Multi-Objective Natural Treatment System

How Clean Water Services' NTS Solved Multiple Water Quality Challenges

A compilation of CWS presentations
Edited March 29, 2019 by Shanna Myers
for biological treatment course; Aalto University, Finland

Original slides provided by: Jamie Hughes & Leila Barker
Regulatory Affairs Department, Clean Water Services

Clean Water Services

Outline

- Clean Water Services
- Overview of Fernhill NTS
- Pilot Study and Results
- Full Scale Design
  - VFW
  - South Wetlands
- Benefits
- Challenges and Next Steps
- Acknowledgements

Clean Water Services

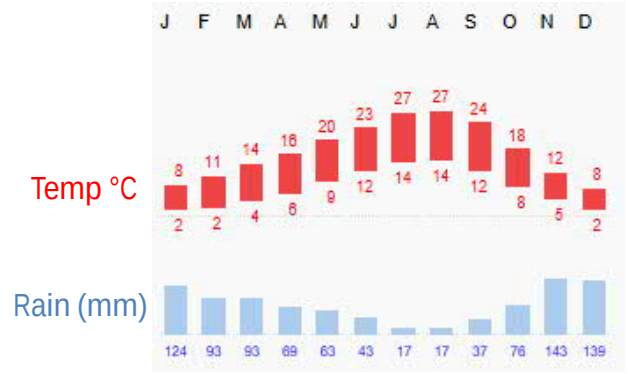
- Public utility district in Oregon, USA that specializes in water resources management.
- Serves ~600000 residents in urban boundary of Washington County (west Portland and surrounding cities).

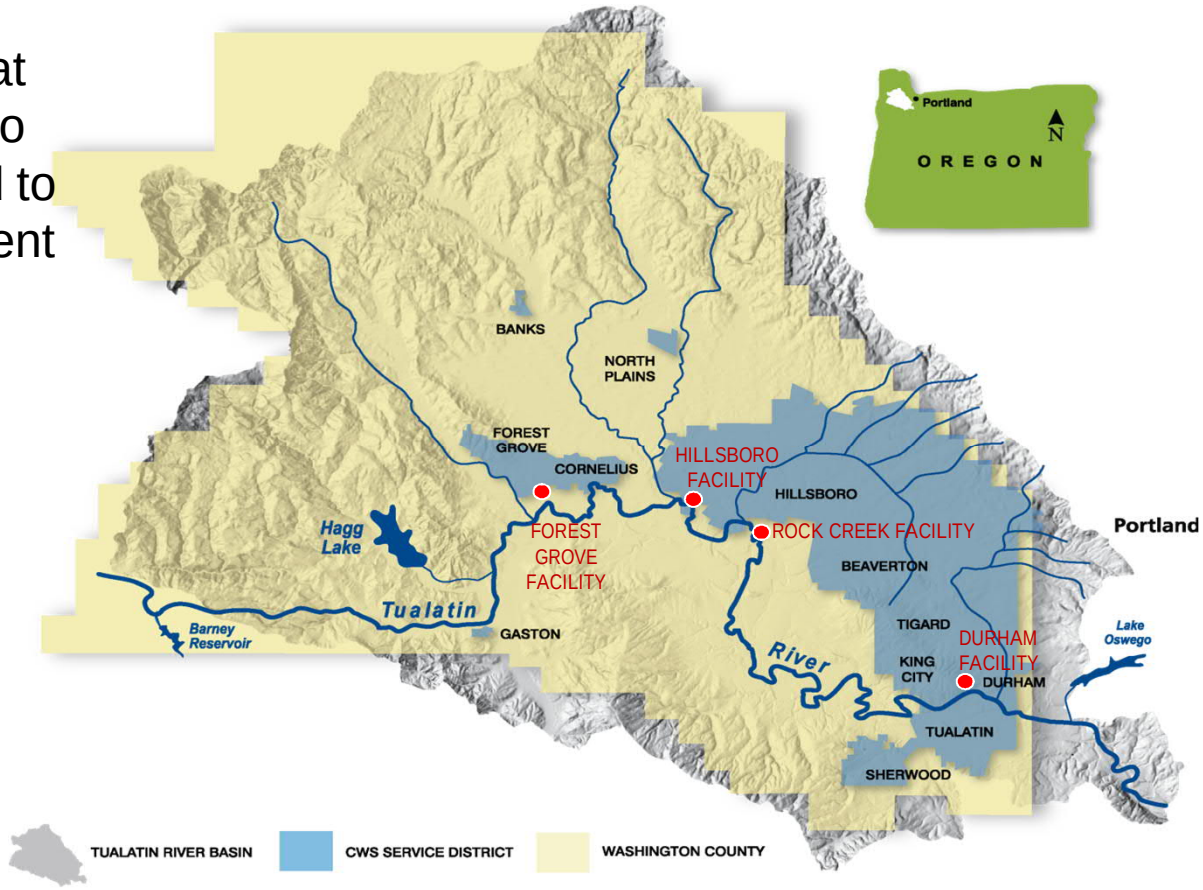
Services include:

- Innovative wastewater and stormwater services
  - Operates 4 WWTFs
  - Municipal separate storm sewer program (MS4)
- River flow management
- Water quality and stream enhancement projects
- More

Why a Natural Treatment System at CWS?

- Previously, dry season flows at the Forest Grove and Hillsboro WWTFs had to be transferred to Rock Creek facility for treatment
- Significant population growth anticipated





Water Quality Drivers in the Tualatin River

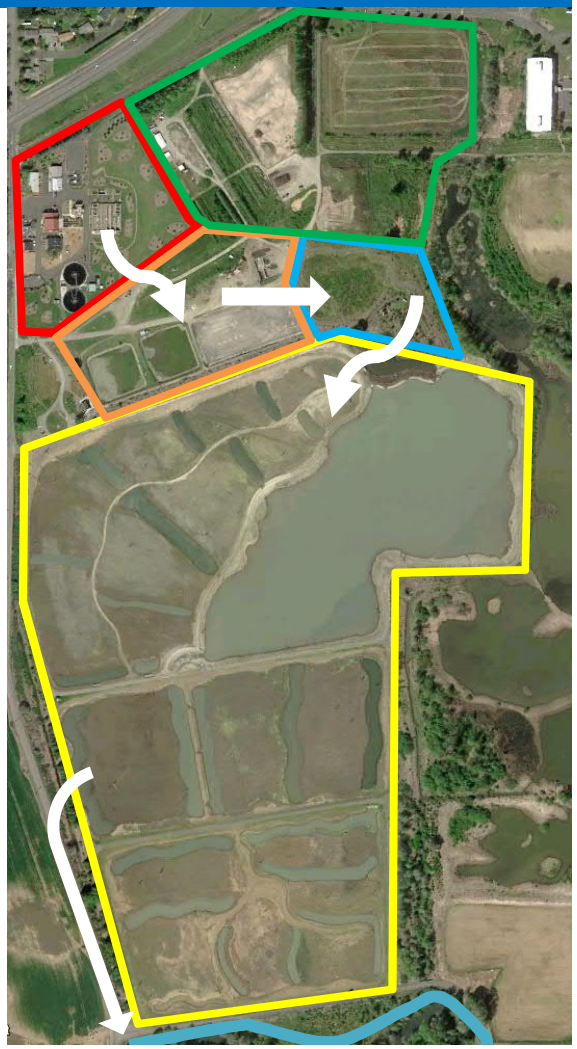
- Phosphorus (FG WWTF)
- Ammonia (Fernhill NTS)
- Temperature (Fernhill NTS)

Forest Grove WWTF

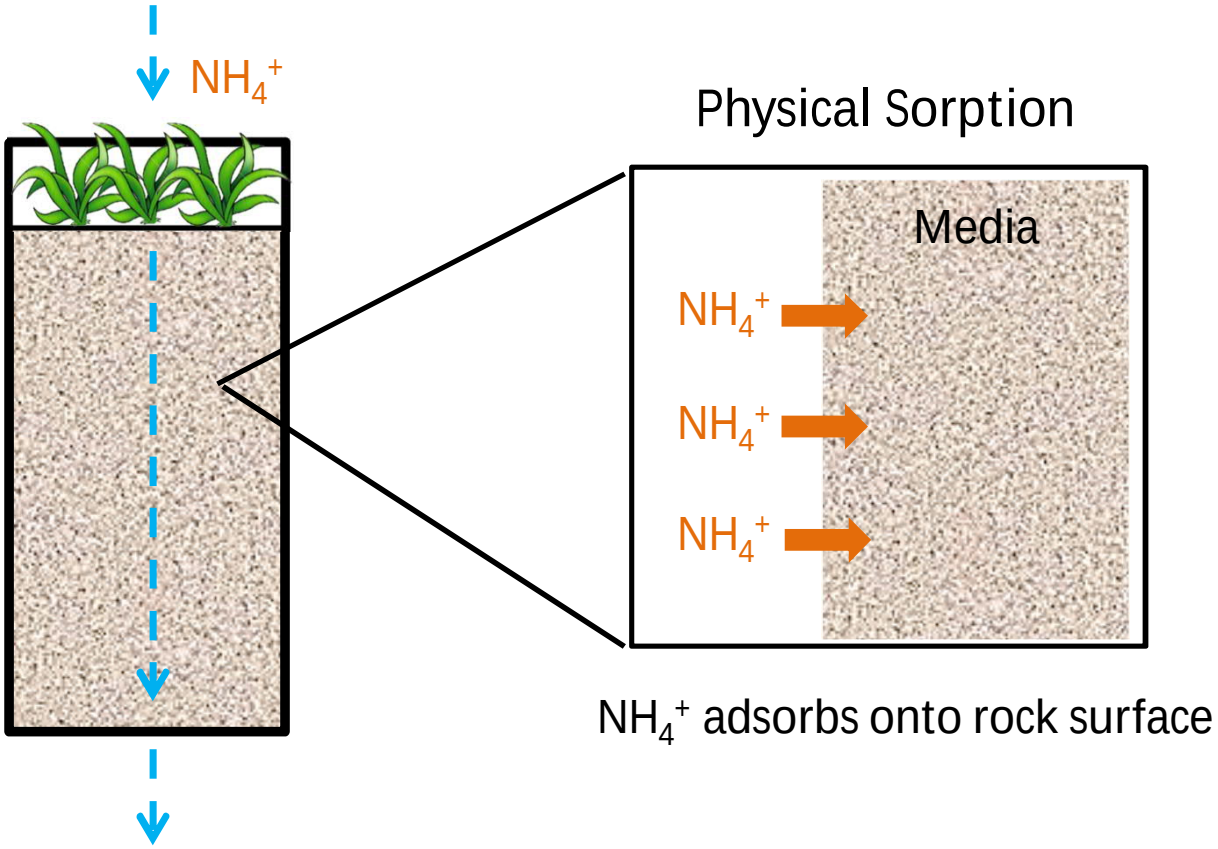
- Secondary treatment
- Focus on biological phosphorus removal
- Avoid nitrification

Fernhill Natural Treatment System

- Forest Grove WWTF
- Vertical Flow Wetlands: Ammonia Reduction
- Lower Treatment Wetland: Demonstration
- South Wetlands: Temperature Reduction
- Tualatin River: Outfall
- Upper Wetlands: TBD



VFW Ammonia Sorption and Nitrification



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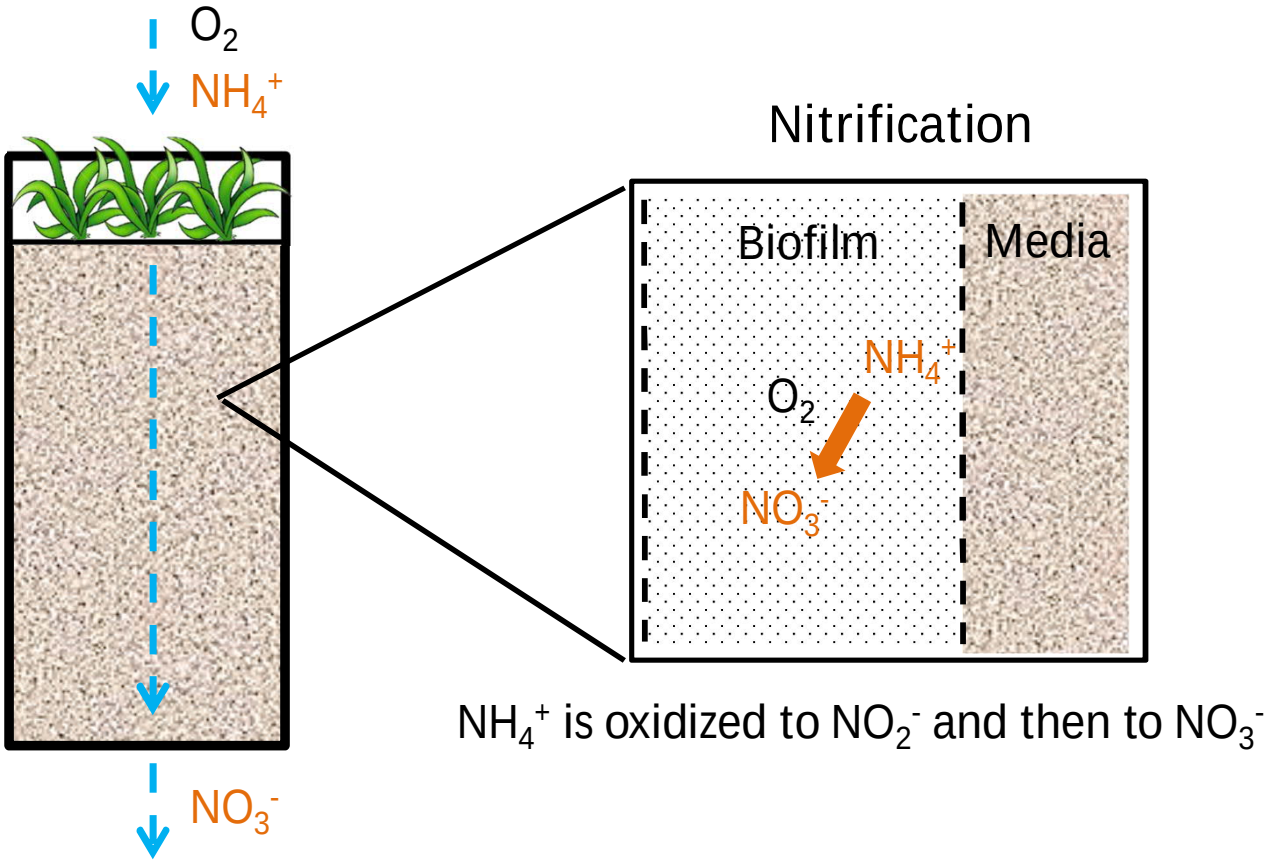
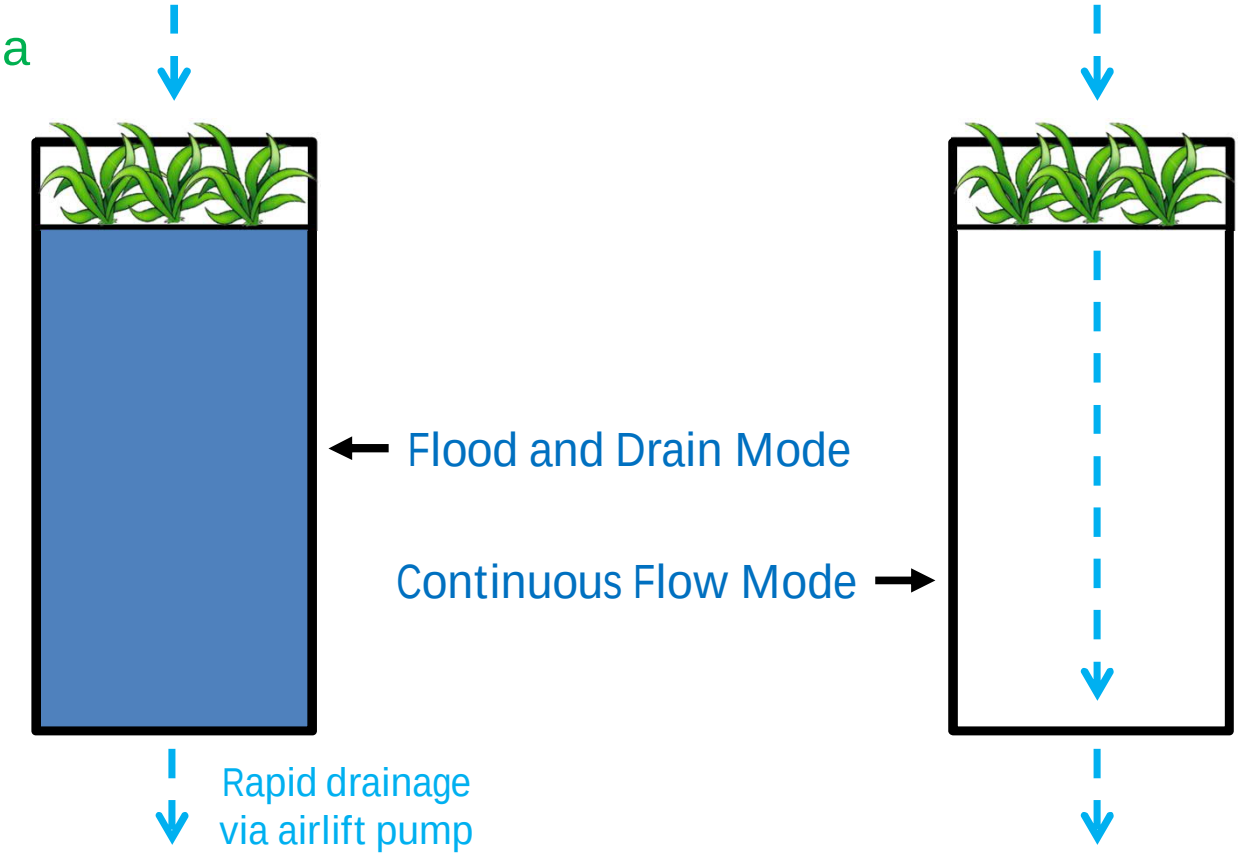


NH_4^+ is oxidized to NO_2^- and then to NO_3^-

VFW Pilot Study

- Two types of rock media
- Nitrification efficiency
- Contaminant removal
- Biofouling
- Flow modes
- Hydraulic loading rates

  (1, 2, 4, 8, 16 m/d)



VFW Pilot Study Results

- High rates of nitrification
  (< 1 mg/L in effluent)
- High percent removal of ammonia at HLRs ≤ 8 m/d
  (> 80% removal)
- Type of media and flow mode did not make a difference

Full Scale VFW Design

- 70000 m^3/d build-out capacity
- 5260 m^2
- 12 cells
- 22500 metric tons of media
- 1,83 m deep
- Designed for both flow modes

Full Scale VFW Design

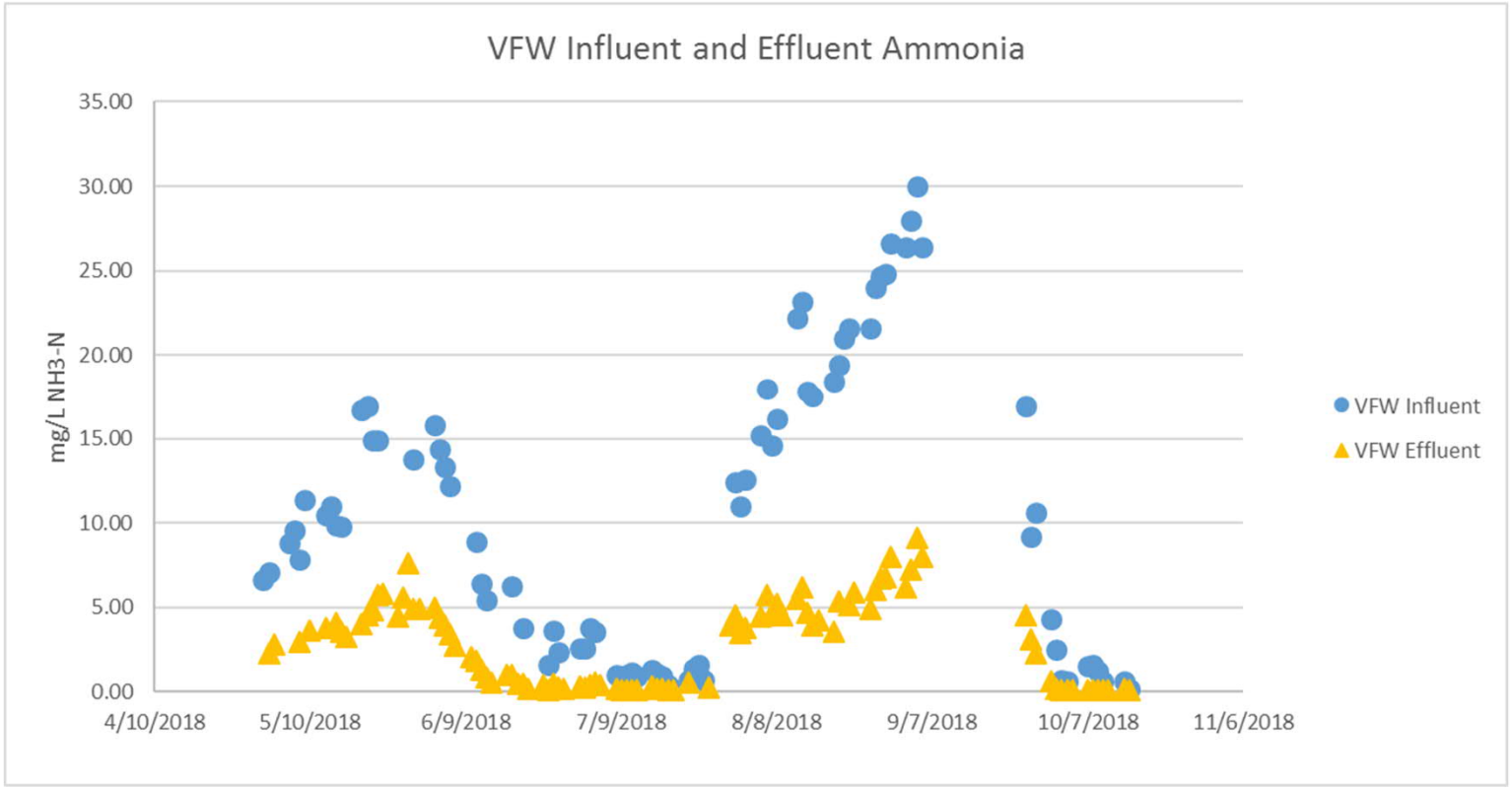
- In flood & drain mode:
  - 1-2 hour cell fill time
  - 60 minute cell drain time

Startup

- Hydraulic testing
- Troubleshooting
- Growing a biofilm

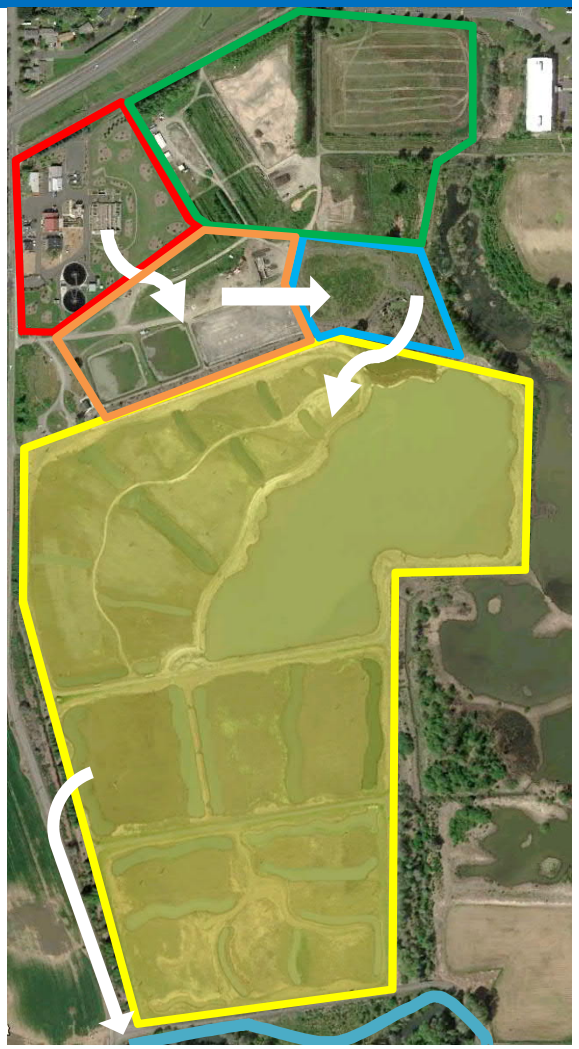
Volunteer Vegetation

VFW Performance



South Wetlands: Surface Flow

- Purpose: temperature reduction
- 36,4 hectares; design HRT of 4-5 days at 19000 m^3/d
- Designed for passive flow
- Open to public



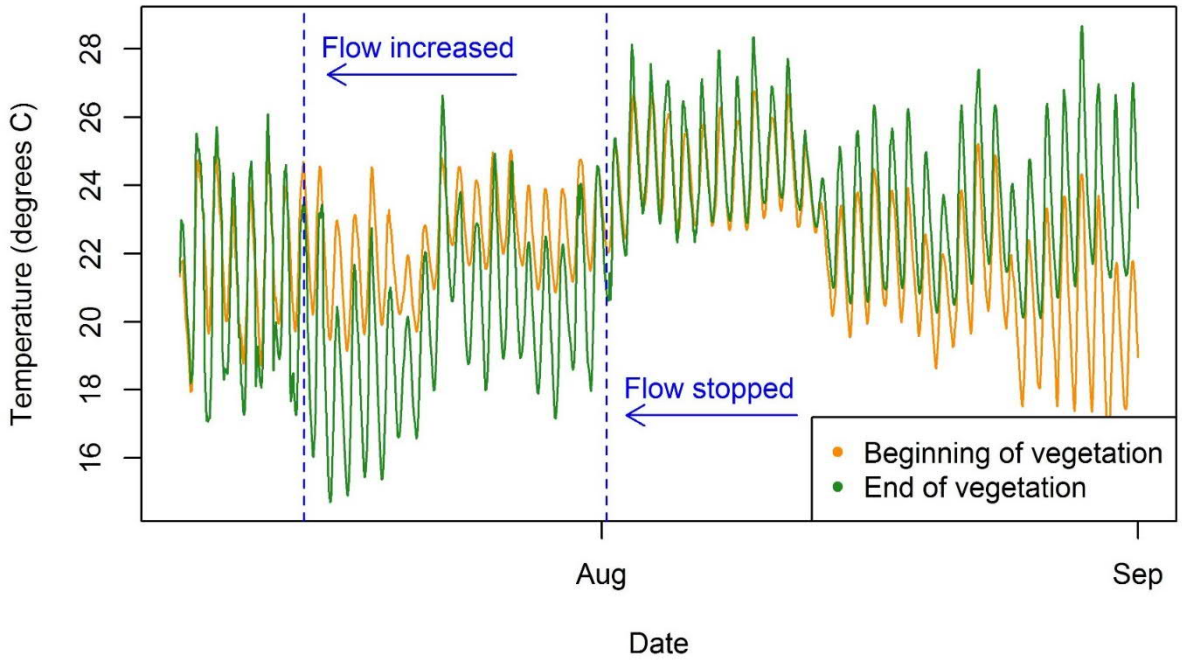
South Wetlands Construction

- 191000 m^3 of soil
- 180 vertical snags/sill logs
- 750000 plants
- 3,2 billion seeds
- 15 water control structures
- Construction began in 2014

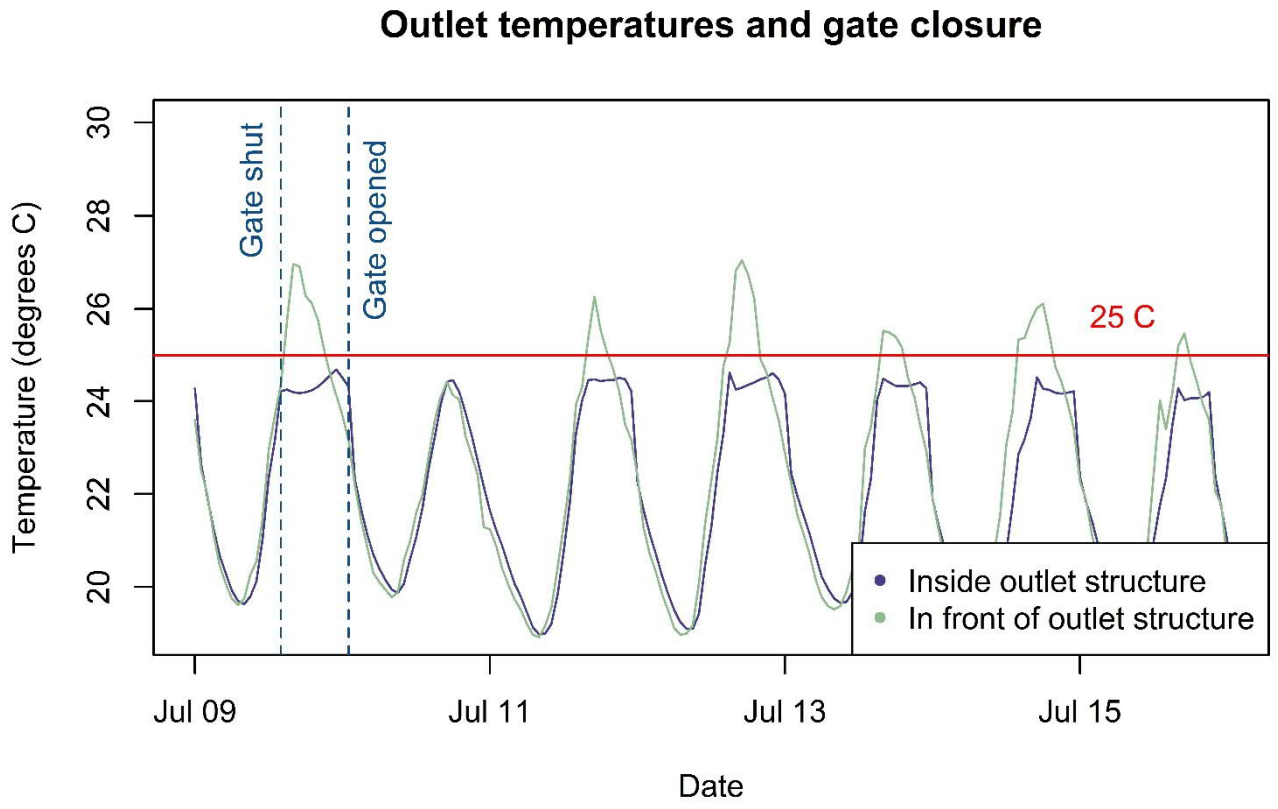
Temperature and DO Monitoring

- Permit requirements for temperature and DO are to be met at the NTS outfall
- Beginning/end/middle of cells
  - Study cooling effects of vegetation
  - Identify areas of concern
- NTS outlet (online sensors)
  - Temperature
  - DO

Temperature Reduction



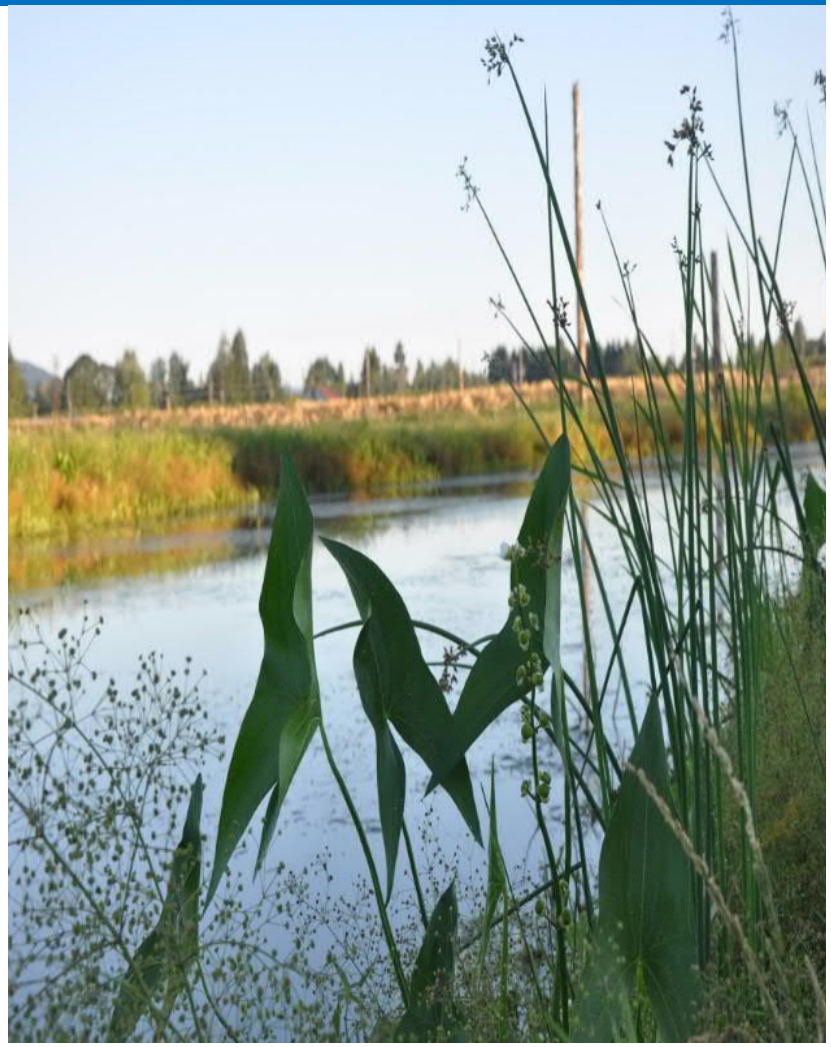
Effect of gate closure



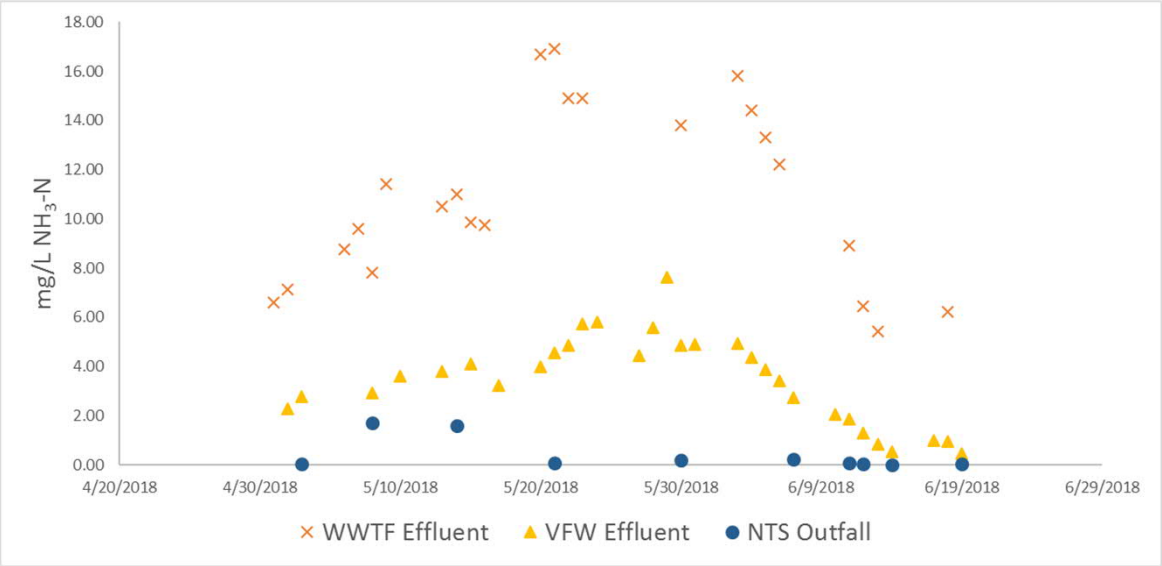
- Automatic closure
- Trigger: 24 °C
- Avoid discharging water warmer than 25 °C

Additional Water Quality Benefits

- Nutrients
- Heavy metals
  - Copper: complexation, uptake, pH levels
- Beneficial algal seeding

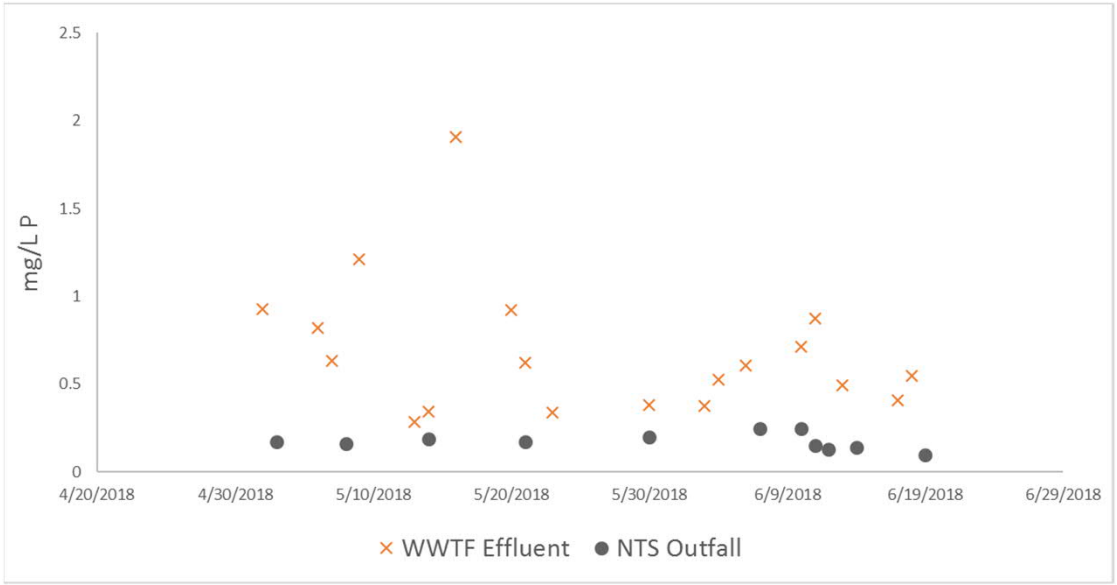


Nutrient Reduction in the South Wetlands



Ammonia

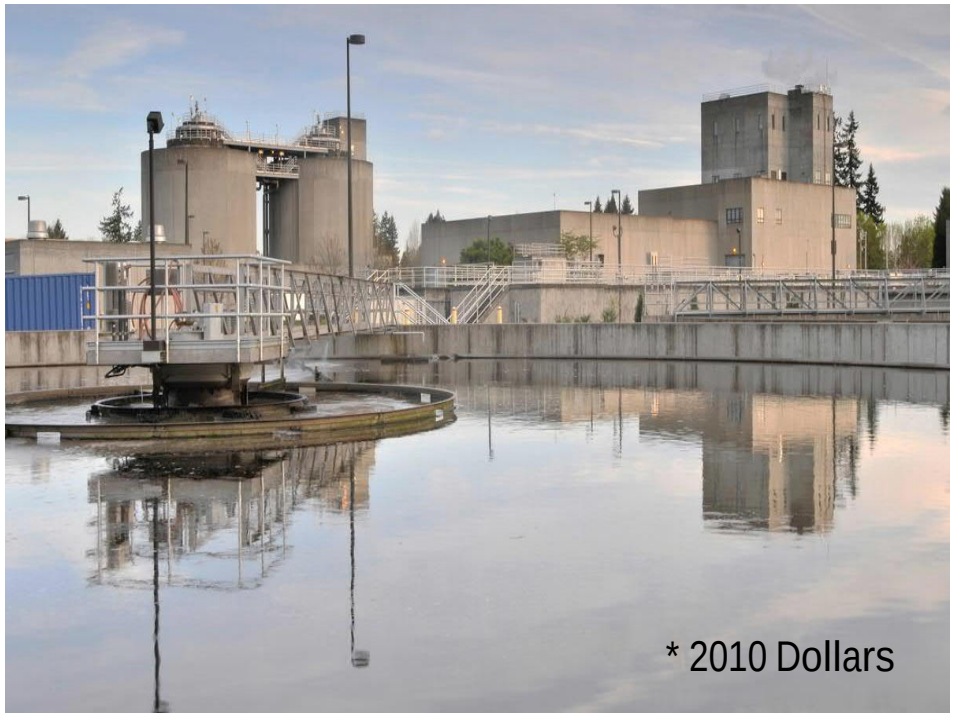
Nutrient Reduction in the South Wetlands



Total Phosphorus

Economic Benefits

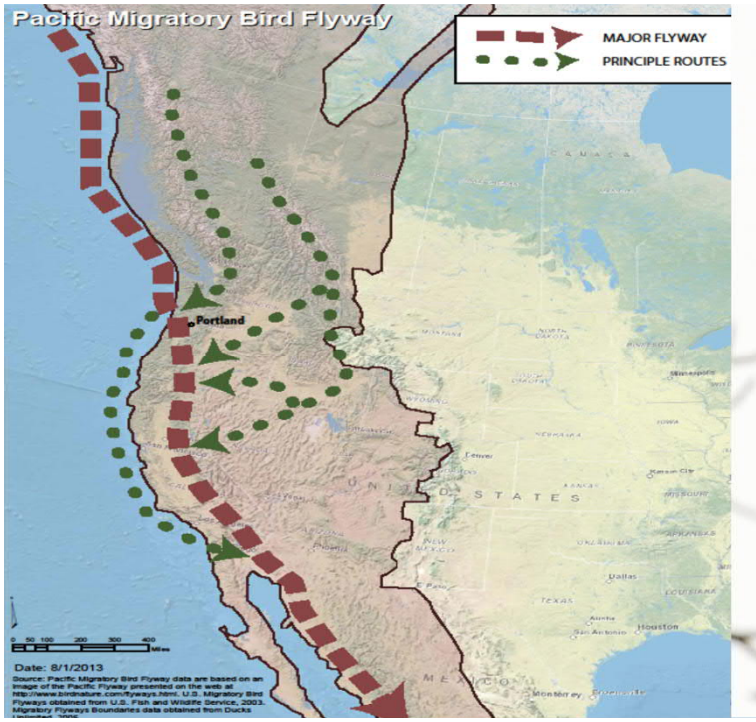
Rock Creek Full Liquids Treatment Train = $31M*



* 2010 Dollars

Fernhill NTS Tertiary Treatment = $18M

Environmental Benefits



Community Benefits

- Birdwatching and hiking
- Education on water quality, wildlife, natural treatment systems
- Bilingual guided walks

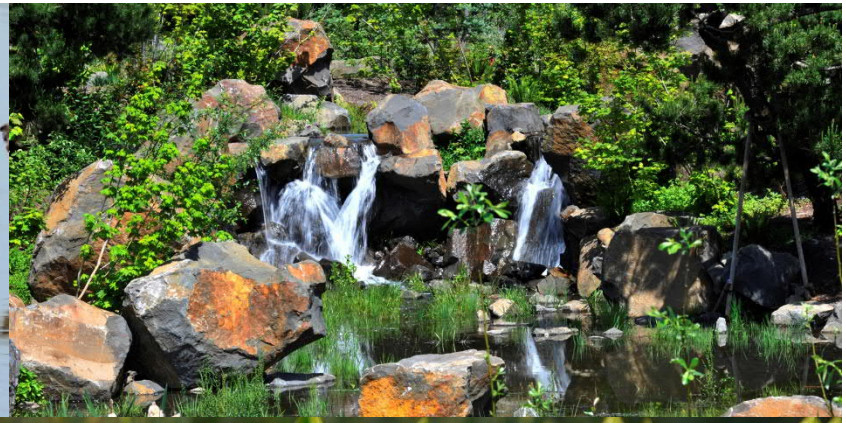
Challenges

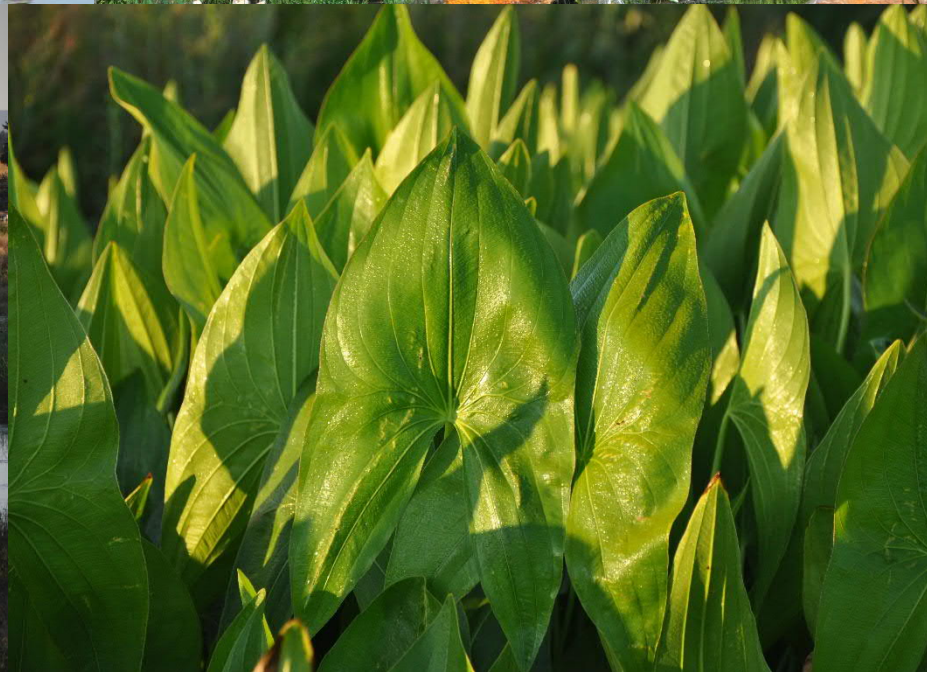
- NTS doesn’t fit current regulatory structure
  - Not easy to permit an NTS
- Significant benefits can be overlooked
  - Focusing on peak temperatures misses a large portion of the story

Next Steps

- Continued testing and optimization
- Full compliance in 2019
- Denitrification/copper removal unit







PARTNERS

- City of Forest Grove
- Fernhill Wetlands Council
- Pacific University
- Public/Private K-12
- Forest Grove/Cornelius Chamber of Commerce/WCVA
- Local Businesses (McMenamins, Maggie's, BJ's)
- Kiwanis/Rotary
- Intertwine, Audubon, Metro. Etc.
- Citizen Participation Organization 15

SUPPORT

- Biohabitats
- Kennedy-Jenks
- CH2M
- Kurisu International
- PLACE Studios
- Cascade Environmental Group
- ABR Inc.
- Waterways Consulting
- Ash Creek Forest Management
- Cole Ecological
- CWS Field Ops

Questions?

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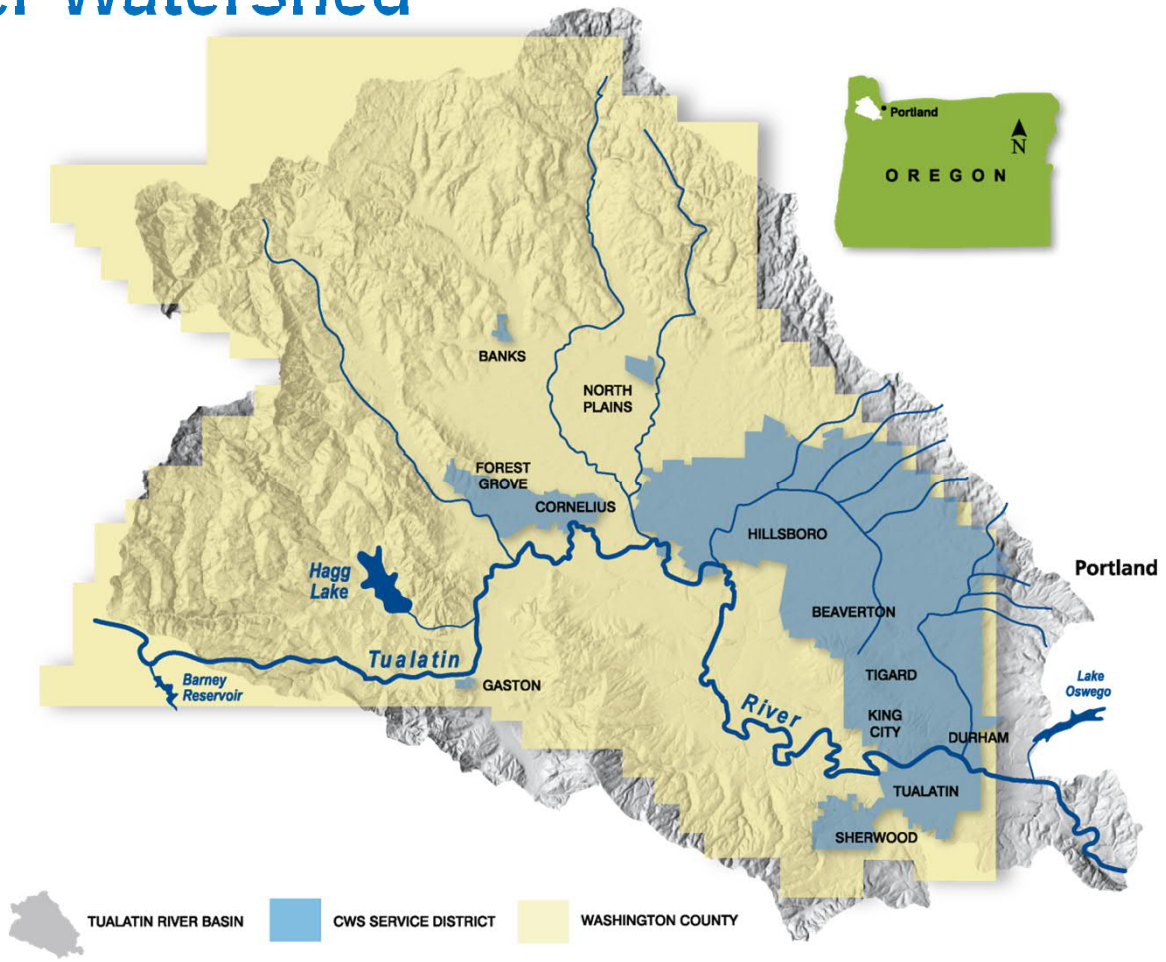
Extra Slides

Tualatin River Watershed



What is a Treatment Wetland?

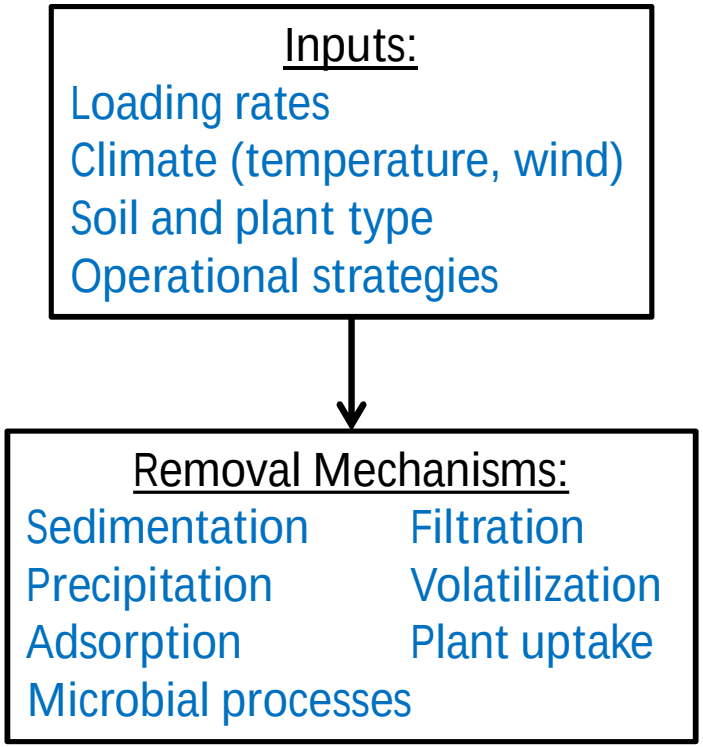
- Wetland: land that is wet part or all of the year
- “Engineered” or “Constructed” wetlands
- Uses natural wetland processes for the treatment of municipal, industrial and agricultural wastewater or stormwater
- Stand-alone systems or add-ons to conventional secondary plants or lagoons
- Benefits:
  - Low energy requirements
  - Easy to operate and maintain
  - Aesthetically pleasing
- Limitations:
  - Large area required
  - Inherent variability in natural systems
  - Regulatory requirements

Treatment Wetland Functions

- Water quality treatment
  - Temperature reduction
  - Nutrient removal
  - BOD removal
  - TSS removal
  - Others (pathogens, metals, trace organics)
- Water storage
- Habitat for plants, fish, birds, wildlife
- Education

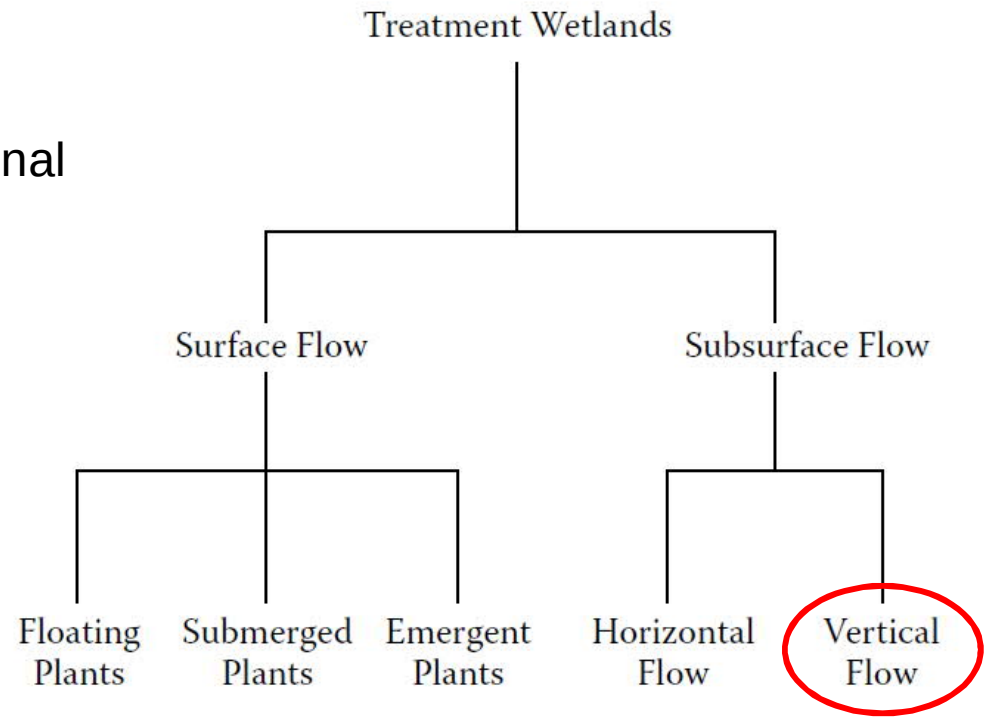
Complex!

Treatment depends on:



Why a Vertical Flow Wetland?

- Purpose: ammonia reduction
- Higher oxygen transfer efficiency
- Ability to operate in different operational flow modes



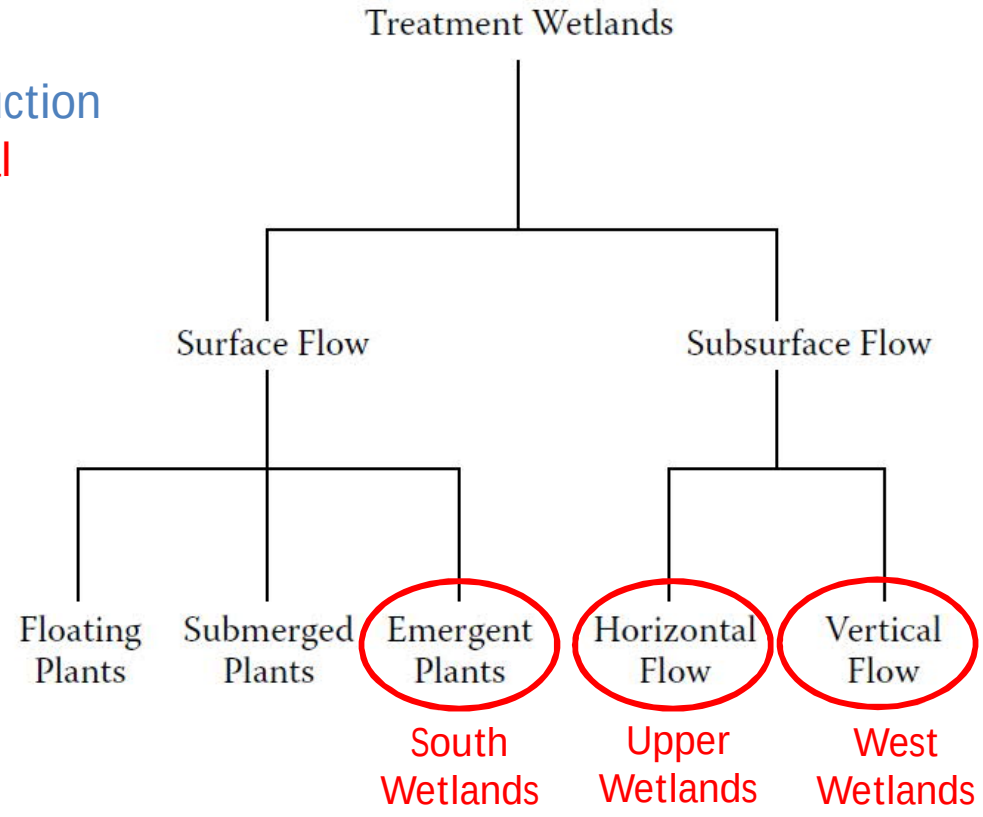
Kadlec and Wallace, 2008

Fernhill NTS Treatment Wetlands

Goals of NTS:

Temperature Reduction

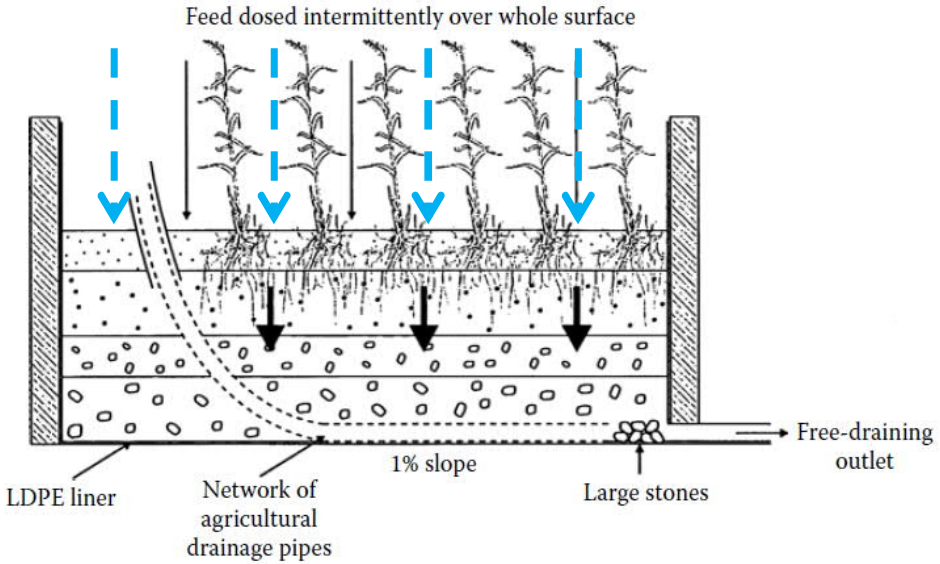
Ammonia Removal



Kadlec and Wallace, 2008

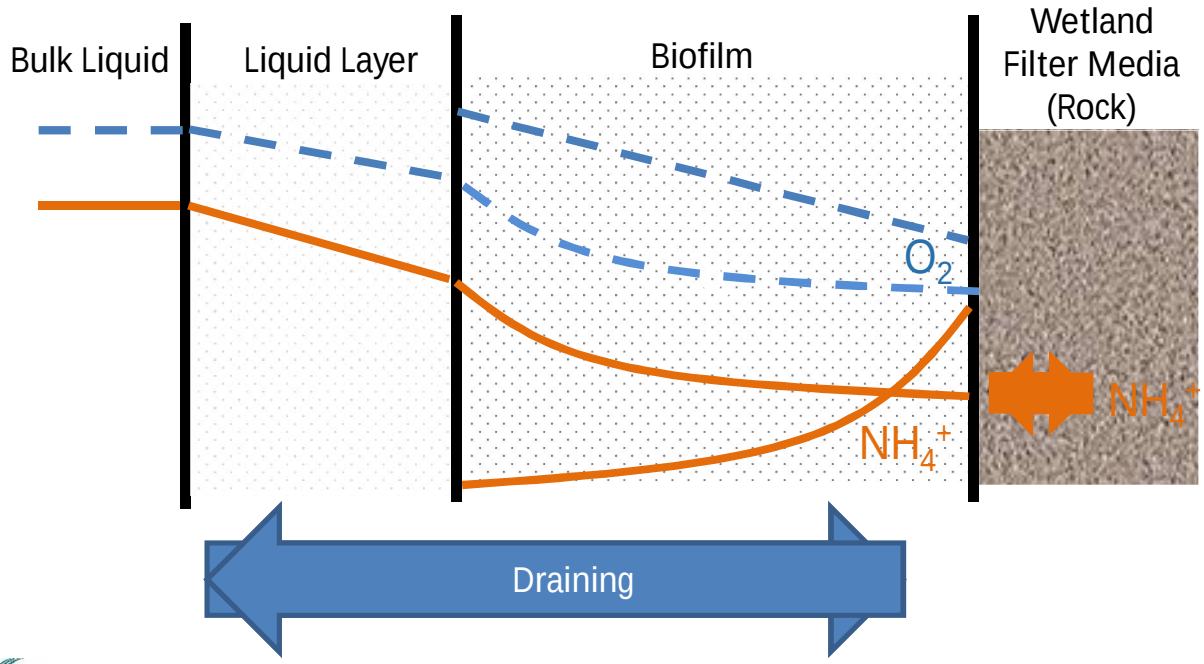
Vertical Flow Wetlands

- Gravel or soil beds planted with wetland vegetation
- Continuous vs. intermittent (pulse) dosing
- Continuous vs. fill-and-drain (tidal flow) operation
- Provides higher levels of oxygen transfer



Kadlec and Wallace, 2008

VFW Ammonia Sorption and Nitrification



- NH_4^+ adsorbs to rocks during dosing
- NH_4^+ is released from rocks during the rest phase

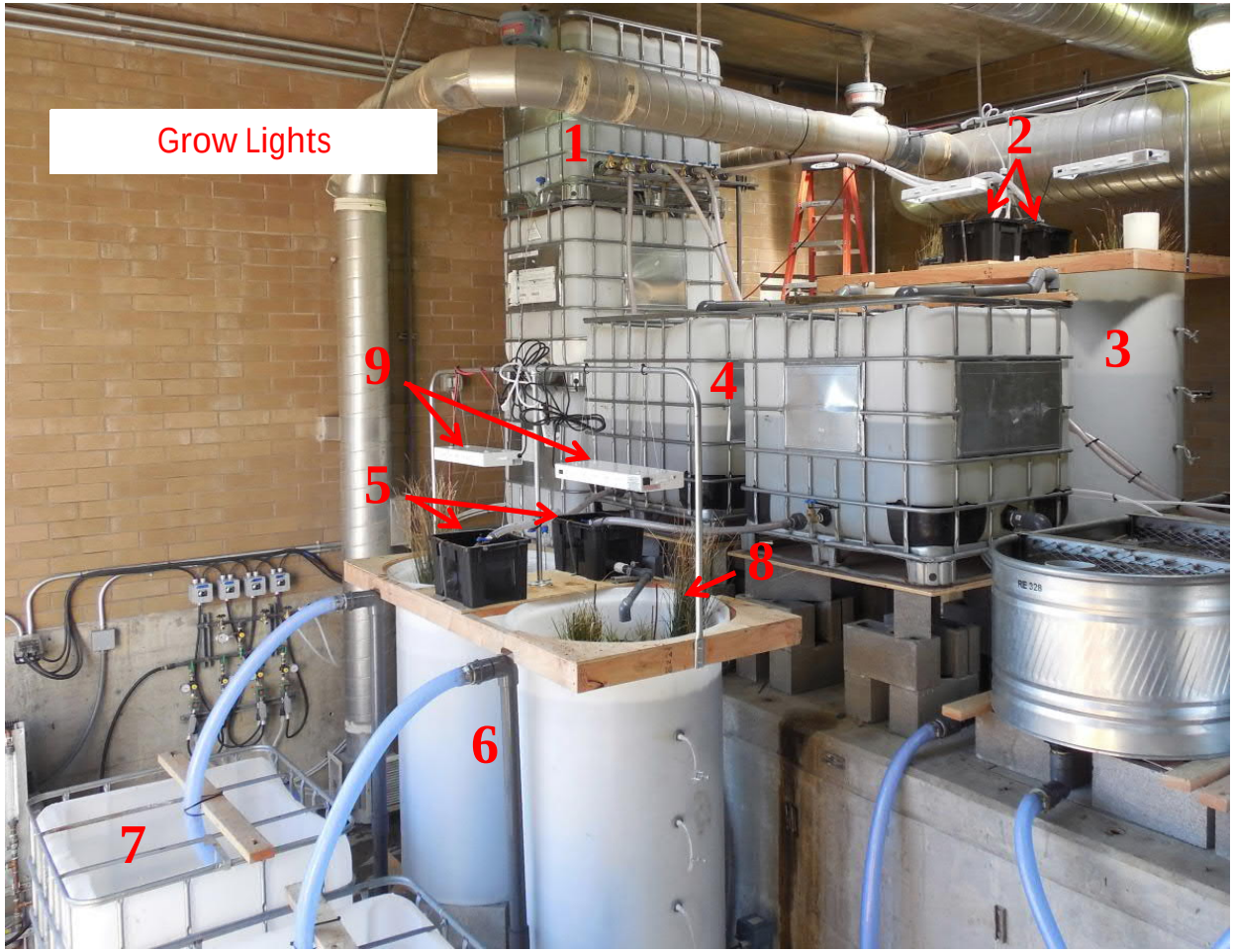
VFW Pilot Study Media Selection

VFW Pilot Study

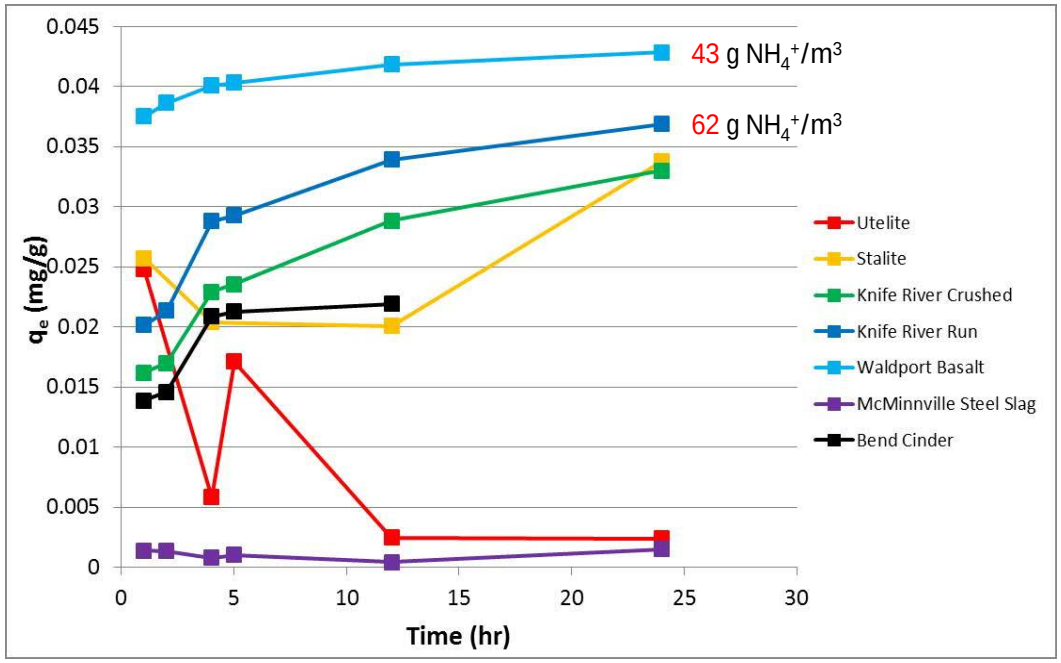
- Tested two types of lightweight aggregate filter media
  - Nitrification efficiency
  - Contaminant removal
  - Biofouling
  - Hydraulic loading modes (“Flood and Drain” and “Continuous”)
  - Hydraulic loading rates

Knife River Round
River Rock

Waldport Angular
Crushed Marine Basalt


Grow Lights
1
2
3
4
5
6
7
8
9

Ammonium Exchange Capacity Test



Local Source

Highest AEC

Knife River Round River Rock

Waldport Angular Crushed Marine Basalt

VFW Column Layout

Top Dressing - Superfines

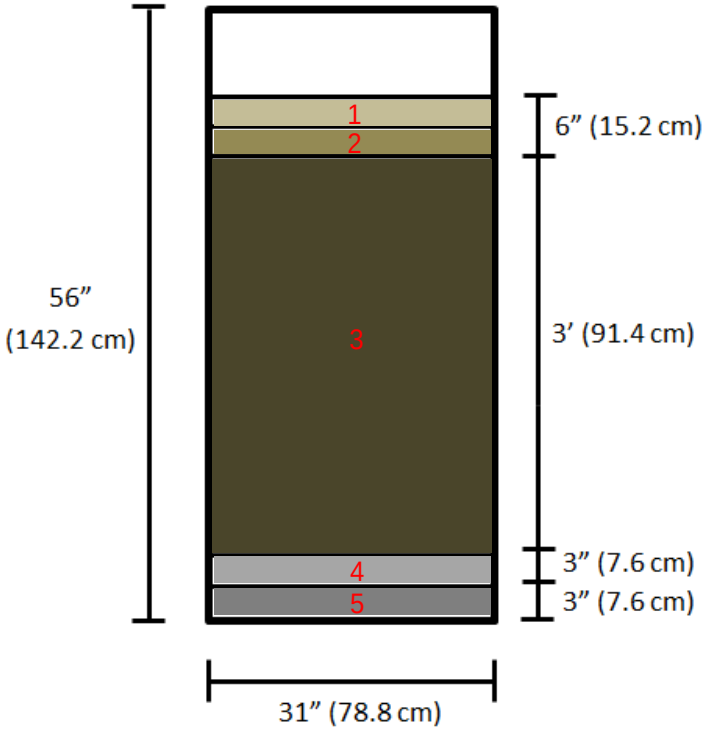
Top Dressing - Fines

Knife River Round
Treatment Media

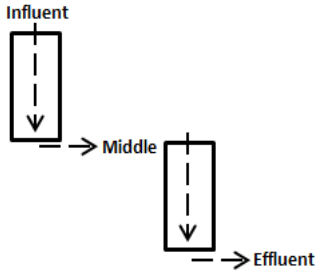
Waldport Crushed Basalt
Treatment Media

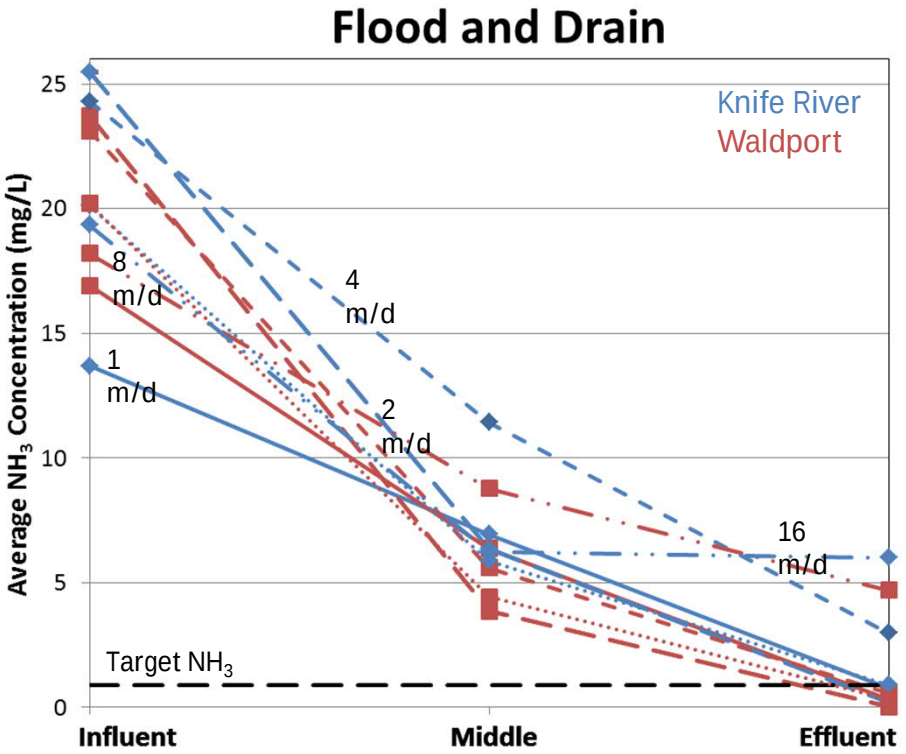
Drainage River Rock

Drainage Cobble



VFW Pilot Study Results



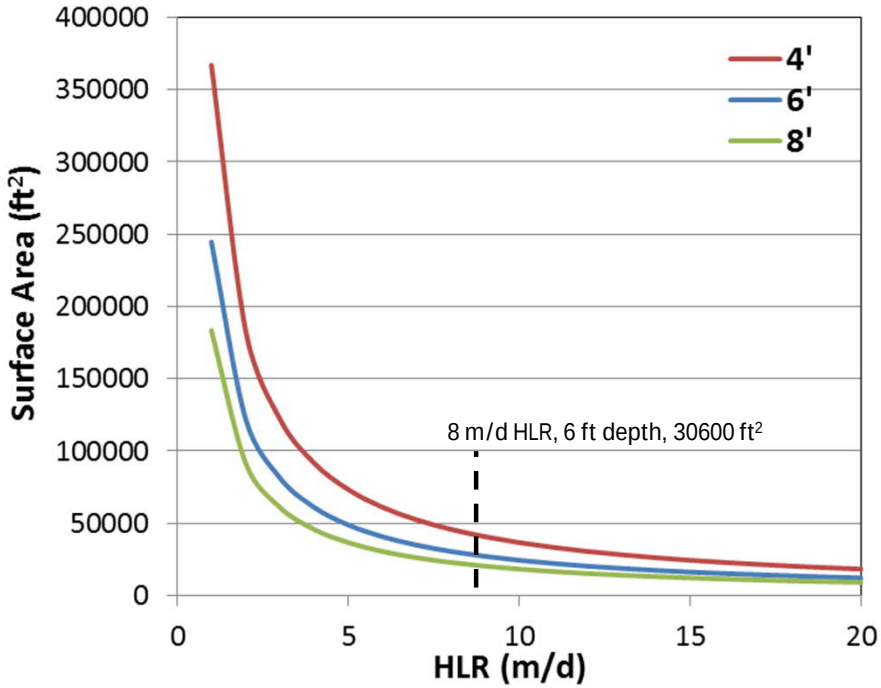


Average Ammonia Removal Performance

		Flood-and-Drain Flow			Vertical-Flow		
		Average NH_3-N Concentration (mg/L)					
HLR (m/d)	**Media Type**	**Influent**	**Effluent**	**% Removal**	**Influent**	**Effluent**	**% Removal**
1	Waldport	16.9 ± 4.4	0.3 ± 0.3	98	16.2 ± 2.3	0.1 ± 0.0	99
	Knife River	13.7 ± 1.2	0.8 ± 0.5	94	16.2 ± 0.9	1.1 ± 1.4	93
2	Waldport	23.7 ± 7.7	0.1 ± 0.0	100	24.7 ± 1.6	0.5 ± 0.7	98
	Knife River	25.5 ± 8.0	0.2 ± 0.3	99	25.6 ± 6.9	3.5 ± 4.6	86
4	Waldport	23.1 ± 9.1	0.6 ± 0.8	97	18.8 ± 1.3	0.2 ± 0.1	99
	Knife River	24.3 ± 5.8	3.0 ± 1.5	88	17.7 ± 0.5	0.2 ± 0.1	99
8	Waldport	20.2 ± 4.7	0.3 ± 0.2	98	18.4 ± 0.3	0.6 ± 0.7	97
	Knife River	19.4 ± 0.6	0.5 ± 0.5	97	18.6 ± 0.1	3.0 ± 1.0	84
16	Waldport	19.4 ± 0.6	3.8 ± 0.3	80	21.1 ± 4.2	4.5 ± 1.9	79
	Knife River	18.2 ± 0.1	4.7 ± 0.7	74	19.3 ± 0.8	4.8 ± 0.2	75

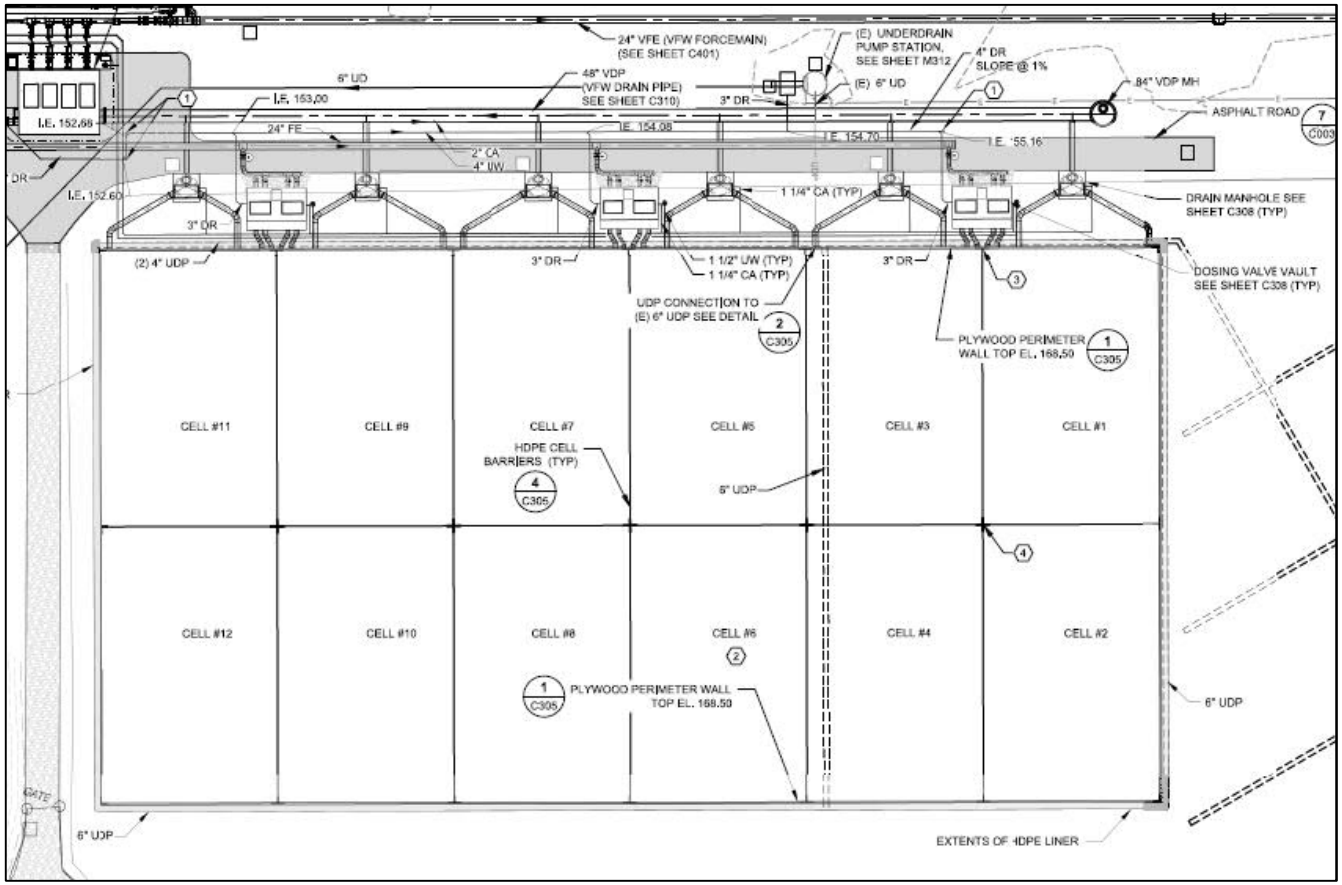
Target Effluent NH_3-N Concentration was < 1mg NH_3-N/L

Vertical Flow Wetlands Design Guidelines

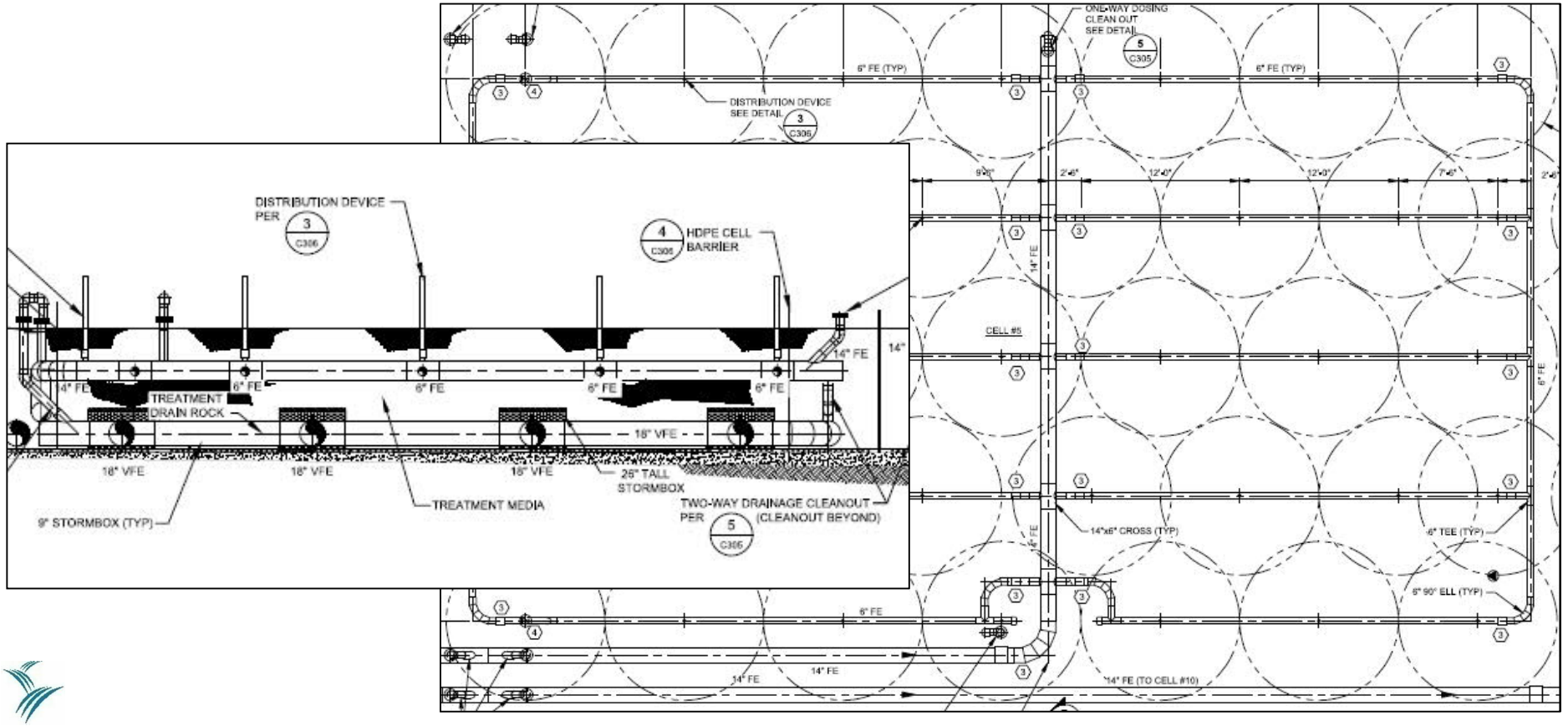


*Design Flowrate: 6 MGD

Full Scale VFW Design



Full Scale VFW Design



Full Scale VFW Design

- Media specifications
  - Gradation
  - Ammonia adsorption
  - Cleanliness

Design and Construction Process

- Design/Bid/Build process
- Construction included:
  - Piping to/from VFW capable of 70000 m^3/d
  - VFW
  - VFW Pump Station
  - Electrical and Operations Building
  - Upgrade of plant compressed air system

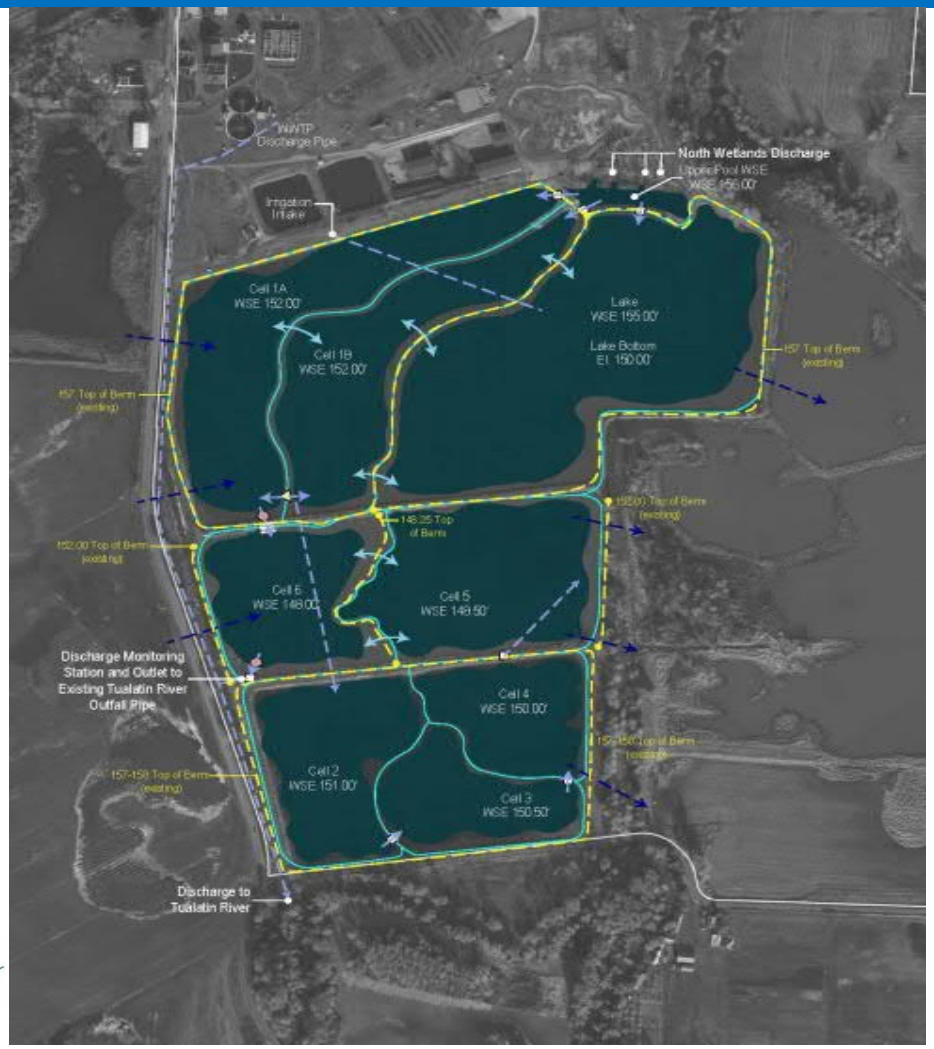
VFW Pump Station

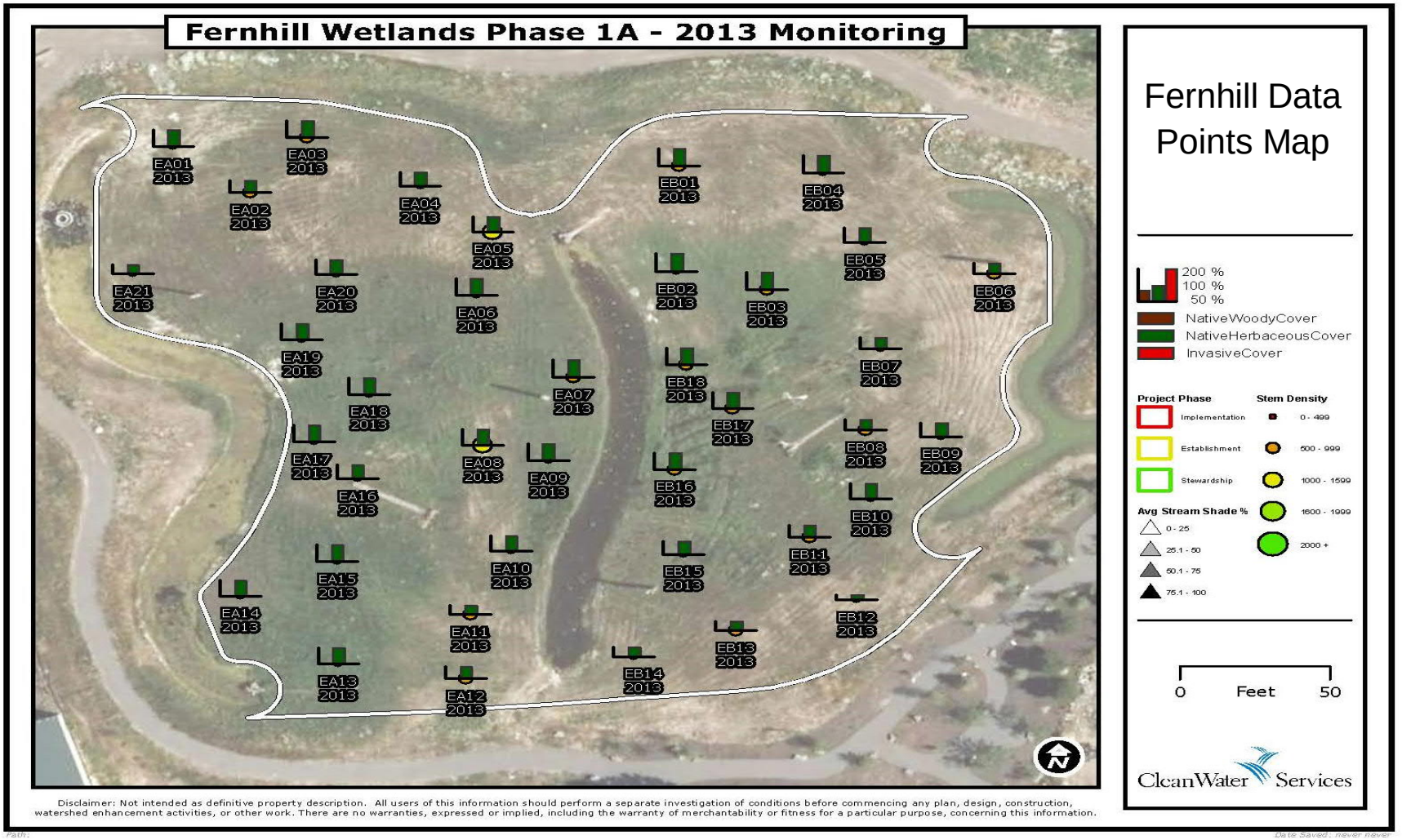
- Four pump system
- 45 kW each
- Intricate wet well design
  - Balances flow to each pump
  - Avoids air entrainment
  - Avoids settling of solids
- Programmed to deliver consistent flow to downstream wetlands & waterfalls
- Allows for VFW effluent recycle

Other Examples of VFWs

Continuous Vertical Flow Wetland, China

Tidal Vertical Flow Wetland, Israel


WWTP
Discharge Pipe
North Wetlands Discharge
Upper Pool WSE
WSE 156.00'
Irrigation
Intake
Cell 1A
WSE 152.00'
Cell 1B
WSE 152.00'
Lake
WSE 155.00'
Lake Bottom
El. 150.00'
157' Top of Berm
(existing)
157' Top of Berm
(existing)
152.00' Top of Berm
(existing)
148.25 Top
of Berm
152.00' Top of Berm
(existing)
Cell 6
WSE 148.00'
Cell 5
WSE 149.50'
Discharge Monitoring
Station and Outlet to
Existing Tualatin River
Outfall Pipe
Cell 4
WSE 150.00'
157-158' Top of Berm
(existing)
Cell 2
WSE 151.00'
Cell 3
WSE 150.50'
Discharge to
Tualatin River


Fernhill Wetlands Phase 1A - 2013 Monitoring
EA01 2013
EA02 2013
EA03 2013
EA04 2013
EA05 2013
EA06 2013
EA07 2013
EA08 2013
EA09 2013
EA10 2013
EA11 2013
EA12 2013
EA13 2013
EA14 2013
EA15 2013
EA16 2013
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EB01 2013
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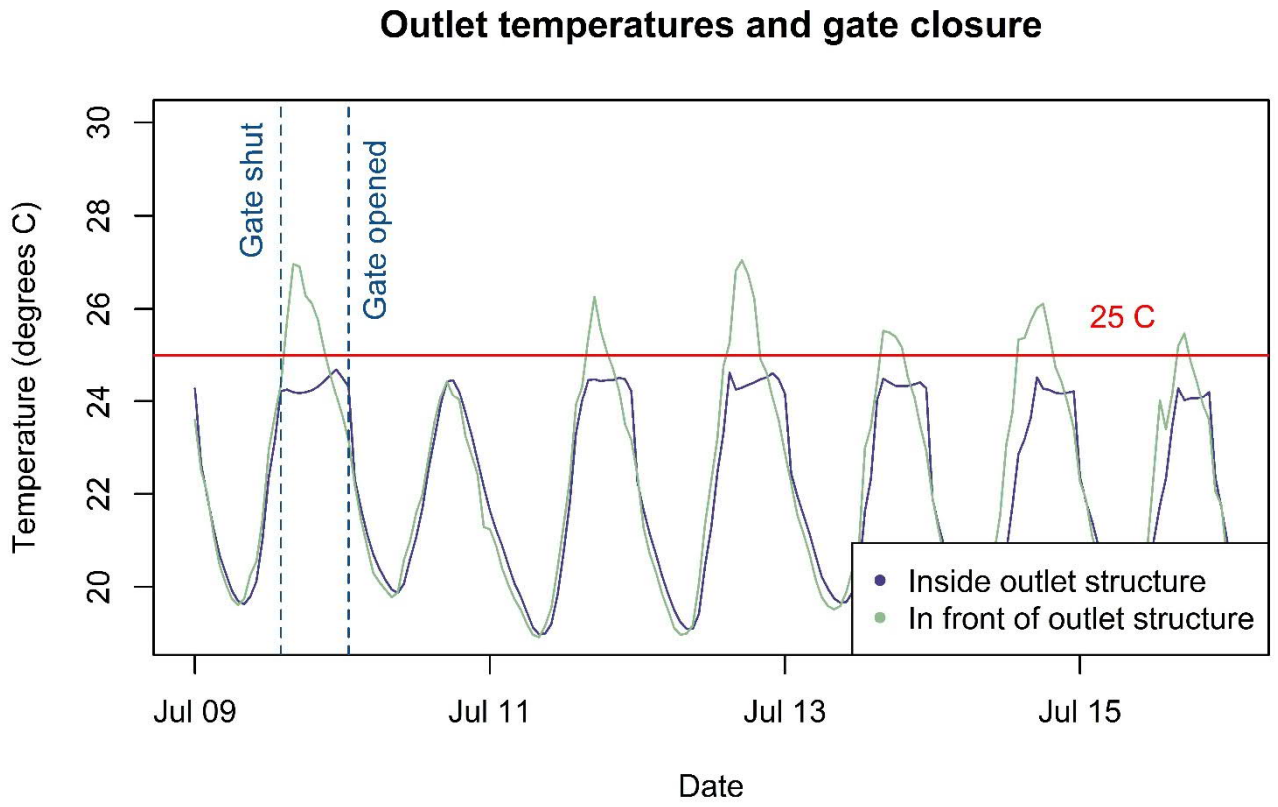
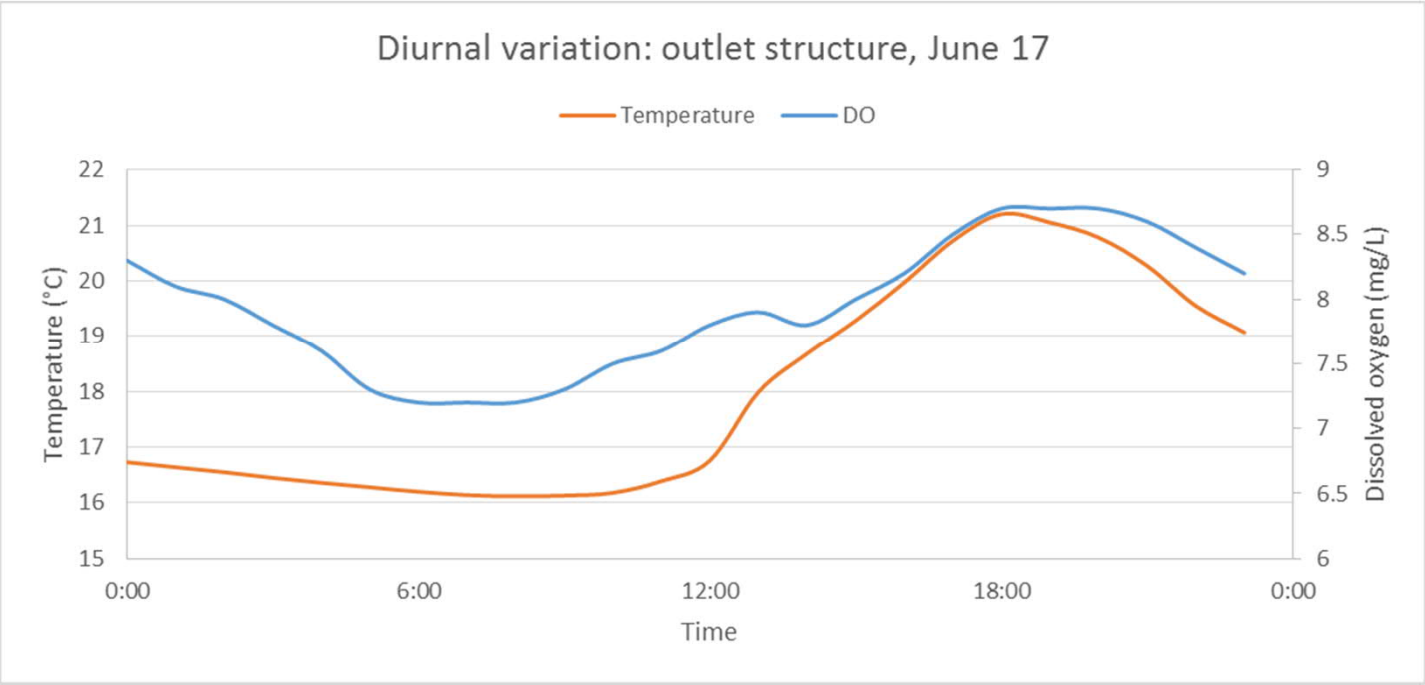
EB05 2013
EB06 2013
EB07 2013
EB08 2013
EB09 2013
EB10 2013
EB11 2013
EB12 2013
EB13 2013
EB14 2013
EB15 2013
EB16 2013
EB17 2013
EB18 2013
Fernhill Data Points Map
200 %
100 %
50 %
NativeWoodyCover
NativeHerbaceousCover
InvasiveCover
Project Phase
Implementation
Establishment
Stewardship
Stem Density
0 - 499
500 - 999
1000 - 1599
1600 - 1999
2000 +
Avg Stream Shade %
0 - 25
25.1 - 50
50.1 - 75
75.1 - 100
0
Feet
50
Clean Water Services
Disclaimer: Not intended as definitive property description. All users of this information should perform a separate investigation of conditions before commencing any plan, design, construction, watershed enhancement activities, or other work. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, concerning this information.
Path:
Date Saved: never never

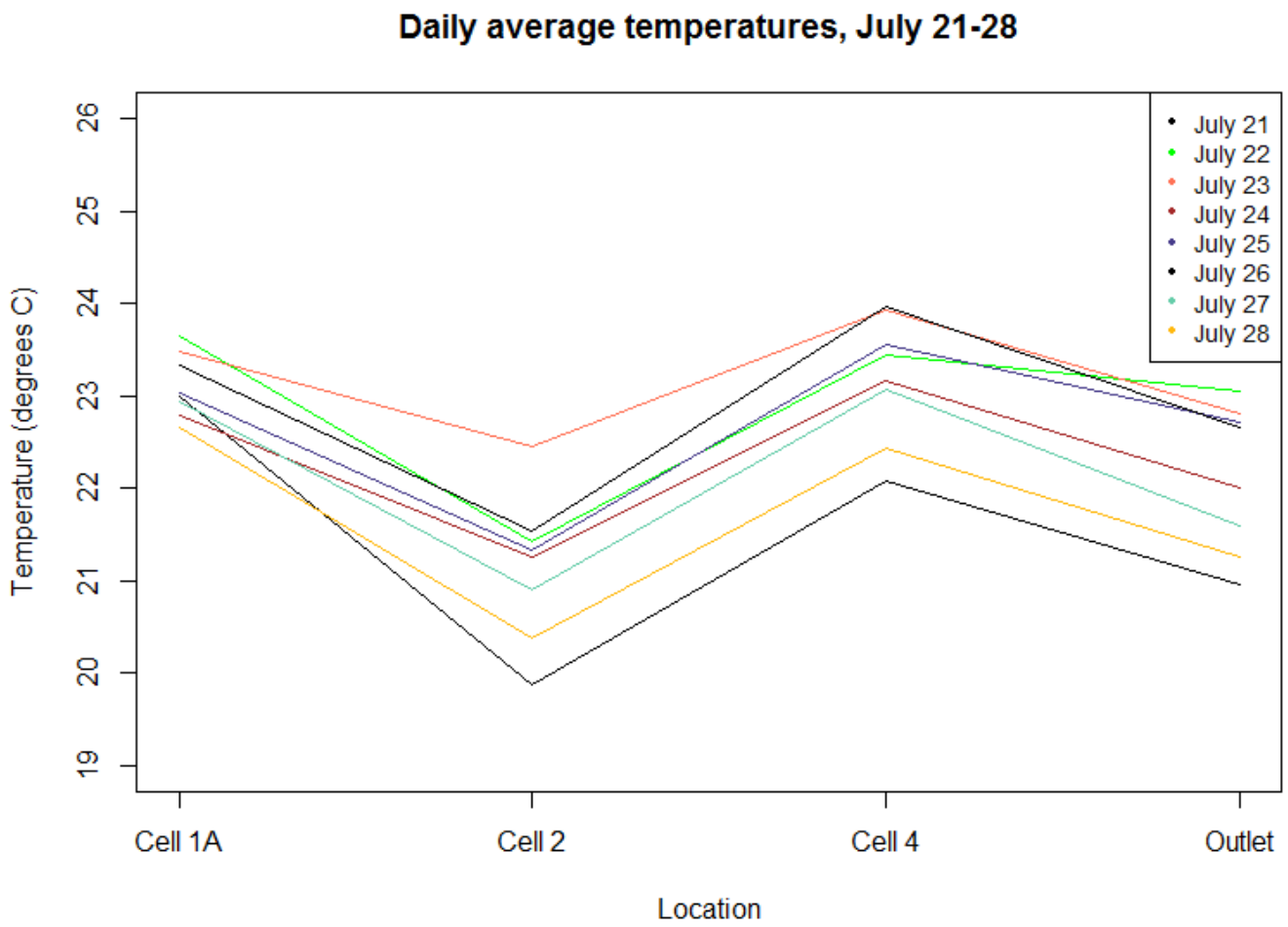
Effect of gate closure



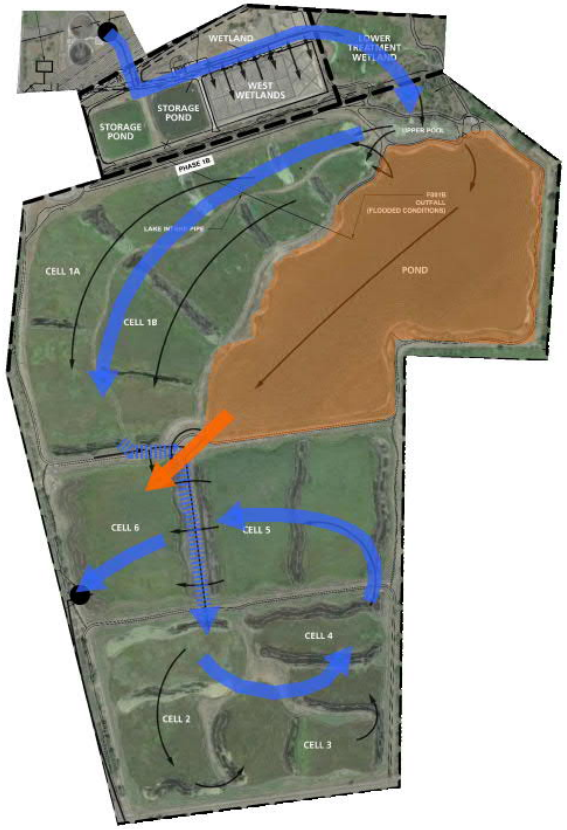
- Automatic closure
- Trigger: 24 °C
- Avoid discharging water warmer than 25 °C

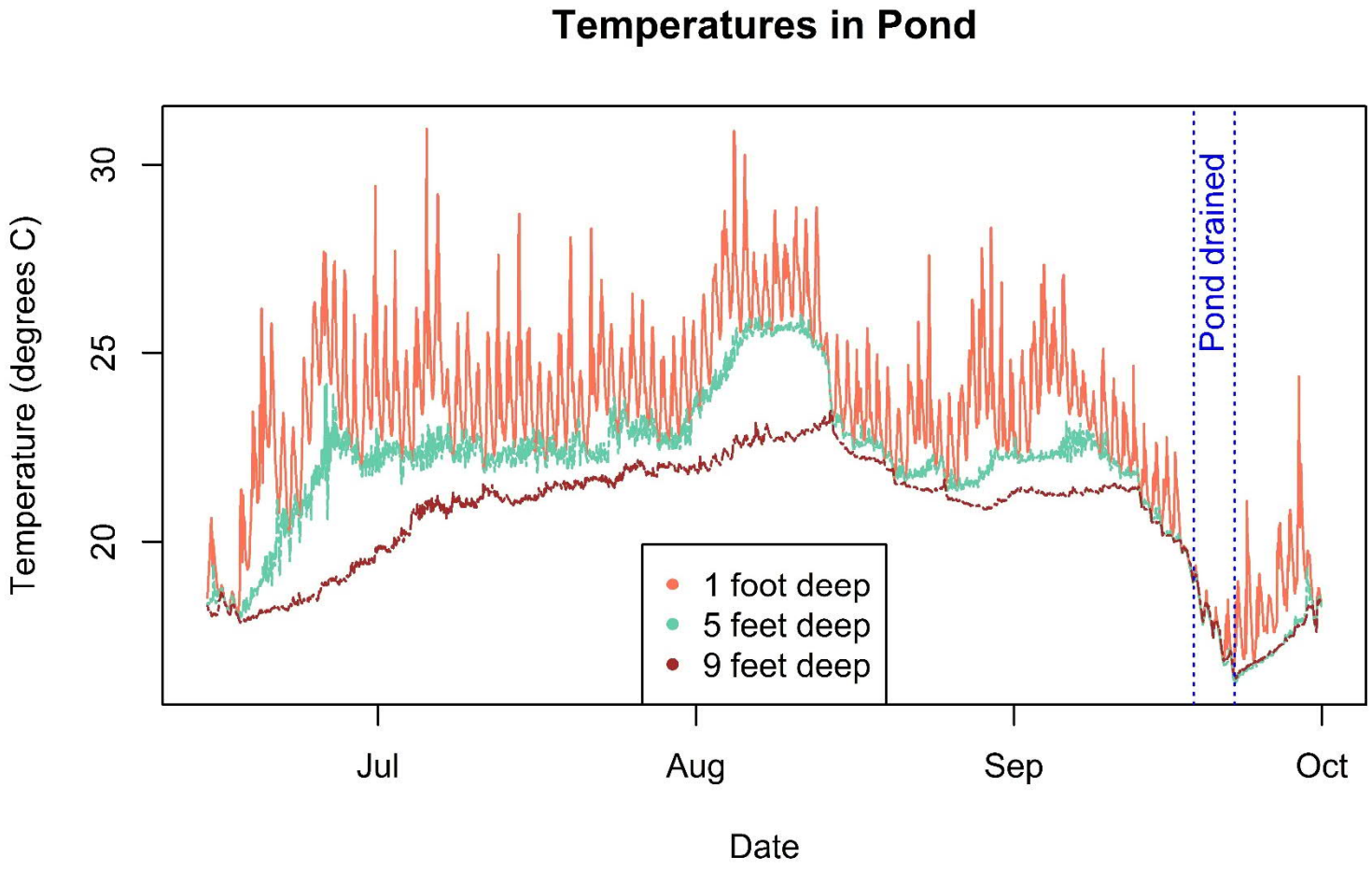
Competing Interests: Low Temperatures, High Dissolved Oxygen

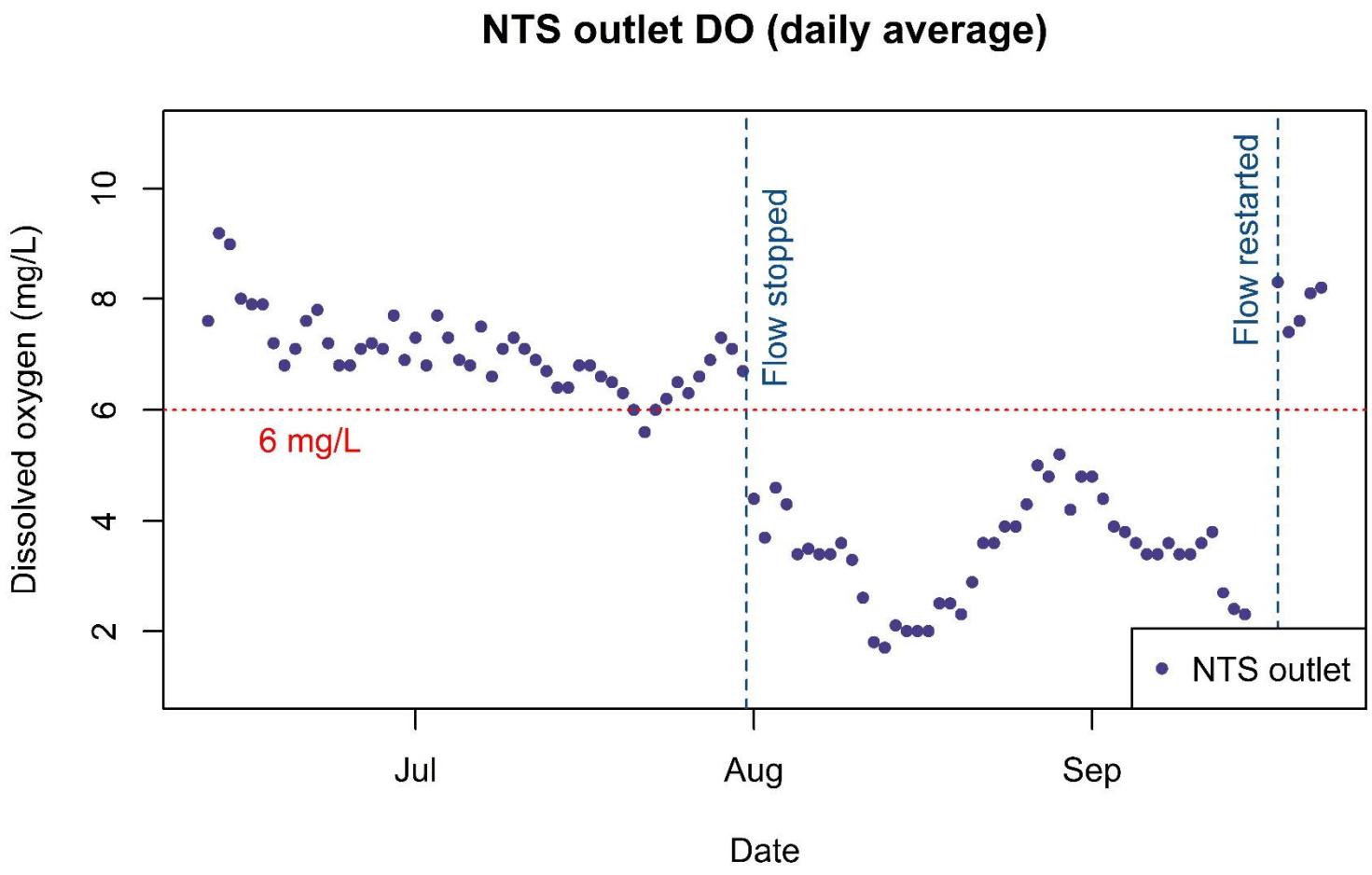



Daily average temperatures, July 21-28
Temperature (degrees C)
19
20
21
22
23
24
25
26
Cell 1A
Cell 2
Cell 4
Outlet
Location
July 21
July 22
July 23
July 24
July 25
July 26
July 27
July 28

5. Thermal stratification in the Pond




Temperatures in Pond
Temperature (degrees C)
20
25
30
Jul
Aug
Sep
Oct
Date
Pond drained
1 foot deep
5 feet deep
9 feet deep


NTS outlet DO (daily average)
Dissolved oxygen (mg/L)
2
4
6
8
10
6 mg/L
Flow stopped
Flow restarted
NTS outlet
Jul
Aug
Sep
Date

Nutrient data

JUNE 2017

Natural Treatment System Monitoring

Flow	Temperature		Excess Thermal Load	DO	Ammonia	TKN	Nitrate + Nitrite	TP
Avg.	Max	Min	Daily	Conc.	Conc.	Conc.	Conc.	Conc.
MGD	Deg F	Deg F	10^6 kcal/day	mg/l	mg/l	mg/l	mg/l	mg/l
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
0.0								
2.1	64	59	13	7.6				
2.0	66	58	23	9.2				
2.0	63	58	23	9.0	0.01	1.0	0.02	0.24
2.5	60	58	20	8.0				
2.2	61	59	27	7.9				
2.0	68	59	57	7.9				
2.0	74	62	74	7.2				
2.1	80	64	90	6.8				
2.0	75	62	74	7.1				
1.9	72	62	63	7.6				
2.0	71	62	49	7.8	0.02	0.9	0.20	0.15
1.8	76	67	106	7.2				
1.7	76	67	86	6.8				
1.7	76	68	67	6.8				
1.7	75	66	50	7.1				
1.6	74	65	50	7.2				
1.8	72	63	66	7.1	0.03	0.7	0.02	0.17
1.8	74	63	17	7.7				
1.7	76	65	89	6.9				

July 2017

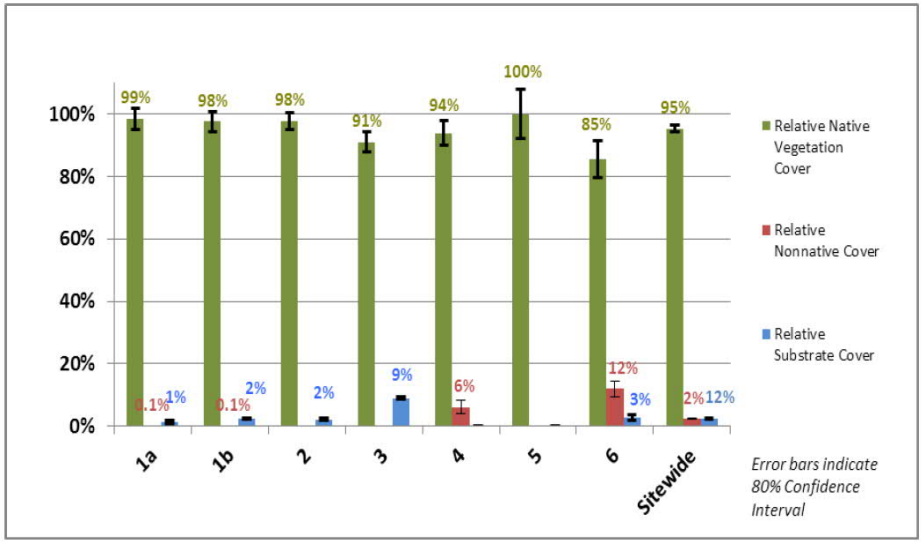
Natural Treatment System Monitoring

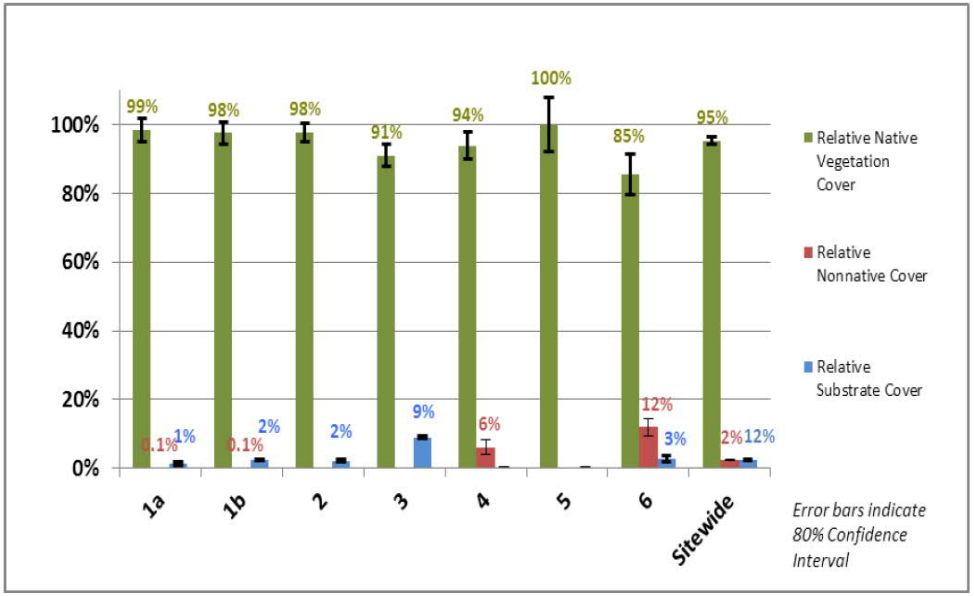
Flow	Temperature		Excess Thermal Load	DO	Ammonia	TKN	Nitrate + Nitrite	TP
Avg.	Max	Min	Daily	Conc.	Conc.	Conc.	Conc.	Conc.
MGD	Deg F	Deg F	10^6 kcal/day	mg/l	mg/l	mg/l	mg/l	mg/l
1.7	75	64	59	7.1				
1.6	76	64	69	7.0				
1.6	74	64	9	7.7				
1.5	76	64	84	7.0				
1.6	76	66	98	6.1				
1.6	78	66	43	6.1	0.02	0.8	0.05	0.14
1.6	72	68	0	7.3				
1.6	77	67	77	6.4				
1.7	77	68	73	6.8				
2.3	76	66	9	7.3	0.02		0.05	0.14
1.8	76	66	35	7.0				
2.3	76	66	28	6.5				
	76	68		6.6				

South Wetlands: Monitoring

- Vegetation: diversity, percent cover, etc.
- Macroinvertebrates
- Water quality: temperature, nutrients, DO, pH, CECs, metals
- Birds: Audubon, bat surveys
- Diversity of wildlife

2017 Plant Survey Data





Species Dominance and Frequency

Figure 5. Dominant Species

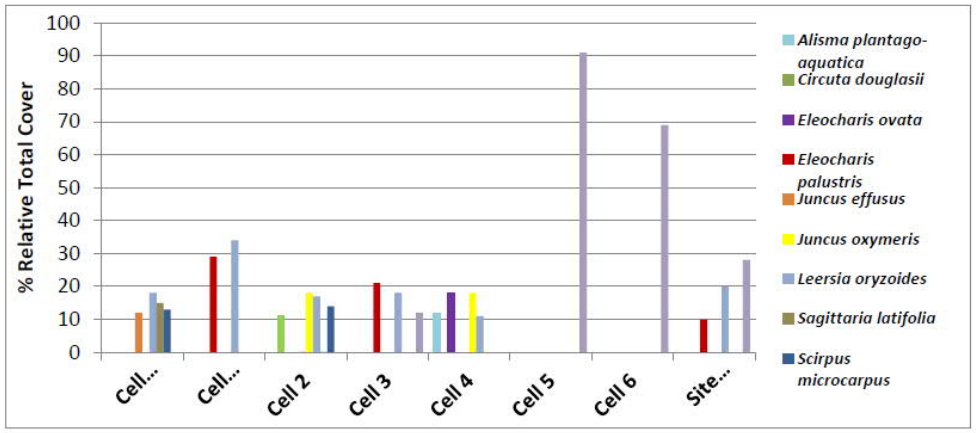
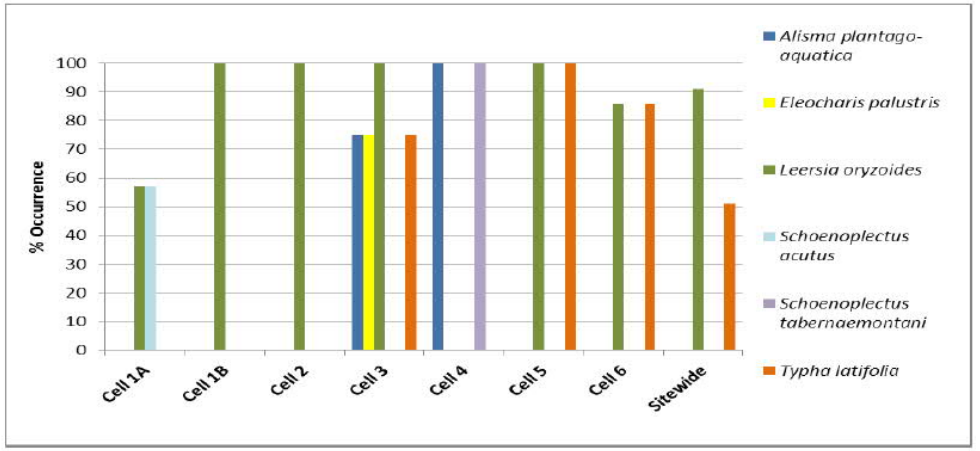
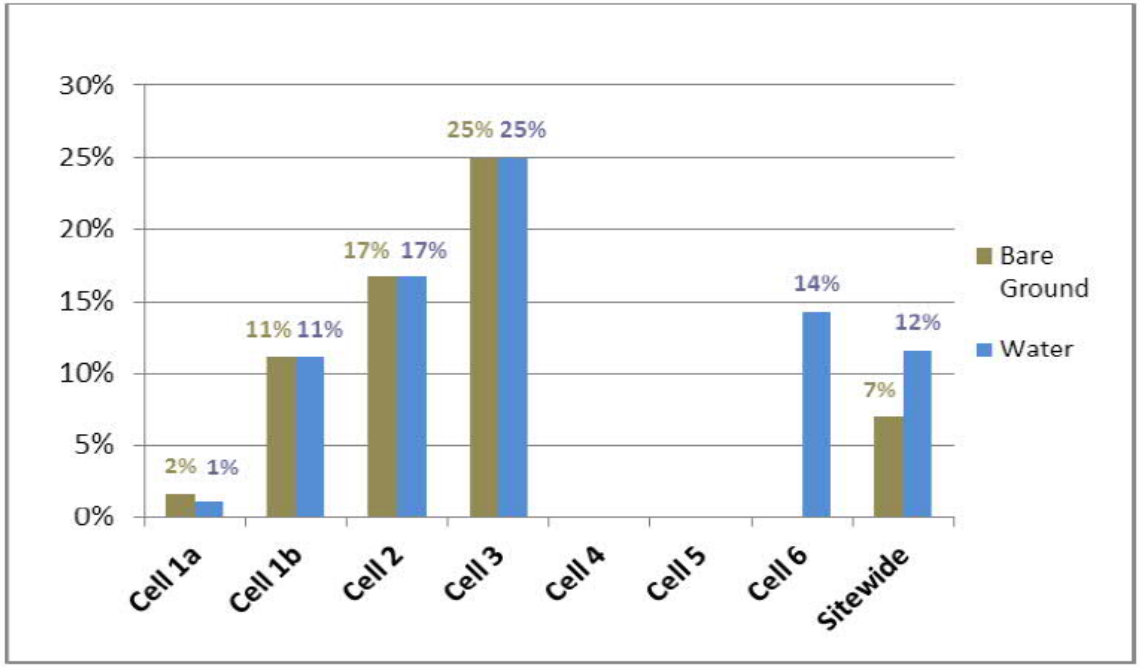


Figure 6. Species Frequency

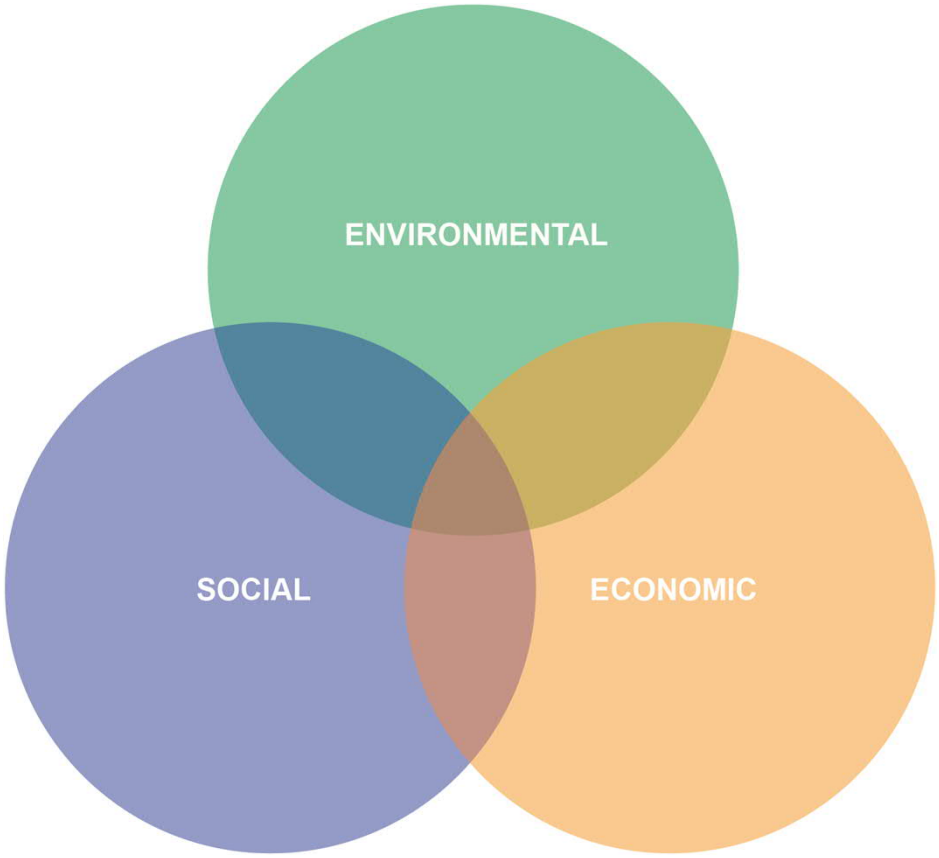


Areas of Sparser Vegetation

Figure 12. Frequency of Occurrence of Bare Substrate Classes



Fernhill NTS Addresses the Triple Bottom Line



Construction Photos


CAT
315D
CAT

VFW in Operation

Achieving Plant Species Diversity