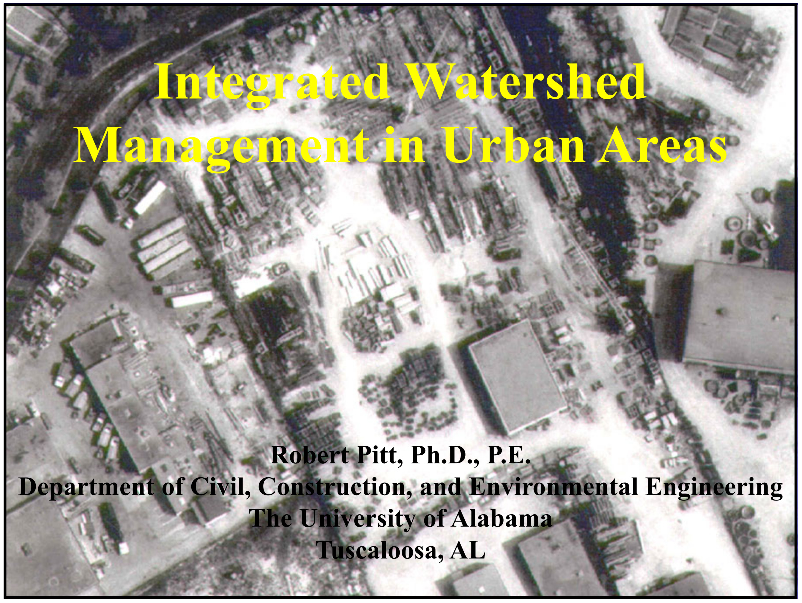
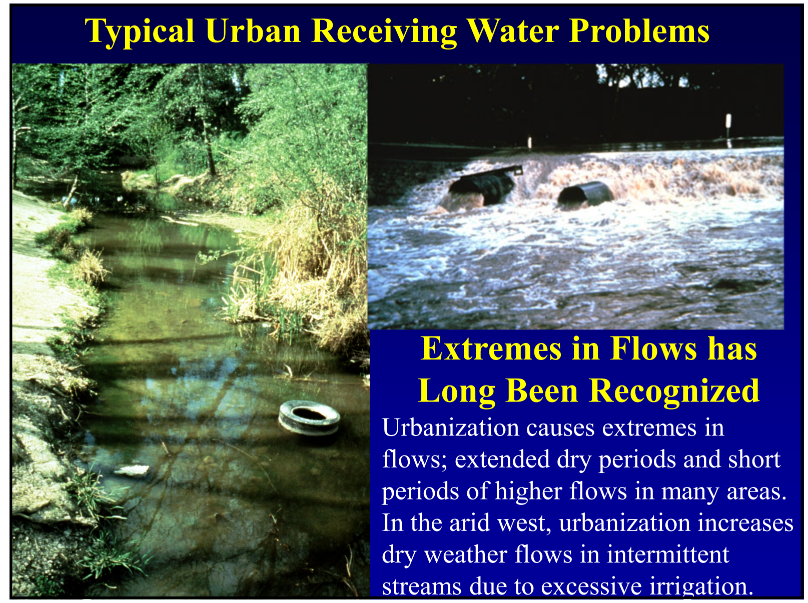

Integrated Watershed
Management in Urban Areas
Robert Pitt, Ph.D., P.E.
Department of Civil, Construction, and Environmental Engineering
The University of Alabama
Tuscaloosa, AL

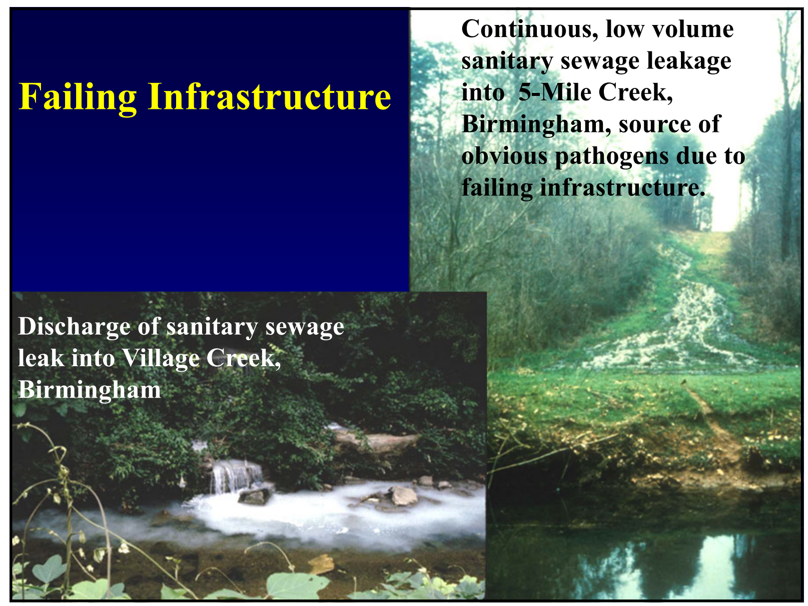
1


Typical Urban Receiving Water Problems
Extremes in Flows has
Long Been Recognized
Urbanization causes extremes in flows; extended dry periods and short periods of higher flows in many areas. In the arid west, urbanization increases dry weather flows in intermittent streams due to excessive irrigation.

2


Nutrient Discharges
Eutrophication and low DO was early driving force for wastewater treatment
WI DNR photos

3


Failing Infrastructure
Continuous, low volume sanitary sewage leakage into 5-Mile Creek, Birmingham, source of obvious pathogens due to failing infrastructure.
Discharge of sanitary sewage leak into Village Creek, Birmingham

4

Urban Wildlife and Sewage Contamination

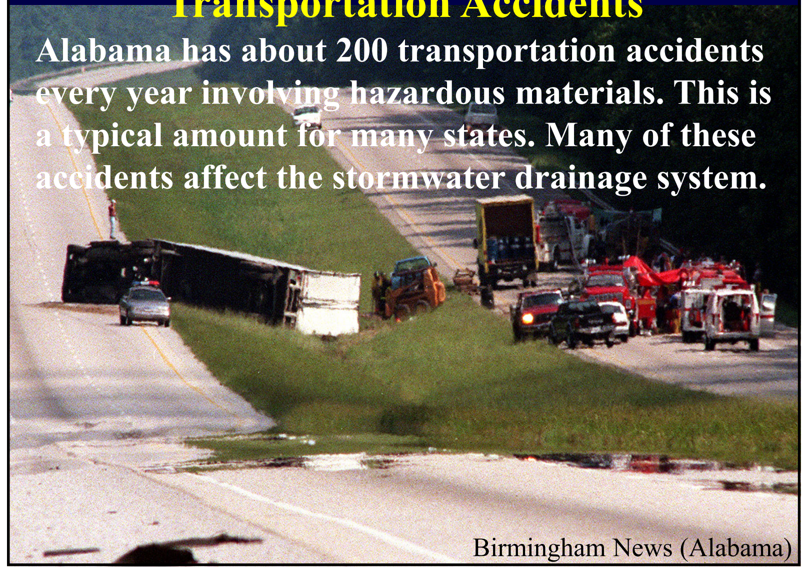
Health effects due to exposure to pathogens in the urban receiving waters can be serious.

WI DNR photo

5

Transportation Accidents

Alabama has about 200 transportation accidents every year involving hazardous materials. This is a typical amount for many states. Many of these accidents affect the stormwater drainage system.



Birmingham News (Alabama)

6

Stormwater Discharges to Groundwater

Moderate to High Groundwater Contamination Potential Associated with Stormwater Infiltration (Example Conditions)

Injection after Minimal Pretreatment	Surface Infiltration with no Pretreatment	Surface Infiltration after Sedimentation Treatment
Lindane, chlordane	Lindane, chlordane	
1,3-dichlorobenzene, benzo (a) anthracene, bis (2-ethylhexl phthalate), **fluoranthene**, pentachlorophenol, phenanthrene, **pyrene**	Benzo (a) anthracene, bis (2-ethylhexl phthalate), fluoranthene, pentachlorophenol, phenanthrene, pyrene	Fluoranthene, pyrene
Enteroviruses, some bacteria and protozoa	**Enteroviruses**	**Enteroviruses**
Nickel, chromium, lead, **zinc**		
Chloride	**Chloride**	**Chloride**

7

Stormwater can be a Resource

Ponds, rain barrels and cisterns for stormwater storage for irrigation and other beneficial uses. Many areas use roof runoff for all domestic needs.

Much of the domestic water needs can be met with waters of impaired quality (30% of in-home use, plus most of outside irrigation uses and fire-fighting use).

8

"Design" Storms for Stormwater Control not Obvious

- Large storms traditionally used for drainage design have several problems when applied to stormwater quality management:
  - a few events cannot adequately represent the wide range of problems that are associated with stormwater quality.
  - large design storms represent a very small fraction of annual discharge.

9

- Some stormwater controls need to be initially sized according to runoff volumes (eg. wet detention ponds), while others need to be initially sized according to runoff flow rates (eg. filters).
- However, continuous simulations are needed to verify performance under the wide range of conditions that can occur, especially as a number of complementary stormwater controls must be used together in most areas as a treatment train.

10

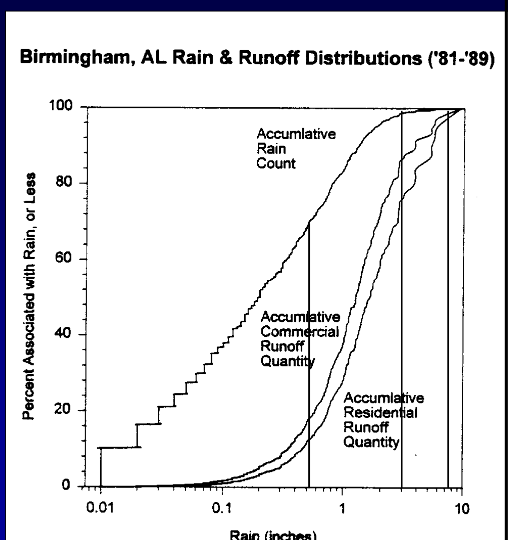
Probability distribution of typical Alabama rains (by count) and runoff (by depth).

<0.5": 65% of rains (10% of runoff)

0.5 to 3": 30% of rains (75% of runoff)

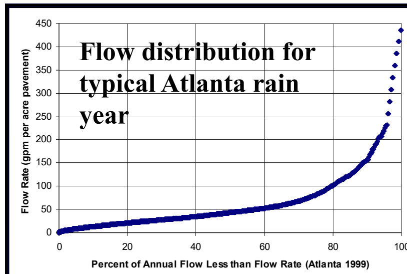
3 to 8": 4% of rains (13% of runoff)

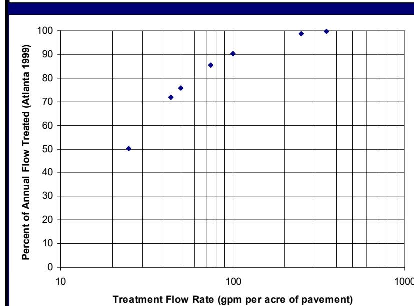
>8": <0.1% or rains (2% or runoff)



From EPA report on wet weather flows, Pitt 1999

11





Continuous Simulation can be used to Determine Needed Treatment Flow Rates:

- 90% of the annual flow for SE US conditions is about 170 gpm/acre pavement (max about 450).

- treatment of 90% of annual runoff volume would require treatment rate of about 100 gpm/acre of pavement. More than three times the treatment flow rate needed for NW US.

12

Conservation Design Approach for New Development

- Better site planning to maximize resources of site (natural drainageways, soils, open areas, etc.)
- Emphasize water conservation and water reuse on site
- Encourage infiltration of runoff at site (after proper treatment)
- Treat water at critical source areas
- Treat and manage runoff that cannot be infiltrated at site

13

Design Issues (<0.5 inches)

- Most of the events (numbers of rain storms)
- Little of annual runoff volume
- Little of annual pollutant mass discharges
- Probably few receiving water effects
- Problem:
  - pollutant concentrations likely exceed regulatory limits (especially for bacteria and total recoverable heavy metals) for each event

14

Suitable Controls for Almost Complete Elimination of Runoff Associated with Small Rains (<0.5 in.)

- **Disconnect roofs and pavement from impervious drainages**
- **Grass swales**
- **Permeable pavement walkways**
- **Rain barrels and cisterns**

15

Disconnect impervious areas

16

Permeable paver blocks have been used in many locations to reduce runoff to combined systems, reducing overflow frequency and volumes (Sweden, and WI).

17

Street and catchbasin cleaning, and inlet controls most effective for smaller rains in heavily paved areas.

18

Design Issues (0.5 to 3 inches)

- Majority of annual runoff volume and pollutant discharges
- Occur approximately once a week
- Problems:
    - Produce moderate to high flows
    - Produce frequent high pollutant loadings

19

Suitable Controls for Treatment of Runoff from Intermediate-Sized Rains (0.5 to 3 in.)

- **Initial portion will be captured/infiltrated by on-site controls or grass swales**
- **Remaining portion of runoff in this rain category should be treated to remove particulate-bound pollutants**

20

Rain Gardens can be Designed for Complete Infiltration of Roof Runoff

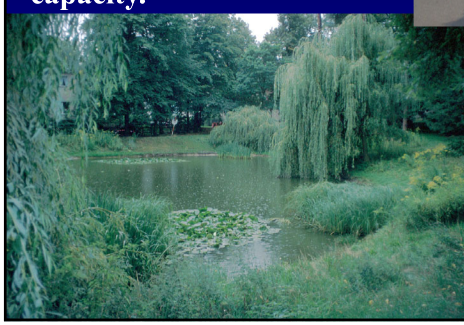
21

Soil modifications for rain gardens and other biofiltration areas can significantly increase treatment and infiltration capacity compared to native soils, plus provide substantial evapotranspiration losses.

(King County, Washington, test plots)

22

Percolation areas or ponds, biofiltration areas, and French drains can be designed for larger rains due to enhanced storage capacity.



23

Temporary parking or access roads supported by turf meshes, or paver blocks, and advanced permeable paver systems can be designed for large capacity.

24

Wet detention ponds, stormwater filters, or correctly-sized critical source area controls are needed to treat runoff that cannot be infiltrated.

25

Design Issues (3 to 8 inches)

- This range of rains can include drainage-design storms (depending on rain intensity and site time of concentration). Most of these storms last for one to two days. Drainage design storms of these depths would last only for a few hours.
- Establishes energy gradient of streams
- Occur approximately every few months (two to five times a year). Drainage design storms having high peak intensities occur every several years to several decades)
- Problems:
  - Unstable streambanks
  - Habitat destruction from damaging flows
  - Sanitary sewer overflows
  - Nuisance flooding and drainage problems/traffic hazards

26

Infrequent very high flows are channel-forming and may cause severe bank erosion and infrastructure damage.

MD and WI DNR photos

27

Controls for Treatment of Runoff from Drainage Events (3 to 8 in.)

- Infiltration and other on-site controls will provide some volume and peak flow control
- Treatment controls can provide additional storage for peak flow reduction
- Provide adequate stormwater drainage to prevent street and structure flooding
- Provide additional storage to reduce magnitude and frequency of runoff energy
- Capture sanitary sewage overflows for storage and treatment

28

Storage at treatment works may be suitable solution in areas having SSOs that cannot be controlled by fixing leaky sanitary sewerage.

Golf courses can provide large volumes of storage.

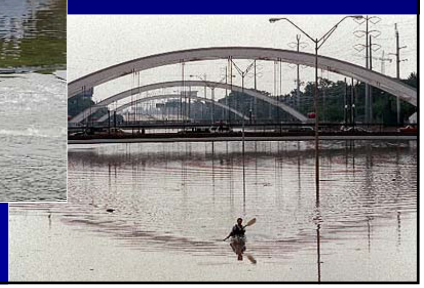
29

Design Issues (> 8 inches)

- Occur rarely (once every several years to once every several decades, or less frequently). Three rains were recorded that were >8 inches in the 37 years between 1952 and 1989 in Huntsville, AL.
- Produce relatively small fraction of the annual pollutant mass discharges
- Produce extremely large flows and the largest events exceed drainage system capacity (depending on rain intensity and time of concentration of drainage area)

30

WI DNR photo



Photos from *Houston Chronicle*.

31

Controls for Treatment of Runoff from Very Large Events (> 8 in.)

- Provide secondary surface drainage system to carefully route excess flood waters away from structures and roadways
- Restrict development in flood-prone areas

32

A suitable urban watershed management plan should incorporate many of the features described above to meet the many site objectives of interest.

- Good site design to fit site conditions (topography and natural drainage pattern; site soils; surrounding land uses and traffic patterns, etc.)
- Pollution prevention to minimize contamination due to material exposure (zinc roofing, for example)
- Combination of infiltration and sedimentation unit processes in large-scale treatment train
- Critical source area treatment (storage areas, loading docks, etc.)

33

Case Study for Industrial Park Incorporating Stormwater Conservation Design

NORTH HUNTSVILLE CONSERVATION DESIGN INDUSTRIAL PARK

34

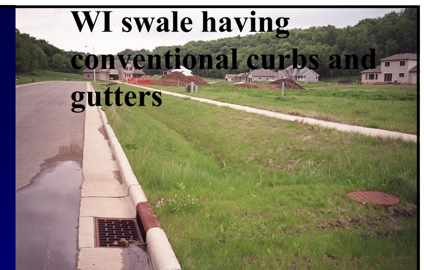
Conservation Design Elements used at the North Huntsville, AL, Industrial Park

- Grass filtering and swale drainages
- Modified soils to protect groundwater
- Wet detention ponds
- Bioretention and site infiltration devices
- Critical source area controls at loading docks, etc.
- Pollution prevention through material selection (no exposed galvanized metal, for example) and no exposure of materials and products.
- Berms and buffers around sink holes to prevent surface runoff from entering these direct connections to the groundwater.

35

Regional swales to collect site runoff and direct to wet detention ponds:

•Length: 1653 ft
•infiltration rate in the swale: 1 in/hr
•swale bottom width: 50 ft
•3H:1V side slopes
•longitudinal slope: 0.026 ft/ft
•Manning's n roughness coefficient: 0.024
•typical swale depth: 1 ft



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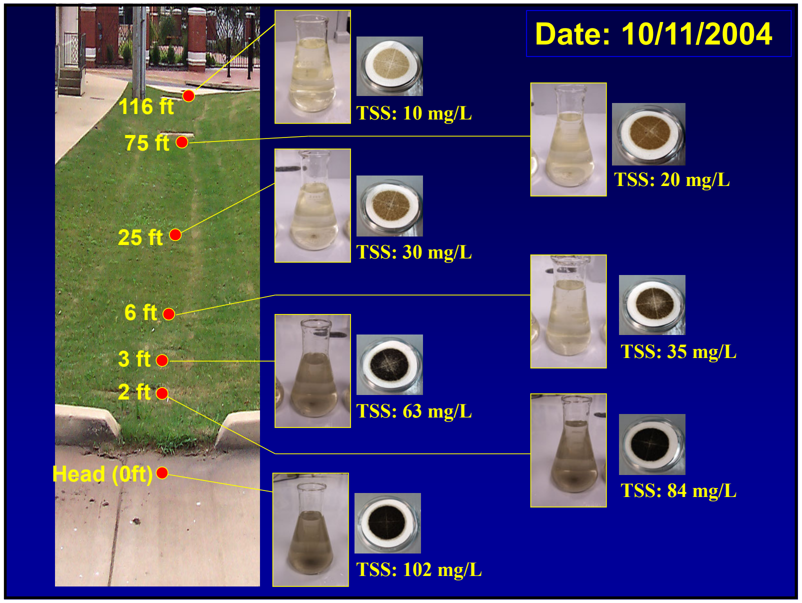
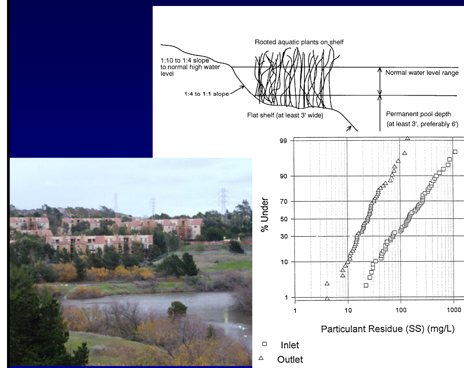


37

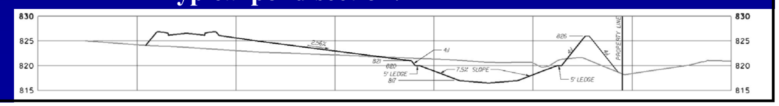
Wet Detention Ponds

The regional swales will direct excess water into the four ponds.



The pond surface areas vary from 0.5 to 1% of the drainage areas, depending on the amount of upland infiltration. The ponds have 3 ft. of standing water above 2 ft. of sacrificial storage. Additional storage volume provides necessary peak flow control.

Typical pond section:



38

Biofilters to drain site runoff (paved parking and roofs) to regional swales:

- Top area: 4400 ft^2
- Bottom area: 2000 ft^2
- Depth: 2 ft
- Seepage rate: 2 in/hr
- Peak to average flow ratio: 3.8
- Typical width: 10 ft
- Number of biofilters: 13 (one per site)

Parking lot biofilter example, Portland, OR

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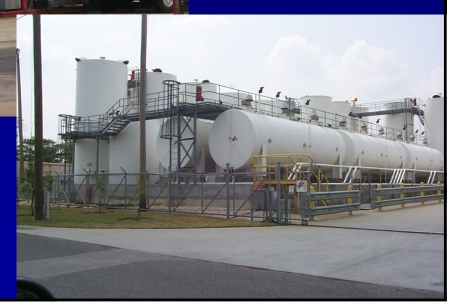
Critical Source Area Control

Covering fueling area



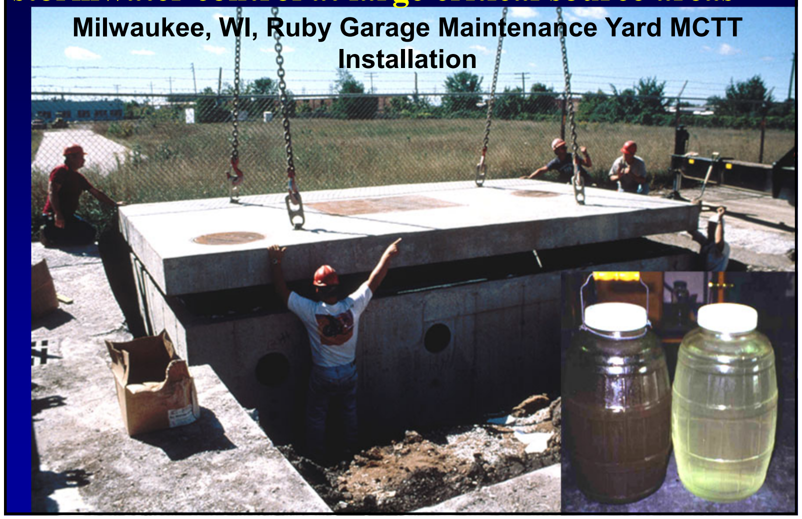
Berm around storage tanks

40

Large parking areas, convenience stores, and vehicle maintenance facilities are also usually considered critical source areas.

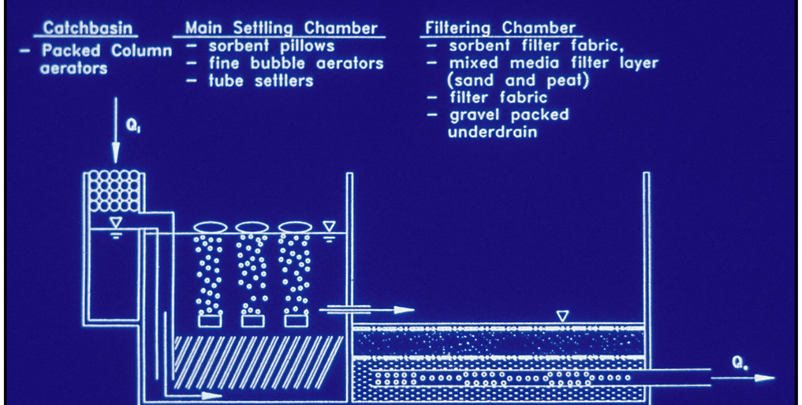
41

Multi-Chambered Treatment Train (MCTT) for stormwater control at large critical source areas



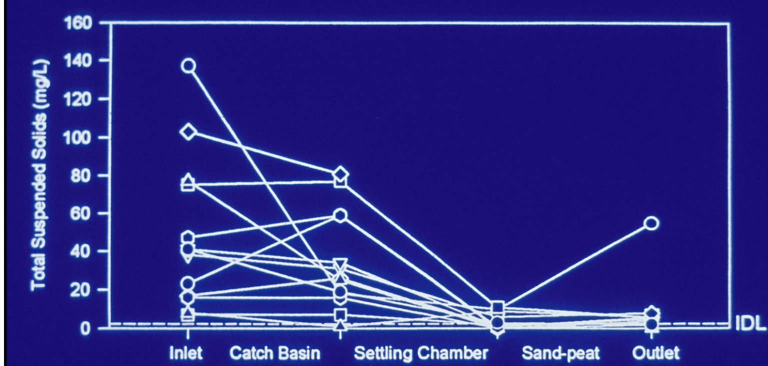
42

MCTT Cross-Section



43

Pilot-Scale Test Results



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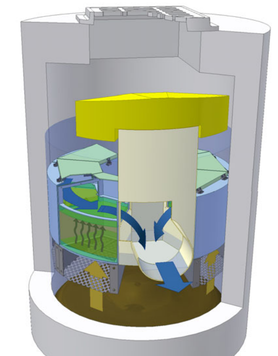
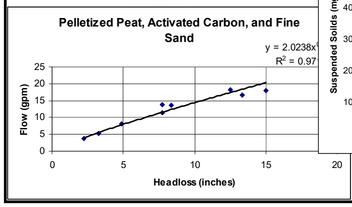
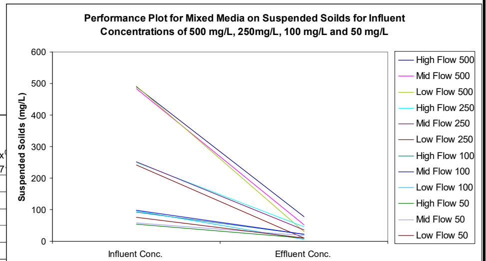
Upflow filter insert for catchbasins at smaller critical source areas



Able to remove particulates and targeted pollutants at small critical source areas. Also traps coarse material and floatables in sump and away from flow path.

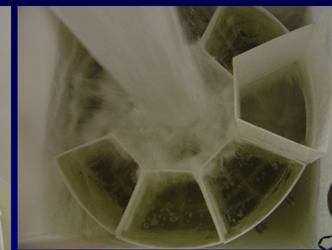
Hydro International, Ltd.



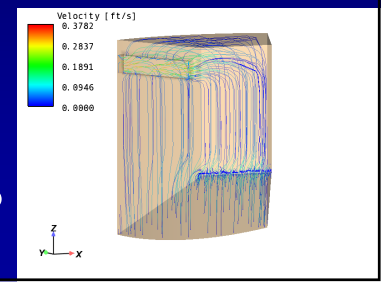


Hydraulic Characterization

Assembling Upflow Filter modules for lab tests

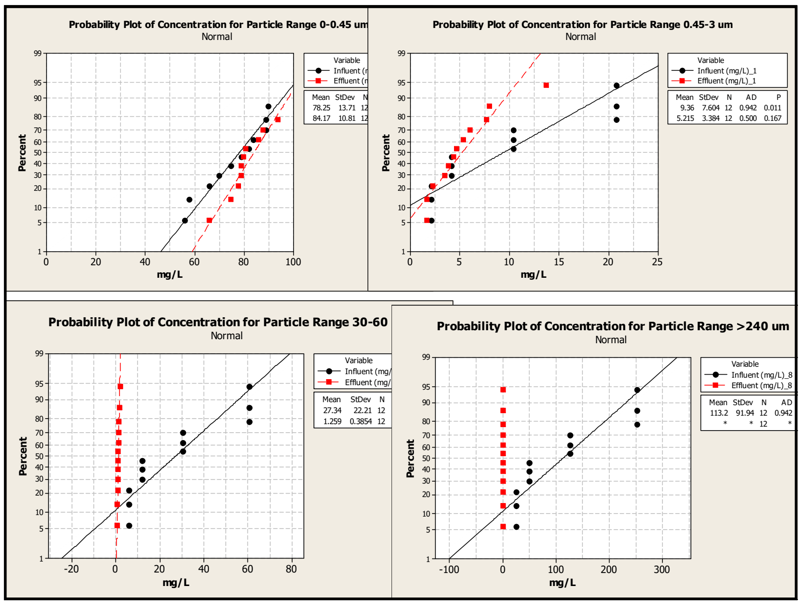


High flow tests



Initial CFD Model Results

Hydro International, Ltd.

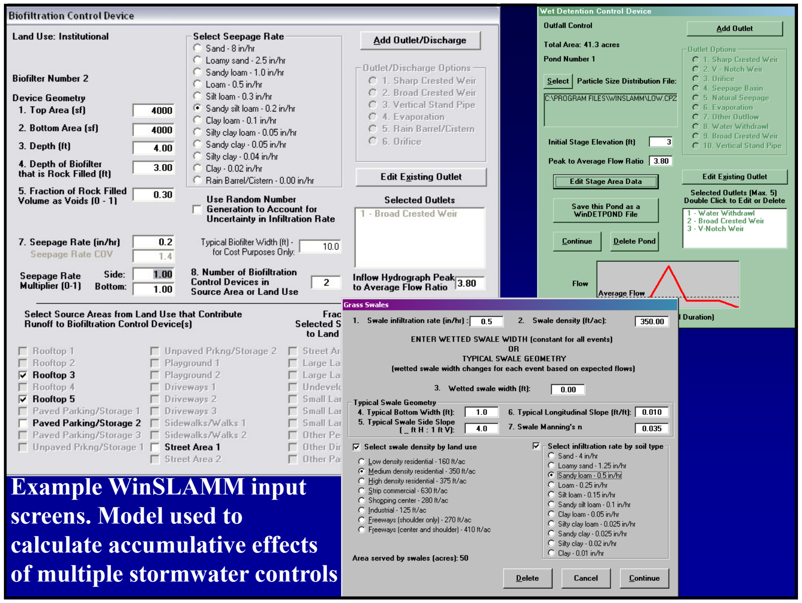


High Zinc Concentrations have been Found in Roof Runoff for Many Years at Many Locations

- Typical Zn in stormwater is about 100 µg/L, with industrial area runoff usually several times this level.
- Water quality criteria for Zn is as low as 100 µg/L for aquatic life protection in soft waters, up to about 5 mg/L for drinking waters.
- Zinc in runoff from galvanized roofs can be several mg/L

Penn State – Harrisburg test site

- Other pollutants and other materials also of potential concern.
- A cost-effective stormwater control strategy should include the use of materials that have reduced effects on runoff degradation.



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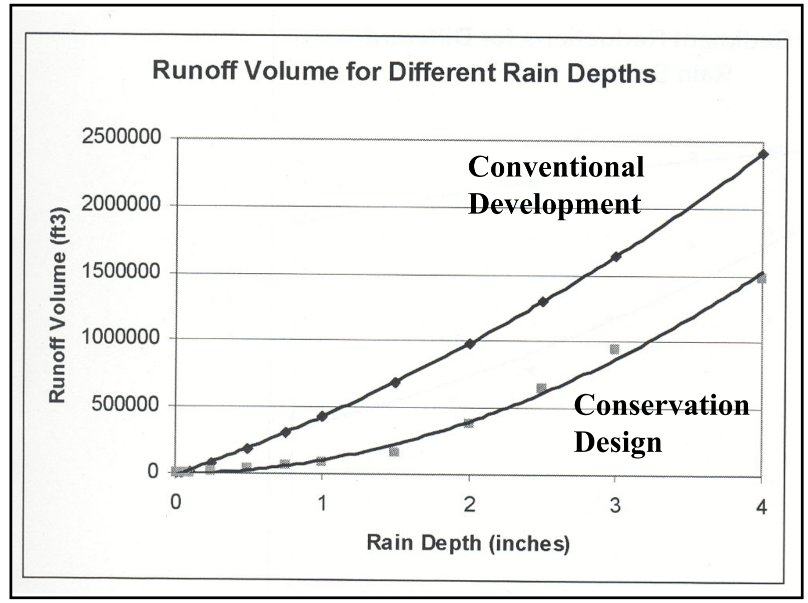

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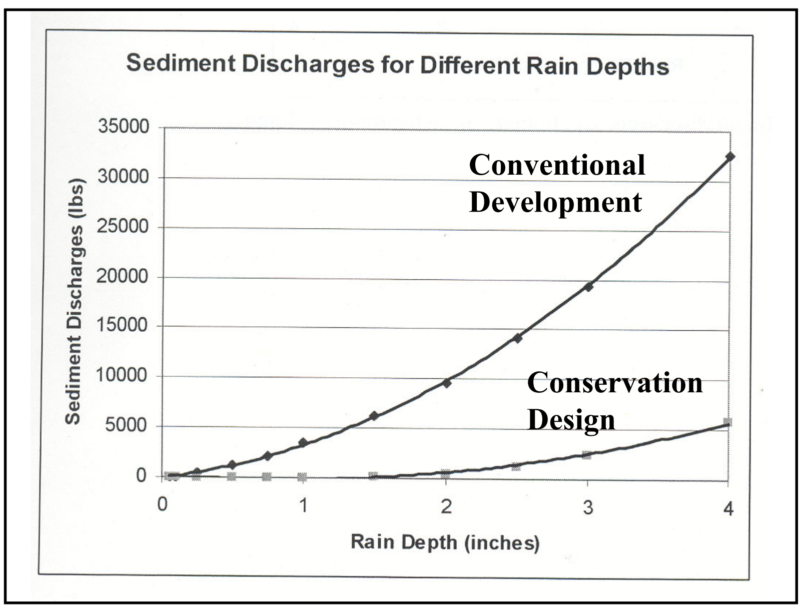

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Conclusions: Combinations of Controls Needed to Meet Many Stormwater Management Objectives

- Smallest storms should be captured on-site for reuse, or infiltrated
- Design controls to treat runoff that cannot be infiltrated on site
- Provide controls to reduce energy of large events that would otherwise affect habitat
- Provide conventional flood and drainage controls

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Acknowledgements

The support of the Tennessee Valley Authority (TVA), Economic Development Technical Services, and the Center for Economic Development and Resource Stewardship (CEDARS) of Nashville, TN supported the extensions to WinSLAMM to enable the use of a decision analysis framework in evaluating alternative stormwater management options. The Stormwater Management Authority of Jefferson County, AL, is also acknowledged for their recent support that enabled cost analyses to be added to WinSLAMM