil borings and grain-size distribution analysis, it was estimated that the maximum capacity of a hyporheic discharge from Pond 2 is approximately 374,000 gallons per day. After review, the District determined that the estimated capacity would not support the planned investment in hyporheic discharge from Pond 2 and elected not to proceed with further investigation. The sand layer that was identified approximately 30 feet bgs could be used for future reference to assess the potential discharge capacity of the soils if hyporheic discharge was again to be considered to the west of the NTS on the west side of Fernhill Road. The District has indicated it intends to pursue other potential hyporheic discharge opportunities at alternate sites along in closer proximity to the Tualatin River where coarse sand layer is closer to the surface and anticipated hydraulic capacity greater.

6 Cost Estimate

A Class 4 cost estimate was developed for the preliminary design presented in Section 5.3. As described in the AACE International (formerly the Association for the Advancement of Cost Engineering) Recommended Practice No. 18R-97 Cost Estimate Classification System, “Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges.” For these estimates, engineering is typically only 1 to 15% complete, and end usage purposes include strategic planning, confirmation of economic and/or technical feasibility and preliminary budget approval or approval to proceed to the next stage. Estimating methods used are gross unit costs/ratios and similar techniques.

For the purpose of the Basis of Design, the cost estimate identifies the direct and indirect capital costs needed to implement the proposed approaches. Direct costs typically consist of costs associated with construction, material disposal, and property acquisition. The cost estimate also includes indirect costs such as design engineering, construction administration / inspection / office support, post-construction surveying, permitting, public outreach/stakeholder engagement, and legal and miscellaneous costs necessary to implement the project and construction.

A base construction cost estimate of $3.7 million was developed for the design. This was based on the extension of unit prices and quantities developed and, where applicable, the addition of lump sum construction cost items.

The expected accuracy ranges for Class 4 estimates are -15% to -30% on the low side to +20% to +50% on the high side depending on complexity, reference information, and inclusion of an appropriate contingency determination. For the Basis of Design, a value of +30% for construction cost contingency was based on judgment of the complexity of the project in a natural / environmental project and the level of project information and development. The construction cost contingency was applied to the base construction cost estimate (Table 6-1) to produce a total construction cost estimate of $4.8 million. It should be noted that the contingency does not consider coverage for major changes to the conceptual design and implementation assumptions that could have a severe impact to construction costs. These would include circumstances like the unsuitability of site materials and available soil stockpiles for the proposed uses, resulting in the importation of 100% of the fill materials.

Finally, the total program cost was estimated, as shown in Table 6-1, by applying a factor of 25% for Engineering/Legal/Miscellaneous to the Total Construction Cost Estimate. A factor of 25% was also used in Fernhill Wetlands Project Conceptual Design Report (December 2012). No factor for escalation has been included in the Program Cost Estimate since it is assumed to be a near-term construction project.

The Fernhill Design Team has used our best professional judgments based on the known and expected site conditions, materials sources, and costs of similar projects. As more detailed information regarding these important factors are identified, analyzed, and considered, projected project costs could rise above or fall below this preliminary opinion of cost.

Table 6-1 Opinion of probable construction and program costs.

Item	Cost
Base Cost of Construction	$3,666,000
Construction Contingency (*assumed 30% of base cost*)	$1,100,000
Total Construction Cost *(includes 30% contingency)*	$4,766,000
Engineering, Legal, and Miscellaneous Costs *(estimated at 25%)*	$916,000
Total Program Cost *(includes 30% contingency & 25% Eng/Leg/Misc costs)*	$5,682,000

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Appendix A

Water Quality Calculations

A Water Quality

A.1 Nitrogen

Influent nitrogen concentrations entering the South Wetlands will influence the final effluent nitrogen concentration, although background nitrogen levels and environmental inputs (e.g., seasonal flooding) also need to be considered. If influent nitrogen is within the range of the background levels that can be expected within a typical free water surface (FWS) wetland or surface flow wetland, no net nitrogen removal will occur. If influent nitrogen concentrations exceed background levels, nitrates may be removed via denitrification.

A.1.1 NITROGEN REMOVAL AND BACKGROUND LEVELS

Background nitrogen concentrations in the South Wetlands can be expected to be in the range of 0.5 to 3.0 mg/L (Kadlec and Wallace, 2009). This background concentration can be attributed to the continuous cycling of biomass within the wetland and atmospheric deposition of nitrates from rainfall. Effluent from the Forest Grove WWTF and Hillsboro WWTF is estimated to have a nitrate concentration of <2.0mg/L and an ammonia concentration <0.2mg/L. Due to the fact that the influent entering the wetland is predicted to have a nitrogen concentration similar to the background nitrogen concentration, there will not likely be any measurable nitrogen reduction of the influent once it has entered the lower wetlands. However, the forms of nitrogen are likely to change. Total Kjeldahl nitrogen (TKN) will likely increase as biomass decays, while nitrate will decrease during denitrification under anoxic conditions.

A.1.2 DENITRIFICATION

Conditions necessary for denitrification include anoxic conditions and the availability of an external carbon source. Both of these conditions will exist in the South Wetlands. If influent nitrate is significantly higher than estimated, for example 10 mg/L, there may not be enough carbon to achieve denitrification. At high nitrate removal rates, carbon may become the limiting factor in denitrification performance (Kadlec and Wallace, 2009). Using a theoretical nitrate concentration of 10 mg/L, two different equations indicate that there will be inadequate carbon for complete denitrification (Table A-1). One equation considers reduced denitrification rates associated with reduced temperatures, while the other assumes a consistent removal rate regardless of temperature. At higher flow rates, both equations yield similar effluent nitrate concentrations. Calculations are detailed in A.5 Calculations. Figure A-1 presents theoretical effluent nitrate concentrations over a wide range of potential removal rates. The figure illustrates these theoretical effluent nitrate concentrations over a range of flow rates entering the wetland, from 4 MGD to 9 MGD.

Table A-1 Denitrification estimates.

Flow (MGD)	HLR (cm/d)	K&K[1,3] Effluent Nitrate (mg/L)	K&W[2] Effluent Nitrate (mg/L)
4	25.68	1.25	3.50
5	32.10	1.71	4.21
6.3	40.44	2.31	4.93
9	57.78	3.57	6.00

Note: Calculations are based on an area of approximately 34 acres of effective emergent wetlands (Cell 1-Cell 5)and an assumption of 10 mg/L influent nitrate

[1]Equation from Kadlec and Knight (2001)

[2]Equation from Kadlec and Wallace (2009)

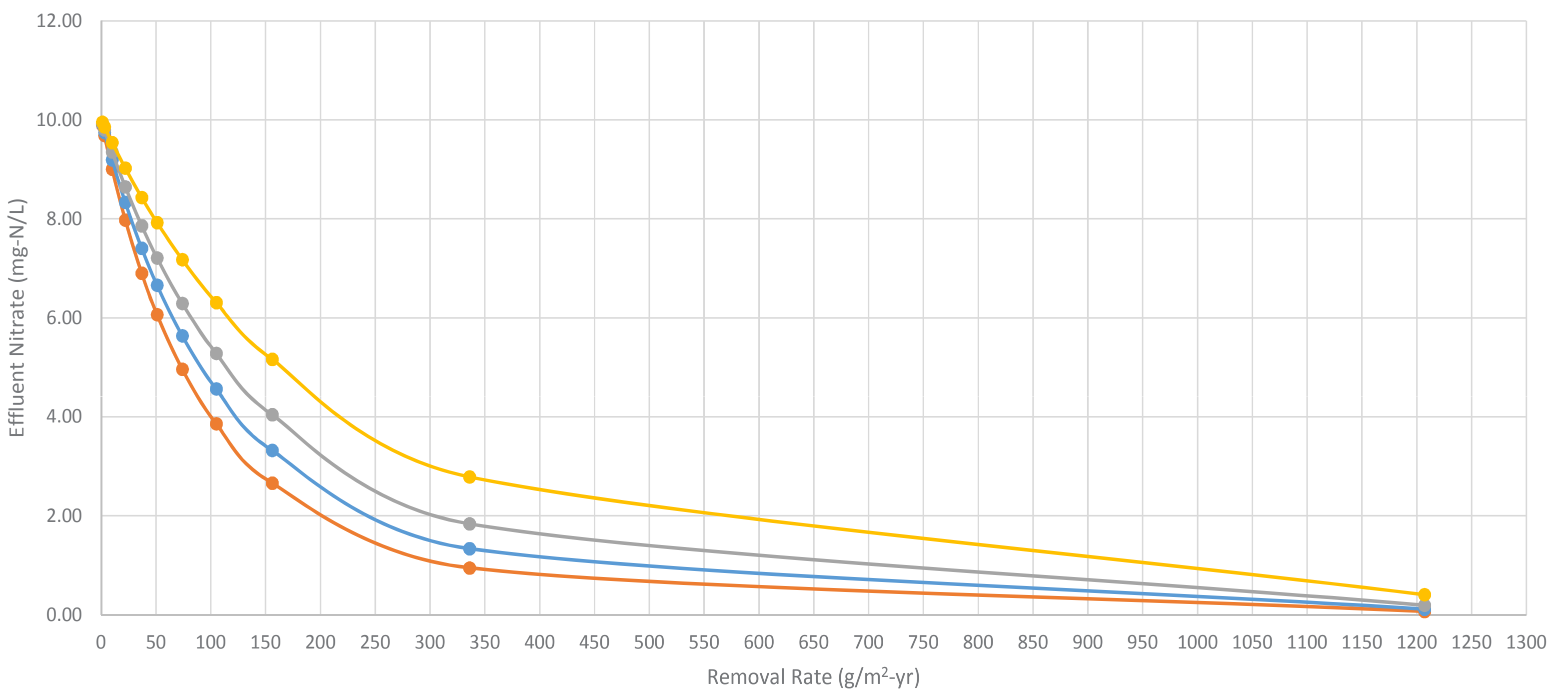
[3]Calculations are adjusted for a temperature of 12 C°

Figure A-1

Basis of Design

Effluent Nitrate Concentration with Varying Removal Rates

South Wetlands
Forest Grove, OR



Legend

FERNHILL DESIGNTEAM

Biohabitats CASCADIA BIOREGION

A.1.3 NITROGEN SUMMARY

Attempting to quantify a consistent effluent nitrogen concentration is difficult, due to the fact that the project site is located in a floodplain and experiences frequent flooding. Additional nitrogen sources associated with flooding, bird migration, and aquatic populations are difficult to predict and may change the wetland effluent nitrogen levels. Therefore effluent nitrogen concentrations leaving the South Wetlands cannot be determined with any significant level of confidence.

A.2 Phosphorus

Phosphorus has several possible fates in a wetland, including sorption, uptake by biomass, and burial in the wetland sediments. Wetland plants play an important role in phosphorus cycling, with increased phosphorus uptake occurring during spring and fall. Therefore, FWS effluent phosphorus concentration can be expected to vary throughout the year. Kadlec and Wallace (2009) summarized total phosphorus (TP) removal in FWS wetlands, listing an average TP removal of 51% TP removal for nine wetlands receiving influent TP ranges between 0.027-1.404 mg/L. The Forest Grove WWTF estimated effluent TP is 0.5 mg/L. Assuming the South Wetlands also achieve a removal of 51%, the effluent TP concentration may be near 0.26 mg/L.

Kadlec and Wallace (2009) cite a median flow-weighted background TP concentration of 0.022 mg/L, characteristic of undeveloped basins. Background TP concentrations are generally higher in basins that are developed, due to anthropogenic inputs. An additional source of phosphorus can be rainfall, with Kadlec and Wallace (2009) providing a typical range of 0.010-0.050 mg/L. Additionally, a portion of TP is biologically unavailable and therefore contributes a small fraction to the background phosphorus levels.

A.2.1 ANNUAL REDUCTION OF PHOSPHORUS

Due to the complexity of phosphorus cycling throughout the year, it can also be valuable to quantify the mass removal of phosphorus expected over the course of the year. Kadlec and Wallace (2009) provide an equation for estimating TP removal, considering both background TP concentrations and making an assumption about a rate constant for removal:

$$J_{net} = k(C-C^*)$$

where,

- J_{net} = net phosphorus uptake (g-P/m2d)
- k = apparent rate constant (m/yr)
- C = phosphorus (g-P/L)
- C* = phosphorus (g-P/L), typical values 4-40 ug/L

The median rate constant, k, listed in Kadlec and Wallace (2009) for ten FWS wetlands in cold climates is 18 m/yr, with a median removal rate of 6 g/m^2-yr. Using this rate constant of 18 m/yr for the South Wetlands and assuming a background TP concentration of 40 ug/L, the median removal rate would be about 3 g/m^2-yr. The 34 acre South Wetlands may be capable of removing about 1.1 kg/d. Calculations are detailed in A.5 Calculations.

As with nitrogen, additional phosphorus sources associated with flooding, bird migration, and aquatic populations are difficult to predict and may change the wetland effluent TP levels. Effluent TP concentrations leaving the South Wetlands cannot be determined with any significant level of confidence.

A.3 Metals

Wetlands are natural repositories of heavy metals because the conditions favor the precipitation of these metals as sulfides, sulfates, oxides, hydroxides, carbonates and carbon. Copper (Cu), nickel (Ni),lead (Pb) and zinc (Zn) readily precipitate, primarily as metal sulfides in anaerobic conditions and as oxides in aerobic conditions. When sulfates are absent, sorption with carbon compounds is also a significant pathway for reducing concentrations of metals in wastewater treatment wetland effluent in both anaerobic and aerobic conditions. This mechanism will depend on the available carbon, which will be higher in surface flow wetlands (200 g/m^2/yr) than subsurface flow wetlands (60 g/m^2/yr) (Kadlec and Wallace, 2009). Plants also play a minor role in reducing concentrations of metals through plant uptake. However, over 90% of wetland metals are precipitated and accumulated in wetland soil. Since the reduction of metals in wastewater treatment wetland effluent is through mechanisms that bind or trap metals in the wetland, they may need to be removed or managed.

The primary form of Cu precipitate in anaerobic conditions will be copper monosulfide (CuS), if sulfate is available in the water. CuS is essentially insoluble except at very low pH. The CuS is buried within accumulating layers of organic peat-like substances. Plants will uptake some of the influent copper, but generally less than 10%. An alternate primary mechanism is sorption on organic compounds (peat or peat-like decomposing plant debris). In 26 wastewater treatment systems worldwide, the removal rates from natural treatment systems were 160 g Cu/m^2/yr for anaerobic wetlands and 66 to 2000 mg Cu/m^2/yr in aerobic wetlands, depending on influent concentrations (Kadlec and Wallace, 2009). Given the light organic load for the South Wetlands, and assuming an influent Cu concentration of about 14.3 ug/L (the maximum expected concentration entering the South Wetlands), the removal rate may be closer to 66 mg/m^2/yr. The current literature is limited, but identified removal rates at two different wetlands of 59 and 81% when influent values were 8.6 and 11.5 ug Cu/L, respectively (Kadlec and Wallace, 2009).

Ni also forms insoluble sulfide compounds in wetlands, and is adsorbed by carbon compounds. In anaerobic wetlands, the potential sulfide production is capable of removing 147 g Ni/m^2/yr from the wastewater flow. In the absence of sulfates and anaerobic conditions, aerobic conditions are potentially able to remove 13 mg Ni/m^2/yr at maximum expected influent concentrations of Ni (~14.6 ug/L) (Kadlec and Wallace, 2009). The current literature suggests very poor removal rates (-7 to 9% removal, given influent values of 5.6 to 11 ug Ni/L) including an increase in effluent Ni concentrations (Kadlec and Wallace, 2009). The actual Ni removal will depend on the presence and amount of iron and manganese, which form co-precipitates with Ni. Under anoxic/anaerobic conditions, these metals may become soluble, releasing Ni and thus increasing the effluent nickel concentration.

Pb is expected to enter the South Wetlands at a maximum value of about 0.36 ug/L. Under anaerobic conditions, Pb will be precipitated as sulfides and carbonates, with over 90% retained in the soil. The median removal rate of Pb for all FWS wetlands is 62%, when influent Pb concentrations range from 1.1 to 300 ug/L (Kadlec and Wallace, 2009).

Zn is an essential element for plants and will therefore be taken up by wetland plants and released when they decay. The primary removal mechanisms for Zn in a wetland are settling, chemical precipitation, co-precipitation and partitioning to sediments. Literature values for Zn concentration reduction range from 18 to 84%, with a median value of 68% when influent values are from 18 to 12000 ug Zn/L (Kadlec and Wallace, 2009).

Calculations for each contaminant are detailed in A.5 Calculations. All metals, including our target pollutants, depend on carbon for sorption. Therefore, the total removal rates will depend on initial concentrations of the metals and the carbon production of the wetlands. Influent nitrate levels will also influence carbon availability, as carbon is utilized during denitrification. Total overall metal removal from the water column will therefore depend on influent masses of metals and available carbon according to the following formula:

$$Cs = [AR_{Cu} + AR_{Pb} + AR_{Ni} + AR_{Zn}] / AR_{net\ sediment}$$

Where AR is the respective accumulation rates of the various metals, Cs is the total concentration of all three metals. AR net sediment is the carbon remaining after that required for denitrification, assumed to be 200 $g/m^2/yr$ (Kadlec and Wallace, 2009).

This formula assumes that sorption sites are limited and mutually exclusive, i.e., a carbon molecule cannot adsorb Pb, Cu, Ni and Zn. It also assumes that the biomass generated in the denitrification process is not subsequently available for metals sorption. This is a conservative assumption.

A.3.1 METALS AND THE ONTARIO CONVENTION

The Ontario Ministry of the Environment has set a lowest effect level of 16 ug/g and severe effect of 110 ug/g of sediments for Cu. Cu is a biocide, and will bio-accumulate in the macroinvertebrate populations as they feed in the sediment. Algae will also accumulate Cu. Ni will not bio-accumulate but is toxic at elevated concentrations. The US EPA set a limit for Ni in drinking water of 52 ug/L and the Ontario convention has set a lowest effect level in sediments of 16 ug/g. Pb is also toxic, but the lowest effect level for sediments is 31 ug/g. The province of Ontario set a lowest effect level for Zn of 120 ug/g and the US EPA set the maximum level for human ingestion at 7.4 mg/L. The accumulation of metals in the wetland sediments will need to be monitored and may require appropriate disposal measures, such as excavation and landfill disposal. However, based on the estimated metals concentrations that will be entering the South Wetland, it will be several hundred years before the sediments are likely to accumulate to Ontario Convention "lowest level effects" concentrations.

Table A-2 summarizes the estimated metal removal for the South Wetlands. Percent removal ranges are based on values given in Kadlec and Wallace (2009) for free water surface wetlands that treated municipal wastewater. The mean percent removal was used to estimate the potential effluent metal concentration and mass of metal accumulated over the course of one year. The project site is located in a floodplain, therefore sediments and associated metals will likely migrate on and off site. Sediment movement makes it difficult to assess probable sediment metal concentrations, thus only total mass values have been given.

Table A-2 Estimated removal rates for the South Wetlands.

Maximum Expected Influent Concentration (ug/L)	Percent Removal (%)	Assumed Percent Removal (%)	South Wetlands Potential Effluent Concentration (ug/L)	Target Concentration[1] (ug/L)	Mass in Sediment (kg/yr)
Cu 14.3	59 to 81	74	3.7	12	9.2
Ni 14.6	-7 to 9	0	14.6	160	0
Pb 0.36	17 to 80	62	0.14	3.2	1.9
Zn 35.4	18 to 84	68	11.3	110	20.9

[1] *Table 20 Aquatic Life Water Quality Fresh Chronic Criteria (DEQ, 2013), assuming 100 mg/L hardness.*

A.4 Contaminants of Emerging Concern

Increasingly, special attention has been given to understanding the environmental and human health toxicological effects of contaminants of emerging concern (CECs). CECs include pharmaceuticals and personal care products (PPCPs), nanomaterials, brominated flame retardants and surfactants. Natural treatment systems have been shown to be highly effective at removing CECs (Oulton et. al., 2010). Researchers speculate that long hydraulic retention times associated with constructed wetlands may be one reason for high CEC removal rates (Conkle et al., 2008). Future topics of investigation include ways to optimize constructed wetland performance for CEC removal (e.g., adjusting hydraulic retention time), increasing aerobic conditions, and identifying most effective plant communities. It is the intent of the District to understand the fate and transport of CECs with NTS in the future.

A.5 Calculations

See below.

CASCADE AERATION CALCULATIONS

Project:	Fernhill South Wetlands	**As of:**	11/27/2013
Location:	Forest Grove, OR	**Calc by:**	MO
		Checked by:	PM

1. Design Information

This spreadsheet calculates the required drop of water, h (in feet) to a achieve a specific desired Dissolved Oxygen Concentration.

*h = r-1/(0.11*a*b*(1+0.046T)*

where h = height of fall (feet)

r = deficit ratio = (Cs-Co)/(Cs-C)

Cs = DO saturation conc. of water at temperature T (mg/L) — $Cs = 14.161 - 0.3943T + 0.007714T^2 - .0000646T^3$

Co = DO concentration of cascade influent (mg/L) — where T = temp of water; deg C

C = required DO level after aeration (mg/L)

T = water temp (C)

a = water quality parameter — *a = 0.8 for secondary effluent, 0.95 for teritary treated effluent from natural treatment system*

b = weir geometry parameter — b = 1.0 for free weirs, 1.1 for concrete steps, 1.3 for step weirs.

2. Calculations

input cell =

	Winter		Summer	
Water Temperature, T:	55	°F	67	°F
	12.78	°C	19.4	°C
DO at inlet (Co):	2.0	mg/L	2.00	mg/L*
Required DO level (C):	6.0	mg/L after aeration	6.0	mg/L after aeration
type of water:	teritary		teritary	
water quality parameter, a:	0.95		0.95	
weir geometry:	step	(free, step, concrete)	step	(free, step, concrete)
weir geometry parameter, b:	1.3		1.3	
Project altitude:	160	ft	160	ft
elevation h:	0.05	km	0.05	km
pressure P:	1.0000	atm	0.9936	atm, 760/(760+C33/32.8)
Saturated DO (Cs):	10.2	mg/L	8.9	mg/L
deficit ratio r:	1.94		2.39	
Drop in height Required, h:	**4.37**	**feet**	**5.40**	**feet**

References:

Downing, A.L. and Truesdale, G.A. (1955) Some factors affecting the rate of solution of oxygen in water Journal of Applied Chemistry. v 5, Oct., p 570-581.

Baca, R.G. and Arnett, R.C. (1976) A Limnological Model for Eutrophic Lakes and Impoundments. Battelle Pacific Northwest Laboratories.

EFFLUENT NITRATE CALCULATION FOR EMERGENT WETLAND CELL 1

Project: Fernhill South Wetlands **As of:** 12/9/2013
Location: Forest Grove, OR **Calc by:** CG
Checked by: PM

1. Design information

This spreadsheet calculates the estimated wetland effluent nitrate concentration.

Equation from Kadlec and Wallace (2009):

$Ne = (1 + k/3q)^{-3} * No$

Where Ne = the estimated effluent nitrate (mg-N/L)
k=nitrate removal rate (g/m2-yr)
q = hydraulic loading rate (cm/d)
No = Influent nitrate (mg-N/L)

Equation from Kadlec and Knight (2001), considers temp:

$Ne = k*No*1.09^{(T-20)}$

Where Ne = the estimated effluent nitrate (mg-N/L)
k=nitrate removal rate (m/yr)
No = influent nitrogen (mg/L)
T = temperature, low avg day temp in dry season

2. Calculations

Input cell =								
Area =	14.74	ac	14.74	ac	14.74	ac	14.74	ac
	58960	m^2	58960	m^2	58960	m^2	58960	m^2
Depth =	0.60	m	0.60	m	0.60	m	0.60	m
k =	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate
Flow	**4**	MGD	**5**	MGD	**6.3**	MGD	**9**	MGD
	15140	m^3/d	18925	m^3/d	23845.5	m^3/d	34065	m^3/d
q =	25.68	cm/d	32.10	cm/d	40.44	cm/d	57.78	cm/d
No	10	mg/L	10	mg/L	10	mg/L	10	mg/L
K&W (2009) Ne	**6.07**	mg-N/L	**6.66**	mg-N/L	**7.21**	mg-N/L	**7.92**	mg-N/L
Mass N =	151.40	kg/d	189.25	kg/d	238.46	kg/d	340.65	kg/d
Temp =	12	Celsius	12	Celsius	12	Celsius	12	Celsius
k =	26.5	m/yr	26.5	m/yr	26.5	m/yr	26.5	m/yr
N Removed	21.48	kg/d	21.48	kg/d	21.48	kg/d	21.48	kg/d
N Remaining	**129.92**	kg/d	**167.77**	kg/d	**216.97**	kg/d	**319.17**	kg/d
K&K (2001) Ne	**3.67**	mg-N/L	**4.74**	mg-N/L	**6.13**	mg-N/L	**9.02**	mg-N/L

Annual Reduction Rates Observed in 72 FWS Wetlands

Percentile	Load Removed (g/m2-yr)	Rate Coefficient m/yr
0	1	2.1
0.1	3	9.6
0.2	10	14.4
0.3	22	18.5
0.4	37	22
0.5	**51**	**26.5**
0.6	74	29
0.7	105	33.6
0.8	156	38.9
0.9	336	54.4
1	1207	133.1

Source: Kadlec and Wallace 2009, Table 9.37

Results using K&W Equation:

	4 MGD	5 MGD	6.3 MGD	9 MGD
Nitrate Removal Rate (g/m2-yr)	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**
1	9.89	9.92	9.93	9.95
3	9.69	9.75	9.80	9.86
10	9.00	9.19	9.35	9.54
22	7.98	8.33	8.65	9.03
37	6.90	7.41	7.86	8.43
51	6.07	6.66	7.21	7.92
74	4.96	5.64	6.29	7.18
105	3.86	4.56	5.28	6.31
156	2.66	3.32	4.04	5.16
336	0.95	1.34	1.84	2.79
1207	0.07	0.11	0.19	0.41

References:

Kadlec, R.H., Knight, R.I., and J. Vymazal (2001) Constructed Wetlands for Pollution Control. IWA Publishing.
Kadlec, R.H. and Wallace, S.D. (2009) Treatment Wetlands. 2nd ed. CRC Press.

EFFLUENT NITRATE CALCULATION FOR SOUTH WETLANDS

Project:	Fernhill South Wetlands	**As of:**	12/9/2013
Location:	Forest Grove, OR	**Calc by:**	CG
		Checked by:	PM

1. Design information

This spreadsheet calculates the estimated wetland effluent nitrate concentration.

Equation from Kadlec and Wallace (2009):

$Ne = (1 + k/3q)^{-3} * No$

Where Ne = the estimated effluent nitrate (mg-N/L)

k=nitrate removal rate (g/m2-yr)

q = hydraulic loading rate (cm/d)

No = Influent nitrate (mg-N/L)

Equation from Kadlec and Knight (2001), considers temp:

$Ne = k*No*1.09^{(T-20)}$

Where Ne = the estimated effluent nitrate (mg-N/L)

k=nitrate removal rate (m/yr)

No = influent nitrogen (mg/L)

T = temperature, low avg day temp in dry season

2. Calculations

Input cell =

	Area =	34.00	ac	34.00	ac	34.00	ac	34.00	ac
		136000	m^2	136000	m^2	136000	m^2	136000	m^2
	Depth =	0.60	m	0.60	m	0.60	m	0.60	m
	k =	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate	51	g/m2-yr, assume median rem. rate
	Flow	**4**	MGD	**5**	MGD	**6.3**	MGD	**9**	MGD
		15140	m^3/d	18925	m^3/d	23845.5	m^3/d	34065	m^3/d
	q =	11.13	cm/d	13.92	cm/d	17.53	cm/d	25.05	cm/d
	No	10	mg/L	10	mg/L	10	mg/L	10	mg/L
K&W (2009	Ne	**3.50**	mg-N/L	**4.21**	mg-N/L	**4.93**	mg-N/L	**6.00**	mg-N/L
	Mass N =	**151.40**	kg/d	**189.25**	kg/d	**238.46**	kg/d	**340.65**	kg/d
	Temp =	**12**	Celsius	**12**	Celsius	**12**	Celsius	**12**	Celsius
	k =	**26.5**	m/yr	**26.5**	m/yr	**26.5**	m/yr	**26.5**	m/yr
	N Removed	**49.55**	kg/d	**49.55**	kg/d	**49.55**	kg/d	**49.55**	kg/d
	N Remaining	**101.85**	kg/d	**139.70**	kg/d	**188.90**	kg/d	**291.10**	kg/d
K&K (2001)	Ne	**1.25**	mg-N/L	**1.71**	mg-N/L	**2.31**	mg-N/L	**3.57**	mg-N/L

Annual Reduction Rates Observed in 72 FWS Wetlands

Percentile	Load Removed (g/m2-yr)	Rate Coefficient m/yr
0	1	2.1
0.1	3	9.6
0.2	10	14.4
0.3	22	18.5
0.4	37	22
0.5	**51**	**26.5**
0.6	74	29
0.7	105	33.6
0.8	156	38.9
0.9	336	54.4
1	1207	133.1

Source: Kadlec and Wallace 2009, Table 9.37

Results using K&W Equation:

	4 MGD	5 MGD	6.3 MGD	9 MGD
Nitrate Removal Rate (g/m2-yr)	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**	**Effl. Nitrate (mg-N/L)**
1	9.76	9.81	9.85	9.89
3	9.30	9.43	9.55	9.68
10	7.89	8.26	8.59	8.98
22	6.08	6.67	7.22	7.93
37	4.51	5.21	5.89	6.84
51	3.50	4.21	4.93	6.00
74	2.41	3.05	3.76	4.88
105	1.55	2.08	2.70	3.78
156	0.84	1.21	1.68	2.59
336	0.19	0.30	0.48	0.91
1207	0.01	0.01	0.03	0.06

References:

Kadlec, R.H., Knight, R.I., and J. Vymazal (2001) Constructed Wetlands for Pollution Control. IWA Publishing.

Kadlec, R.H. and Wallace, S.D. (2009) Treatment Wetlands. 2nd ed. CRC Press.

EFFLUENT PHOSPHORUS CALCULATION FOR EMERGENT WETLAND CELL 1

Project:	Fernhill South Wetlands	**As of:**	12/9/2013
Location:	Forest Grove, OR	**Calc by:**	CG
		Checked by:	PM

1. Design information

This spreadsheet calculates the estimated wetland effluent phosphorus concentration.

$J_{net} = k(C-C^*)$

Where J_{net} = net phosphorus uptake (g-P/m2-d)

k = apparent removal rate constant (m/yr)

C = influent phosphorus concentration (g-P/L)

C* = background phosphorus (g-P/L), typical values 4-40 ug/L

$P_{removed} = J_{net} * A$

Where $P_{removed}$ = phosphorus uptake (kg/yr)

J_{net} = net phosphorus uptake (g-P/m2-yr)

A = wetland area (m^2)

2. Calculations

Input cell =		
C	0.00050	g-P/L
C*	0.00004	g-P/L
k	18	m/yr
J_{net}	0.00828	g-P/m2-d
	3.022	g-P/m2-yr
A	14.74	ac
	58960	m2
$P_{removed}$	178	kg/yr

For Reference:

Avg Phosphorus Removal from **Cold Climate** FWS Wetlands

Study Site	TP mg/L	k (m/yr)	g/m2-yr
1	0.016	96	3.1
2	0.113	50	2.43
3	0.113	18	0.52
4	0.225	87	13.2
5	0.281	18	4.11
6	0.296	20	18.15
7	0.454	3	8.43
8	0.82	13	4.04
9	2.26	0	21.6
10	2.88	14	18.44
Averages	**0.7458**	**18**	**6.27**

Source: Kadlec and Wallace 2009, Table 10.12

Avg Phosphorus Removal in FWS Wetlands

Study Site	TP in Mg/L	% Reduction
1	0.027	44
2	0.054	62
3	0.3	37
4	0.87	49
5	0.87	66
6	0.87	64
7	0.92	54
8	1.297	37
9	1.404	50
Average	**0.735**	**51**

Source: Kadlec and Wallace 2009, Table 10.8

Reference:

Kadlec, R.H. and Wallace, S.D. (2009) Treatment Wetlands. 2nd ed. CRC Press.

METALS REMOVAL AND SEDIMENT ACCUMULATION CALCULATIONS

Project:	Fernhill South Wetlands	**As of:**	12/9/2013
Location:	Forest Grove, OR	**Calc by:**	CG
		Checked by:	PM

1. Design information

This spreadsheet calculates the estimated accumulation of metals in the South Wetlands.

$M_{eff} = M_{in} * (1-R)$

Where M_{eff} = effluent metal concentration (mg/L)

M_{in} = influent metal concentration (mg/L), from Basis of Design Report Table 5.1

R = removal (%), based on values in Kadlec and Wallace (2009)

$M_{rem} = 3785*M_{in}*R*$

Where Mrem = mass of metal removed (g/d)

$AR = M_{rem}/Area$

Where AR is accumulation rate (g/m^2-yr)

Area = total wetland area (m^2)

Cs = AR/Carbon

Where Cs = Concentration of metal in sediment (g/m^2-yr)

Carbon = Estimated carbon in FWS wetland (g/m^2-yr)

2. Calculations

Input cell =

Copper Removal Calculations

M_{in}	0.0143	mg/L
R	74%	
M_{eff}	0.00372	mg/L
Design Flow	6.3	MGD
M_{rem}	40.1	g/MGD-d
	14619.3	g/MGD-yr
	92101.6	g/yr
Area	34	ac
	136,000	m^2
AR	0.677	g/m^2-yr
Carbon	200	g/m^2-yr
Cs	0.00339	g Cu/m^2-yr

Nickel Removal Calculations

M_{in}	0.0146	mg/L
R	0	
M_{eff}	0.0146	mg/L
Design Flow	6.3	MGD
M_{rem}	0.0	g/MGD-d
	0	g/MGD-yr
	0	g/yr
Area	34	ac
	136,000	m^2
AR	0.000	g/m^2-yr
Carbon	200	g/m^2-yr
Cs	0	g Ni/m^2-yr

Lead Removal Calculations

M_{in}	0.00036	mg/L
R	62%	
M_{eff}	0.00014	mg/L
Design Flow	6.3	MGD
M_{rem}	0.8	g/MGD-d
	308.356	g/MGD-yr
	1942.65	g/yr
Area	34	ac
	136,000	m^2
AR	0.014	g/m^2-yr
Carbon	200	g/m^2-yr
Cs	7.1E-05	g Pb/m^2-yr

Zinc Removal Calculations

M_{in}	0.0354	mg/L
R	68%	
M_{eff}	0.01133	mg/L
Design Flow	6.3	MGD
M_{rem}	91.1	g/MGD-d
	33256.1	g/MGD-yr
	209513	g/yr
Area	34	ac
	136,000	m^2
AR	1.541	g/m^2-yr
Carbon	200	g/m^2-yr
Cs	0.0077	g Zn/m^2-yr

Reference:

Kadlec, R.H. and Wallace, S.D. (2009) Treatment Wetlands. 2nd ed. CRC Press.

Appendix B

Records of Observed Bird Species & Development of Representative Species

eBird

Home | About | Submit Observations | Explore Data | My eBird | Help & Info

Sign In or Register

Translate to: English | Español | Français | Português

« Start Over

Bird Observations

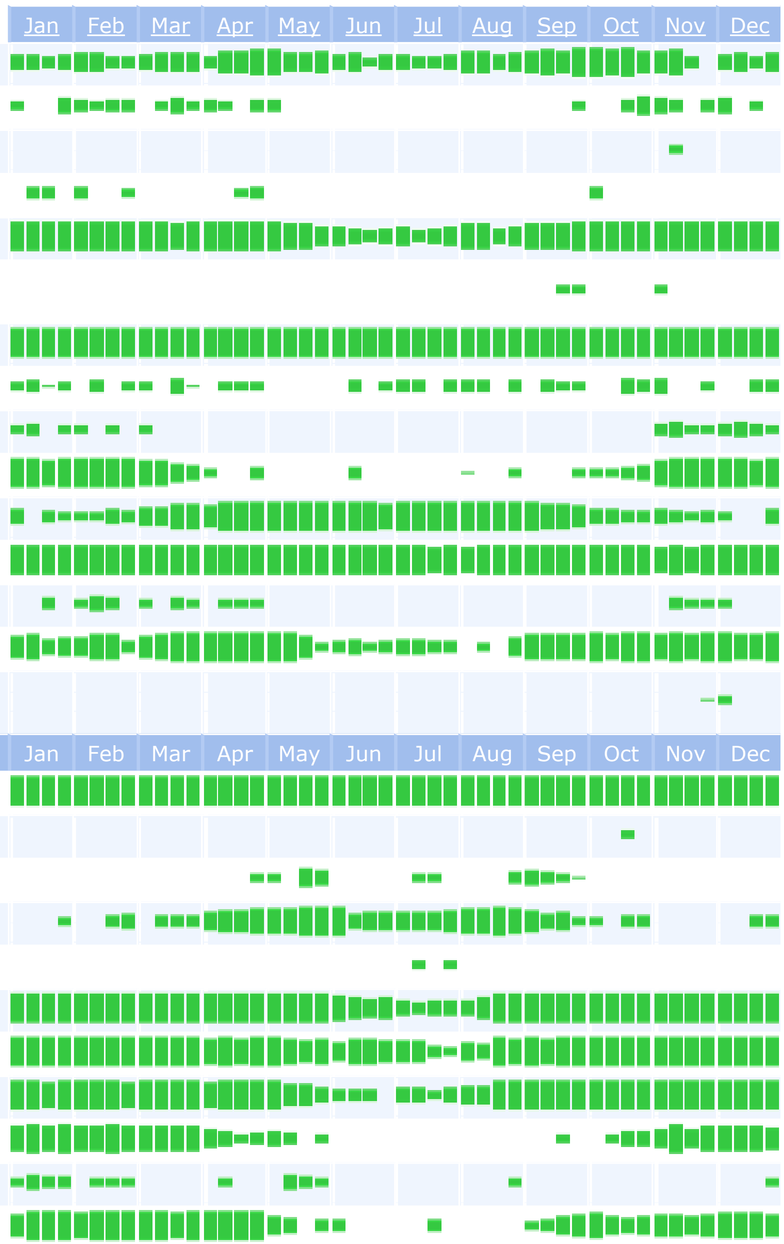
Date Range: Change Date

1/1 - 12/31, 2003-2013 **Combine Years**

For Change Location

[Fernhill Wetlands]

210 species (+25 other taxa)



Greater White-fronted Goose	MAP
Snow Goose	MAP
Ross's Goose	MAP
Brant	MAP
Cackling Goose	MAP
Greater White-fronted x Cackling Goose (hybrid)	MAP
Canada Goose	MAP
Cackling/Canada Goose	MAP
Trumpeter Swan	MAP
Tundra Swan	MAP
Wood Duck	MAP
Gadwall	MAP
Eurasian Wigeon	MAP
American Wigeon	MAP
Eurasian x American Wigeon (hybrid)	MAP
Mallard	MAP
Gadwall x Mallard (hybrid)	MAP
Blue-winged Teal	MAP
Cinnamon Teal	MAP
Blue-winged/Cinnamon Teal	MAP
Northern Shoveler	MAP
Northern Pintail	MAP
Green-winged Teal	MAP
Canvasback	MAP
Redhead	MAP
Ring-necked Duck	MAP

210 species (+25 other taxa)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greater Scaup	MAP												
Lesser Scaup	MAP												
Greater/Lesser Scaup	MAP												
Ring-necked Duck x scaup sp. (hybrid)	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surf Scoter	MAP												
Bufflehead	MAP												
Common Goldeneye	MAP												
Barrow's Goldeneye	MAP												
Hooded Merganser	MAP												
Common Merganser	MAP												
Red-breasted Merganser	MAP												
Ruddy Duck	MAP												
duck sp.	MAP												
California Quail	MAP												
Ring-necked Pheasant	MAP												
Pacific Loon	MAP												
Common Loon	MAP												
Pied-billed Grebe	MAP												
Horned Grebe	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red-necked Grebe	MAP												
Eared Grebe	MAP												
Horned/Eared Grebe	MAP												
Western Grebe	MAP												
Clark's Grebe	MAP												
Western x Clark's Grebe (hybrid)	MAP												
Double-crested Cormorant	MAP												
American White Pelican	MAP												
Brown Pelican	MAP												
American Bittern	MAP												
Great Blue Heron	MAP												
Great Egret	MAP												
Snowy Egret	MAP												
Green Heron	MAP												
Black-crowned Night-Heron	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turkey Vulture	MAP												
Osprey	MAP												
Golden Eagle	MAP												
Northern Harrier	MAP												

210 species (+25 other taxa)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sharp-shinned Hawk	MAP												
Cooper's Hawk	MAP												
Accipiter sp.	MAP												
Bald Eagle	MAP												
Red-shouldered Hawk	MAP												
Red-tailed Hawk	MAP												
Rough-legged Hawk	MAP												
hawk sp.	MAP												
Virginia Rail	MAP												
Sora	MAP												
rail sp.	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American Coot	MAP												
Sandhill Crane	MAP												
Black-bellied Plover	MAP												
Pacific Golden-Plover	MAP												
Semipalmated Plover	MAP												
Killdeer	MAP												
Black-necked Stilt	MAP												
Spotted Sandpiper	MAP												
Solitary Sandpiper	MAP												
Greater Yellowlegs	MAP												
Lesser Yellowlegs	MAP												
Whimbrel	MAP												
Black Turnstone	MAP												
Sanderling	MAP												
Semipalmated Sandpiper	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western Sandpiper	MAP												
Least Sandpiper	MAP												
Baird's Sandpiper	MAP												
peep sp.	MAP												
Pectoral Sandpiper	MAP												
Sharp-tailed Sandpiper	MAP												
Dunlin	MAP												
Stilt Sandpiper	MAP												
Ruff	MAP												
Short-billed Dowitcher	MAP												
Long-billed Dowitcher	MAP												
Short-billed/Long-billed Dowitcher	MAP												
Wilson's Snipe	MAP												

210 species (+25 other taxa)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wilson's Phalarope	MAP												
Red-necked Phalarope	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red Phalarope	MAP												
shorebird sp.	MAP												
Black-legged Kittiwake	MAP												
Sabine's Gull	MAP												
Bonaparte's Gull	MAP												
Franklin's Gull	MAP												
Heermann's Gull	MAP												
Mew Gull	MAP												
Ring-billed Gull	MAP												
Western Gull	MAP												
California Gull	MAP												
Herring Gull	MAP												
Thayer's Gull	MAP												
Glaucous-winged Gull	MAP												
Western x Glaucous-winged Gull (hybrid)	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring x Glaucous-winged Gull (hybrid)	MAP												
Glaucous Gull	MAP												
Herring x Glaucous Gull (hybrid)	MAP												
gull sp.	MAP												
Caspian Tern	MAP												
Black Tern	MAP												
Common Tern	MAP												
Forster's Tern	MAP												
Rock Pigeon	MAP												
Band-tailed Pigeon	MAP												
Eurasian Collared-Dove	MAP												
Mourning Dove	MAP												
Great Horned Owl	MAP												
Vaux's Swift	MAP												
Anna's Hummingbird	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rufous Hummingbird	MAP												
hummingbird sp.	MAP												
Belted Kingfisher	MAP												
Acorn Woodpecker	MAP												
Red-breasted Sapsucker	MAP												

210 species (+25 other taxa)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Downy Woodpecker	MAP												
Hairy Woodpecker	MAP												
Northern Flicker	MAP												
Pileated Woodpecker	MAP												
American Kestrel	MAP												
Merlin	MAP												
Peregrine Falcon	MAP												
Prairie Falcon	MAP												
Olive-sided Flycatcher	MAP												
Western Wood-Pewee	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Willow Flycatcher	MAP												
Pacific-slope Flycatcher	MAP												
Empidonax sp.	MAP												
Black Phoebe	MAP												
Say's Phoebe	MAP												
Western Kingbird	MAP												
Northern Shrike	MAP												
Hutton's Vireo	MAP												
Warbling Vireo	MAP												
Steller's Jay	MAP												
Western Scrub-Jay	MAP												
American Crow	MAP												
Common Raven	MAP												
Northern Rough-winged Swallow	MAP												
Purple Martin	MAP												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tree Swallow	MAP												
Violet-green Swallow	MAP												
Bank Swallow	MAP												
Barn Swallow	MAP												
Cliff Swallow	MAP												
swallow sp.	MAP												
Black-capped Chickadee	MAP												
Chestnut-backed Chickadee	MAP												
Bushtit	MAP												
Red-breasted Nuthatch	MAP												
White-breasted Nuthatch	MAP												
Brown Creeper	MAP												
House Wren	MAP												
Pacific Wren	MAP												

210 species (+25 other taxa)

Species	Map
Marsh Wren	MAP
Bewick's Wren	MAP
Golden-crowned Kinglet	MAP
Ruby-crowned Kinglet	MAP
Western Bluebird	MAP
Swainson's Thrush	MAP
Hermit Thrush	MAP
American Robin	MAP
Varied Thrush	MAP
European Starling	MAP
American Pipit	MAP
Cedar Waxwing	MAP
Lapland Longspur	MAP
Orange-crowned Warbler	MAP
Nashville Warbler	MAP
MacGillivray's Warbler	MAP
Common Yellowthroat	MAP
Yellow Warbler	MAP
Yellow-rumped Warbler	MAP
Black-throated Gray Warbler	MAP
Townsend's Warbler	MAP
Wilson's Warbler	MAP
Yellow-breasted Chat	MAP
Spotted Towhee	MAP
American Tree Sparrow	MAP
Chipping Sparrow	MAP
Brewer's Sparrow	MAP
Savannah Sparrow	MAP
Fox Sparrow	MAP
Song Sparrow	MAP
Lincoln's Sparrow	MAP
Swamp Sparrow	MAP
White-throated Sparrow	MAP
White-crowned Sparrow	MAP
Golden-crowned Sparrow	MAP
Dark-eyed Junco	MAP
Western Tanager	MAP
Black-headed Grosbeak	MAP

210 species (+25 other taxa)

Species	Map
Lazuli Bunting	MAP
Red-winged Blackbird	MAP
Tricolored Blackbird	MAP
Western Meadowlark	MAP
Yellow-headed Blackbird	MAP
Brewer's Blackbird	MAP
Brown-headed Cowbird	MAP
Bullock's Oriole	MAP
blackbird sp.	MAP
Purple Finch	MAP
House Finch	MAP
Red Crossbill	MAP
Pine Siskin	MAP
Lesser Goldfinch	MAP
American Goldfinch	MAP
Spinus sp. (goldfinch sp.)	MAP
Evening Grosbeak	MAP
House Sparrow	MAP

KEY: | = insufficient data | = rare to widespread

Download Histogram Data

South Wetlands
Habitat Use by Representative Bird Species

NOTES: M = Migrates through area without stopping for long time periods
N= Neotropical migratory species (e.g., migrate south of US/Mexico border)
R = Permanent Resident (year-round)
S = Short-distance migrant (elevational to regional)
W = Winters in Metro region.

Primary: F= feeding, N=nesting
Secondary: f= feeding, n=nesting

Species			Seasonality	Migratory Status	Federal Status	ODFW Status	Habitat Zones				General Species Notes
Represent. Species	Common Name	Descriptor/ Group	(At Fernhill Wetlands, based on eBird records)	(For Metro Region, based on Healthy Streams Plan, Clean Water Services, June 2005)			Open Water (shallow to deep)	Mudflat	Wetland (emergent, scrub-shrub, forested)	Upland (forest/ grassland)	(Primary sources: The Sibley Guide to Birds (2000), Cornell Lab of Ornithology's All About Birds: http://www.allaboutbirds.org/guide/)
Breeding Species (or species with populations peaking in summer, includes residents and migrants present during summer breeding season)											
X	Clark's Grebe	grebes	mostly summer	W / M	None	None	F, N	f, n			Uncommon, nests on lakes with marshy vegetation. Winters on open lakes. Dives for fish.
	American White Pelican	pelicans/cormorant	spring - fall				F	n	N		Uncommon to common locally. Roosts on sandbars and small low islands. Nest is a shallow depression scraped in the ground. Forages in shallow sheltered waters.
	Green Heron	wading birds	peaks in spring-summer, uncommon in	N / S	None	None	F		f, N		Uncommon and local along wooded streams & along edges of wooded ponds, where it crouches in shadows waiting for fish to swim by. Nests and roosts singly in trees.
	American Bittern	wading birds	summer only, uncommon	S / N	None	None	f	f	F, N		Uncommon and local in marshes, where it hides among grasses and reeds. Feeds on fish & other aquatic animals.
	Greater White-fronted Goose	swans & geese	year-round	W / M	None	None	F	f	f, N	f, n	Common locally to uncommon. Found grazing on ag land, marshes, and prairies. Nests low in a lined scrape in the ground.
X	Cackling Goose	swans & geese	year-round	Variable	None	None	F	f	f, N	f	Smaller version of Canada Goose, now recognized as separate species. Common. Found in lakes, ponds, and marshes. Nests along ponds and streams.
	Wood Duck	dabbling ducks	year-round but peaks in summer	S	None	None	F, N		f, n	f, n	Uncommon on sheltered ponds, rivers, swamps, or wherever there is standing water along trees. Nests in tree cavities or boxes.
	Gadwall	dabbling ducks	year-round	W / M	None	None	F	f	f, N	n	Common on fresh water and sheltered salt water; nest on ground near water.
X	Cinnamon Teal	dabbling ducks	peaks in spring-summer, uncommon in	N	None	None	F	f	f, N	n	Common locally on shallow ponds in or near marshy vegetation. Nests are a depression on the ground, near water.
X	Ruddy Duck	diving ducks	year-round, peaks in winter	W / M	None	None	F, N	f	f, n		Common on lakes, ponds, and sheltered bays. Nests in marshy vegetation in shallow water.
X	Osprey	diurnal raptor	spring - fall	N	None	None	F, N	n	f	n	Nest in forks of trees, rocky outcrops, utility poles, artificial platforms or offshore islets
X	Bald Eagle	diurnal raptor	year-round	S	List Threatd	List Threatd	F	f	f	N	Found near water. Nest in forested areas adjacent to large bodies of water. Prefer tall, mature trees that afford view of surroundings.
	Ring-necked Pheasant	upland game	mostly spring - fall	R	N/A -alien	N/A -alien			f	F, N	Non-native. Uncommon and somewhat local in open fields and along brushy and weedy hedgerows or forest edges.
X	Virginia Rail	rails, coots, cranes	year-round but peaks in spring/summer	R / S	None	None	f	f	F, N		Uncommon in wet marshes with cattails or other reedy plants, secretive but occasionally walks out in the open along edges.
	Sora	rails, coots, cranes	spring - summer	S / N	None	None	F, N	f	f, n		Common to uncommon in wet marshes, mainly with grassy vegetation. Covered floating nest.
X	Semipalmated Plover	sandpipers, plovers	mostly late summer	M	None	None		F	f, N		Common on open mudflats and beaches. Nests on tundra and shingle beaches. Ground nest placement.
	Greater Yellowlegs	sandpipers, plovers	year-round but peaks in spring/summer	W / M	None	None	f	F	N		Common in any shallow-water or mudflat habitat. Nests around ponds in patchy forest.
	Semipalmated Sandpiper	sandpipers, plovers	summer - fall	W / M	None	None	f	F	f, N	n	Uncommon to rare on mudflats; common on grassy tundra. Nests in scrapes on low mound or small island under shrub or grassy vegetation.
X	Western Sandpiper	sandpipers, plovers	spring - fall	W / M	None	None		F	N		Common on mudflats and sandy beaches. Covered nest on ground.
	Long-billed Dowitcher	sandpipers, plovers	spring - fall	W / M	None	None	f	F	N		Common on shallow ponds with muddy bottoms. Nests on ground in deep depression in grass.
	California Gull	gulls	year-round but peaks in summer/fall	S	None	None	f	F	f	f, N	Common on ponds, lakes, and coastlines. Nest is a scrape in sand or dirt, often lined with vegetation.
X	Caspian Tern	terns	spring - summer	N	None	None	F		N		Common locally. Nest in small colonies over sand islands. Patrols over open water along lagoons, lakes and rivers.
	Belted Kingfisher	kingfishers	year-round				F		f, N	n	Uncommon but widespread around any sheltered open water with small fish. Burrow into earthen banks to nest.
	Vaux's Swift	swifts	spring - fall	N	None	None	f	f	f	F, N	Uncommon. Nests in large hollow trees. Forages in forest openings, especially above streams.
	Rufous Hummingbird	hummingbirds	spring - summer	N	None	None			f, n	F, N	Common breeder in open coniferous forests and riparian woods.
	Downy Woodpecker	woodpeckers	year-round	R	None	None			f, n	F, N	Common in wooded habitats, especially riparian woods. Nest in dead trees or in dead parts of live trees.
	Western Wood-Peewee	tyrant flycatchers	spring - summer	N	None	None	f	f	f, n	F, N	Common in mature deciduous and mixed forests and forest edges. Forages from perch.
X	Willow Flycatcher	tyrant flycatchers	summer	N	None	SV	f	f	F, N	f, n	Uncommon and local in low brushy vegetation in wet areas, especially riparian willow thickets.
	Warbling Vireo	vireos	spring - summer	N	None	None			f, n	F, N	Common in large trees near water. Nests consist of suspended cup of gathered materials.
	Western Scrub Jay	jays, crows	year-round	R	None	None			f, n	F, N	Common in brushy areas and oak woods. Nests fairly low in trees and shrubs.
	Northern Rough-winged Swallow	swallows	spring - fall	N	None	None	F	f	f, N	f, n	Forages over open areas, especially ponds and rivers.
	Bushtit	chickadees, nuthatche	year-round	R	None	None			F, n	f, N	Common in brushy or open woods.
	Marsh Wren	wrens	year-round	N	None	None			F, N	f, n	Common locally in marshes of tall grass, cattails, or reeds. Nests are dome-like and lashed to vegetation.
	Swainson's Thrush	thrushes	spring - fall	N	None	None			f, n	F, N	Common in mature mixed woods. Nests in shrubs in forest understory.
	Orange-crowned Warbler	wood warblers	intermittently year-round	N	None	None			F, N	f, n	Common. Breeds in dense deciduous brush such as willow and alder thickets. Nests on or near ground, often on steep slope.
X	Yellow warbler	wood warblers	spring - fall	N	None	None			F, N	f, n	Common and widespread in any wet brushy habitat. Builds nest in vertical fork of a shrub or small tree.
	Wilson's warbler	wood warblers	spring - fall	N	None	None			f, n	F, N	Common in extensive brushy woods with dense understory near water. Nests in bowl of vegetation, usually placed on ground.
	Black-headed Grosbeak	tanagers, cardinals, all	spring - fall	N	None	None			f, n	F, N	Common in mature deciduous woods; also in other wooded and brushy habitats. Nests in outer branches of small deciduous tree or shrub near a stream.
	Lazuli Bunting	tanagers, cardinals, all	spring - summer	N	None	None			F, N	f, n	Common in any brushy or weedy habitat, especially along streams in arid regions. Nests in shrub close to ground.
X	Savannah Sparrow	emberizine sparrows	year-round, but peaks spring - fall	S / N	None	None			f, n	F, N	Common and widespread in open grassy/weedy habitats, including marshes, fields, and dunes; less common in brushy habitats. Nests usually on ground in thick areas.
	Song Sparrow	emberizine sparrows	year-round	R	None	None			f, n	F, N	Common and widespread in brushy areas near water. Nests hidden in grasses or weeks, sometimes near ground or high, often near water.
	Bullock's Oriole	icterids	spring - summer	N	None	None			f	F, N	Locally common in deciduous trees in or near open areas. Hanging, neatly woven nest placed in isolated trees, at edges of woodlands, along watercourses, etc.
	Evening Grosbeak	finches & old world sp	spring - winter						f	F, N	Common but irregular in mixed forests. Nest a flattened saucer of materials placed in tree or large shrub.
	Lesser Goldfinch	finches & old world sp	year-round, but peaks summer - fall	S	None	None			f, N	F, n	Common in patchy open habitat. Often nests in cottonwoods/willows along rivers, though they nest in a variety of trees and bushes.
Wintering Species (or species with populations peaking in winter)											
X	Western Grebe	grebes	fall - spring	W	None	None	F, N		n		Common locally. Winters on open lakes, bays, and ocean. Nests build on floating vegetation on lakes with marshy vegetation.
	Red-necked Grebe	grebes	fall - winter				F, N		n		Uncommon. Winters on deep open water or large lakes, dives for fish. Nests are a floating mound of plant matter on marshy ponds, with bulk of nest below water line.
	Great Egret	wading birds	year-round but peaks in fall - spring	W / M	None	None	f		F, N		Common in wetlands. Nests and roosts in mixed colonies in trees. Forages in shallow water or in grassy marshes.
	Black-crowned Night Heron	wading birds	uncommon, fall - winter	S	None	None	f		F, N		Common, but nests and roosts in colonies hidden in trees, foraging mainly at night.
X	Tundra Swan	swans & geese	fall - spring	W / M	None	None	F	f	n	N	Common locally at a few habitual gathering places. Nests on the ground in a large open bowl usually on a mound.
	American Widgeon	dabbling ducks	year-round but peaks in fall - spring	W / M	None	None	F		f, n	f, N	Common on fresh water and sheltered salt water. Often forages on ponds and grazes in fields. Nests in depression on ground, often far from water.
X	Northern Shoveler	dabbling ducks	year-round but peaks in fall - spring	W / M	None	None	F		N		Common on marshy ponds, strained food from the water's surface. Nests in scrape in short vegetation near water.
	Green-winged Teal	dabbling ducks	year-round but peaks in fall - spring	S	None	None	F	f	N	n	Common in very shallow marshes and flooded fields or on mudflats. Nests on ground in meadows, grasslands, brush thickets, or woods near water.
	Canvasback	diving ducks	fall - spring	W / M	None	None	F		f, N	n	Common locally, often in rafts on lakes and bays. Nests on marshy ponds in emergent vegetation over water and occasionally on land.
X	Ring-necked Duck	diving ducks	fall - spring	W / M	None	None	F, N		n		Uncommon. Usually in small flocks on freshwater ponds. Nests in marshes among dense emergent plants, especially those with wooded edges.
	Lesser Scaup	diving ducks	fall - spring	W / M	None	None	F, N	f	n		Common in large flocks on ponds, lakes, and bays. Nest in marshy veg in or near lakes and pond; nests placed on ground or in mound of veg over water.
X	Common Goldeneye	diving ducks	uncommon, fall - winter	M	None	None	F		N	n	Common on lakes, rivers, and bays. Nests in tree cavities around shallow marshy lakes and beaver ponds (or in nest box).
	Bufflehead	diving ducks	fall - spring	W / M	None	SU	F	f	N	n	Common on lakes, harbors, and bays. Forages in open, shallow water or over mudflats exposed at low tide. Nest in tree cavities near ponds and rivers.
X	Northern Harrier	diurnal raptor	most of year with peak in fall - winter	N	None	None			F, n	f, N	Uncommon but widespread. Courses low over marshes, farmland, and grasslands. Nest on the ground in fields or marshes.
	Dunlin	sandpipers, plovers	fall - spring	W / M	None	None	f	F	f, N	n	Common along sandy beaches and on mudflats, probing busily in mud or shallow water. Nests in shallow scrape in ground lined with vegetation.
X	Western Gull	gulls	fall - spring	R / S	None	None	F	f	f, n	f, N	Common on ponds, lakes, and coastlines. Also seen foraging on agricultural lands and loitering in parking lots/restaurants. Nest is a scrape in ground.
	Thayer's Gull	gulls	fall - spring	W / M	None	None	F		f	N	Uncommon. Picks food off surface of water. Roosts in parking lots, open fields, and similar areas. Nest is shallow bowl of moss/grass placed on narrow cliff ledge.
	Ruby-crowned Kinglet	kinglets, gnatcatchers	fall - spring	R	None	None			f, n	F, N	Common in wooded areas. Nests in tall conifers in spruce woods; at other times found in low brush or deciduous woods.
	American Pipit	tanagers, cardinals, all	fall - spring	W / M	None	None		f	f, n	F, N	Common. Winters on expansive open ground, fields, marshes, mudflats, and beaches. Nests in cup of materials on ground with overhanging vegetation.
X	Yellow-rumped Warbler	wood warblers	fall - spring	S	None	None			f, n	F, N	Common and conspicuous; in many areas the only warbler likely to be seen in winter. Use open areas with scattered trees like streamside woodlands. Nest in trees.
	Fox Sparrow	emberizine sparrows	fall - spring	W / M	None	None			f, n	F, N	Common in dense brush within woods. Nest on the ground or in low crotches of shrubs or trees.
X	Lincoln's Sparrow	emberizine sparrows	fall - spring	S / N	None	None			f, n	F, N	Common but inconspicuous. Winters in grassy patches near brush and trees, often near water. Nests in dense brushy areas.
	Swamp Sparrow	emberizine sparrows	fall - spring	W / M	None	None			F, N	f, n	Uncommon in wet marshes or at pond edges in dense vegetation such as cattails. Nests usually places near base of shrubs, slightly above ground.
	Golden-crowned Sparrow	emberizine sparrows	fall - spring	R	None	None			f, n	F, N	Common. Nests in dense brush or stunted trees. Winters in any weedy or brushy area.
	Western Meadowlark	icterids	fall - spring							F, N	Common in open spaces of native grasslands and ag fields for spring and summer breeding and winter foraging. Nests on ground in small depression.

Monthly Habitat Use by Representative Bird Species

Seasonal Habitat Associations for Representative Species			Primary & Secondary Habitat Associations				Primary Habitat Associations by Month (Feeding, Nesting [as applicable])											
Breeding Species (or species with populations peaking in summer)		**Seasonal Presence**	**Open Water**	**Mudflat**	**Wetland**	**Upland**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Clark's Grebe	grebes	mostly summer	F, N	f, n						OW, OW	OW, OW	OW, OW	OW, OW			OW		
Cackling Goose	swans & geese	year-round	F	f	f, N	f	OW	OW	OW	OW, W	OW, W	OW, W	OW, W	OW	OW	OW	OW	OW
Cinnamon Teal	dabbling ducks	peaks in spring-summer, uncommon in wint	F	f	f, N	n	OW	OW	OW, W	OW, W	OW, W	OW, W	OW, W	OW, W	OW, W	OW		OW
Ruddy Duck	diving ducks	year-round, peaks in winter	F, N	f	f, n		OW	OW	OW	OW, OW	OW, OW	OW, OW	OW, OW	OW	OW	OW	OW	OW
Bald Eagle	diurnal raptor	year-round	F	f	f	N	OW, OW	OW, OW	OW, OW	OW, OW	OW, OW	OW	OW	OW	OW	OW	OW	OW
Osprey	diurnal raptor	spring - fall	F, N	n	f	n			OW, OW	OW, OW	OW, OW	OW, OW	OW, OW	OW, OW	OW, OW	OW	OW	
Virginia Rail	rails, coots, cranes	year-round but peaks in spring/summer	f	f	F, N		W	W	W, W	W, W	W, W	W, W	W, W	W	W	W	W	W
Semipalmated Plover	sandpipers, plovers	mostly late summer		F	f, N								M, W	M, W	M, W	M, W		
Western Sandpiper	sandpipers, plovers	spring - fall		F	N					M, W	M, W	M, W	M, W	M, W	M, W	M, W	M, W	
Caspian Tern	terns	spring - summer	F		N					OW, W	OW, W	OW, W	OW, W	OW, W				
Willow Flycatcher	tyrant flycatchers	summer	f	f	F, N	f, n					W, W	W, W	W, W	W, W				
Yellow warbler	wood warblers	spring - fall			F, N	f, n					W, W	W, W	W, W	W, W	W, W			
Savannah Sparrow	emberizine sparrows	year-round, but peaks spring - fall			f, n	F, N				U, U	U, U	U, U	U, U	U, U	U, U	U, U	U, U	
Wintering Species (or species with populations peaking in winter)		**Seasonal Presence**	**Open Water**	**Mudflat**	**Wetland**	**Upland**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Western Grebe	grebes	fall - spring	F, N		n		OW	OW	OW	OW	OW	OW			OW	OW	OW	OW
Tundra Swan	swans & geese	fall - spring	F	f	n	N	OW	OW	OW							OW	OW	OW
Northern Shoveler	dabbling ducks	year-round but peaks in fall - spring	F		N		OW	OW	OW	OW	OW	OW	OW	OW	OW	OW	OW	OW
Ring-necked Duck	diving ducks	fall - spring	F, N		n		OW	OW	OW	OW	OW				OW	OW	OW	OW
Common Goldeneye	diving ducks	uncommon, fall - winter	F		N	n	OW	OW	OW	OW							OW	OW
Northern Harrier	diurnal raptor	most of year with peak in fall - winter			F, n	f, N	W	W	W	W	W		W	W	W	W	W	W
Western Gull	gulls	fall - spring	F	f	f, n	f, N	OW	OW	OW							OW	OW	OW
Yellow-rumped Warbler	wood warblers	fall - spring			f, n	F, N	U	U	U	U	U				U	U	U	U
Lincoln's Sparrow	emberizine sparrows	fall - spring			f, n	F, N	U	U	U	U	U				U	U	U	U

Habitat Usage:

Primary — F= feeding; N=nesting

Secondary — f= feeding; n=nesting

Habitat Types:

OW = open water
M = mudlfat
W = wetland
U = upland/forest

Orange = times when breeding/nesting activity is likely
Blue = breeding/nesting activity is unlikely

Appendix C

Reference Wetland Sites

C Wetland Reference Sites

To better understand regional conditions that support and maintain wetland systems, the project team conducted a study of four existing wetlands within and adjacent to the Portland metropolitan region. Here we describe the approach and findings of this study and summarize the applicability of each of the sites to the design, implementation, and management of the proposed Fernhill Wetland complex.

C.1 Purpose and Intent

One of the most important components of a functioning wetland system is the plant community that the wetland sustains. As primary producers, wetland plants perform a vital role in the ecology of the wetland. In the case of the natural treatment system being proposed at Fernhill, wetland plants are the primary element in the desire to improve water quality by reducing water temperatures prior to discharging into the Tualatin River. Because plants are a crucial element in the success of the natural treatment approach, where there is a desire to achieve strong (e.g., 80%) coverage, understanding their tolerance to prolonged inundation is important to the design process.

To provide a baseline dataset for use in the design process, the Fernhill Design Team conducted a study to provide botanic and hydrologic reference data at four carefully selected, regionally significant wetland sites. Selected reference sites cover a range of hydrologic regimes, including deep riverine flooding, beaver ponding, and managed flooding associated with hydraulic structures. Correlation of plant species locations with mid-growing season water depth, in addition to estimates of seasonal flooding, is expected to provide guidance for the design of grading, flow regimes, and plant communities at Fernhill.

C.2 Site Descriptions

Four sites were selected for this investigation: Killin Marsh, Multnomah Marsh, Mirror Lake, and Barney Reservoir Arm 2 (Figure C-1). Each of these sites is unique in terms of their hydrology, flora, and wetland function, but together, they provide a range of reference conditions to meet expected design challenges at Fernhill (Table C-1). Treated wastewater inputs to Fernhill will vary both seasonally and diurnally, and water will need to be moved through the site through much or all of the growing season. In addition, due to its location within the floodplain of the Tualatin River, portions of the site will experience rapid changes in flow depths and velocities associated with annual high flow events. As a result, one of the design challenges is to develop plant communities that can withstand variations in flow, both seasonally and diurnally, higher velocity conditions, and inundation during the growing season.

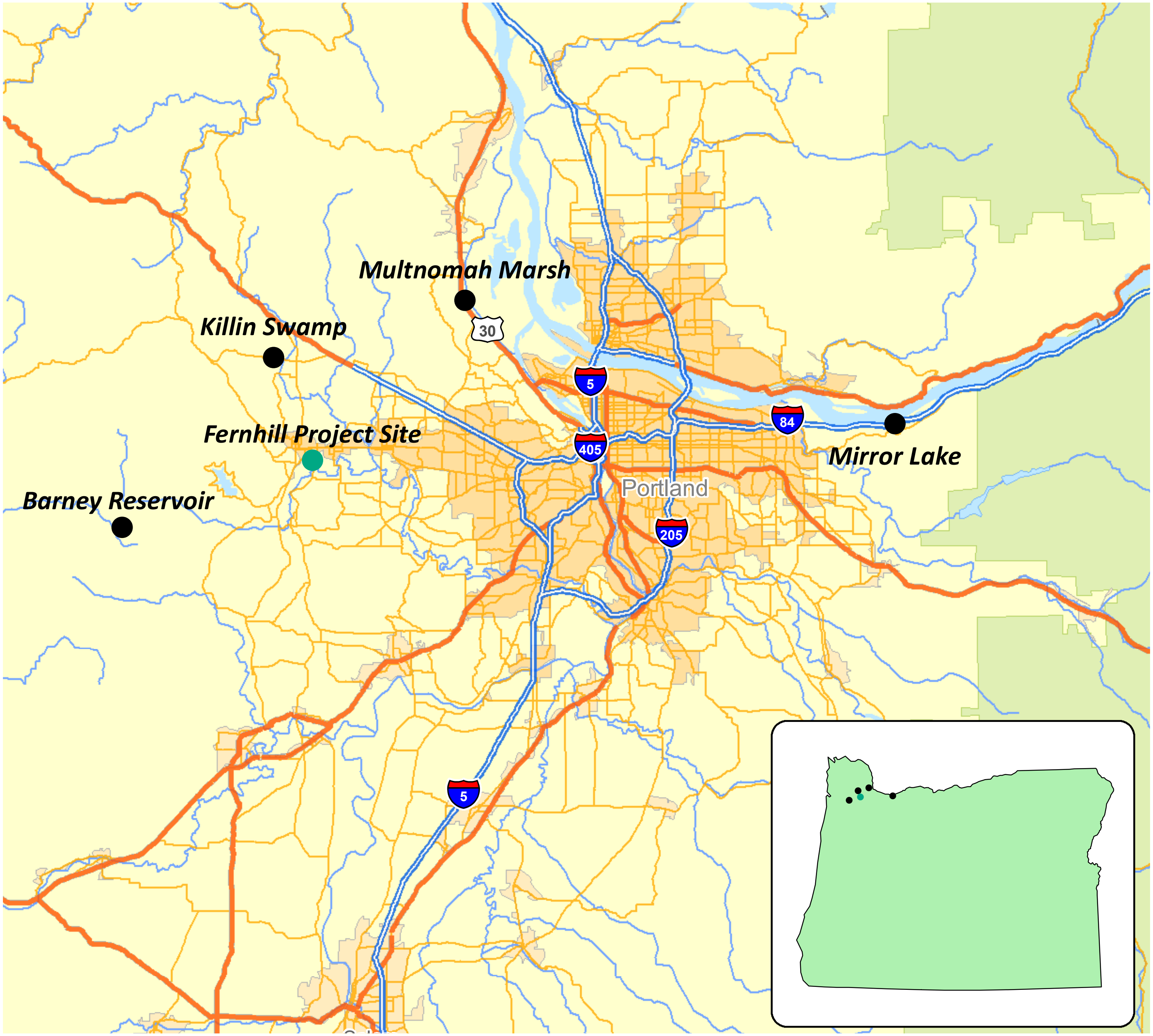


Figure C-1
Basis of Design

Reference Site Location - Portland Metropolitan and Surrounding Areas

South Wetlands
Forest Grove, OR

Legend

- Reference Sites
- Project Site
- Roads
- Streams

N

0 5 10 miles

FERNHILL DESIGNTEAM

Biohabitats CASCADIA BIOREGION

Table C-1 General characteristics of wetland reference sites.

Site	Location	Geomorphic Position	Summer Low Flow Inputs	Type of Management
Killin Marsh	Tributary to West Fork Dairy in Tualatin Basin	In-channel wetland with beaver dams	Approximately 2-3 cfs from two tributaries	Passive
Multnomah Marsh	Floodplain of Multnomah Channel near confluence of Columbia and Willamette Rivers	Seasonally inundated floodplain of Multnomah Channel	Approximately 1-2 cfs from 2 tributaries	Seasonal water level control through hydraulic structures and upland weed management
Mirror Lake	Floodplain of Columbia River in Columbia River Gorge	Seasonally inundated floodplain of Columbia River	Approximately 8-12 cfs from one primary tributary and several smaller tributaries	Passive though hydrology constricted by culvert at Hwy84
Barney Reservoir Arm 2	Trask River headwaters in Coast Range	Isolated arm of Barney Reservoir with adjacent steep hillslopes	Approximately 1-2 cfs from one primary tributary	Water level control through hydraulic structure

To address several of these challenges, we identified Multnomah Channel Marsh and Mirror Lake, which are within the floodplain of the Columbia River. These sites can provide valuable insight during the design process because they occur within the floodplain of the Columbia and Willamette Rivers, which typically experiences relatively brief high water events in winter, gradually declining water levels in early spring, followed by a sometimes dramatic and prolonged periods of high water in late spring through early summer. This later high water event falls in the middle of the growing season and therefore has a powerful and unique influence on vegetation. We expect plant communities at this site to be well-adapted to variable flooding and flows during the growing season.

We selected Killin Marsh because of its proximity to Fernhill and its geomorphology, hydrology and soils. Killin is a peat swamp with a very broad cross-section and low-gradient profile, as well as expansive areas of deep inundation and a diverse flora of hydrophytic vegetation.

Initially, Maroon Pond was selected as a fourth reference site, but was too overrun with reed canary grass to provide information on hydrophytic vegetation, especially in shallow water areas. As an alternative, we selected the Arm Two Mitigation Site at Barney Reservoir. This site consists of a constructed wetland at the downstream end and an upper portion that is primarily natural beaver ponds and wetlands. Much of the natural flora in the upper wetland has established very successfully in the constructed lower wetland, providing valuable evidence of the adaptability of the species present. Also, the site is nearly free of reed canary grass, allowing some investigation of the ecotone between uplands and wetlands that is so often dominated by this invasive grass.

C.2.1 KILLIN MARSH

Killin Marsh is a freshwater wetland west of Banks, Oregon, in the foothills of the Oregon Coast Range (Figure C-1). Topographically, this wetland occupies a broad, shallow basin that is relatively flat in cross-section and very gradually sloped from the upstream end to its terminus with the West Fork of Dairy Creek (Photo C-1). There are two major, perennial tributaries that drain into Killin Marsh, along with several intermittent and ephemeral drainages (Figure C-2). At the time of the assessment, in July, approximately 2 cubic ft per second (cfs) of flow was being provided to the wetland. One tributary, which drains the hills to the north, provides approximately 1.5 cfs through a channel that has been ditched along the north edge of the valley floor. The other major tributary drains the hills to the west and provides approximately 0.5 cfs and has been ditched along the south edge of the valley floor.

Photo C-1 View of Killin Marsh

Historically, the wetland was ditched, tiled, and leveed. The drained areas were farmed for many decades, and during this time the underlying peat soils oxidized with exposure to air. Drainage also allowed peat fires to burn through portions of the site. Fires, oxidation and drainage caused the soil surface to subside and gradually become wetter in spite of the effects of drain tiles and ditching. Ultimately, much of the site became so low that farming and even pasture uses were rendered impractical. Gradually, native plants that had been pushed to the margins reoccupied much of the wetland, including large expanses of ash forest, Geyer willow and spiraea. Reed canary grass also invaded large areas of the swamp. In 1957, the current alignment of Highway 6 was constructed, isolating a small portion of the swamp from farming activities. This isolation, combined with less disturbed adjoining uplands, has allowed more cover and diversity of native wetland vegetation to persist in this area.

Metro purchased the Killin site (not including the southern portion) for conservation in 1996. Since that time, Metro has ceased to manage the ditch, and beaver have constructed a series of small dams across the ditch, impounding over 300 acres of water in areas already reoccupied with Oregon ash, Geyer willow and spiraea. Because of subsidence, beaver-impounded water depths now exceed inundation tolerances for these species on much of the site, and many acres of ash, willow and spiraea now consist of dead, standing and downed brush and snags. In the deeper portions of the swamp, the resulting landscape is dominated by tangles of dead brush interspersed with areas of deep-water emergent and floating aquatic vegetation (Photo C-2).

Figure C-2

Basis of Design

Killin Marsh Reference Site

South Wetlands
Forest Grove, OR

Legend

- Survey Point
- Control Point
- Beaver Dam

0′ 250′ 500′

N

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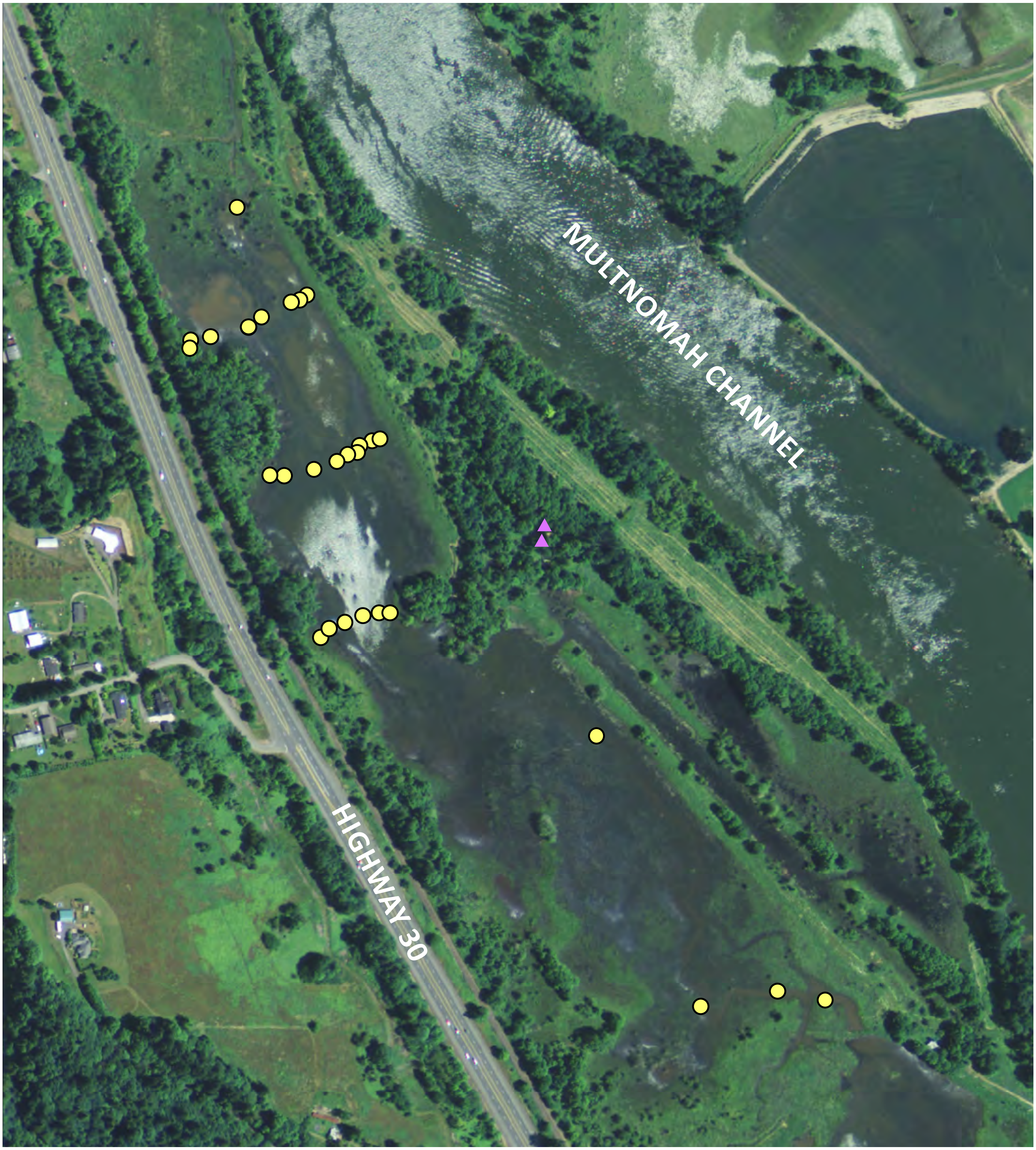
Photo C-2 Example of areas where increased inundation associated with beaver dams has resulted in stands of dying willow, spiraea, and ash.

C.2.2 MULTNOMAH MARSH

Multnomah Marsh is located along the western margin of the Multnomah Channel between the cities of Portland and Scappoose (Figure C-3). The wetland complex is part of a system of wetlands associated with the lower Columbia River Estuary. Prior to European settlement, these tidal, floodplain wetlands covered vast areas along the Columbia River between the Columbia River Gorge and the mouth. Seasonally inundated floodplains and perennial wetland lakes were especially common at the confluence of the Columbia and Willamette Rivers. Wetland conditions were maintained through the scouring action of annual flood events on the Columbia.

Since settlement, many of these wetlands have been diked, drained, and filled to support agriculture and other land uses. The construction of upriver dams in the Columbia Basin has greatly reduced the height and extent of the spring snowmelt flood on the Columbia River, resulting in less frequent periods of inundation in these floodplain wetland complexes and a dampened tidal regime. Consequently, restoration efforts designed to restore historic hydrologic conditions at these sites have often included hydraulic structures to seasonally enhance water surface elevations.



Legend
Survey Point
Control Point

0′ 250′ 500′
N

Figure C-3
Basis of Design
Multnomah Marsh Reference Site

South Wetlands
Forest Grove, OR

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Photo C-3 Upstream end of one of the hydraulic control structures at Multnomah Marsh.

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Metro purchased the 300-acre Multnomah Marsh site in 1998 and in 2001 several hydraulic structures were installed (Photo C-3). Metro's efforts have enhanced this site's natural wetland hydrology by prolonging the duration of inundation over much of the site with the water control structures (Figure C-3). The intent of hydrologic enhancement was to improve conditions for native wetland vegetation, inhibit reed canary grass, and provide off-channel rearing habitat for juvenile salmonids. These efforts have been moderately successful and as a result, some species typical of lower Columbia wetlands, such as the Columbian sedge (*Carex aperta)* and wapato (*Sagittaria latifolia)* have rebounded. At the same time, reed canary grass has retreated from deeper water areas, especially where prolonged inundation greater than two feet occurs (Zonnick, pers. comm.). One downside to the water control structures is the partial separation of the site from the influence of the Columbia River, including tidal pulses at lower water levels. The water control structures are typically closed in December and reopened around the second week of July.

Other than floodwaters entering the site from the Multnomah Channel, the site receives inputs from two small, perennial streams that drain the Tualatin Hills. Although these tributaries are perennial, flow during our site visit in July totaled approximately 0.5 cfs from both tributaries combined. Significantly higher flow is provided to the site during the winter high flow season when water levels are controlled by the hydraulic structures.

C.2.3 MIRROR LAKE

Mirror Lake is located in Rooster Rock State Park and is owned and managed by Oregon Parks and Recreation Department (Figure C-1). The lake is located along the south shore of the Columbia River in the historic floodplain (Figure C-4). Mirror Lake is similar in many respects to Multnomah Marsh. Both wetlands are part of the lower Columbia River estuarine system and share many of the same plant species. The hydrology of both sites is dominated by high flow conditions on the Columbia River and tides. In addition to the inputs from the Columbia River, both sites have inflows from upslope watersheds, although the flows into the Mirror Lake system are much greater.

Following the construction of the railroad and, more significantly, Highway 84, Mirror Lake has been separated from the Columbia River through a hydraulic structure, in this case, a culvert (Photo C-4). The culvert is relatively small, compared to the potential flux of water capable of entering the site from the Columbia River and the inputs from tributaries draining the Columbia Gorge plateau. During our field assessment in July 2013, we estimated a total of 8 to 10 cfs was being provided to the lake from tributary drainages, primarily from Latourell Creek. The effect of the undersized culvert is to dampen tidal fluxes and limit flushing flows from Latourell Creek when the Columbia River stage is low.

Photo C-4 View of twin box culverts at downstream end of Mirror Lake.

Upstream of the culverts the site consists of a large body of open water that grades into shallow open water fringed by vegetated wetlands (Photo C-5). The large open body of water, referred to as Mirror Lake, may actually be a borrow pit associated with construction of Highway 84. Many of the “floodplain lakes” that occur along the lower Columbia River Gorge were either created or enhanced by construction of Highway 84.

Figure C-4
Basis of Design
Mirror Lake Reference Site

South Wetlands
Forest Grove, OR

Legend
Survey Point
Control Point

0´ 350´ 700´
N

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Photo C-5 Open water in the distance at the downstream end of Mirror Lake grading to a channel with wetland vegetation along the margins in the upstream direction.

C.2.4 BARNEY RESERVOIR ARM 2

Barney Reservoir is municipally-owned with operations overseen by the Barney Reservoir Joint Ownership Commission. The Reservoir is located in the headwaters of the Trask River, which flows to Tillamook Bay (Figure C-1). The reservoir was constructed in 1970 by the City of Hillsboro with much of the water transferred out of the Trask and into the Tualatin River for municipal and industrial use. One arm of the reservoir has been modified to support wetlands via construction of an earthen levee and water control structure (Photo C-6).

Other than the structural enhancements near the confluence with Barney Reservoir, hydrology at this site is driven largely by the activities of beaver, which have constructed a number of simultaneously subtle and monumental dams across the valley floor, creating large open ponds and marginally wet areas of varying widths and depths (Figure C-5). The cross section of the basin becomes abruptly narrower and more V-shaped at the upstream, eastern end and beaver activity becomes limited to burrowing and small dams before ceasing altogether as the gradient of the stream increases.

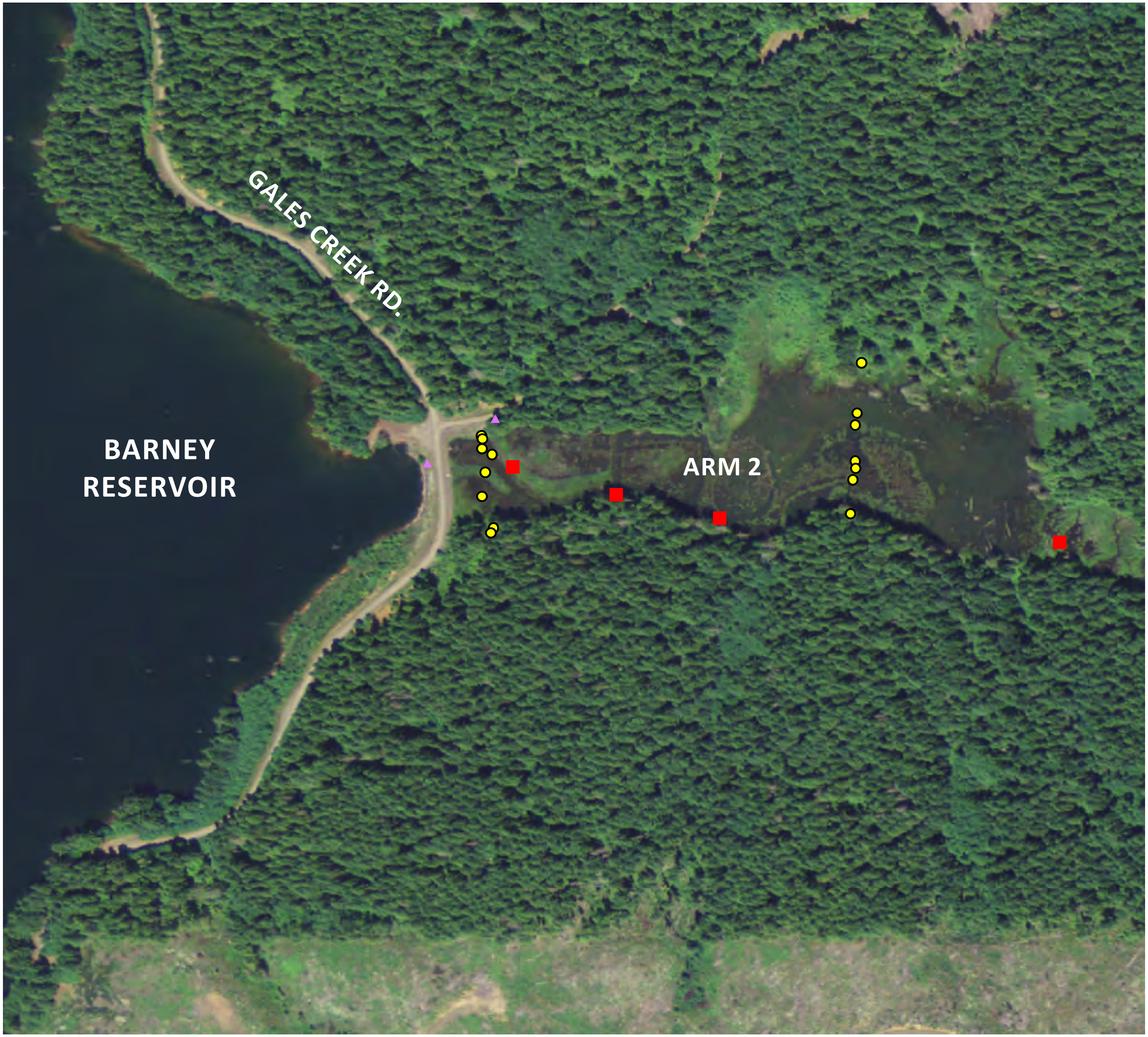
Photo C-6 View of earthen dam and water control structure at the Barney Reservoir Arm 2 mitigation wetland site.

Figure C-5

Basis of Design

Barney Reservoir Arm 2 Reference Site

South Wetlands
Forest Grove, OR



C.3 Site Assessment Methods

The primary objective of the study was to characterize water depths at the various reference sites in relation to the botanical community. Each site was sampled once in July or August of 2013, providing a snapshot of site conditions at low flow conditions. Sampling at low flow conditions allowed for characterization of the site during the height of the growing season, which allowed for identification of perennially inundated areas supporting emergent vegetation.

Each of the sites had a consistent sampling approach which included the following elements:

- Benchmark: Elevation benchmarks were established at each of the sites, which were then tied to the water surface elevation at the time of the survey, to provide an opportunity to sample the same site in the future using a consistent datum.
- General Site Notes: Upon accessing each site, general site information was collected including notes on landscape setting, gross geomorphologic features, and plant communities present.
- Transects: Transects were established perpendicular to the flow paths of channels, wetlands and ponds in locations that appeared to represent the range of conditions on each site. The effort focused exclusively on wetland and aquatic habitats. No plot data was collected in adjoining riparian and upland areas, although prevalent plant species in these areas were identified. The number of transects sampled at each site was dependent on the complexity of the habitat and difficulty of maneuvering through the site. At each transect data was collected at more or less regular intervals, additional sampled collected at important or unique plant populations or geomorphologic features, such as stream channels. Plot data consisted of water depth and estimates of cover within a 2-meter square plot centered around the survey point. Cover for each species was estimated, as well as cover of open water, mudflat, standing dead snags and downed wood.
- Hydrology: A qualitative, reconnaissance-level assessment of each of the sites was conducted to estimate hydrologic inputs. This assessment focused on surface water and was limited to publicly accessible locations, typically at road crossings.

As most of the survey areas were inundated at the time of the study, nearly all water depth and plant data were collected from canoes. The only exception to this sampling approach was at Mirror Lake where water levels were considerably lower at the time of the survey relative to a more normal flooding regime. This was most likely due to the fact that flows on the Columbia River were abnormally low for mid-summer conditions. To capture the species that were tolerant of flooded conditions the vegetation sampling was extended above the water surface at the time of the survey by up to five feet, based on an observed “bath tub ring” along an adjacent bedrock outcrop. Elevations above the water surface at the time of the survey were estimated.

Samples were collected of any unknown plant species for later identification in the lab. *The Flora of the Pacific Northwest* (Hitchcock et al., 1973) was used for plant identification and nomenclature and cross-referenced to current nomenclature and taxonomic revisions with the *Urbanizing Flora of Portland* (Christie et al., 2009).

C.4 Results

C.4.1 KILLIN MARSH

Killin Marsh was sampled on July 9, 2013. A total of 20 points were sampled along three cross-sections, extending approximately 3,000 ft along the length of the marsh (Figure C-2). A total of nine plant species were identified within the sampling plots. Most of these species occurred in water depths greater than 1.5 ft (Figure C-6). Open water dominated most of the sampling plots at Killin with the most vegetated plot only reaching 50% coverage of vegetation as compared to open water (Table C-2). This is likely due to increasing water depths associated with beaver activity and the lack of significant seasonal changes in water depths.

Table C-2 Summary of percentages of vegetated cover and open water at each reference site.

Site	Vegetated Cover (percent)					Open Water (percent)			
	Species Sampled	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Killin	9	0	50	18.7	14.5	50	100	81.3	14.5
Multnomah Marsh	13	0	100	39.5	34.2	0	100	57.9	32.9
Mirror Lake	19	0	100	59.9	31.0	0	100	35.1	33.1
Barney	20	0	90	47.3	26.7	10	100	52.7	26.7

Except on the shaded and isolated southern edge, shallower areas and marginal wet areas are thoroughly dominated by reed canary grass. A mid-summer water depth of about 18 inches seems to be a tipping point where reed canary grass gives way to largely native emergent and aquatic species. The south edge of the swamp is shaded by adjoining timber and has been isolated from farming disturbance since 1957 by construction of the current alignment of Highway 6. As a result, this portion of the wetland contains a richer diversity of plants, even on the wetland margins, that includes northern cluster sedge (*Carex arcta)*, blister sedge (*Carex vesicaria)*, slough sedge (*Carex obnupta)*, northern bugleweed (*Lycopus uniflorus)*, blue skullcap (*Scutellaria lateriflora)*, and several other herbs.

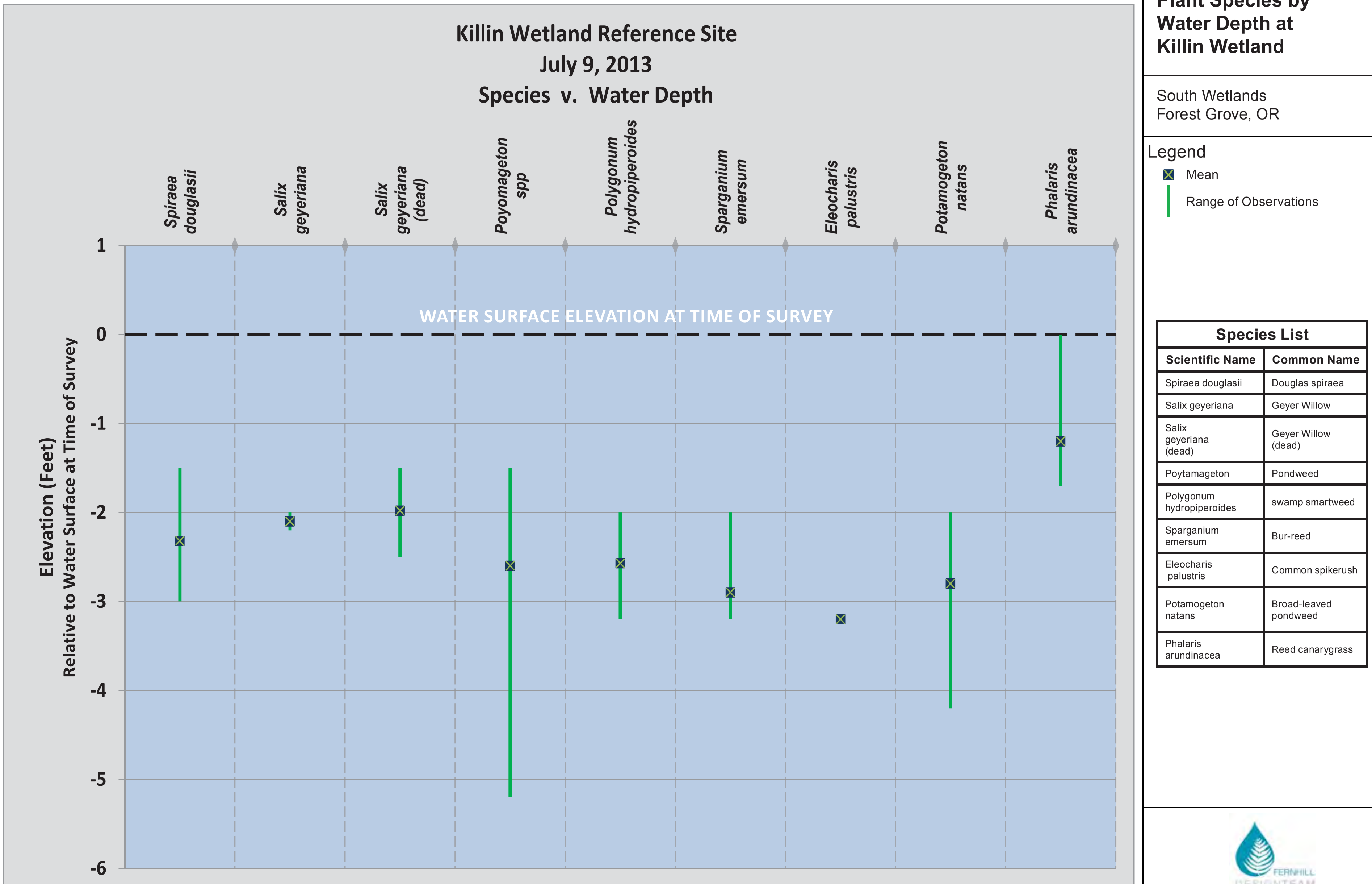
One especially interesting feature of the marsh, particularly in the isolated southern portion, is the presence of peat islands and floating logs. Many of these islands and logs are attached to the substrate by roots, but a few are actually floating and can move freely around the marsh. Rice cutgrass (*Leersia oryzoides*) is the most prevalent species on the islands, but northern bugleweed (*Lycopus uniflorus)*, northern cluster sedge (*Carex arcta)*, broom sedge (*Carex scoparia)* and others are also present. A wetland scrub fringe surrounds portions of the marsh and includes a variety of native wetland shrubs and trees. Above the scrub fringe, riparian and upland vegetation, typical of the Oregon Coast Range, dominates except where the land is being managed for agriculture or other uses.

Figure C-6

Basis of Design

Plant Species by Water Depth at Killin Wetland

South Wetlands
Forest Grove, OR



Species List	
Scientific Name	**Common Name**
Spiraea douglasii	Douglas spiraea
Salix geyeriana	Geyer Willow
Salix geyeriana (dead)	Geyer Willow (dead)
Poytamageton	Pondweed
Polygonum hydropiperoides	swamp smartweed
Sparganium emersum	Bur-reed
Eleocharis palustris	Common spikerush
Potamogeton natans	Broad-leaved pondweed
Phalaris arundinacea	Reed canarygrass

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This is a site in flux. Due to its history of clearing, drainage and agriculture, combined with subsequent re-inundation, water depths are probably substantially deeper than the pre-settlement condition. New layers of peat are undoubtedly accumulating under the water, but the rate of this accumulation is unknown but likely to be slow. The impact of invasive plant and aquatic animal species on the future condition of this wetland system is also unknown. Reed canary grass dominates areas of the marsh where mid-summer water depths are currently less than approximately 18 inches. Rather than a succession of diverse native plant communities as accumulating peat raises the profile of the marsh, reed canary grass appears likely to march across and dominate the site. Nutria and carp are both present and are influencing vegetation patterns in unknown ways. Bullfrogs are common and likely impacting native amphibian species.

Beaver are having a profound and unfolding influence on the site. They are continually clipping vegetation and promoting woody plant communities that are either less palatable to beaver (red elderberry) or are prolific resprouters (willows), or both (*Spiraea*, twinberry). Dam construction and associated ponding are drowning out less hydrophytic species, and the dams themselves are providing substrates for certain emergent plant species, such as bur-reed. In areas where reed canary grass is prevalent, clipping native woody vegetation appears to be favoring the growth and dominance of reed canary grass.

Several plant species occurring at Killin provide shade, filtration, and habitat. Floating peat islands and floating logs could shade water, as well as provide substrate for a number of plant species and wildlife, particularly turtles and birds (Photo C-7). Likewise, standing snags, and dead and downed wood provide important shade and habitat structure at Killin.

Photo C-7 Example of floating peat islands within Killin Marsh.

C.4.2 MULTNOMAH MARSH

Multnomah Marsh was sampled on July 14, 2013. A total of 28 points were sampled along four cross-sections, extending approximately 3,000 ft along the length of the southern basin of the marsh (Figure C-3). At the time of the survey the hydraulic control structures were closed and the site was still impounding water with limited inflow from tributaries draining the Tualatin Hills. A total of twelve plant species were identified within the sampling plots. Sampled plants occupied a range of depths that differed from what was observed at Killin Marsh (Figure C-7). This is most likely due to management activities that control the maximum elevation of the water surface when the main river systems are not flooding, providing hydrologic stability to the system and a gradual draw down at the peak of the growing season. The percentage of vegetative cover within each plot was highly variable throughout the Multnomah Marsh sample plots with a mean near 40% and a standard deviation of 34% (Table C-2). Reed canary grass (*Phalaris arundinacea*) was not observed in water depths greater than 2 feet within the sampling plots.

Photo C-8 View of Multnomah Marsh under mid-summer inundation conditions showing transition from upland to open water.

Photo C-9 View of Multnomah Marsh (from approximately the same location as Photo 8) during mid-summer low water conditions after the gates were opened on the water control structure.

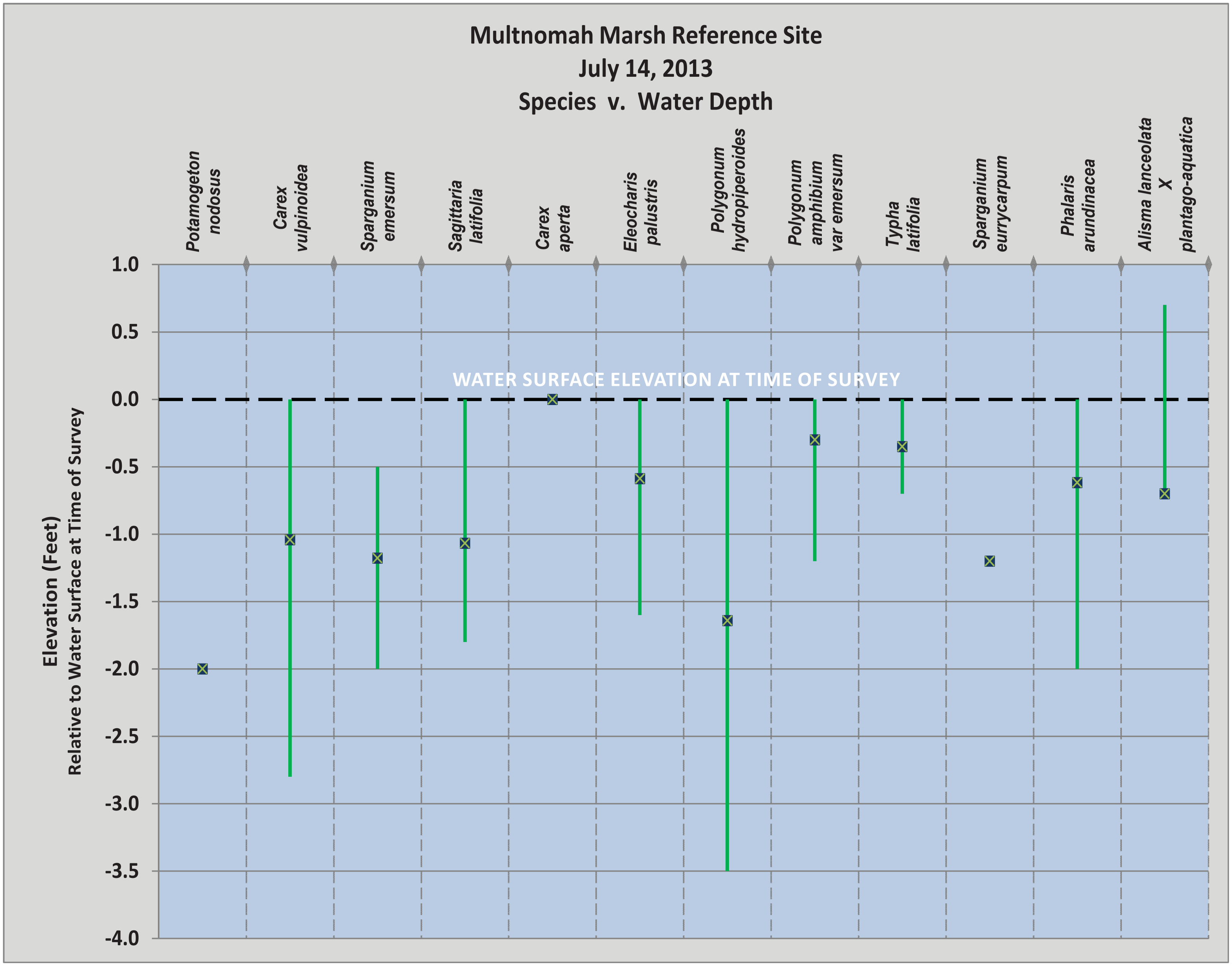

Figure C-7
Basis of Design
Plant Species by Water Depth at Multnomah Marsh

South Wetlands
Forest Grove, OR

Legend
Mean
Range of Observations

Species List

Scientific Name	Common Name
Potamogeton nodosus	Long-leaf pond-weed
Carex vulpinoidea	fox sedge
Sparganium emersum	Bur-reed
Sagittaria latifolia	Wapato
Carex aperta	Columbia sedge
Eleocharis palustris	Common spikerush
Polygonum hydropiperoides	Swamp smartweed
Polygonum amphibium var emersum	Longroot smart-weed
Typha latifolia	Cattail
Sparganium eurrycarpum	Giant bur-reed
Phalaris arundinacea	reed canarygrass
Alisma lanceolata X plantago-aquatica	Water plantain

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The wetland includes several complexes, meandering channels and large seasonal ponds. Vegetation patterns on the site are driven primarily by water depth and duration. Typically, reed canary grass dominates the riparian and wetland fringes to a mid-summer water depth of approximately two feet. Below this level, reed canary grass gradually gives way to a predictable pattern of sedges, rushes, wetland grasses and forbs, and eventually, floating aquatics (Photos C-8 and C-9). The deepest water areas are mostly open water with floating aquatic vegetation. Carp, nutria and bullfrogs are prevalent at this site, as are reed canary grass, lance-leaved water plantain, parrot feather, and other wetland and aquatic weeds.

Because of the frequent (nearly annual) deep flooding regime, this site does not support floating peat islands. We did not note any floating logs, and these features, if they occur, would be ephemeral on this site due periodic deep water associated with floods on the Willamette and Columbia Rivers.

C.4.3 MIRROR LAKE

Mirror Lake was sampled on July 17, 2013. A total of 19 points were sampled along three cross-sections, extending approximately 3,000 ft through the lake and up into the tributary channels (Figure C-4). The water surface was relatively low at the time of the survey due to low flow conditions on the Columbia River. It was estimated that water surfaces are typically 2 to5 feet higher in July, which encompasses the declining limb of the annual Columbia River snowmelt flood in normal runoff years. The site had a relatively high diversity of plant species with a total of nineteen plant species identified within the sampling plots, although eleven of those species were only observed at a single sample plot. Sampled plants occupied a range of depths despite significant variability in water depths both seasonally and from year to year (Figure C-8). Percentage of vegetative cover within each plot was highest at Mirror Lake than at the other three sites, primarily due to the presence of floating and emergent aquatic species (Table C-2). Reed canary grass (*Phalaris arundinacea*) was not observed within inundated areas although, as noted previously, the water surface elevation was lower than normal.

Mirror Lake is unique in many regards from the other sites in the study. The uplands surrounding Mirror Lake support a much greater diversity of plant species than at downstream sites, such as Multnomah Channel, due to the influence of the rich Columbia River Gorge flora. The streams flowing into Mirror Lake have strong perennial flows as well as good quality gravels and other in-stream habitat elements, and therefore support healthy runs of Coho salmon. Also, this site supports a very robust population of the introduced woolly sedge(*Scirpus cyperinus)* (Photo C-10).

Photo C-10 Mirror Lake at a low water condition looking downstream with woolly sedge dominating the margins.

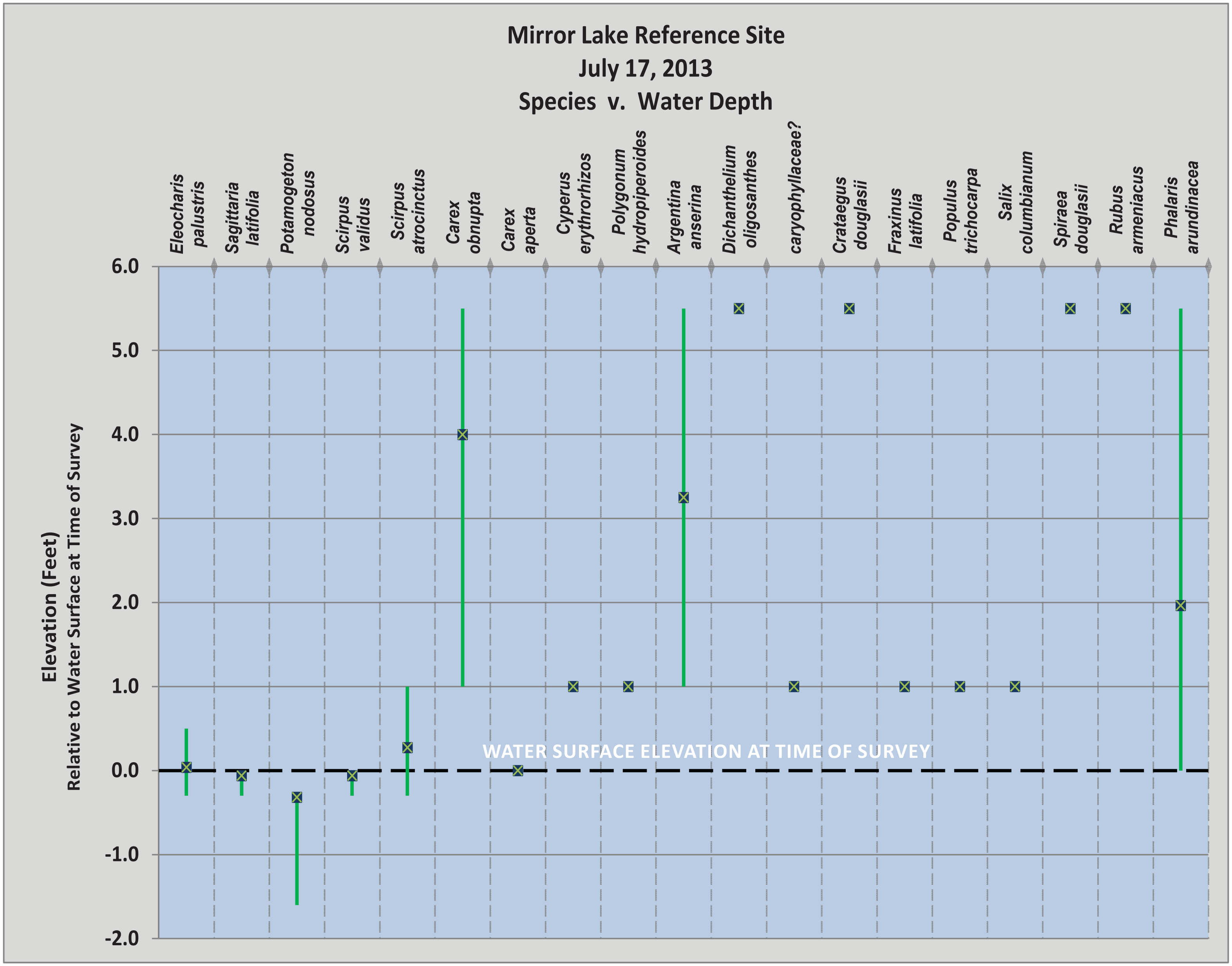

Figure C-8

Basis of Design

Plant Species by Water Depth at Mirror Lake

South Wetlands
Forest Grove, OR

Legend

- Mean
- Range of Observations

Species List	
Scientific Name	**Common Name**
Eleocharis palustris	Common spikerush
Sagittaria latifolia	Wapato
Potamogeton nodosus	Long-leaf pond-weed
Scirpus validus	Soft-stem bulrush
Scirpus atrocinctus	Blackgirdle bulrush
Carex obnupta	Slough sedge
Carex aperta	Columbia sedge
Cyperus erythrorhizos	Red-root flatsedge
Polygonum hydropiperoides	Silverweed
Argentina anserina	Silverweed
Dichanthelium oligosanthes	Heller's rosette grass
caryophyllaceae?	Carnation
Crataegus douglasii	Black hawthorn
Fraxinus latifolia	Oregon ash
Populus trichocarpa	Black cottonwood
Salix columbianum	Columbia River willow
Spiraea douglasii	Douglas spiraea
Rubus armeniacus	Himalayan Black-berry
Phalaris arundinacea	Reed canarygrass

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The Mirror Lake site encompasses Mirror Lake as well as a complex of meandering stream channels that flow into it. The lake is broad and shallow, with areas of floating and submerged aquatics, including a variety of native pond weeds (*Potamogetonaceae spp)*. The shallow margins of the Lake and stream banks support dense stands of common spikerush (*Eleocharis palustris)*, wapato (*Sagittaria latifolia)*, and softstem bulrush (*Scirpus validus)*. At slightly higher elevations woolgrass (*Scirpus cyperinus)*, Columbian sedge (*Carex aperta)*, slough sedge (*Carex obnupta)*, and silverweek (*Argentina anserine).* Above this elevation reed canary grass becomes increasingly dominant.

C.4.4 BARNEY RESERVOIR ARM 2

Barney Reservoir was sampled on September 9, 2013. A total of 15 points were sampled along two cross-sections, extending approximately 1,500 ft up into the wetland (Figure C-5). A total of four large beaver dams were observed at the time of the survey, each of which extended across the entire width of the wetland complex. The site had a relatively high diversity of plant species with a total of twenty plant species identified within the sampling plots. Nine of those species were only observed at a single sample plot. Sampled plants occupied a relatively narrow range of depths (Figure C-9), which may be a function of the site conditions rather than intolerance to depths greater than 2.5 feet. Percentage of vegetative cover within each plot was fairly high with a mean of 47% and a standard deviation of 26% (Table C-2). Reed canary grass (*Phalaris arundinacea*) was not observed at the site providing an opportunity to evaluate conditions without the presence of a weed species that tends to dominate most other wetland sites in the region.

Beaver activity creates dramatic habitat diversity at the site. Beaver ponds at Barney are relatively stable and support floating peat islands and many floating logs. These in turn support several species of sedges, grasses, and forbs, including sundews and muskflower. Deep water areas surrounding the peat islands are largely open, but include several patches of floating pond weed (*Potamogeton*), as well as submerged aquatics. Several species grow on the beaver dams themselves, most notably cattail (*Typha latifolia*), which the beaver seem to be incorporating in their structures (Photo C-11). The stout rhizomes and fine roots of the cattail appear to be helping bind the dams together.

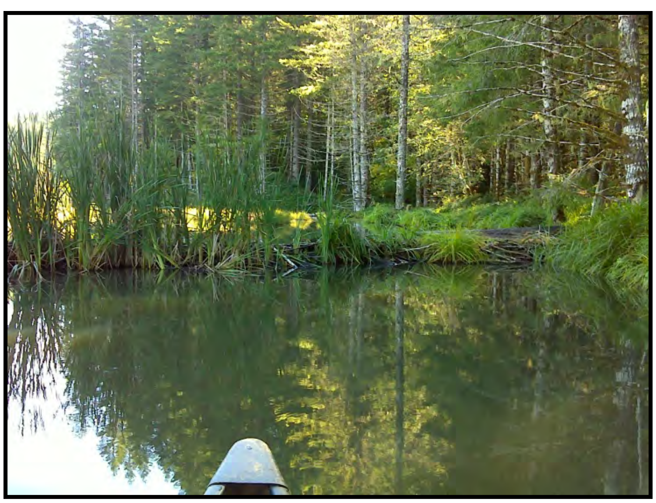

Photo C-11 View of one of the many beaver dams at Barney Reservoir Arm 2.

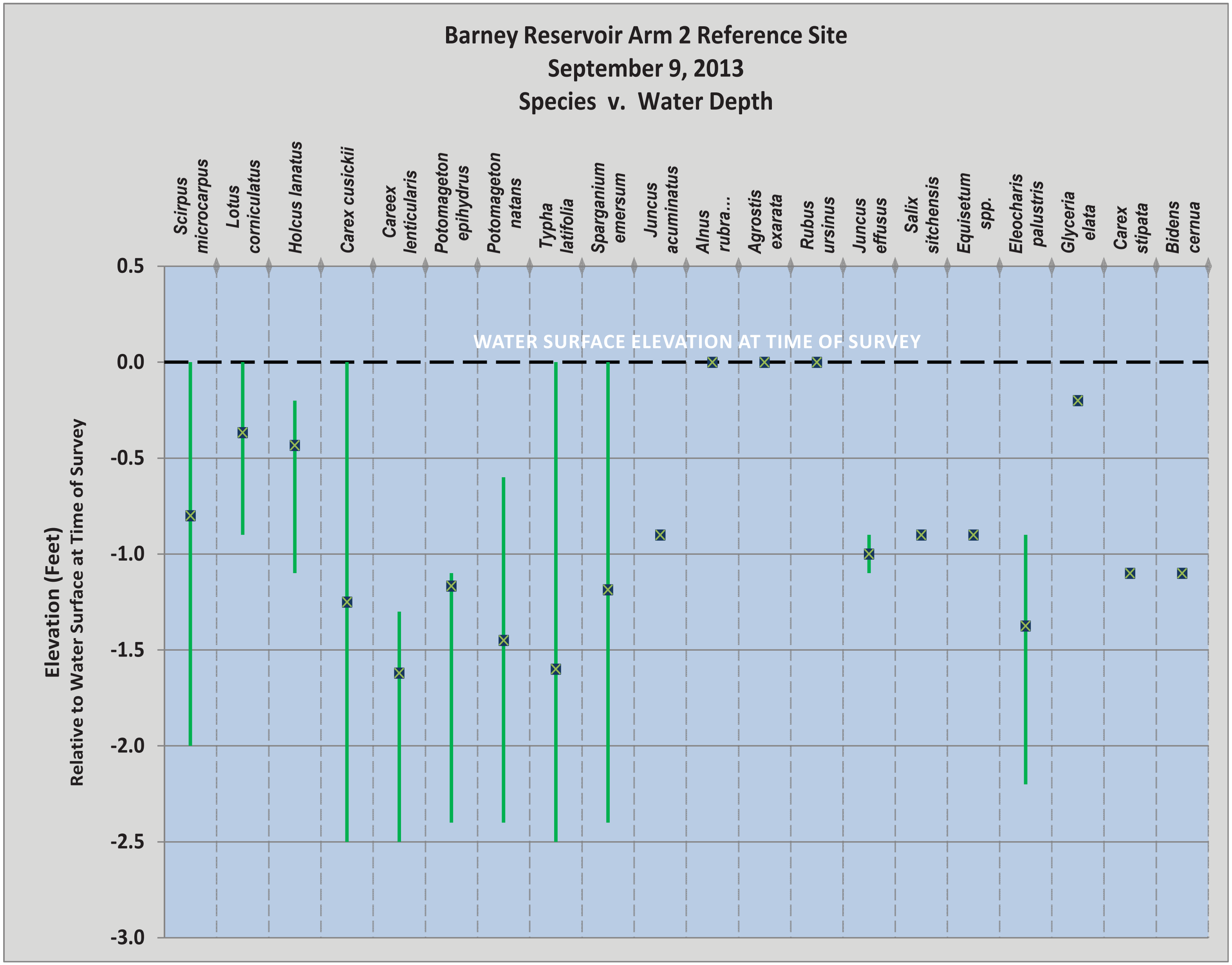

Figure C-9

Basis of Design

Plant Species by Water Depth at Barney Reservoir Arm 2

South Wetlands
Forest Grove, OR

Legend

- Mean
- Range of Observations

Species List

Scientific Name	Common Name
Scirpus microcarpus	Small-fruit bulrush
Lotus corniculatus	Bird's-foot Trefoil
Holcus lanatus	Velvet grass
Carex cusickii	Cusick's sedge
Careex lenticularis	Lakeshore sedge
Potomageton epihydrus	Ribbon-leaf pondweed
Potomageton natans	Broad-leaved pondweed
Typha latifolia	Cattail
Sparganium emersum	Bur-reed
Juncus acuminatus	Pointed rush
Alnus rubra (seedlings)	Red alder
Agrostis exarata	Spike bentgrass
Rubus ursinus	Dewberry
Juncus effusus	Soft rush
Salix sitchensis	Sitka willow
Equisetum spp.	Horsetail
Eleocharis palustris	Common spikerush
Glyceria elata	Tall mannagrass
Carex stipata	Sawbeak sedge
Bidens cernua	Nodding beggar's tick

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Margins of the beaver ponds support a variety of emergent, wet prairie, scrub and forest vegetation. There are many snags, stumps and floating logs, including durable conifer snags created recently by rising water tables associated with beaver activity (Photo C-12). Herbs in shaded wet areas include tall mannagrass (*Glyceria elata*) and small-fruit bulrush (*Scirpus microcarpus*). More open areas support these species, as well as a variety of sedges, rushes and forbs. Upstream, vegetation quickly transitions to thickets of willow, spiraea, ninebark, and a wide variety of wetland herbs, and then to dense stands of red alder and salmonberry. Upslope forests are typical of mid-elevation coastal Douglas-fir stands, with Douglas-fir, hemlock, western red cedar, big leaf maple, and red alder, plus a wide variety of shrubs and woodland grasses and forbs.

Photo C-12 Open water habitat at Barney Reservoir Arm 2 interspersed with floating logs, snags, and dense emergent (in background).

Implications of this site for treatment wetland design include the variability of vegetation types, integration of large wood, and several species of wetland plants that might be applied at the Forest Grove site. In particular lakeshore sedge (*Carex lenticularis)* and Cusick's sedge (*Carex cusickii)*, which occupy and help bind peat islands, have potential applications.

C.5 Summary of Depth Ranges

The reference sites contain rich arrays of hydrophytic vegetation. Some of these plants provide important functions such as shade, filtration, stabilization, wildlife habitat, forage, or some combination of these. Plants found at each reference site are listed in Appendix B along with the habitat types that each species typically occupies. Comparisons between common habitat types and the range of depths that each species was observed at each site produce the generalizations outlined in Table C-3.

Table C-3 General overview of depth ranges found for aquatic and emergent plant communities within each reference area.

Site	Aquatic Species	Emergent Species
Killin	-4.0 to -2.0 ft	-3.0 to -1.0 ft
Multnomah Marsh	-3.0 to 0 ft	-1.5 to 0.5 ft
Mirror Lake	-1.5 to -0.5 ft	> 0.5 ft
Barney	-1.0 to -2.5 ft	-2 to 0 ft

C.6 Study Limitations and Future Study Recommendations

This effort was not intended to be a complete floristic study of each of the selected sites. Because each site was only sampled once, it represents a snapshot in time. Many plant species require that identification be conducted at a particular time of year. Consequently, some plants may have been missed or were not identifiable due to the timing constraints of the study. Long-term it may be valuable to revisit each of these sites in future years at the same time of year as well as under different seasons or during different parts of the growing season. All future studies could be tied to the same local datum using the rebar monumentation that was established at the site. All that would be required to repeat these studies would be a GPS unit and metal detector to find the monument and rod and level survey equipment.

Another valuable piece of information that would be useful at each of these sites, but was outside the scope of our study, would be continuous water level data over several years. A continuous depth recorder could easily be installed at each of the sites, along with a staff plate, and tied to the local elevation datum. This would provide valuable information about the variability in depth seasonally and from year to year. The sampling point could also be equipped with a temperature logger to understand temperature conditions in each of the reference wetlands and how temperatures vary seasonally.

The study is also limited by the fact that it does not identify potential barriers to successful vegetation establishment or health of the community. For example, many of the sites are impacted by the presence of high densities of carp and other invasive species. Although we know that carp are present and that they impact the vegetation, the extent of their impact is unknown. Carp are also present at Fernhill in large numbers. Understanding the impact that carp may have on vegetation is an important piece of information as we identify which plant species to recommend for Fernhill. On-site field trials of plantings, especially of aquatics in Fernhill Lake, could provide valuable insights to the tolerances of these species for carp and other potential limiting factors to establishment of certain aquatic vegetation species.

Appendix D

Trails Plan Elements

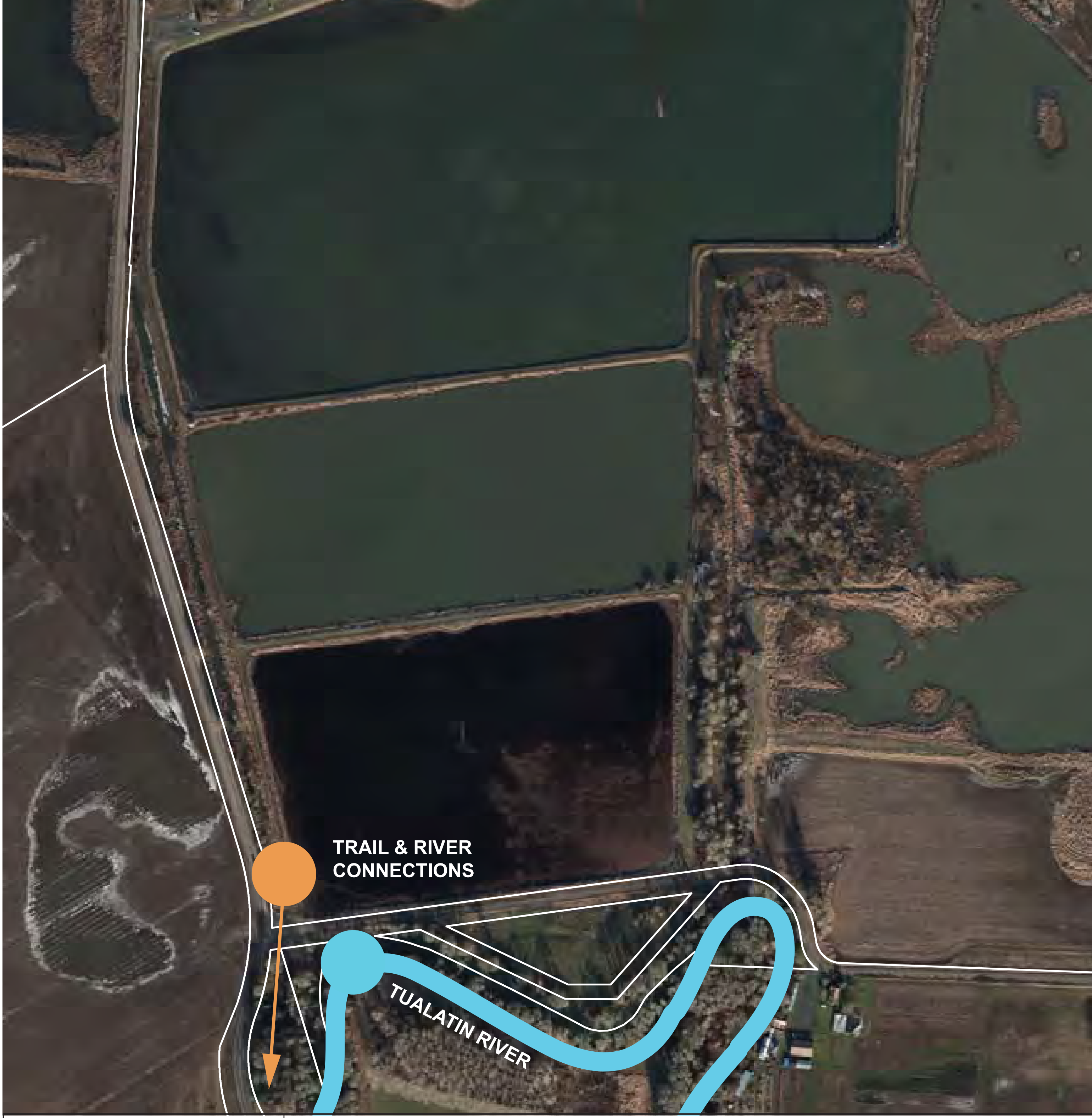


Figure D-1
Basis of Design

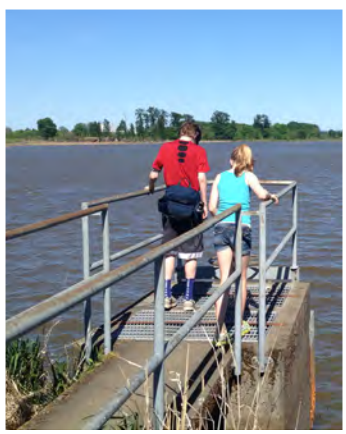
Fernhill Trails
Regional Context

South Wetlands
Forest Grove, OR


6. Water Garden


7. View NW


1. Berm at Ponds 1 & 3


10. View SE


9. Eagle Perch Pond


8. Viewing Structure

0' 200' 400'
N

Figure D-2
Basis of Design
Existing Site

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South Wetlands
Forest Grove, OR

15
0′

Figure D-3

Basis of Design

NW Parking Improvements Concept Sketch

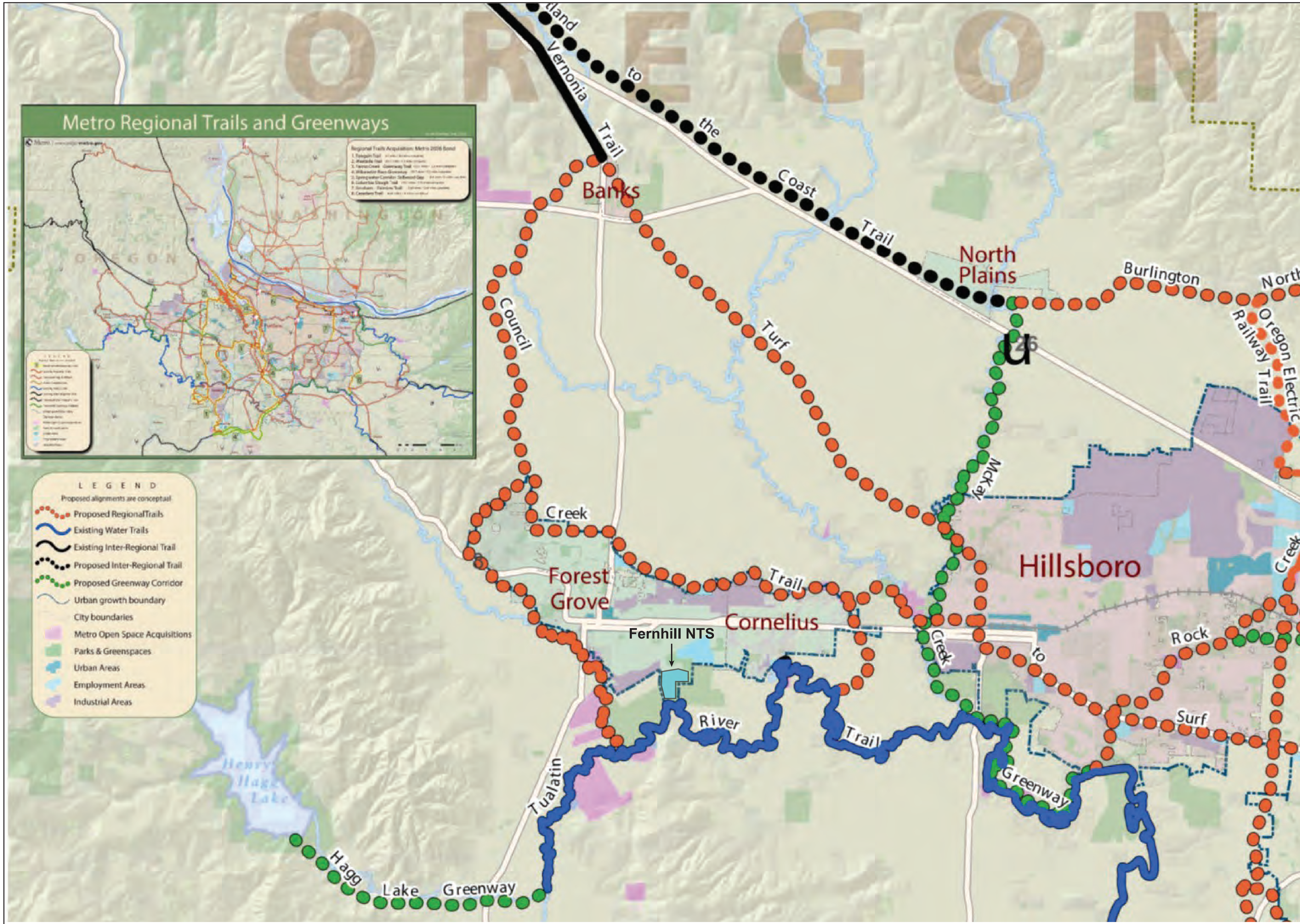
South Wetlands
Forest Grove, OR

0′ 20′ 40′

N

Figure D-4
Basis of Design
Metro Regional Trails

South Wetlands
Forest Grove, OR



Map Source: Metro

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Figure D-5.1

Basis of Design

Outdoor Learning at North Shore

South Wetlands
Forest Grove, OR

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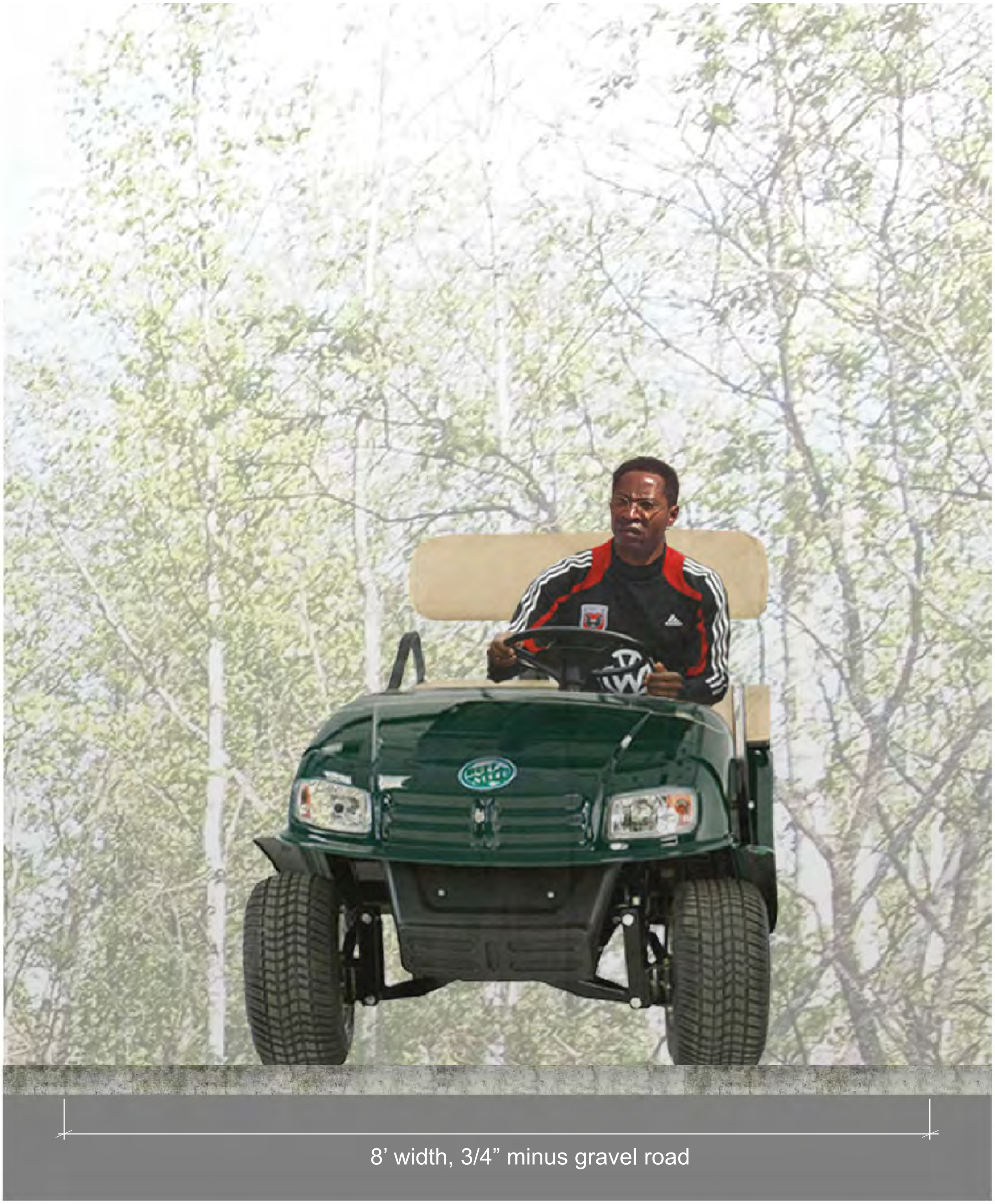

Figure D-5.2
Basis of Design
Maintenance Road

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Existing Viewing S

Observation Point

Outdoor Learning

LEGEND

EXiSTING PATH

GRAVEL SERVICE ROAD

SINGLE TRACK TRAIL

BRIDGES

SITE ENTRANCE

PARKING

OUTDOOR LEARNING

ELEVATED VIEWPOINT

VIEWING STRUCTURE

CAR BLIND

SHELTER

GATE

VIEWS

Figure D-6

Basis of Design

Site Precedents

South Wetlands

Forest Grove, OR