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New Advances in Stormwater Treatment Practices

Presented by:

Daniel J. O'Leary, P.E.

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INTRODUCTION

What are we trying to protect?

And from what?

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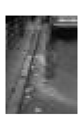
Sources of Surface Water Pollution



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More Sources of Surface Water Pollution

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First Generation SWM Ponds

- Generally Detention (Dry) Ponds
- Added as Afterthought to Completed Site Plans
- Minimal Water Quality Benefits
- Out of Sight...Out of Mind
- Maintenance?

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I. Selecting the Most Effective Stormwater Practice

Depends on seven watershed and site factors:

1. Watershed Management Objectives
2. Terrain and Climate Factors
3. Nature of Development Site
4. Stormwater Treatment Criteria
5. Physical Feasibility Factors
6. Community and Environmental Factors
7. Location and Permitting Issues

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#1. Different Watershed Objectives Shape Local Stormwater Strategies

- Cold-water streams
- High quality warm-water streams
- Nutrient-sensitive waters
- Bacteria-limited watersheds
- Aquifer protection
- Wetland protection

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Challenges in Protecting Coldwater Streams from Stormwater

Stormwater degrades many elements of aquatic habitat needed by trout, salmon and other sensitive fish species:

- Stream warming
- Lower dry weather flows in low order streams
- Sediment deposition
- Loss of pool and riffle structure
- Potential toxicity due to copper and chlorides
- Barriers to fish migration

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Stormwater Strategies to Protect Coldwater Streams

- Need to emphasize recharge
- Channel protection storage needed for instream habitat
- Forested stream buffers are essential
- Carefully locate practices in relation to stream and buffer
- Consider downstream impacts of ponds (warming)
- Avoid creating future fish barriers

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Challenges in Protecting Nutrient-Sensitive Watersheds

Stormwater nutrient loads cause eutrophication in lakes, reservoirs and coves

- Practices differ greatly in phosphorus removal capability
- 40% removal appears to be top phosphorus removal rate
- Turf and lawn produces high phosphorus levels
- Few practices show potential to reduce soluble nitrogen
- Septic systems may be major nutrient source from low density development

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Stormwater Strategies for Nutrient-Sensitive Watersheds

- Combination of BSD and stormwater practices for best load reduction
- Minimize turf and lawn area created
- Best phosphorus removal achieved by:
  - Large and well designed wet ponds or wetlands
  - Bioretention and dry swales
- Mediocre phosphorus removal reported for:
  - Dry ED, organic sand filters, grass channels

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Challenges in Protecting Bacteria-Limited Watersheds

- Drinking water, beaches, shellfish beds and recreational uses affected in most watersheds
- Stormwater concentrations exceed standards by factor of 20 to 50
- Crypto and giardia are also found in urban stormwater
- Stormwater practices cannot reduce bacteria levels by 99%
- Detective work is needed to isolate where, when and how bacteria enters the watershed
- Ability to meet standards depends on development intensity and weather conditions

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Ability to Treat Bacteria-Limited Watersheds With Current Practices

Type of Stormwater Practice	Median Removal Rate	Mean Outflow Concentration (counts/100ml)
Ponds	65%	5144
Sand Filters	51%	5899
Grass Channels	-58%	2506

Source: Watershed Protection Techniques 3 (1)

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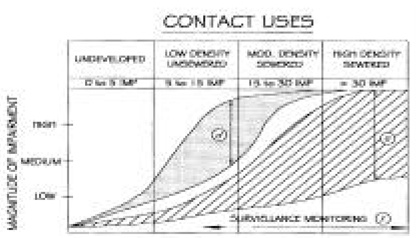
Conceptual Model for Bacteria Management in Urban Watersheds



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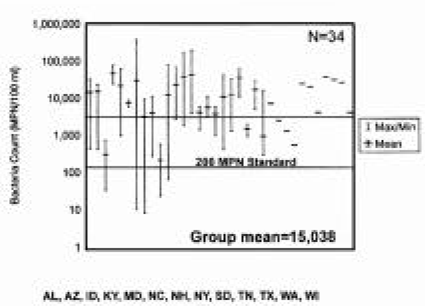

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Stormwater Strategies for Bacteria-Limited Watersheds

- Attack human wastewater sources first
- Utilize soil filtration and infiltration
- Design ponds for high light conditions and long retention
- Swales and ditches may be a source
- Integrate bioretention into stream buffers
- Improve sand filter designs
- Source control for pets, geese, and hobby farms

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Challenges in Protecting Aquifers from Stormwater Impacts

- Conservation of natural areas
- Recharge often important to maintain water supply
- Hotspot stormwater can contaminate groundwater
- Stormwater creates sinkholes in karst areas
- Need to setback from wellhead areas

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Stormwater Strategies to Protect Aquifers

- Promote recharge and infiltration, unless site is a hotspot
- Fully treat stormwater prior to discharge
- Perform better geotechnical testing
- Avoid pooling stormwater in karst areas

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Challenges in Protecting Wetlands from Stormwater Impacts

- Recent research indicates that stormwater can alter the hydro period of wetlands
- Stormwater increases the water level fluctuation (WLF) within the wetland
- Even a modest WLF or “bounce”:
  - Reduces wetland plant richness
  - Reduces thin stemmed species
  - Promotes invasive species
  - Reduces amphibian diversity

Source: Azous and Horner (1997)

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Stormwater Strategies to Protect Freshwater Wetlands

- Design to maintain wetland hydro period:
  - Keep mean monthly WLF less than 8 inches
  - No more than six WLF excursions of more than 6 inches per year
  - Limit duration of WLF to less than three days
- Provide upstream nutrient control for sensitive bogs and fens
- Be stringent in use of natural wetlands for stormwater treatment
- Avoid restrictions at wetland outlets

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2. Adapt Practices to Prevailing Terrain and Climate Factors

- Low relief
- Karst
- Glacial till
- High snowfall regions

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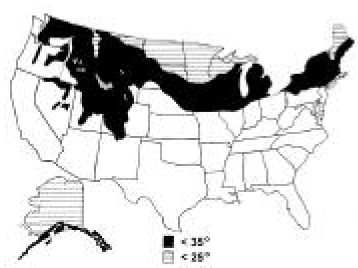
Normal Maximum Daily Temperature for January



Source: U.S. DOC, 1975

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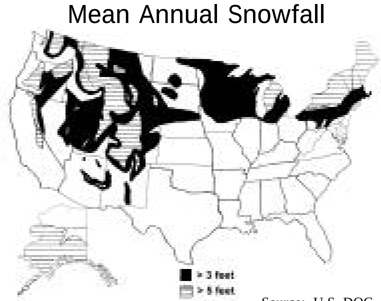
Mean Annual Snowfall



Source: U.S. DOC, 1975

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Cold Climate Design Challenges

- Pipe Freezing / Frost Heave
- Decreased Biological Activity & Settling Velocities
- Lower Oxygen Levels in Bottom Sediment
- Reduced Soil Infiltration
- Shorter Growing Season
- Snow / Deicer Management

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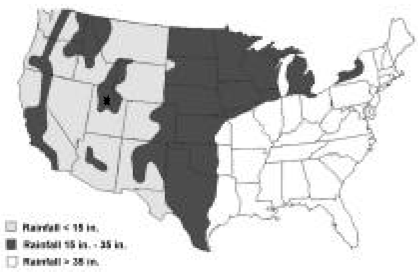
Distribution of Rainfall in the United States



Source: U.S. DOC, 1975

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Arid Climate Design Challenges

- Evaporation rates are much higher
- Pollutant concentrations in stormwater are much greater
- Vegetative cover is sparse
- Sediment movement is great

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#3. Nature of Development Site Influences Stormwater Strategy

- Larger residential sites
- Smaller commercial sites
- Stormwater hotspots
- Ultra-urban sites (e.g., redevelopment & infill)

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Challenges in Managing Stormwater at Larger Residential Sites

- Lawns produce more runoff than many think
- Residential areas are phosphorus and bacteria hotspots
- Conventional subdivisions create needless impervious cover
- Traditional roof/curb/pipe/pond drainage system
- Homeowners demand attractive and nuisance-free practices
- Greater chance of impacting stream or buffer

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Stormwater Strategies for Larger Residential Sites

- BSD can reduce impervious area by 25 to 40% at many sites
- Provide treatment on the lot, along streets and at the bottom of a site:
  - Disconnect and treat rooftop runoff
  - Use swales rather than curb and gutter
  - Grade backyards to buffers or swales
  - Smaller Cpv and Qp at downstream ponds

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Stormwater Credits for Better Site Design

- Conservation of Natural Areas
- Rooftop Disconnection
- Non-rooftop disconnection
- Sheetflow to stream buffer
- Grass channels (biofilters)
- Environmentally sensitive lot development
- Credits can reduce required WQ_v by 10 to 35% and Re_v by 50 to 100%

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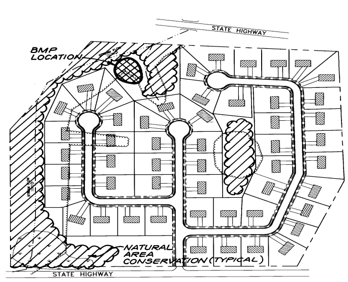
Conservation of Natural Area Credit



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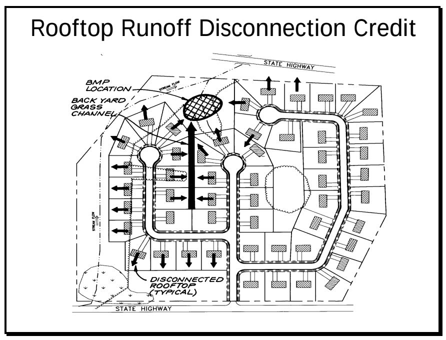

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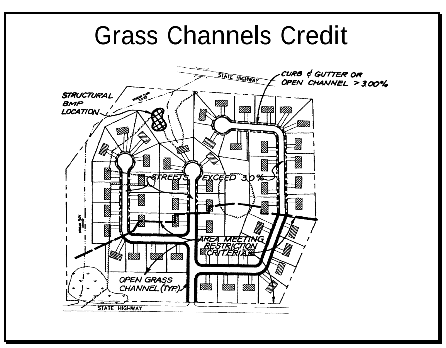

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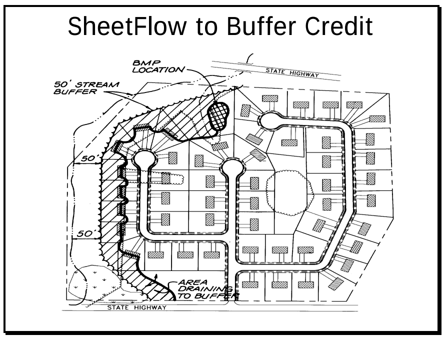

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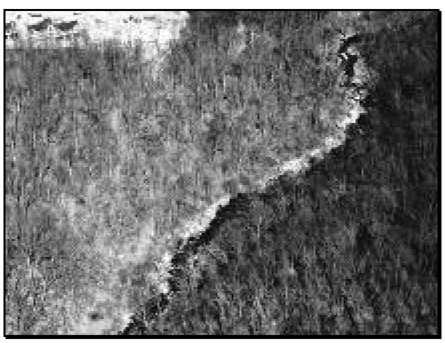

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Challenges in Managing SW at Small Commercial Sites

- Parking lots comprise over 50% of site
- Parking lots are a hotspot for hydrocarbon and metals
- Not much room to locate practices on the surface
- Drainage area constrains many practices (ponds and wetlands)

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Stormwater Strategies for Small Commercial Sites

- BSD can shrink parking lots by 10 to 15%
- Use green space for Rev and WQv
- Provide treatment around parking lots
  - bioretention area
  - sand filters
  - filter strips
  - permeable pavement
- Treat rooftop runoff in landscaping areas
- Avoid "stormwater in a can" solutions
- Check for hotspots before infiltrating

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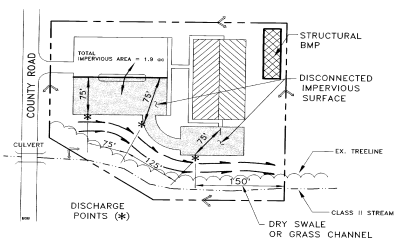
Non-Rooftop Runoff Disconnection Credit



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#4. No Single Practice Achieves All Stormwater Treatment Objectives

- A combination of practices are often needed to provide desired level of:
- groundwater recharge
- channel protection
- stormwater quality treatment
- overbank flood control
- flood plain expansion

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#5. Some Practices Cannot be Used Because of Site Constraints

- Soils
- Water table
- Drainage area
- Slope restriction
- Head
- Ultra urban areas

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#6. The Impact of Practices on the Community Needs to be Assessed

- Ease of maintenance
- Community acceptance
- Construction and maintenance costs
- Habitat creation
- Landscaping

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Challenges of BMP Maintenance

- Inability to physically locate BMPs
- Inability to track responsible parties
- Dedicated staff not assigned to inspection
- Designs not conducive to easy maintenance
- Lack of enforcement authority and access
- Owners of BMPs are unaware of their responsibilities
- Proliferation of BMPs that require intensive maintenance
- Insufficient funding sources

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#7. Where Practices are Located at a Site Makes a Big Difference

Need to locate practices in relation to:

- Wetlands
- Stream channels
- 100-year flood plain
- Stream buffer
- Water wells
- Critical habitats
- Forest conservation areas
- Utilities, roads, and structures

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II. Integrated Stormwater Management

Integration of site design practices and procedures with the design and layout of stormwater infrastructure to attain quality and quantity goals using the following elements or steps:

- Better Site Design Practices and Techniques
- Unified Design Criteria
- Downstream Assessment
- Stormwater Credits for Site Design
- Selection of Structural Stormwater Controls

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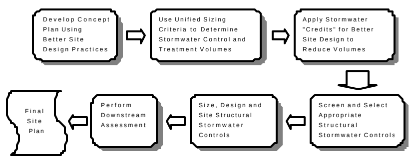
Steps in Addressing the Unified Stormwater Sizing Criteria



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Unified Approach for Stormwater Management

- Water Quality Criteria
- Groundwater Recharge Criteria
- Channel Protection Criteria
- Overbank Flood Protection Criteria
- Flood Plain Expansion Criteria
- Runoff Reduction (Better Site Design Practices)

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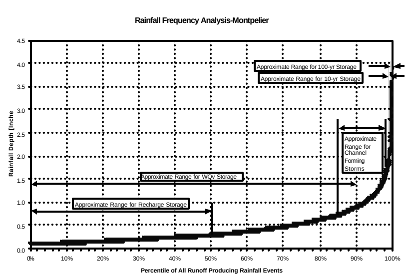

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Basic Elements of Stormwater Practice Design

- Runoff Reduction
- Runoff Conveyance
- Runoff Pre-treatment
- Runoff Treatment
- System Maintenance
- Secondary Environmental Impacts

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Effective Stormwater Treatment Practices

- Ponds
- Wetlands
- Infiltration
- Stormwater Filters
- Open Channels

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Definitions

- DA = Drainage Area
- Rev = Recharge Capability
- WQv = Pollutant Removal Capability
- Cpv = Channel Protection Capability
- Qp = Overbank Flood Protection
- TSS = Total Suspended Solids
- TP = Total Phosphorus
- TN = Total Nitrogen

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Definitions (continued)

- Maintenance = maintenance score
- Comm. Accept. = community acceptance score
- Cost = construction cost score

Score ranked from 1 to 5, with a lower score indicating either a high benefit or low drawback, and a higher score indicating either low benefit or high drawback.

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Stormwater Ponds

- Micropool extended detention (ED) pond
- Wet pond
- Wet extended detention pond
- Multiple pond system pond
- Pocket pond

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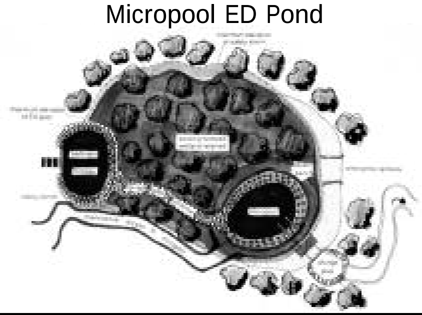
Micropool ED Pond



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Micropool ED Pond

DA = > 10 acres
Maintenance = 3.5

Comm. Accept. = 3.0
Cost = 1.0

Treatment

Rev	
Cpv	X
WQv	?
Qp	X

Pollutant Removal

TSS = 50 | TP = 30 | TN = 30

Reference: National Pollutant Removal Database for STPs, 2nd Edition, Center for Watershed Protection, June 2000. Additional info available through ASCE's National Stormwater BMP Database (http://www.asce.org/pdf/bibl1.pdf through bibl6. pdf)

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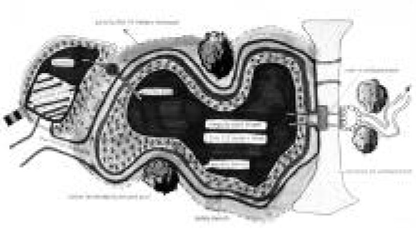
Wet Pond



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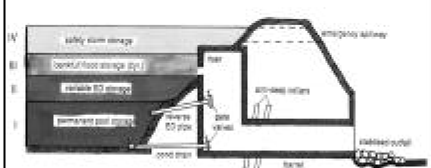
Standard Pond System Design
Cross-Section View



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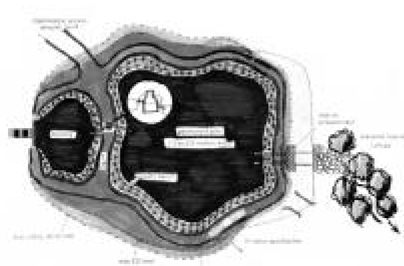
Wet ED Pond



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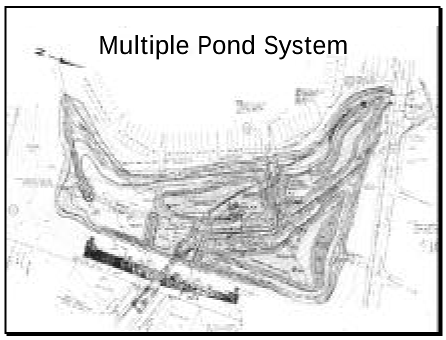

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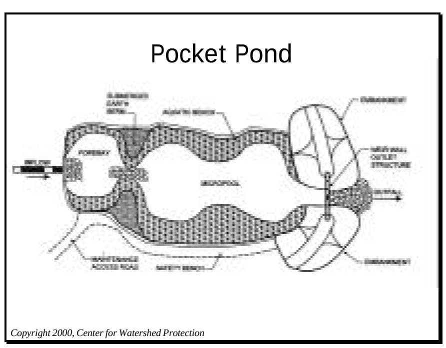

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Stormwater Wetlands

- Shallow wetland
- Shallow extended detention (ED) wetland
- Pond/Wetland system
- Pocket wetland
- Submerged gravel wetland

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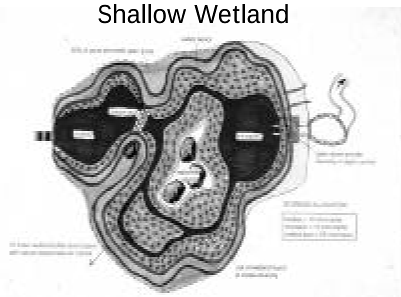
Shallow Wetland



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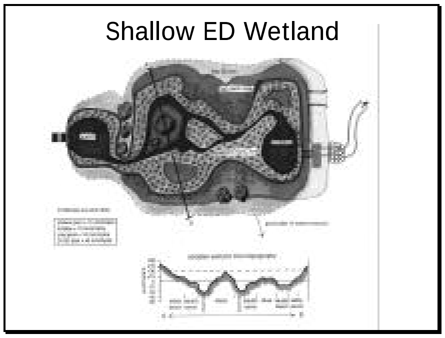

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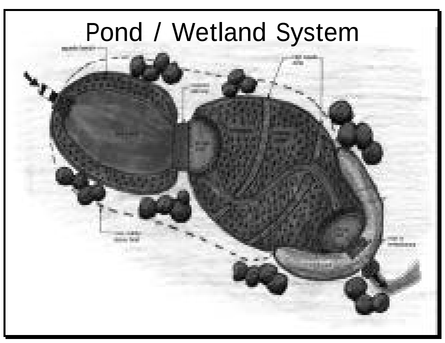

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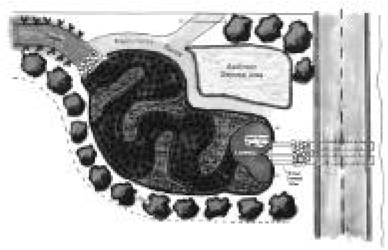
Pocket Wetland



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Infiltration Practices

- Infiltration Trench
- Infiltration Basin
- Porous Pavement

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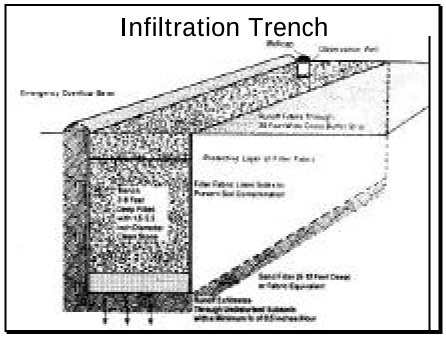

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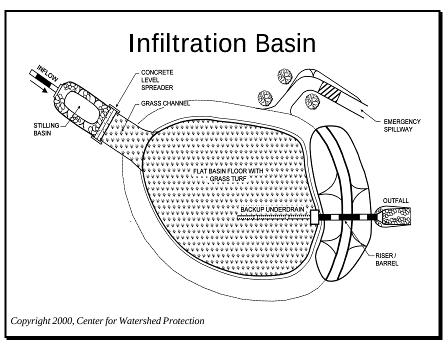

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Infiltration Basin Limitations

- Failure rates of 25 to 100% recorded in the field
- Algal growth/organic deposition lead to sealing

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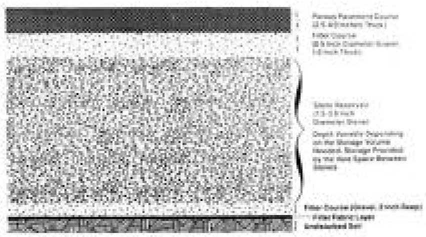
Porous Pavement



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Filtering Practices

- Surface sand filter
- Underground sand filter
- Perimeter sand filter
- Organic filter
- Pocket sand filter
- Bioretention areas

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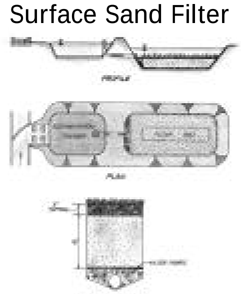
Surface Sand Filter



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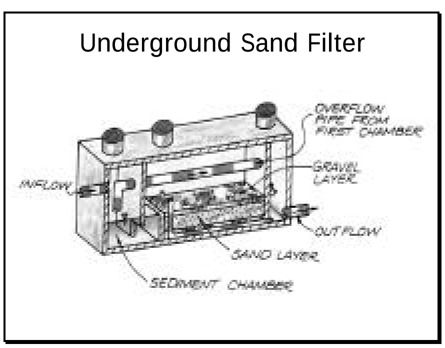

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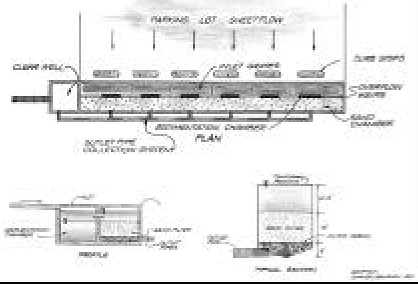
Perimeter Sand Filter



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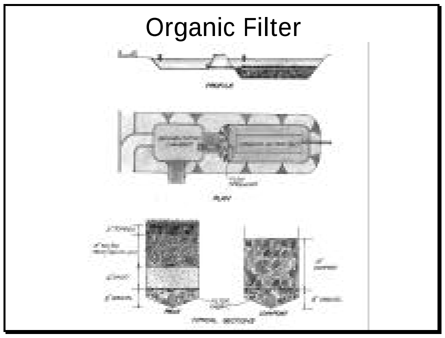

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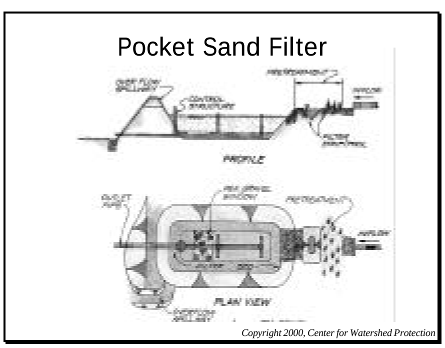

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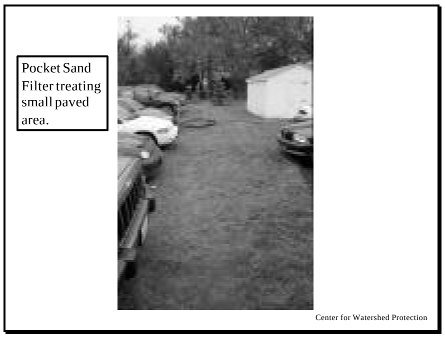

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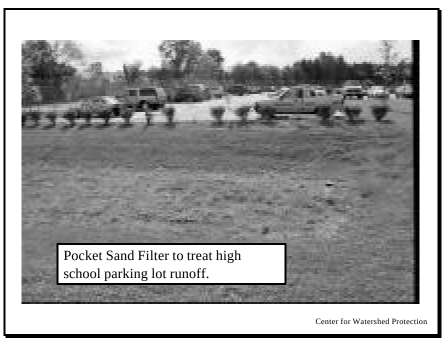

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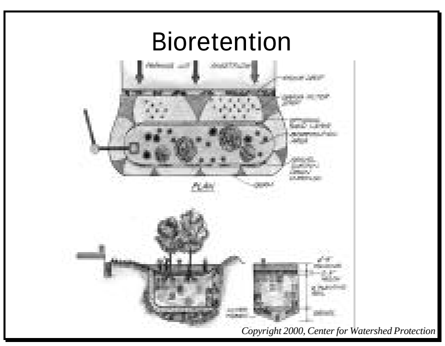

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Open Channel Practices

- Dry Swale
- Wet Swale

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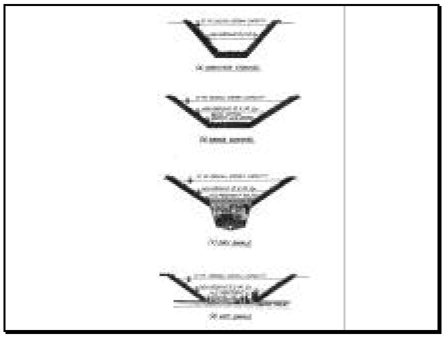

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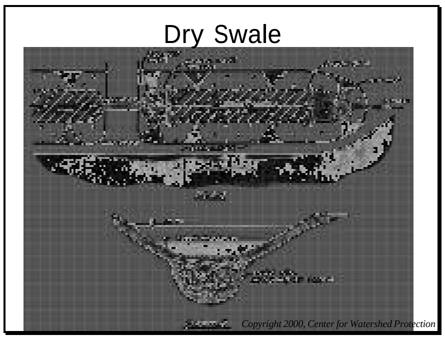

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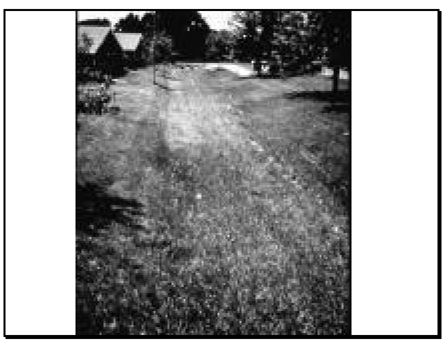

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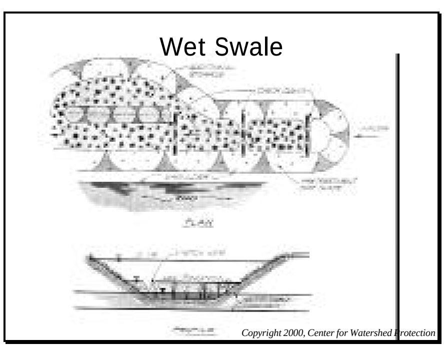

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Proprietary Devices

- Lots of “Better Mousetraps” now available.
- Research before you buy.
- Independent testing of some brands now under way.

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Micropool ED Pond Design Notes

- Micropool and forebay prevent resuspension and clogging
- Useful for “fingerprinting”
- Low community acceptance
- Inundation may harm trees
- Cost effective urban retrofit option

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Micropool ED Pond

DA = > 10 acres
Maintenance = 3.5

Comm. Accept. = 3.0
Cost = 1.0

Treatment

Rev	
Cpv	X
WQv	?
Qp	X

Pollutant Removal: TSS = 50 | TP = 30 | TN = 30

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Wet Pond Design Notes

- Algal uptake/settling increases nutrient removal
- Documented improvement in adjacent property values
- Careful location to prevent environmental impacts
- Stream warming limits use in trout streams (Use III & IV)
- Benches create fringe wetlands

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Wet Pond

DA = > 25 acres *
Maintenance = 1.5
* unless groundwater intercepted

Comm. Accept. = 1.5
Cost = 2.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal: TSS = 79 | TP = 49 | TN = 32

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Wet ED Pond Design Notes

- Provides most storage per land consumed
- Can help provide downstream bank erosion
- Reverse-slope pipe prevents clogging
- Frequent inundation creates landscaping challenges

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Wet Extended Detention Pond

DA = > 25 acres
Maintenance = 2.0

Comm. Accept. = 2.0
Cost = 2.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 80 | TP = 55 | TN = 35

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Multiple Pond System Design Notes

- Highest pollutant removal observed of any pond option
- Long flow path is key in removal
- Useful option at complex or linear sites
- Internal cells formed by gabions or embankment

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Multiple Pond System

DA = > 25 acres
Maintenance = 2.0

Comm. Accept. = 1.5
Cost = 3.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 91* | TP = 76* | TN = no data

* limited pollutant removal data

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Pocket Pond Design Notes

- Excavate to groundwater to create pool
- Not a good option for residential developments
- Pool levels will fluctuate
- Low habitat and amenity value

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Pocket Pond

DA = < 5 acres
Maintenance = 4.0

Comm. Accept. = 3.0
Cost = 1.5

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 87 * | TP = 78 | TN = 28*

* limited pollutant removal data

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Shallow Wetland Design Notes

- Deeper forebay and micropool are essential
- Shallow depths over remaining surface area
- High Surface Area to Volume Ratio
- Complex internal microtopography
- Potential wildlife habitat creation
- Consumes most land of any pond/wetland option

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Shallow Wetland

DA = > 25 acres
Maintenance = 3.5

Comm. Accept. = 2.0
Cost = 3.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 83 | TP = 43 | TN = 26

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Shallow ED Wetland Design Notes

- Range of depth zones essential
- 2-3 foot maximum vertical ED limit
- Sharply reduces land consumption for wetlands

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Shallow ED Wetland

DA = > 25 acres
Maintenance = 3.0

Comm. Accept. = 2.5
Cost = 3.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 69* | TP = 39* | TN = 56*

* limited pollutant removal data

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Pond/Wetland System Design Notes

- Redundant pollutant removal pathways
- First cell is a deeper pool
- Highest removal recorded for pond/wetland options
- Saves space

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Pond/Wetland System

DA = > 25 acres
Maintenance = 2.0

Comm. Accept. = 1.5
Cost = 3.0

Treatment

Rev	
Cpv	X
WQv	X
Qp	X

Pollutant Removal

TSS = 71 | TP = 56 | TN = 19

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Pocket Wetland Design Notes

- Excavate to groundwater
- Water elevations tend to fluctuate
- More difficult to maintain
- Risk of stagnation, odor, mosquitoes
- Not a high visibility practice

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Pocket Wetland

DA = < 5 acres
Maintenance = 4.0

Comm. Accept. = 3.0
Cost = 2.0

Treatment

Rev	
Cpv	
WQv	X
Qp	?

Pollutant Removal

TSS = 57* | TP = 57* | TN = 44*

* limited pollutant removal data

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Infiltration Trench Design Notes

- Field verification of soil permeability essential
- Helps meet groundwater recharge
- Highly restricted practice
- Longevity is less than 5 years without multiple pretreatment
- Should not be used if contributing drainage is a hotspot

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Infiltration Trench

DA = < 5 acres
Maintenance = 5.0

Comm. Accept. = 2.0
Cost = 3.5

Treatment

Rev	X
Cpv	?
WQv	X
Qp	?

Pollutant Removal

TSS = 100* | TP = 42* | TN = 42*

* limited pollutant removal data

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Infiltration Basin Limitations

- Failure rates of 25 to 100% recorded in the field
- Algal growth/organic deposition lead to sealing

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Infiltration Basin

DA = < 10 acres
Maintenance = 5.0

Comm. Accept. = 4.0
Cost = 3.0

Treatment

Rev	X
Cpv	?
WQv	X
Qp	?

Pollutant Removal

TSS = 90* | TP = 65* | TN = 50*

* limited pollutant removal data

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Porous Pavement Design Notes

- Vacuum Sweeping needed
- Construction Stage Sediment Control critical
- Overflow Inlets as backup
- Asphalt, concrete or concrete-grid can be used for inlet
- Needs long term, informed owner
- Winter-time plowing/sanding can be a problem

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Porous Pavement

DA = < 5 acres
Maintenance = 5.0

Comm. Accept. = 1.0
Cost = 3.0

Treatment

Rev	X
Cpv	?
WQv	X
Qp	?

Pollutant Removal

TSS = 95* | TP = 65* | TN = 83*

* limited pollutant removal data

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Surface Sand Filter Design Notes

- Pretreatment essential (dry or wet sedimentation)
- Grass cover crop is an option
- Need maintenance access to filter bed
- Useful to treat hotspot runoff

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Surface Sand Filter

DA = < 10 acres *
Maintenance = 3.5
* may be larger in some instances

Comm. Accept. = 2.5
Cost = 4.0

Treatment

Treatment	
Rev	ex
Cpv	?
WQv	X
Qp	

Pollutant Removal

TSS = 87 | TP = 59 | TN = 32

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Underground Sand Filter Design Notes

- Useful option in ultra-urban areas
- OSHA confined space
- Saves space, but can be expensive

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Underground Sand Filter

DA = < 2 acres *
Maintenance = 4.0
* may be larger in some instances

Comm. Accept. = 1.0
Cost = 4.5

Treatment	
Rev	
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 80* | TP = 50* | TN = 35*

* limited pollutant removal data

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Perimeter Sand Filter Design Notes

- Useful option for parking lots
- Lowest head requirement of filters
- Lower cost if located so it doesn't bear traffic
- Saves space

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Perimeter Sand Filter

DA = < 2 acres *
Maintenance = 3.5
* may be larger in some instances

Comm. Accept. = 1.0
Cost = 4.0

Treatment

Rev	
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 79* | TP = 41* | TN = 47*

* limited pollutant removal data

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Organic Filter Design Notes

- Organic media can include compost or peat
- Use a conservative permeability coefficient
- Replacement of media every 2 to 5 years
- Greater hydrocarbon, metal and bacteria removal

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Organic Filter

DA = < 10 acres *
Maintenance = 3.5
* may be larger in some instances

Comm. Accept. = 2.5
Cost = 4.0

Treatment

Rev	
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 88 | TP = 61 | TN = 41*

* limited pollutant removal data

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Pocket Sand Filter

DA = < 2 acres
Maintenance = 4.0

Comm. Accept. = 2.5
Cost = 3.0

Treatment

Rev	
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 80 * | TP = 40 * | TN = 35 *

* limited pollutant removal data

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Bioretention Design Notes

- Ideal use for small "green spaces"
- Media comprised of sand, soil, mulch, and grass
- Inlet drop and grading are very important
- Proper landscaping is essential

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Bioretention

DA = < 2 acre
Maintenance = 2.0

Comm. Accept. = 2.0
Cost = 2.5

Treatment

Rev	X
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = no data | TP = 65* | TN = 49*

* limited pollutant removal data

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Dry Swale Design Notes

- High space requirement
- Swale has engineered soil matrix and underdrains to promote filtration and prevent "nuisance water"
- Ideal for open section roads and low density residential streets

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Dry Swale

DA = < 5 acres *
Maintenance = 2.0
* may be larger in some instances

Comm. Accept. = 1.5
Cost = 2.5

Treatment

Rev	X
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 93* | TP = 83* | TN = 92*

* limited pollutant removal data

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Wet Swale Design Notes

- Used when water table is close to surface
- Creates a linear series of wetland cells
- Not recommended for residential areas

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Wet Swale

DA = < 5 acres *
Maintenance = 2.0
* may be larger in some instances

Comm. Accept. = 1.5
Cost = 2.0

Treatment

Rev	
Cpv	
WQv	X
Qp	

Pollutant Removal

TSS = 74*
TP = 28*
TN = 40*

* limited pollutant removal data

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