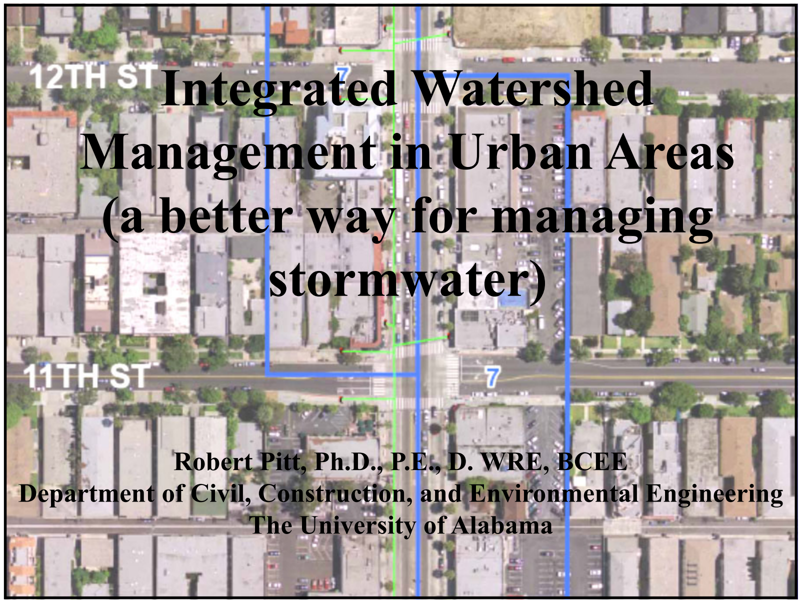


Integrated Watershed Management in Urban Areas (a better way for managing stormwater)

Robert Pitt, Ph.D., P.E., D. WRE, BCEE
Department of Civil, Construction, and Environmental Engineering
The University of Alabama

1

Presentation Topics

- Need for integration of urban water elements
- Problems that must be overcome
- Emerging approaches and new opportunities

2

Ancient springs at Delphi, Greece (site of Oracle) (bronze age center of the universe) – water has always been central to our culture

3

Typical Urban Receiving Water Problems

Photos of Coyote Creek, San Jose, CA

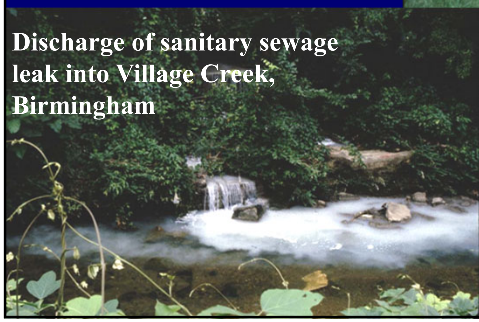
Extremes in Flows

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.

4

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

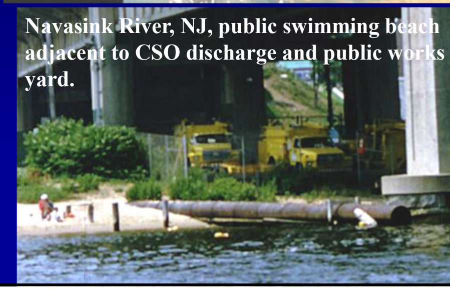
5

Urban Wildlife and Sewage Contamination

Potential health effects due to exposure to pathogens in urban receiving waters.

However, kids still play in urban creeks and swim near outfalls

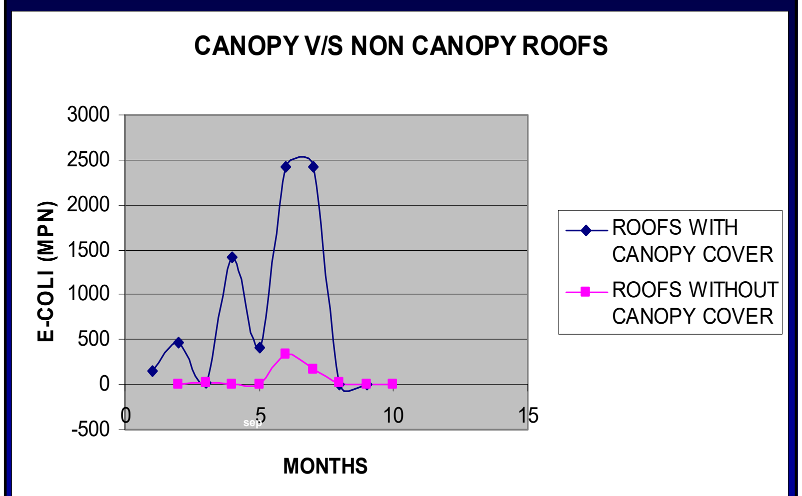
WI DNR photo



Navasink River, NJ, public swimming beach adjacent to CSO discharge and public works yard.

6

Sewage only source of urban water bacteria?



Canopy is tree overstory and habitat for birds and squirrels

7

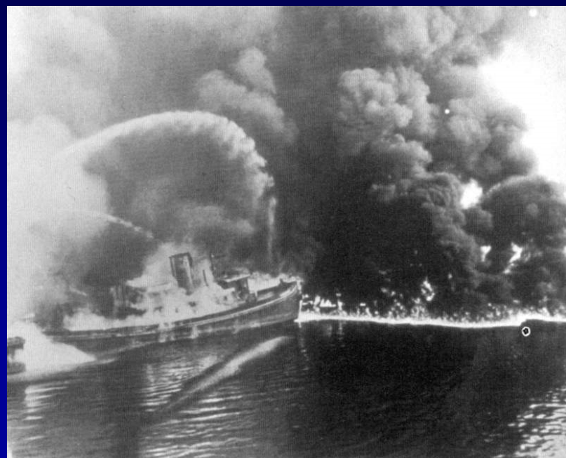
Transportation Accidents

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)

8

Cuyahoga River in Cleveland often Caught on Fire Between 1952 and 1969 (this embarrassment lead to the passage of the 1972 Clean Water Act)



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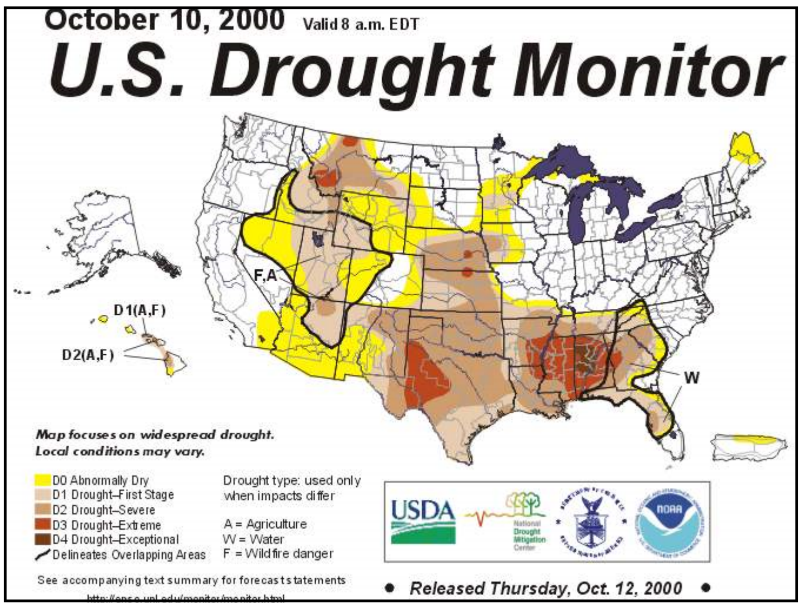
Fire from 200,000 gallons of spilled gasoline into an urban creek, Bellingham, Washington, 2000.

Bellingham News photos

10



11

Stormwater can be a Resource

Ponds and cisterns used 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).

12

Rain water tank to capture roof runoff for reuse (winery in Heathcote, Australia)

Tankage volume for 4,000 ft^2 roof (ft^3), Birmingham, AL	Fraction of annual roof runoff used for irrigation
1,000	56%
2,000	56
4,000	74
8,000	90
16,000	98

Cistern tank, Kamiros, Rhodes (ancient Greece, 7th century BC)

13

Combinations of Infiltration Controls to Reduce Runoff Volume

3.6 acre new residential area on Birmingham Southern College campus	Total Annual Runoff (ft^3/year)	Increase Compared to Undeveloped Conditions
Undeveloped	46,000	--
Conventional development	380,000	8.3X
Grass swales and walkway porous pavers	260,000	5.7
Grass swales and walkway porous pavers, plus roof runoff disconnections	170,000	3.7
Grass swales and walkway porous pavers, plus bioretention for roof and parking area runoff	66,000	1.4

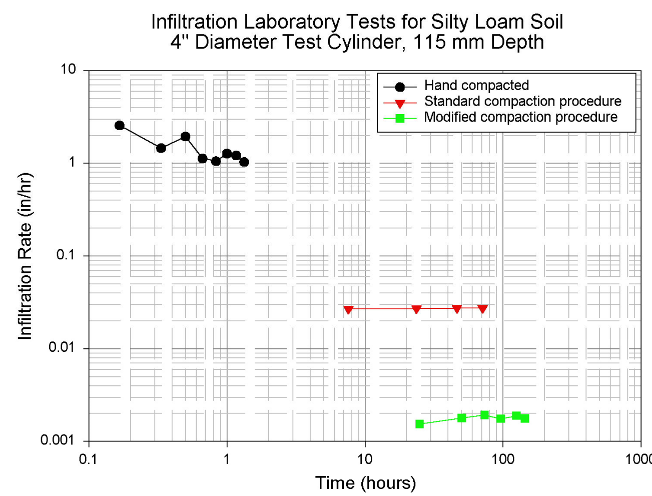
14

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**

15



However, infiltration severely limited by compaction and clogging of typical disturbed urban soils

16

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)

17

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

- 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.

18

"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.

19

- 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.

20

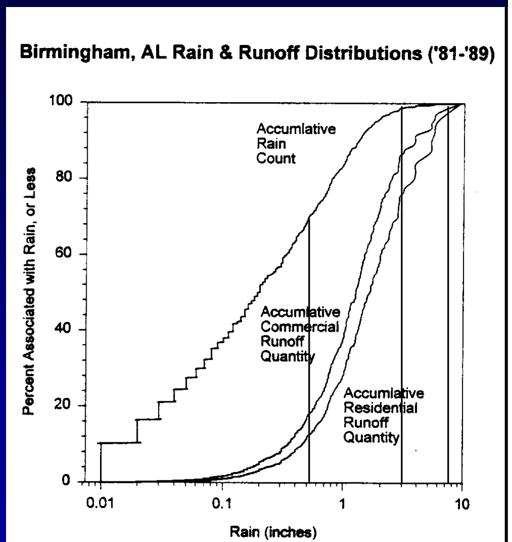
Probability distribution of typical Alabama rains (by count) and runoff (by depth).

<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)

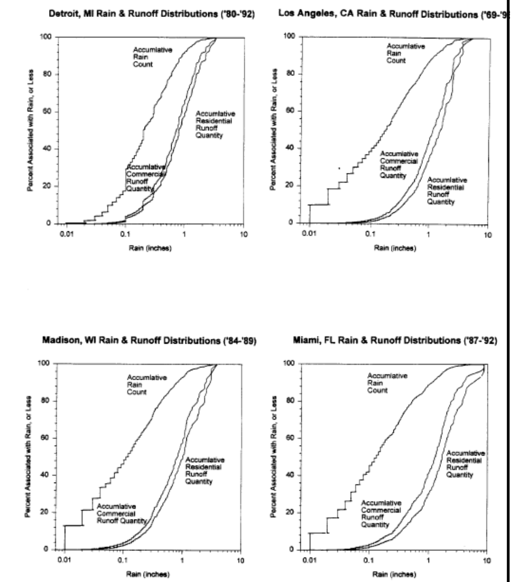
>8”: <0.1% or rains (2% or runoff)



EPA report on wet weather flows, Pitt, *et al.* 1999

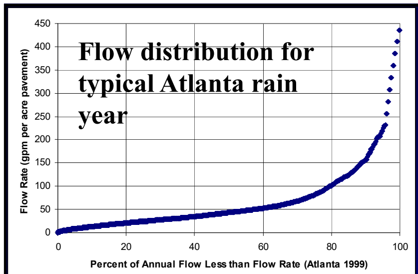
21

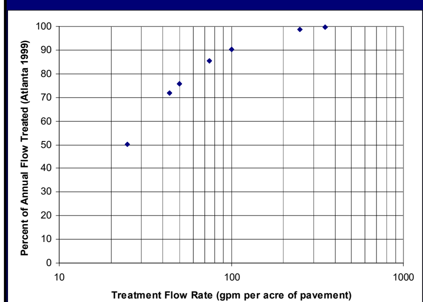
Same pattern in other parts of the country, just shifted.



Pitt, *et al.* (1999)

22





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

- 90% of the annual flow for SE US conditions is at 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.

23

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

24

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

25

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**

26

Disconnect impervious areas

Milwaukee, WI, examples from the early 1980s during watershed planning efforts

27

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

Street cleaner outside of the Palace of the Engineers, Moscow, Russia

28

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

29

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

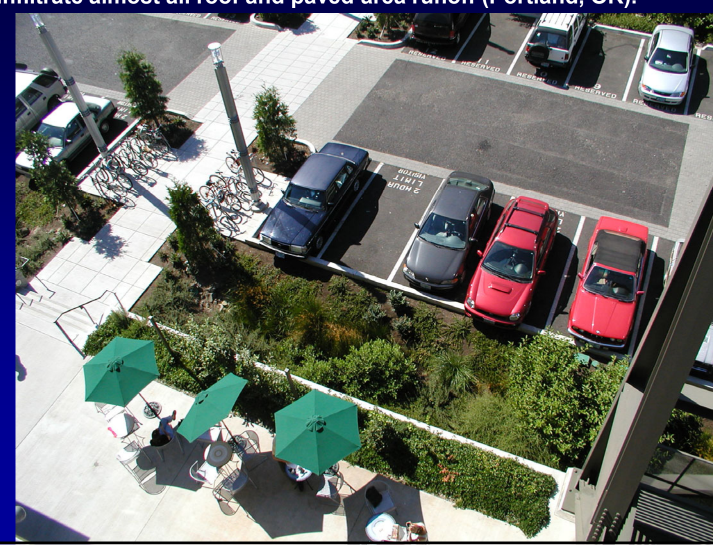
- **Initial portion will be captured/infiltrated by on-site controls or grass swales**
- **Remaining portion of runoff in this rain category should be treated to remove particulate-bound pollutants**

30

Rain Gardens can be Designed for Complete Infiltration of Roof Runoff

31

Bioretention areas can be located between buildings and parking areas to infiltrate almost all roof and paved area runoff (Portland, OR).



32

Calculated Benefits of Various Roof Runoff Controls (compared to typical directly connected residential pitched roofs)

Annual roof runoff volume reductions	Birmingham, Alabama (55.5 in.)	Seattle, Wash. (33.4 in.)	Phoenix, Arizona (9.6 in.)
Cistern for reuse of runoff for toilet flushing and irrigation (10 ft. diameter x 5 ft. high)	66	67	88%
Planted green roof (but will need to irrigate during dry periods)	75	77	84%
Disconnect roof drains to loam soils	84	87	91%
Rain garden with amended soils (10 ft. x 6.5 ft.)	87	100	96%

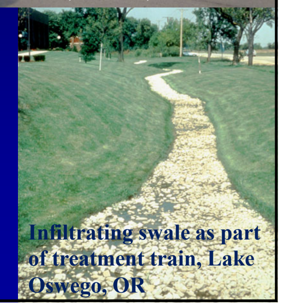
There are therefore a number of potential controls for roof runoff, from the conventional to the unusual, that can result in large runoff reductions.

33

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

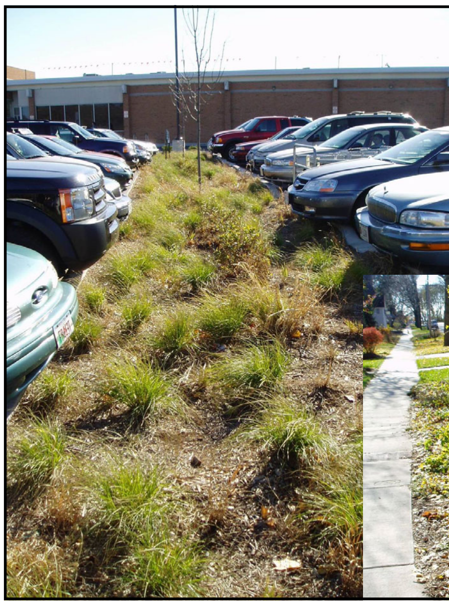

Edison Museum, Detroit, MI

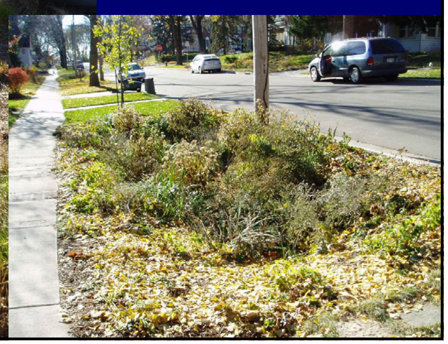

Berlin, Germany


Infiltrating swale as part of treatment train, Lake Oswego, OR

34

Recent Bioretention Retrofit Projects in Commercial and Residential Areas in Madison, WI





35

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


Essen, Germany


Malmo, Sweden


Madison, WI

36

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

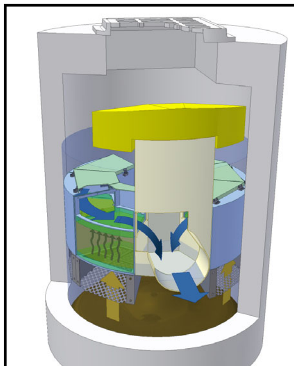
One of the original sand filters in Austin, TX

Pre-treatment pond before infiltrating swale, Lake Oswego, OR

Multi-chambered treatment train (MCTT), Minocqua, WI

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

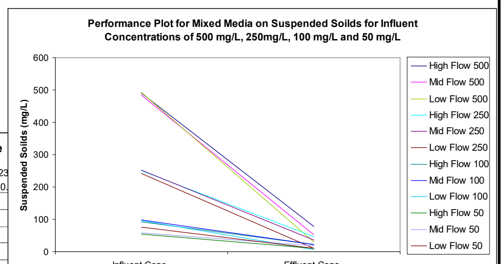
Milwaukee, WI, Ruby Garage Maintenance Yard MCTT Installation

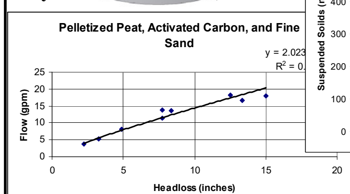


Hydro International, Ltd.

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.





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

Stormwater drainage channels in the Agora, Athens, Greece, built by Peistratus in the 6th century, BC and still working today.

41

Excavation of ancient Roman stormwaterdraiange pipes, Rome (about 100 AD)

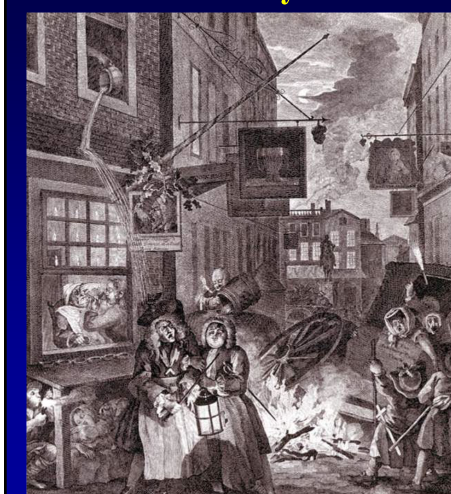
J. Harper photo

42

Our approach to urban drainage can be devastating to the environment, including recharge of groundwaters

43

One Early Method of Getting Rid of Sanitary Wastewater



Sanitary wastewater conveyance has only been around since the late 1800s with the introduction of the flush toilet (invented by Thomas Crapper). People dumped wastes into gutters, ditches, and out open windows, with the assumption that dogs and pigs would eat it, or be washed off during rains. People started wearing hats at this time….

"Sewer" is from the old English for "seaward."

44

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

MD and WI DNR photos

45

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

46

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

Leeds, AL, wastewater treatment plant, SSO storage tank

Golf courses can provide large volumes of storage.

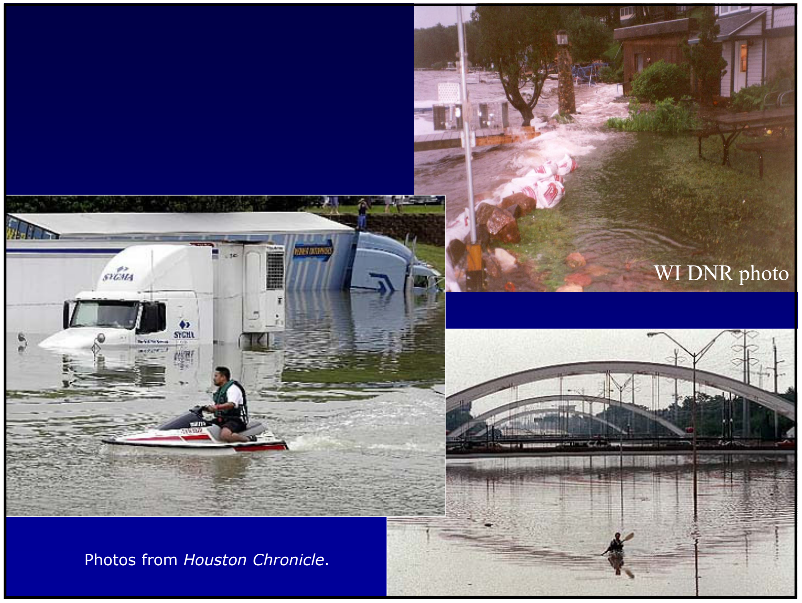
Madison, WI

47

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)

48



Photos from *Houston Chronicle*.

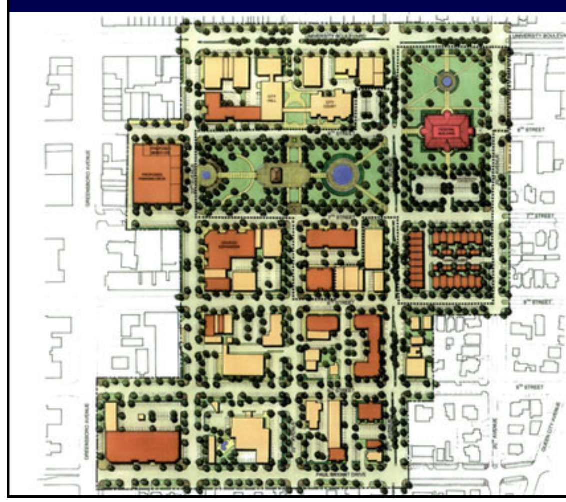
Controls for Treatment of Runoff from Very Large Events (> 8 in.)

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

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 (roofing, for example)
- Combination of infiltration and sedimentation unit processes in large-scale treatment train
- Critical source area treatment (storage areas, loading docks, etc.)

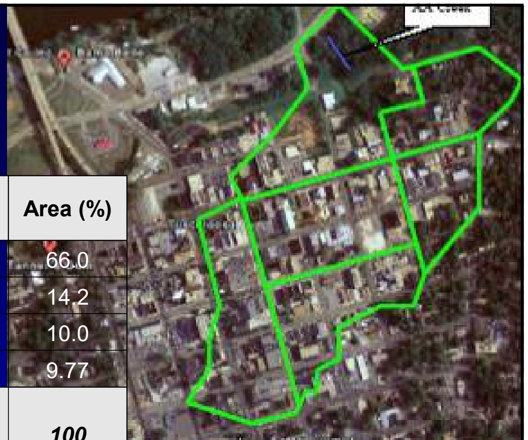
Downtown Tuscaloosa Redevelopment



DOWNTOWN TUSCALOOSA

Conducted a preliminary evaluation of the downtown Tuscaloosa area that contains the redevelopment sites.

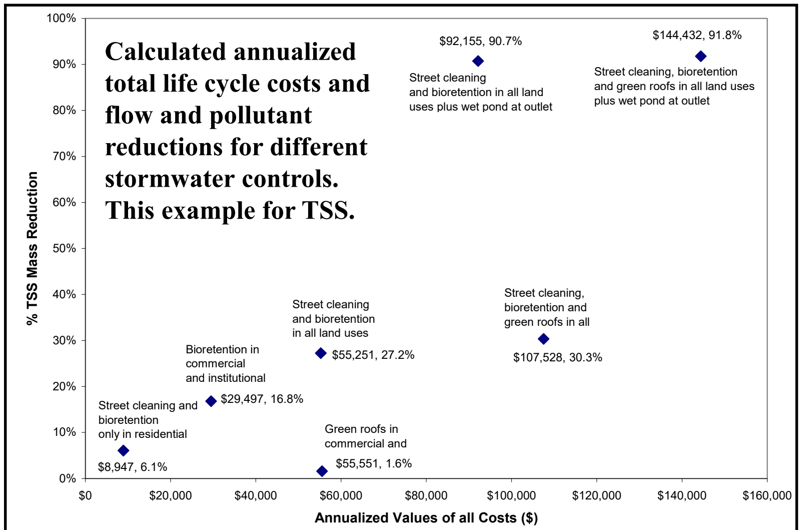
Land Use	Area (ac)	Area (%)
Commercial	72.9	66.0
Residential	15.7	14.2
Institutional	11.0	10.0
Other	10.8	9.77
TOTAL	***110***	***100***



Soils are mostly hydrologic group B and are classified as silt or loam, having typical infiltration rates of about 0.5 in/hr, although most of the soils are highly disturbed and will need to be restored.

53

Calculated annualized total life cycle costs and flow and pollutant reductions for different stormwater controls. This example for TSS.



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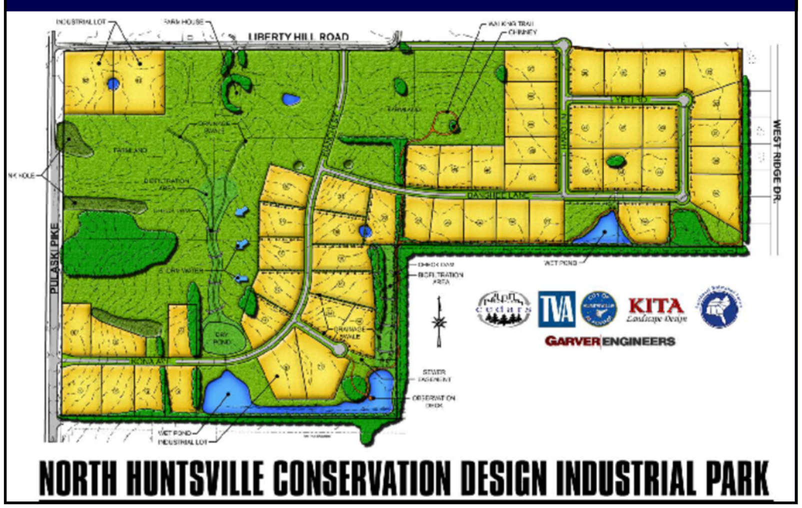
Case Study for Industrial Park Incorporating Stormwater Conservation Design



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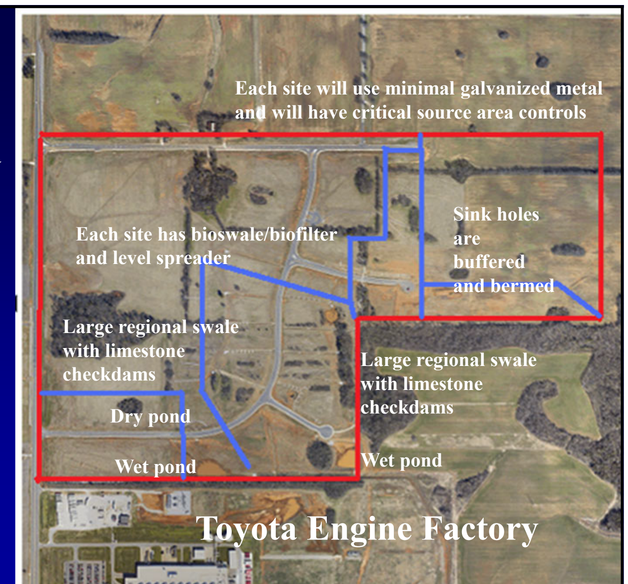
The North Huntsville Industrial Park is a new development of 250 acres with 50 lots, each about 2 to 4 acres.



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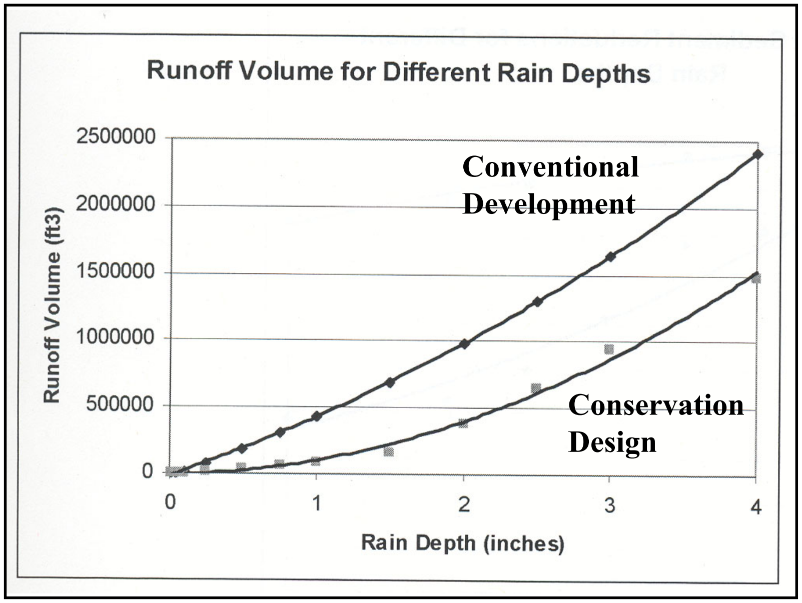
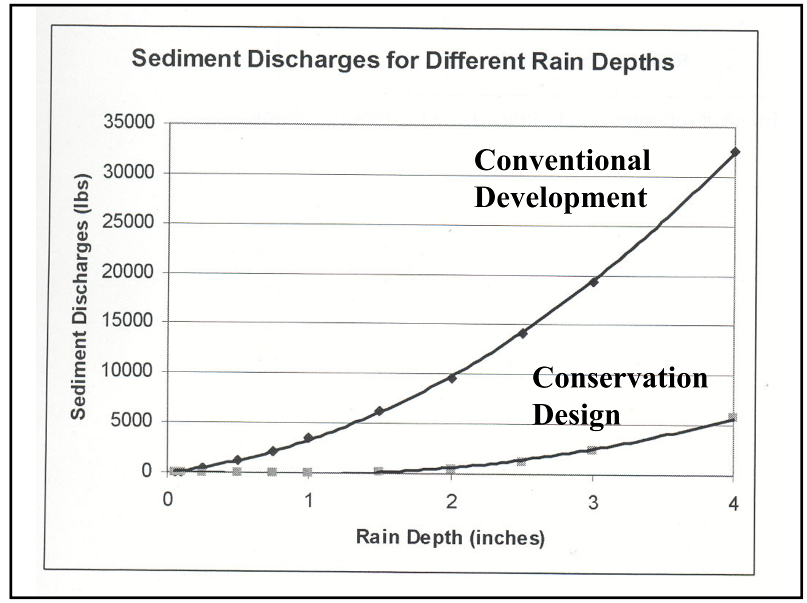

Runoff Volume for Different Rain Depths
Runoff Volume (ft3)
2500000
2000000
1500000
1000000
500000
0
0
1
2
3
4
Rain Depth (inches)
Conventional Development
Conservation Design

57


Sediment Discharges for Different Rain Depths
Sediment Discharges (lbs)
35000
30000
25000
20000
15000
10000
5000
0
0
1
2
3
4
Rain Depth (inches)
Conventional Development
Conservation Design

58


Cedar Hill Site Design, Crossplains WI
Explanation
Wetpond
Infiltrations Basin
Swales
Sidewalk
Driveway
Houses
Lawns
Roadway
Woodlot
N
500 0 500 1000 Feet

59


Grass Swales
Wet Detention Pond
Infiltration Basin/Wetland
Reduced Street Width
WI DNR photos

60

Reductions in Runoff Volume for Cedar Hills (calculated using WinSLAMM and verified by site monitoring)

Type of Control	Runoff Volume, inches	Expected Change (being monitored)
Pre-development	1.3	
No Controls	6.7	515% increase
Swales + Pond/wetland + Infiltration Basin	1.5	78% decrease, compared to no controls 15% increase over pre-development

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Performance of Controls at Cross Plains Conservation Design Development

Water Year	Construction Phase	Rainfall (inches)	Volume Leaving Basin (inches)	Percent of Volume Retained (%)
1999	Pre-construction	33.3	0.46	99%
2000	Active construction	33.9	4.27	87%
2001	Active construction	38.3	3.68	90%
2002	Active construction (site was approximately 75% built-out)	29.4	0.96	97%

WI DNR and USGS data

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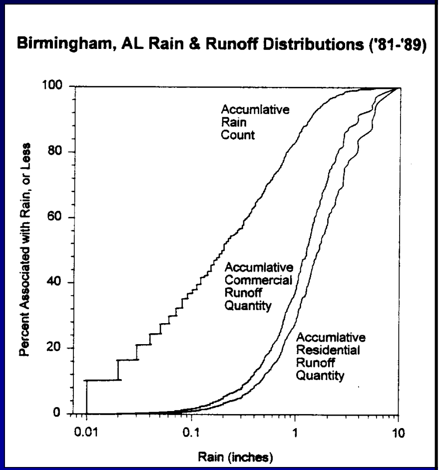
Combinations of Controls Needed to Meet Many Stormwater Management Objectives

- 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 flooding and drainage controls



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