Selecting the Most Cost Effective BMPs for the Removal of Specific Nonpoint Source Pollutants

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Brown AND Caldwell

Hydrology: Most rainfall events are 1-inch or less

Manage common rain events for WQ improvement

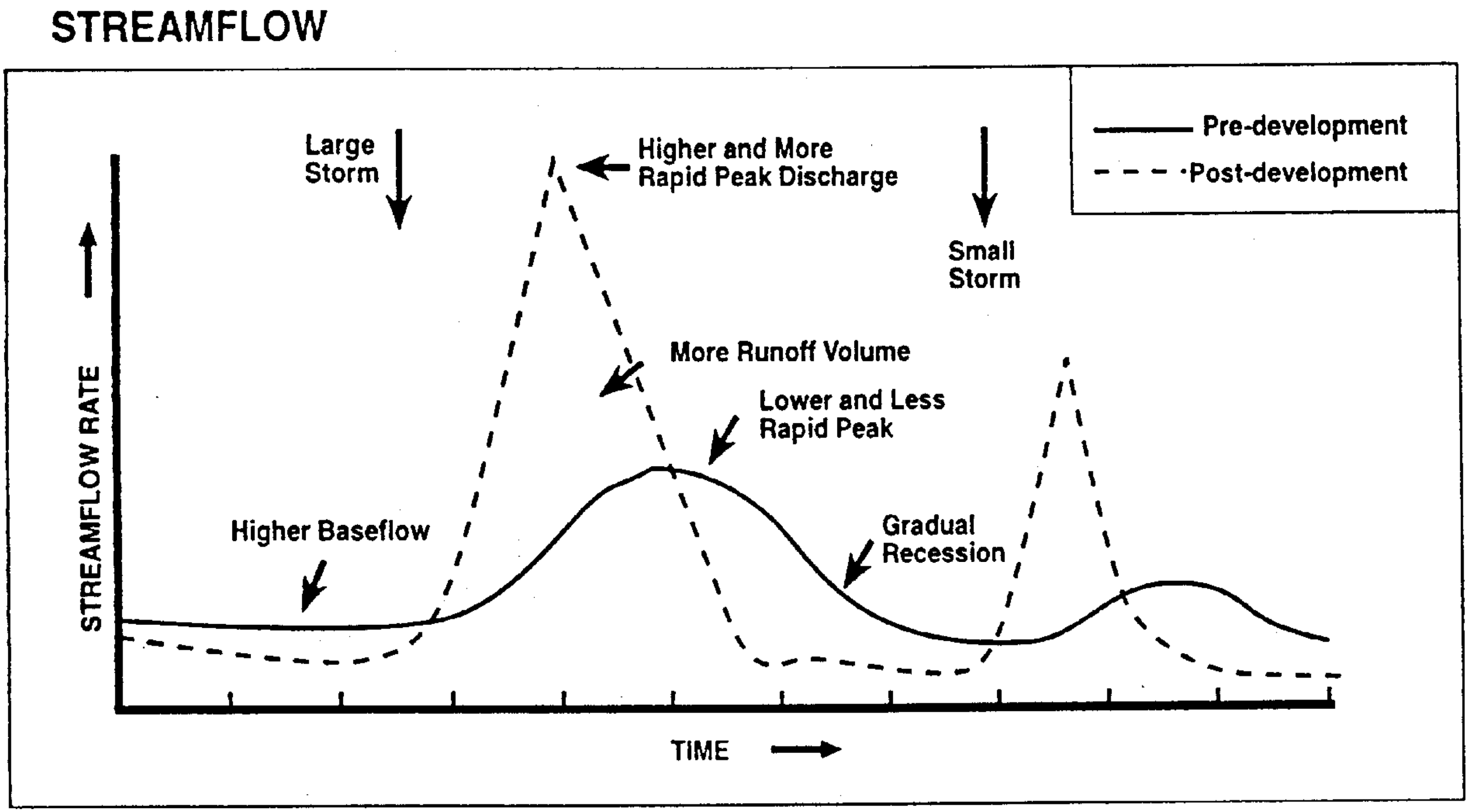
Rainfall Event Range (inches)	Mean Rainfall Depth (inches)	Mean Rainfall Duration (hours)	Fraction of Annual Rain Events	Number of Annual Events in Range
0.00-0.10	0.041	1.203	0.427	56.683
0.11-0.20	0.152	2.393	0.142	18.866
0.21-0.30	0.252	3.073	0.080	10.590
0.31-0.40	0.353	3.371	0.055	7.312
0.41-0.50	0.456	3.702	0.048	6.325
0.51-1.00	**0.713**	**4.379**	**0.129**	**17.102 (117)**
1.01-1.50	1.221	5.758	0.051	6.733
1.51-2.0	1.726	7.852	0.024	3.145
2.01-2.50	2.271	8.090	0.011	1.470
2.51-3.00	**2.704**	**10.675**	**0.006**	**0.726**
3.01-3.50	3.246	9.978	0.003	0.391
3.51-4.00	3.667	13.362	0.002	0.260
4.01-4.50	4.216	15.638	0.001	0.149
4.51-5.00	4.796	17.482	0.000	0.056
5.01-6.00	5.454	23.303	0.001	0.167
6.01-7.00	6.470	40.500	0.000	0.019
7.01-8.00	7.900	31.500	0.000	0.019
8.01-9.00	8.190	3.500	0.000	0.019
>9.00	10.675	46.250	0.001	0.075

Minimal runoff from pervious areas and N-DCIA

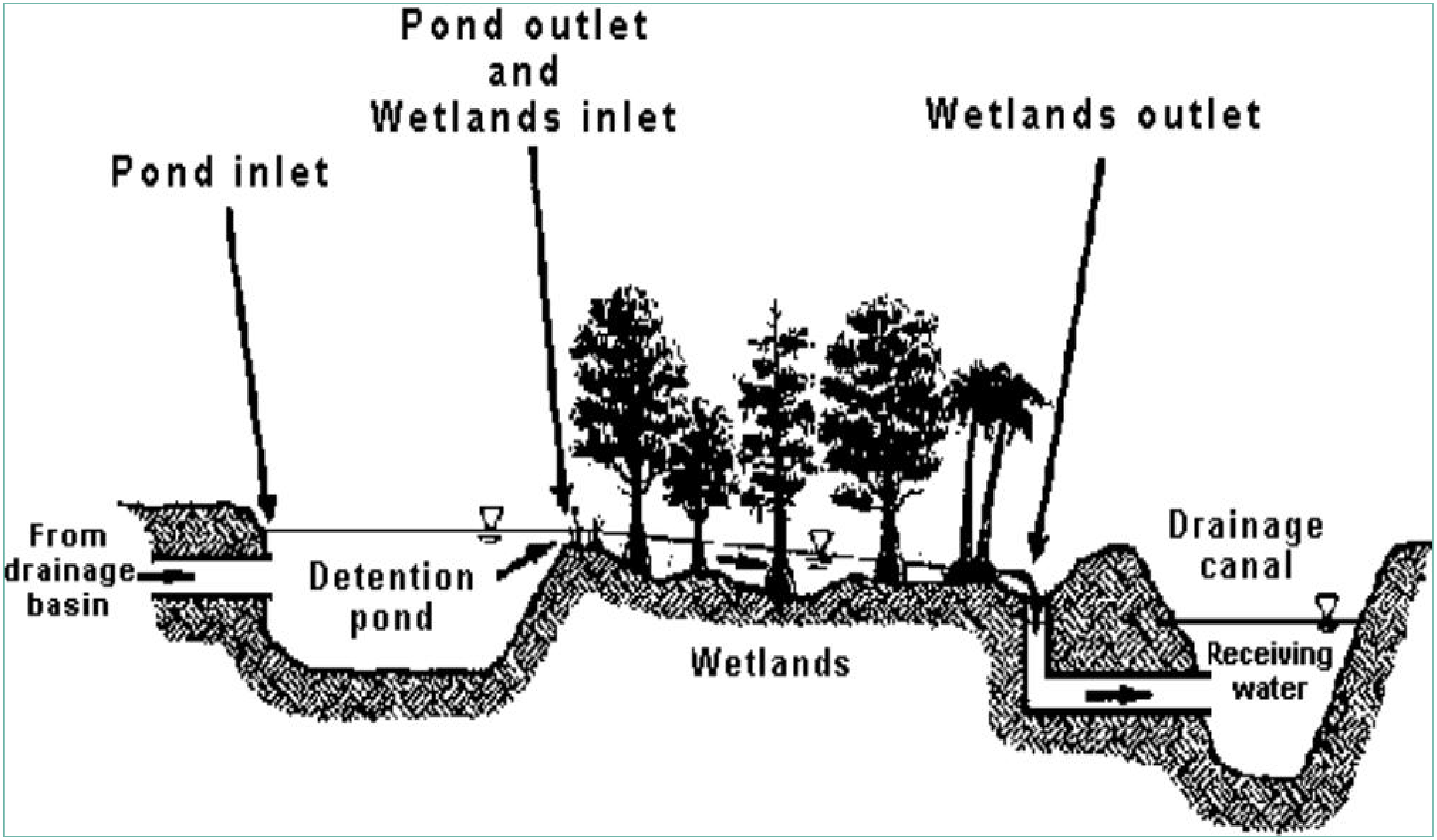
Even in HSG ‘D’ soils – DCIA is the driver

	Runoff depth for curve number of—												
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77

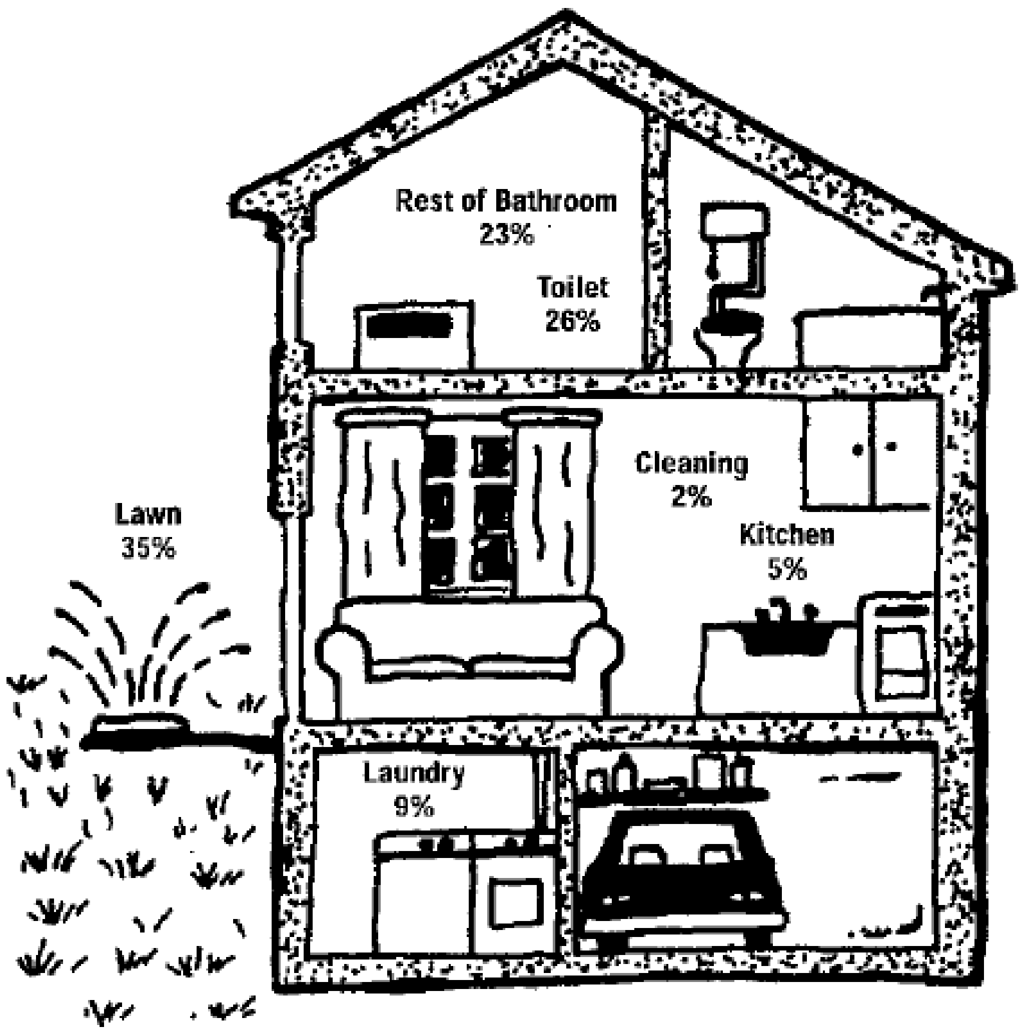
Development Impacts Streams and Estuaries



Valuable Freshwater Resource Is Lost to Tide



Up to 60% of our water use does not require potable water



Which Pollutants? Which Forms?

- Sediment
- Biochemical oxygen demand
- Pathogens
- Phosphorus: **SRP, OP**, TP
- Nitrogen: TKN = Org N + **NH_3**; **NOX = NO_2 + NO_3**

  TN = TKN + NOX

  (Only some forms of nutrients are bioavailable)
- Metals
- Toxic compounds

Organic or inorganic, dissolved or particulate

BMP Selection Criteria

- Land area availability/ownership/access
- Site characteristics
- Regulatory requirements and constraints
- Mass pollutant load reduction/environmental benefits
- Construction/Annual O&M/Life cycle cost
- Maintenance staff availability/sophistication
- Decreased maintenance of problem areas
- Public acceptance
- Funding partners/Grant potential
- **Piggyback on other planned capital improvements**
- Regional vs. many smaller systems

Evaluation and Selection of Projects

- Identify primary and secondary pollutants
- Determine min and max influent pollutant concentrations and stormwater flow rates
- Determine desired removal efficiencies
- Identify available land area
- Identify effective treatment train components
- Evaluate potential treatment trains based on BMP Selection Criteria Factors
- Implement best solution – keep pushing forward, you will have obstacles!

L1

Treatment Train - Implementing Cost Effective BMPs For Non-Point Source Management

MAXIMIZE → MINIMIZE

Runoff & Load Generation → **Conveyance and Pretreatment** → **Additional Treatment & Attenuation** → **Final Treatment and Attenuation**

Runoff & Load Generation

- Regulations
- Public education
- Erosion control
- Roof runoff
- Disconnect IA
- Landscaping
- Pervious paving
- Pavement cleaning

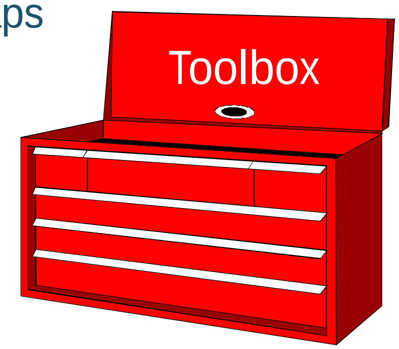
GI

Conveyance and Pretreatment

- Swales
- Catch Basins
- Inlets filters
- Oil/water separators
- Trash/sediment traps

Additional Treatment & Attenuation

- Detention
- Wetland
- Storage
- Sediment sump



Final Treatment and Attenuation

- Retention
- Detention
- Wetland
- Chemical
- Ozone
- UV
- Reuse
- End of pipe

Slide 10

L1 I would remove

LHawks, 3/4/2013

Relative Comparison of Structural BMP Pollutant Removal Effectiveness

POLLUTANT	INFILTRATION / VOLUME REDUCTION	DETENTION	WETLAND [1]	CHEMICAL COAGULATION	FILTRATION / UV	FILTRATION / OZONE	LIQUID / SOLIDS SEPARATION STUCTURE
Nitrogen	H - VH	L - M	L – H	L - M	L - M	L - M	L
Phosphorus	H - VH	L - M	L – H	H - VH	L - M	L - M	L
TSS	H - VH	H	H	H - VH	H - VH	H -VH	L – M
BOD	H - VH	L - M	M	M	M – H	M – H	L – M
Heavy Metals	H - VH	L - M	M - H	M - H	L - M	L – M	L – M
Pathogens	H - VH	L	L	H - VH	VH	VH	L
Gross Solids	H - VH	H	H	L - H	VH	VH	H-VH

1. Highly dependent on influent pollutant concentration and hydraulic loading rate

VH – Very High H – High M – Medium L- Low

End of Pipe Stormwater Treatment

- Typically for gross solids and sediment removal but new medias effective for removing other pollutants
- Used extensively for removal of primary pollutants
- Minimal land required
- Relatively inexpensive
- Can be implemented relatively quickly

BC Design for CalTrans

Baffle Box
CDS Unit
Vortechnics
Stormceptor
Many others

Comparison of BMP Treatment Efficiencies for Primary Pollutants

Type of BMP	Estimated Removal Efficiencies (% Load Reduction)			
	TN	TP	TSS	BOD
INFILTRATION/REUSE Volume Reduction 1.00" VOLUME 1.50" VOLUME	 80 90	 80 90	 80 90	 80 90
WET DET (14-21 day WSRT)	25-35	60-70	90	50-70
WET DET/FILTER	0-10	50	85	70
DRY DETENTION	10-20	20-40	20-60	20-50
DRY DET/FILTER	(-)-20	(-)-20	40-60	0-50
CHEMICAL TREATMENT	20-40	80-90	>90	30-60
WETLAND TREATMENT	(-)-90	(-)-90	50-90	(-)-50

Volume Reduction

No volume = no load
Also reduces conveyance requirements and cost.

Disconnect Impervious Areas

Rainwater Harvesting and Reuse

Stormwater Storage and Reuse

Low Impact Development
and Infiltration Practices
(permeability of native soils critical)

Permeable Pavers and Porous Pavement

Subgrade and proper material installation critical to success.
Maintenance required.

Rainwater Harvesting and Reuse
(relatively clean water)

1-inch of runoff over 3,000 sf = 1,870 gallons.

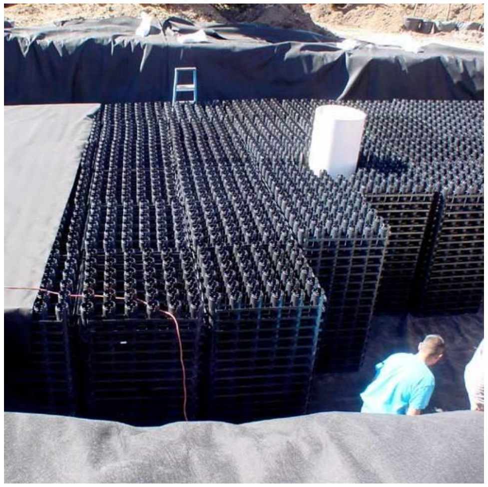
55 gallon rain barrels provide minimal storage for a typical single family home.

HDPE Tanks ~ $1/gallon storage

Stormwater Reuse

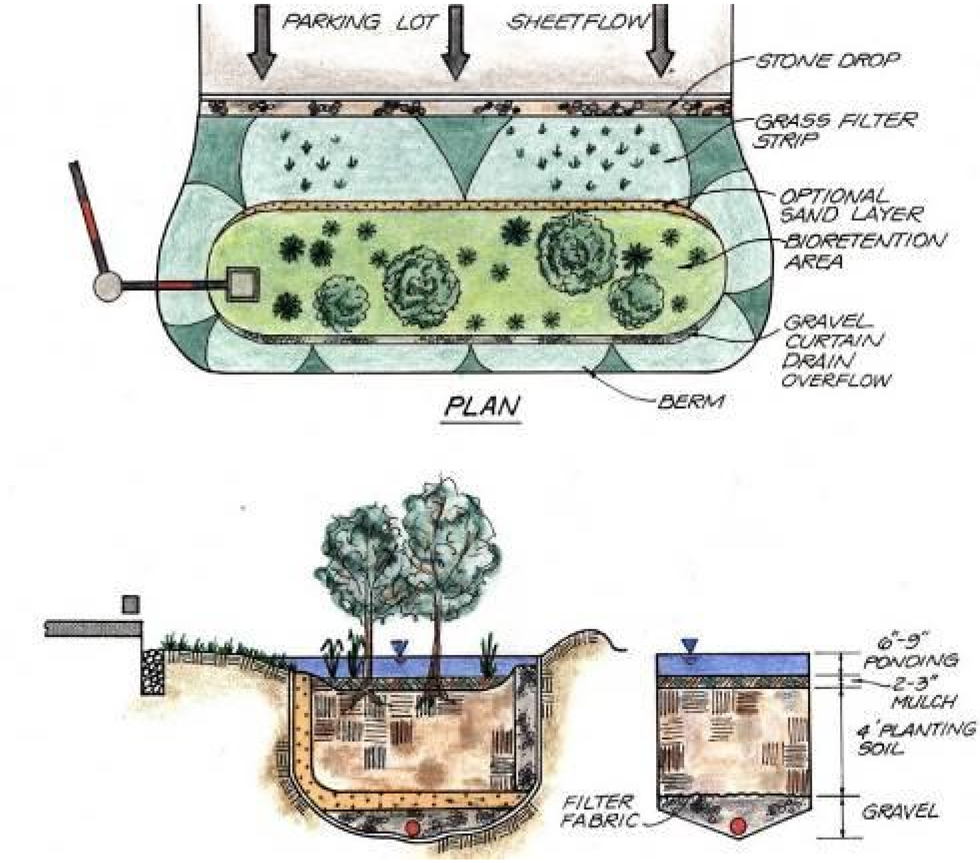
Reduces runoff volume and pollutant load and reduces potable water demand.

Higher concentrations of pollutants than rainwater but can be used for irrigation and gray water.



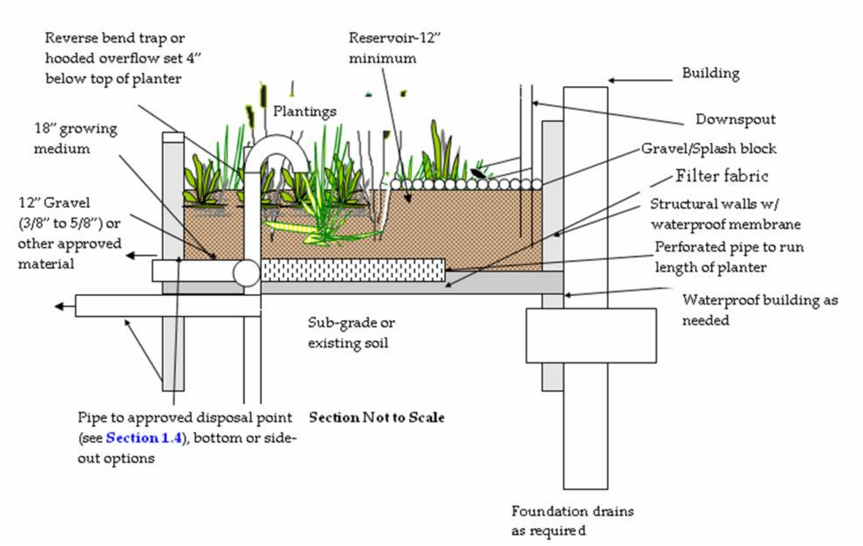
Must have sediment removal element prior to any underground storage with ability to remove sediment.

Bioretention Area (different than biofiltration)



Research to improve TP and TN removal.
Aluminum precipitates for TP (4-5x).
Anaerobic zone for denitrification.

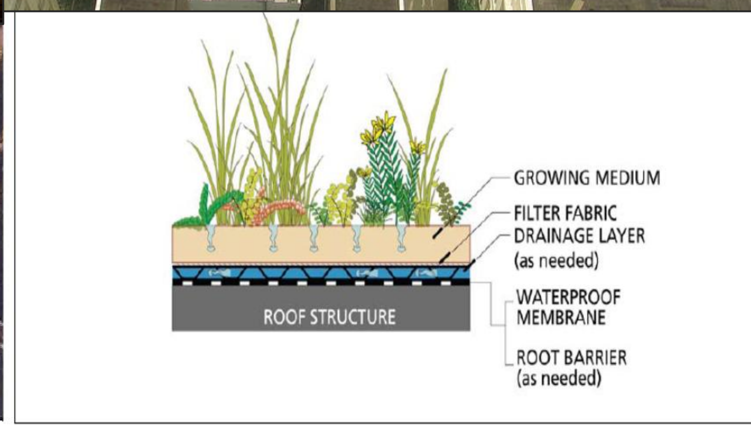
Biofiltration/Biodetention



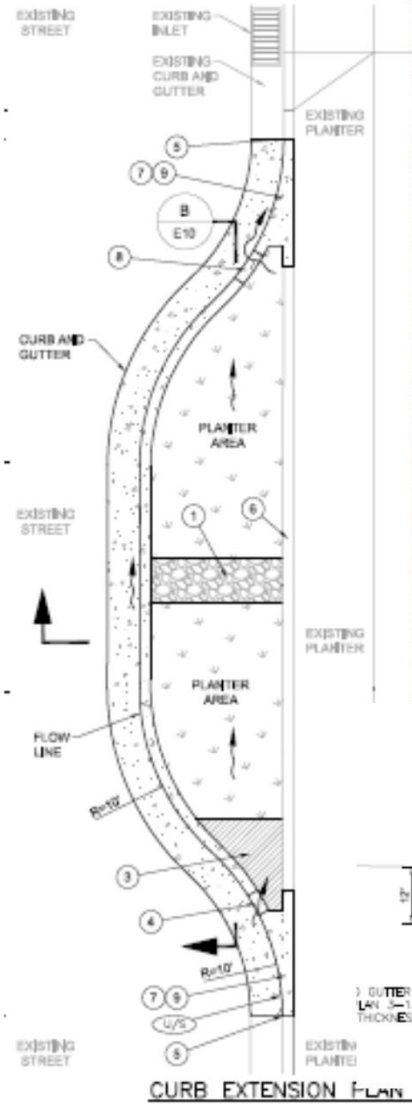
Lower volume reduction than bioretention
but can achieve substantial pollutant concentration reduction.
Dense vegetation/engineered soil key.

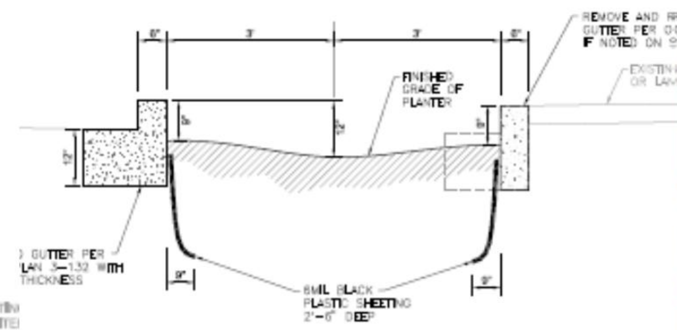
Bioswales

Blue/Green Roof

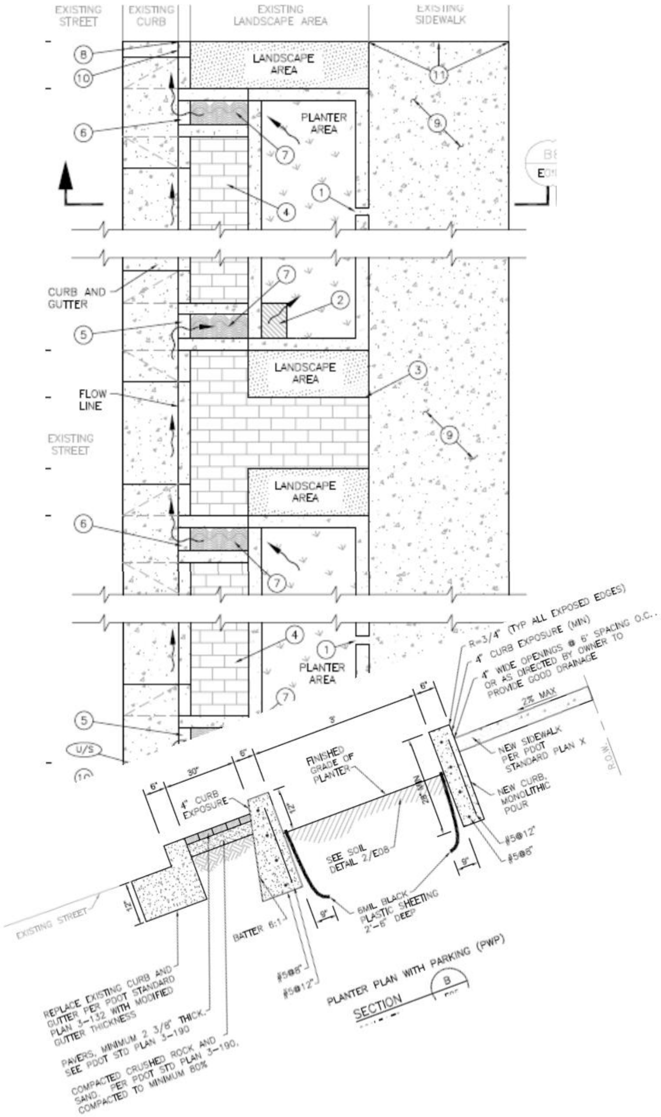


Curb Extension





Sidewalk Planter



Wet Detention and Wetland Treatment

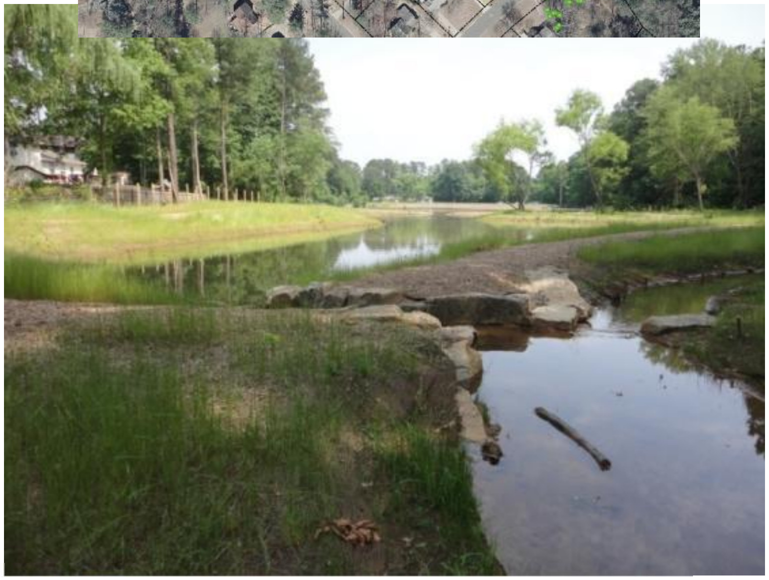
PPV and residence time key factor for wet detention effectiveness (21+ days)

Significant land area required for wetlands, efficiencies highly dependent on influent concentrations and hydraulic loading rate, plan for future maintenance.

- emergent marsh w/ open water pools
- submerged aquatic vegetation (SAV)
- hardwood elements
- design to minimize short circuiting

Lake Claiborne Restoration

- Removed 442,043 lbs/yr TSS/restored PPV
- Completed in 6 months
- $1.2M Construction Cost
- $3.68/lb TSS
- County average cost per pound is $10/lb TSS
- Homeowners happy
- Monitor for WQ and habitat improvements




15 Acre SAV/Wet Detention System treats 600 acres
Construction cost $1M
Annual O&M cost $20,000
Property owned by FDOT

Enhanced Treatment Using Coagulants

- Achieves significantly higher removal efficiencies than traditional treatment methods for many pollutants; **80-90% TP, 99.9% pathogen removal**
- Requires significantly less land than traditional methods
- Typically has the lowest life cycle cost per mass TP and pathogen removed
- Improves receiving surface water quality for aesthetics, recreational use or public health
- Provides source water protection and controls growth of algae and bacteria (including blue-green algae)

How Does the Process Work?

Removal of particulate pollutants

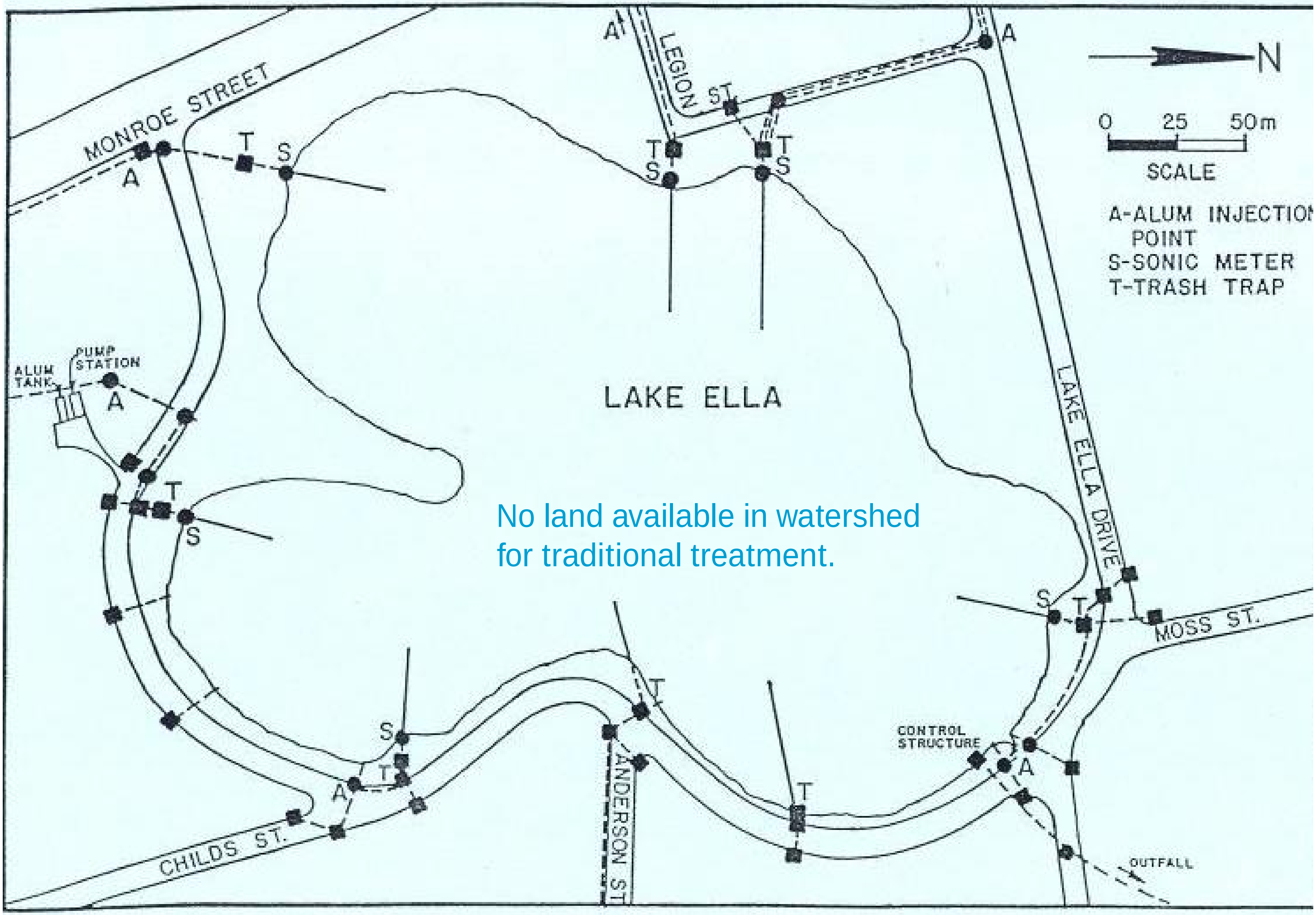
$$Al_2(SO_4)_3 \ + \ 6HCO_3^- \ \text{----->} \ 2Al(OH)_3 \ (ppt) \ + \ 3SO_4^{-2} \ + \ 6CO_2$$

Removal of dissolved phosphorus

$$Al_2(SO_4)_3 \ + \ 2PO_4^{-3} \ \text{----->} \ 2AlPO_4 \ (ppt) \ + \ 3SO_4^{-2}$$

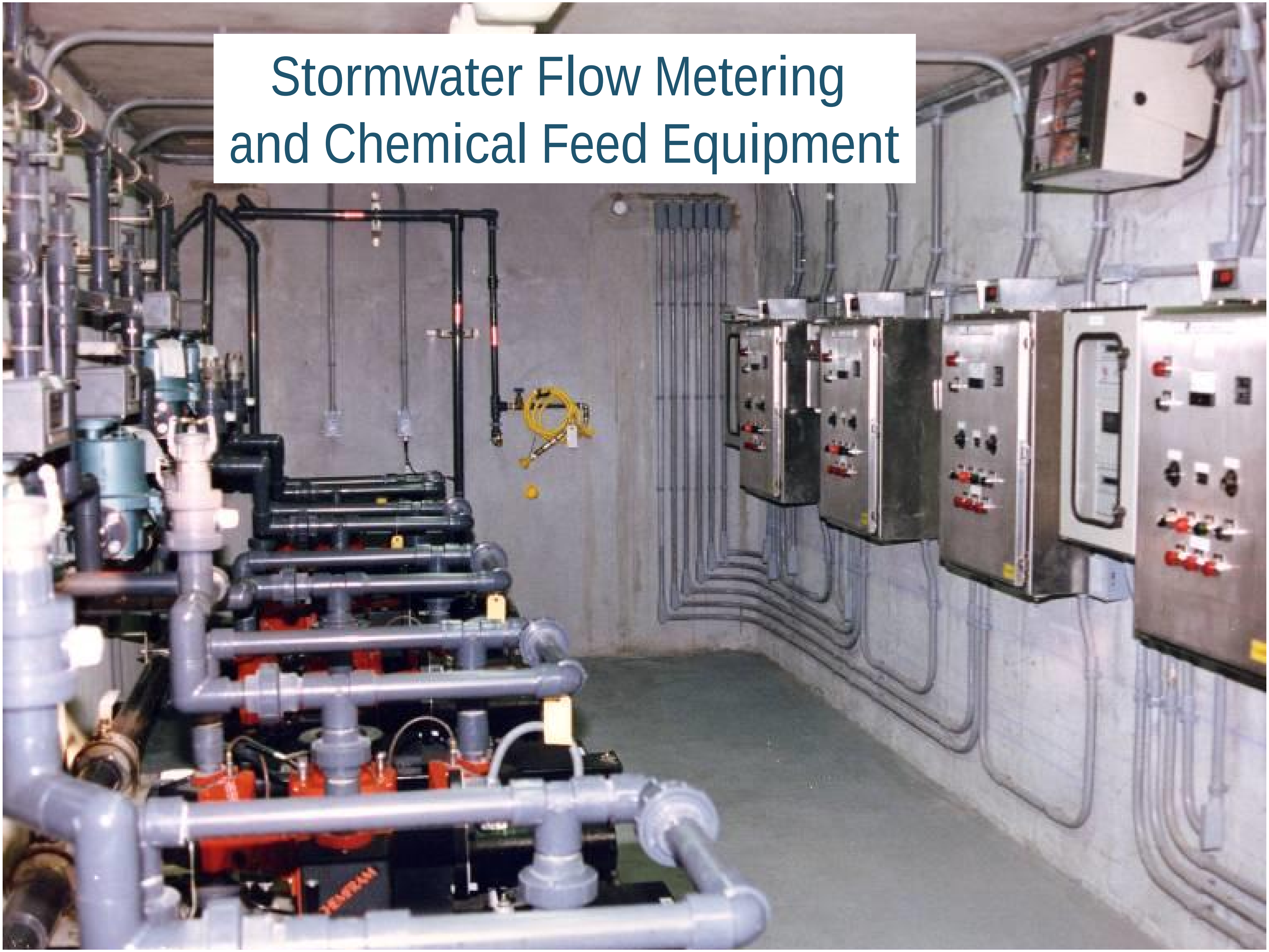
The addition of acid salts consumes alkalinity and reduces water pH, however, a pH buffer is rarely required.


Before Stormwater Chemical Treatment



No land available in watershed for traditional treatment.

Stormwater Flow Metering and Chemical Feed Equipment




After Stormwater Chemical Treatment

Largo Central Park

1200 acre watershed treated using 3 acre pond, floc pumped to SS
Construction cost = $1,000,000
Annual O&M cost = $50,000


Stormwater
Treatment Process

LCWA Nutrient Reduction Facility

Treats flows up to 300 cfs and 50,000 ac-ft of water per year from a 60,000 ac watershed. Meets P TMDL requirements for entire watershed.
Construction Cost $7.5M
Annual O&M Cost $1M

Floc Removal and Dewatering

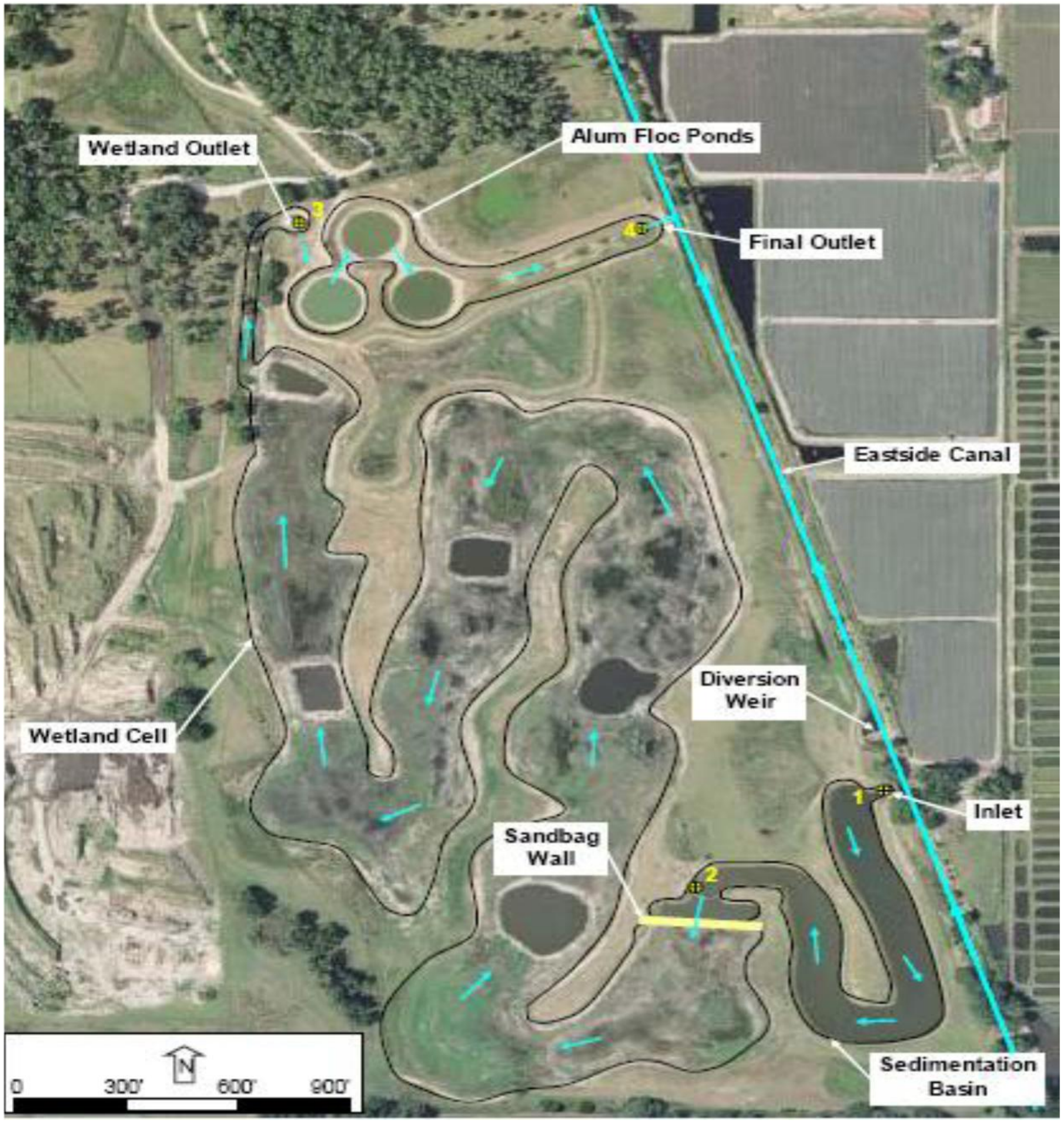
Capital Trail Cascade Park

Aero Photo
727.520.8181
www.aerophoto.com

Capital Cascades Park

Image # 1406020094
Date 06.02.14

Enhanced Wetland Treatment System to Meet TMDL



6500 acre watershed treated
Flows up to 100 cfs diverted

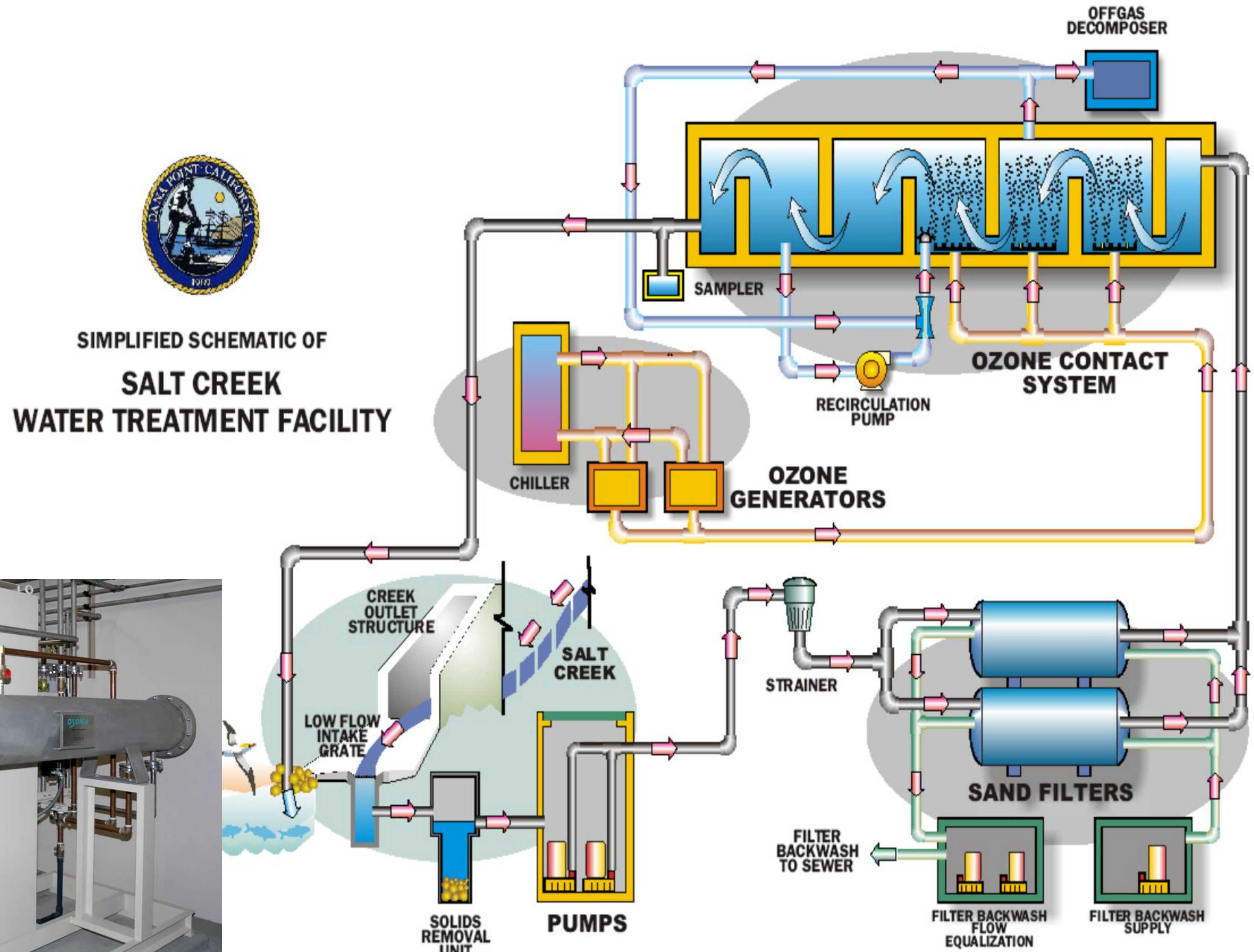
Construction cost = $2,000,000
Annual O&M cost = $75,000

Reduces chemical requirements; wetland alone achieves desired TP reduction during lower flows.

Dewatered floc used to amend constructed wetland treatment soils to bind P

Annual load reductions = 2,000 kg TP, 1,300 kg TN, 18,000 kg TSS

Ozone Disinfection



Influent and Treated Water Monitoring Results

Summary of Representative Data (through July - 06)			
Location	**Minimum**	**Maximum**	**Mean**
Influent			
Total Coliform (MPN/100mL)	**1,400**	**160,000**	**33,539**
Fecal (E. Coli) (MPN/100mL)	**170**	**30,000**	**4,266**
Enterococcus (MPN/100mL)	**15**	**37,000**	**5,859**
Treated Water			
Total Coliform	**2**	**30**	**6**
Fecal (E. Coli)	**2**	**30**	**2**
Enterococcus	**1**	**140**	**13**

Treats 1 cfs Baseflow; Construction Cost $3M,
Annual O&M Cost $40,000

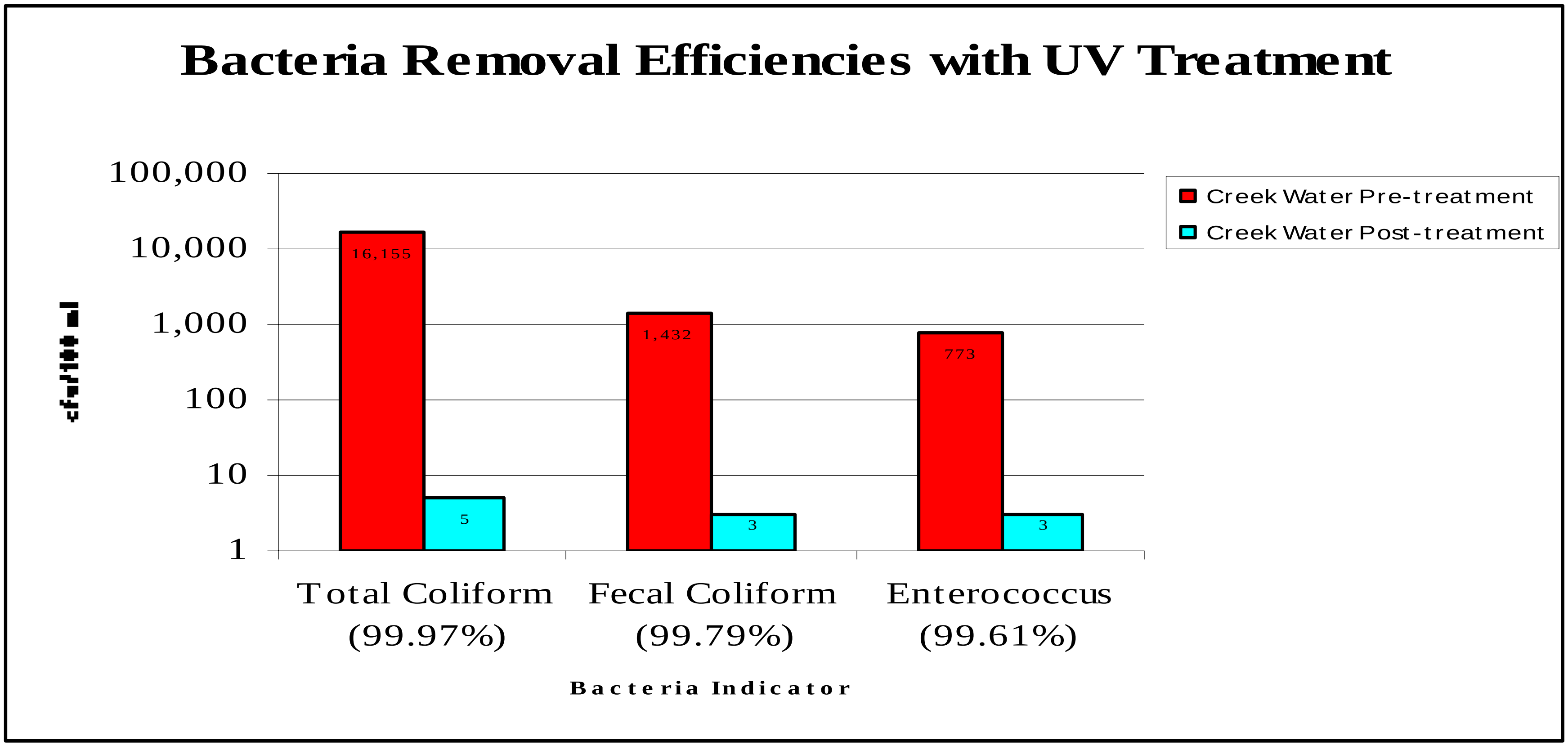
UV Disinfection

- Intake line from creek inside of existing box culvert
- Wet well with alternating pumps
- Basket filters
- Multimedia filters
- UV light bulbs
- Discharge from facility re-introduced to creek inside existing box culvert

3 Year Monitoring Results

- >99% Bacteria Kill in Treated Water from the Plant

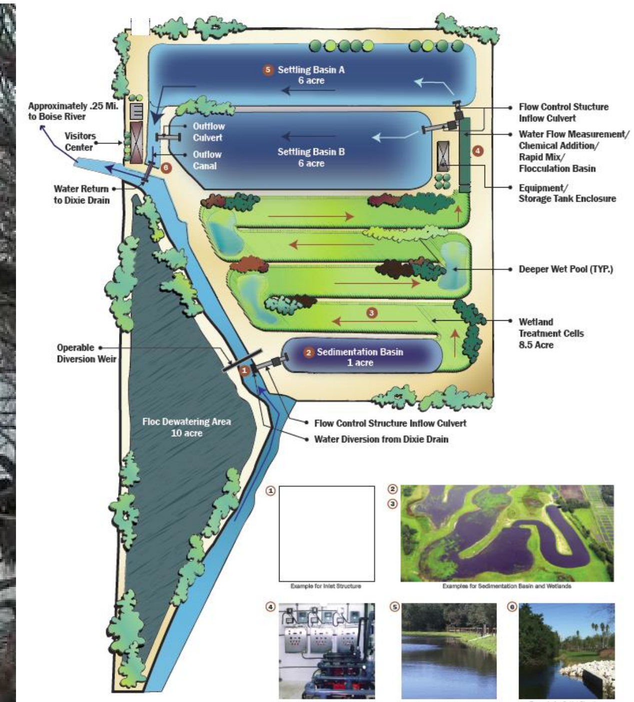
Treats 0.33 cfs Baseflow, Construction Cost $400,000; Annual O&M Cost $20,000



City of Boise, Idaho

Dixie Drain Enhanced Water Quality Treatment Phosphorus Offset Project

- Nutrient removal
- Integrated watershed approach



- Will be first nonpoint source project used to offset total phosphorus requirements in a wastewater NPDES permit
- Includes coagulant addition facility to precipitate TP from the diverted agricultural flows

Recreational and Educational Elements

Include recreational elements to allow a stormwater treatment system to be useful to the public and a benefit to community

BMP Life Cycle Cost Comparisons are highly variable

Retrofit BMP	Life Cycle Cost per kg TP removed ($)	Life Cycle Cost per kg TN removed ($)
Pet Waste Education	**150 - 300**	**20 - 40**
Second Generation Baffle Box	**400 – 1,600**	**250 - 500**
Wet Detention Pond	200 - 2,400	100 - 1,000
Dry Detention Basin	1,500 - 7,000	1,250 - 2,500
LID - Bioretention	1,000- 40,000	500 - 5,000
Stream Restoration	1,000 - 4,000	300 - 600
Chemical Treatment	**90 - 180**	**50 - 100**
Enhanced Wetland Treatment	**100 - 200**	**100 - 200**

Larger - regional systems tend to have significantly lower life cycle costs per mass of TP and TN removed than many smaller systems. LID for new construction is more cost effective.

Questions

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Stormwater Pollutant Sources

POLLUTANT	PRIMARY SOURCES
Particulates	Erosion, sedimentation, pavement wear, atmosphere-fossil fuels, maintenance
Nutrients – N and P	Fossil fuels, fertilizer application, pets, septic tanks, sewer spills, wastewater reuse
Zinc	Tire wear, motor oil, grease
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear, insecticides
Chromium	Metal plating, moving engine parts, brake linings
Nickel	Diesel fuel and gasoline, lubricating oils, metal plating, bushing wear, brake linings, asphalt
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt
Pathogens	Birds, animal waste, septic tanks, sewer spills
Synthetic organics	Industrial processes, pesticides, insecticides, spills, asphalt

Maximize Implementation of Non-Structural BMPs

Nutrient Management
Street Sweeping
Catch Basin Cleanout
Material Storage

Typically cost effective pollutant load reduction