Effects of Stormwater Runoff from New Development

Robert Pitt, Ph.D., P.E., D.WRE, BCEE
Department of Civil, Construction, and Environmental Engineering
University of Alabama
Tuscaloosa, AL, USA 35487

Presentation based on material further discussed in: Burton, G.A. Jr., and R. Pitt. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Photo by Lovena, Harrisburg, PA

1

Stormwater Management Steps

- Identify beneficial use impairments
- Identify causes of impairments
- Identify sources (magnitude, seasonality, flow phases, etc.) of problem constituents
- Identify, select, and design controls suitable for problem pollutants and locations
- Implement controls, conduct validation monitoring, modify controls as needed

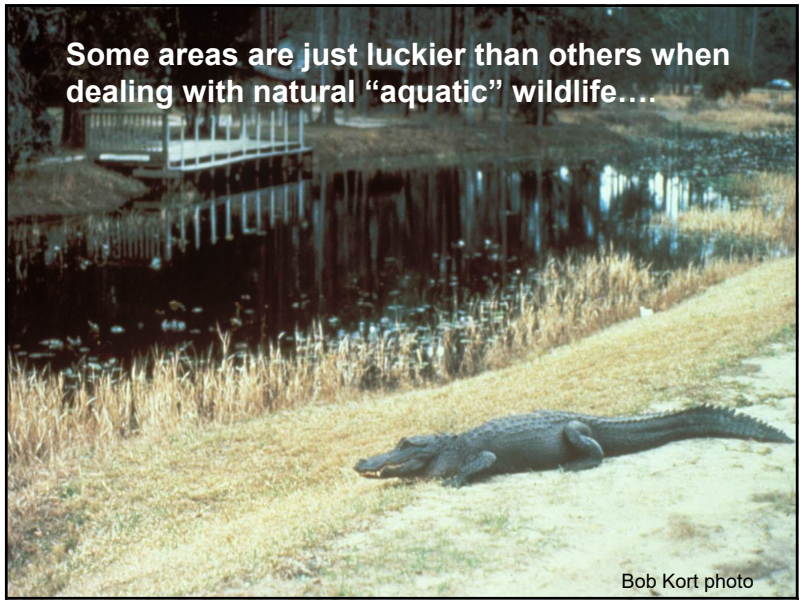
2

Major Receiving Water Beneficial Uses

- Stormwater Conveyance (flood prevention)
- Recreation (non-water contact) Uses
- Biological Uses (Warm water fishery, aquatic life use, biological integrity, etc.)
- Human Health Related Uses (Swimming, Fishing, and Water Supply)

3

4



5

Basic Goals for Urban Streams

- Stormwater conveyance and aesthetics should be the basic beneficial use goals for all urban waters.
- Biological integrity should also be a goal, but with the realization that the natural stream ecosystem will be severely modified with urbanization.
  - "Biological integrity is the capacity to support and maintain a balanced, integrated and adaptive biological system having the full range of elements [the form] and process [the function] expected in a region's habitat." James Karr 1991, modified

6

- Certain basic stormwater controls at the time of development, plus protection of stream habitat, may enable partial use of some of these goals in urbanized watersheds.
- Water contact recreation, consumptive fisheries, and water supplies are not appropriate goals for most heavily urbanized watersheds.

7

Receiving Water Effects of Water Pollutant Discharges

- **Sediment (amount and quality)**
- **Habitat destruction (mostly through high flows [energy] and sedimentation)**
- **Eutrophication (nutrient enrichment)**
- **Low dissolved oxygen (from organic materials)**
- **Pathogens (mostly from municipal wastewater and agricultural runoff)**
- **Toxicants (heavy metals and organic toxicants)**
- **Temperature**
- **Debris and unsafe conditions**
- **etc.**

8

Sediment transported in stormwater causes significant receiving water impacts.

9

Construction Site Erosion Adversely Affects Real Estate Sales

10

Extremes in Flows cause Infrastructure Damage and Habitat Destruction

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.

11

12

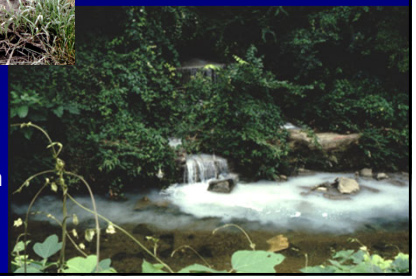
Historical approach to urban drainage has been devastating to the environment and local hydrology (especially recharge of groundwaters)

WI DNR photo

13

Bacteria Sources

Bacteria sources include sewage, in addition to substantial urban wildlife and pet contributions



14

We have known about these problems for many years:

Beach Closings in the US in 1994 (*Water Envir. & Tech*. 1995)

Sanitary Sewer Overflows (SSOs)	584 (43%)
Stormwater Runoff	345 (25%)
Combined Sewer Overflows (CSOs)	194 (14%)
Agricultural Runoff	136 (10%)
Wastewater Treatment Plant Malfunctions	106 (7.8%)

15

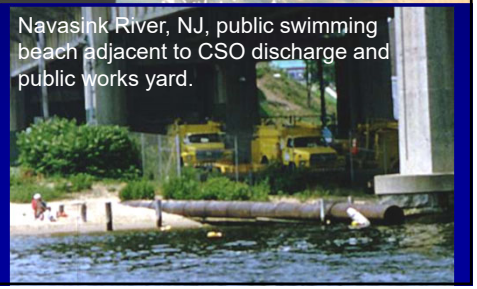
Urban Wildlife and Sewage Contamination

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.



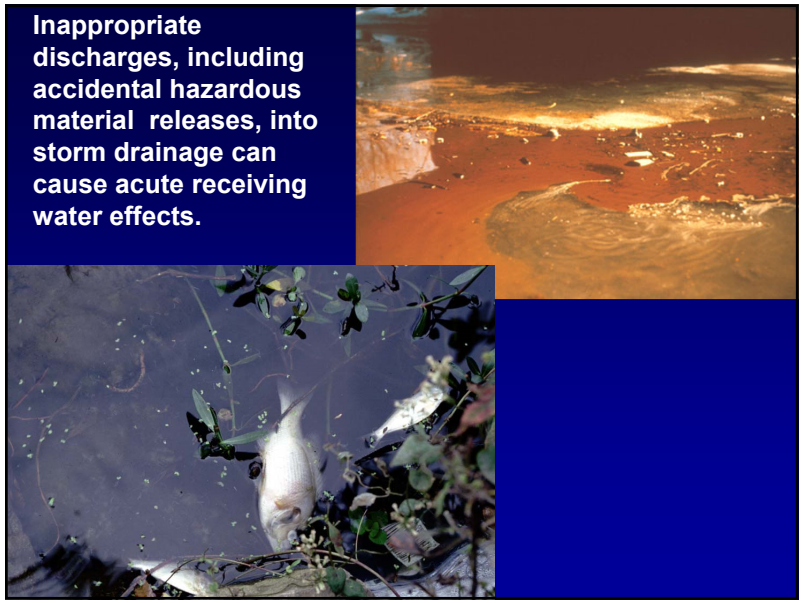
16

WI DNR photos

Eutrophication dramatically detracts from recreational uses, along with affecting aquatic life

17

Inappropriate discharges, including accidental hazardous material releases, into storm drainage can cause acute receiving water effects.



18

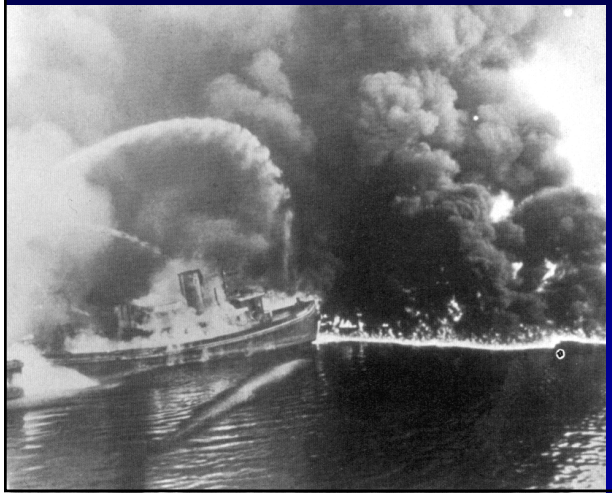
Transportation Accidents

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)

19

Cuyahoga River in Cleveland Often Caught on Fire Between 1952 and 1969



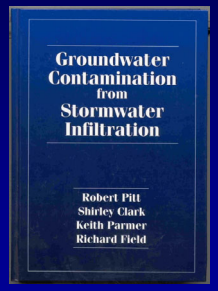
This embarrassment lead to the Clean Water Act of 1972

Coombs and Boucher

20

Groundwater Contamination

The potential for groundwater contamination associated with stormwater infiltration needs to be considered.



Book published by Ann Arbor Press/CRC, 219 pages. 1996, based on EPA research and NRC committee work.

Road cut showing direct recharge pathways to Edwards Aquifer, Austin, TX

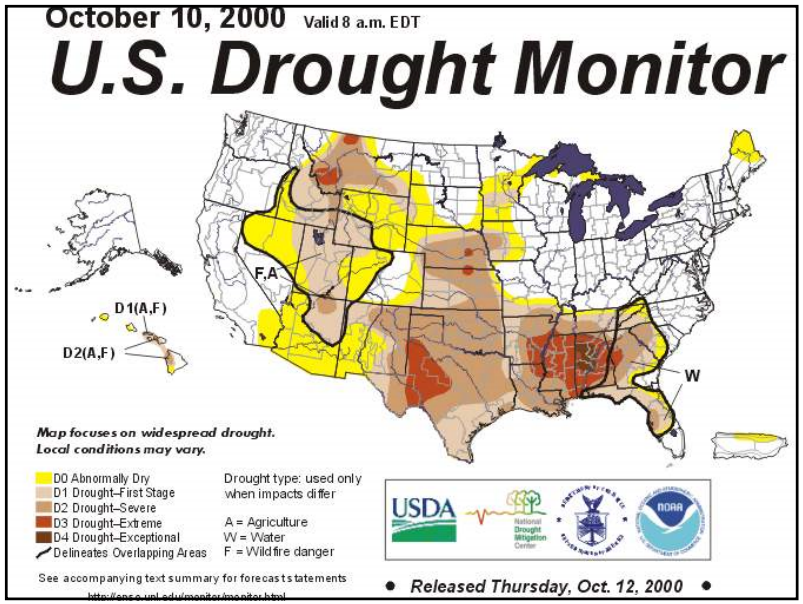
http://civil.eng.ua.edu/~rpitt/Publications/BooksandReports/Groundwater%20EPA%20report.pdf

21

Moderate to High Groundwater Contamination Potential

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

22



23

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.

Auckland, New Zealand

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).

24

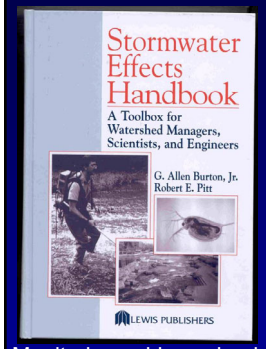
Rain water tank to capture roof runoff for reuse (winery in Heathcote, Australia)

Water volume storage Kansas City, MO (ft^3 of storage per ft^2 roof area)	Percentage of annual roof runoff used for irrigation to meet ET needs
0.01	29%
0.02	39
0.05	56
0.12	74
0.50	99

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

25

Evaluation Monitoring



Monitoring guidance book published by CRC Press, August 2001. 911 pgs. Contains many evaluation monitoring case studies.

- What is going on in the receiving water?
- What are "natural" conditions?
- What conditions should be expected for your specific conditions?
- What is a good "control" for comparison?
- Is the receiving water responding to improved stormwater management?

26

Basic Study Approach to Quantify Receiving Water Problems using Reference Conditions

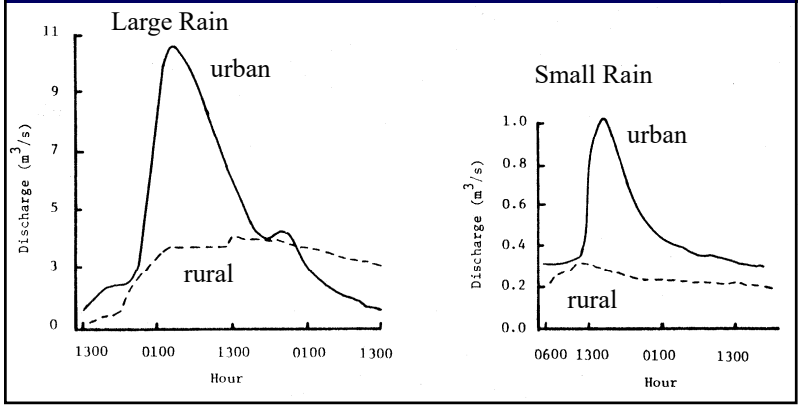
Experimental designs can be organized in one of the following basic patterns:

1. Parallel watersheds (developed and undeveloped)
2. Upstream and downstream of a city
3. Long-term trend

Preferably, most elements of all of the above approaches can be combined in a staged approach for the same area.

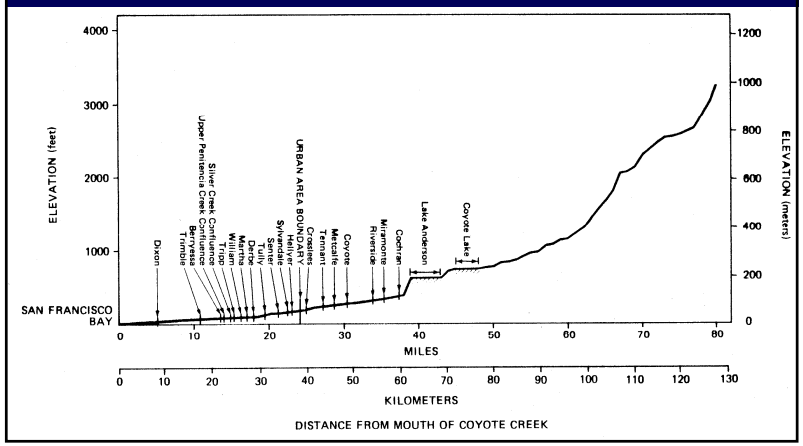
27

Parallel Stream Study (urban and rural stream) (Bellevue, WA)



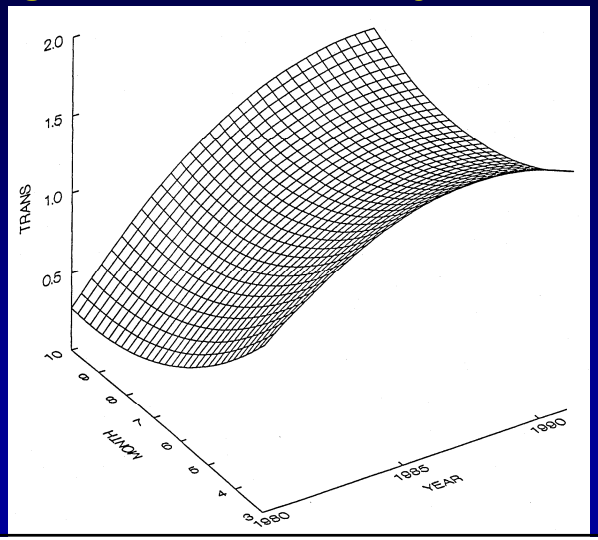
28

Longitudinal Trend Study (above and below city) (San Jose, CA)



29

Long-Term Trend Study (Sweden)



30

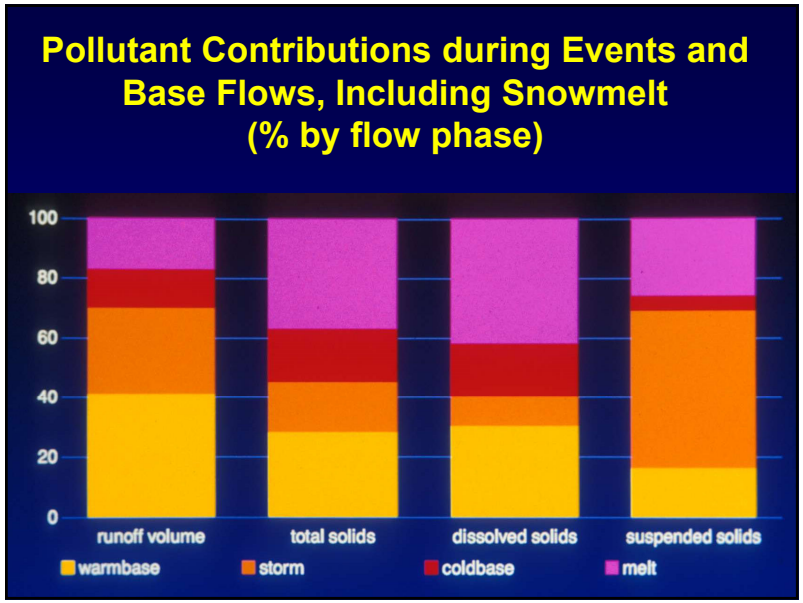
Outfall Monitoring to Characterize Stormwater

31

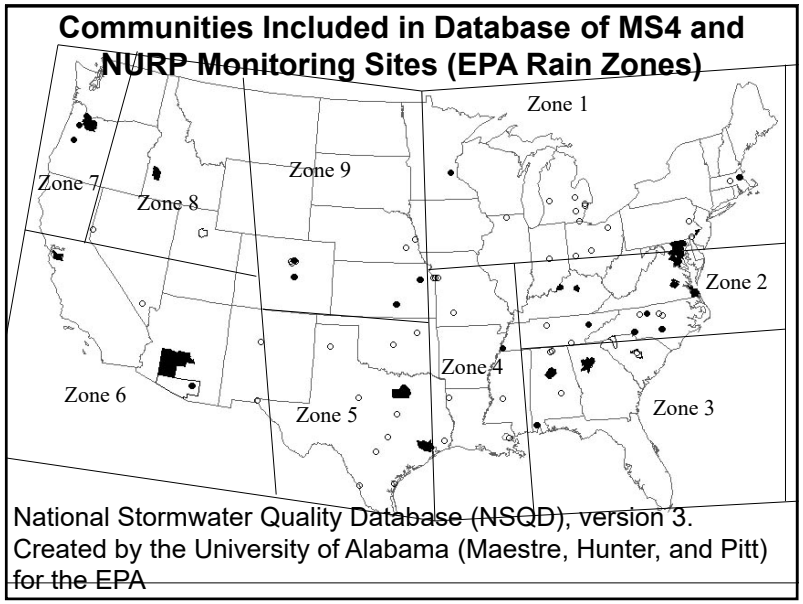
Sheetflow Monitoring to Calibrate Models to Identify Sources of Stormwater Pollutants

32

33

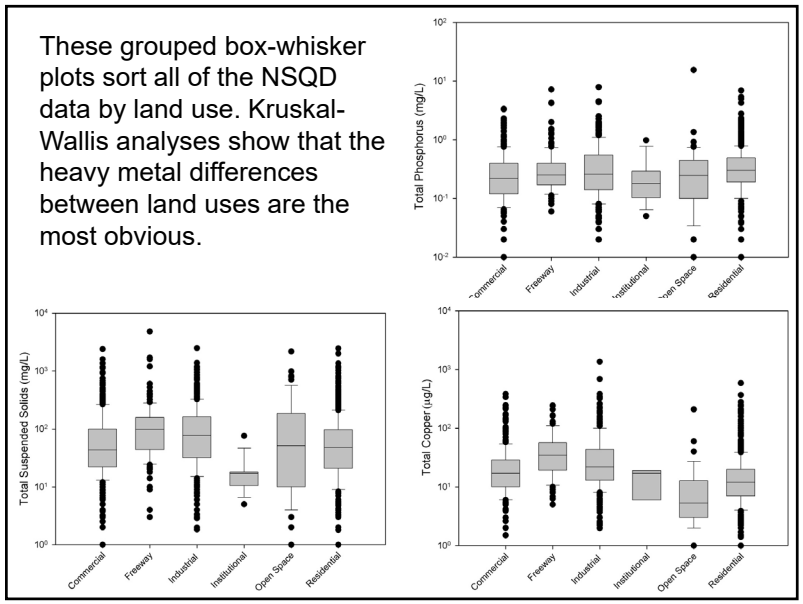


34



35

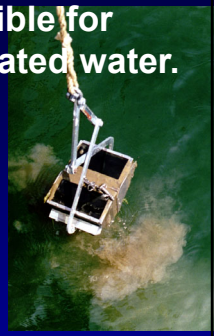
These grouped box-whisker plots sort all of the NSQD data by land use. Kruskal-Wallis analyses show that the heavy metal differences between land uses are the most obvious.



36

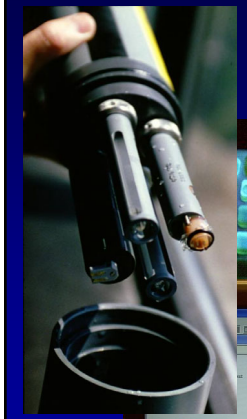
Contaminated sediments in urban receiving waters likely much more responsible for biological impacts than contaminated water.

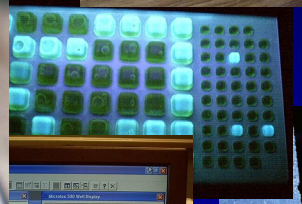
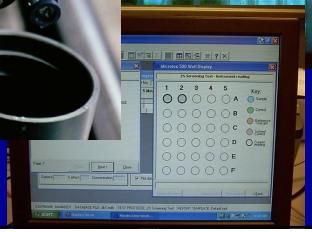


37

We are Evaluating New Analytical Methods to Reduce Monitoring Costs and to Provide Better Data

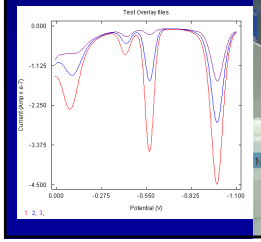



38

We are Developing New Applications for Advanced Instrumentation



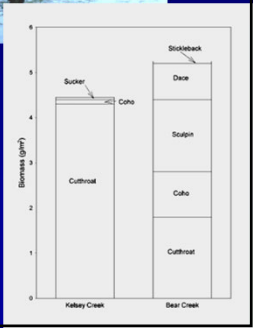



39

Fish surveys in urban streams typically find similar biomass as in control streams, but sensitive native fish have been displaced by hardy exotics

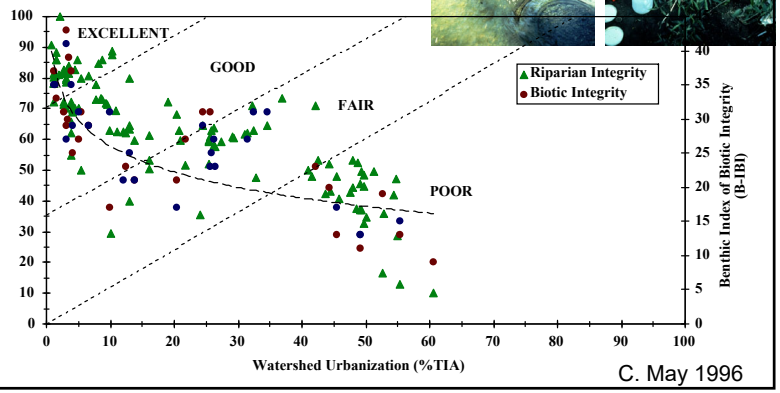


WI DNR photo



40

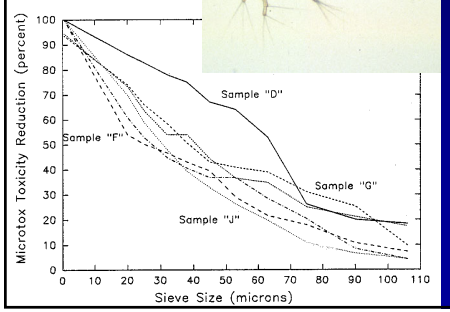
Benthic macroinvertebrate populations on natural and artificial substrates have been extensively used to indicate receiving water effects.



C. May 1996

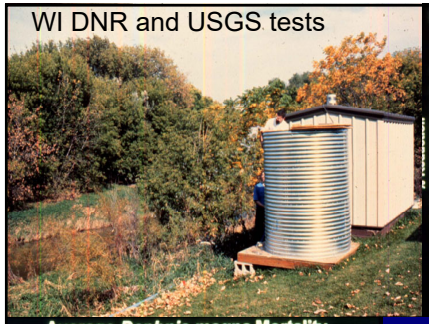
41

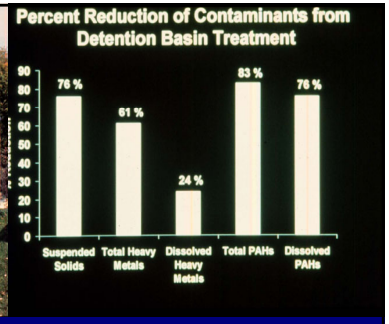
Toxicity tests using stormwater find much of the toxicity associated with small particulates, not just filtered portions of the water.

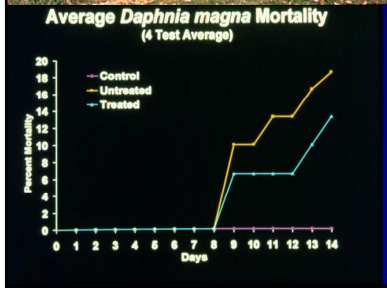


42

WI DNR and USGS tests

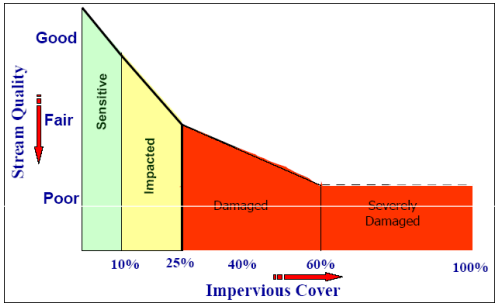






Side-stream bioassay tests demonstrated the benefits of stormwater controls for the removal of fine particulates. Residual toxicity remains, however.

43

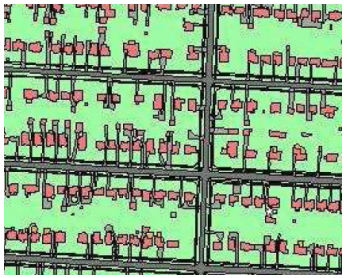


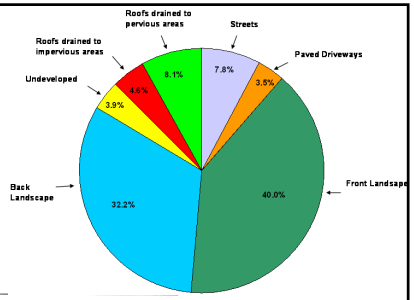
It is possible to simplify much of the receiving water biological data to relate degradation to levels of development.

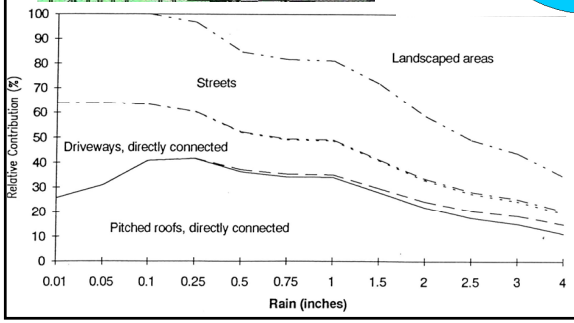
Urban Steam Classification	Sensitive 0 – 10% Imperviousness	Impacted 11– 25% Imperviousness	Damaged 26–100% Imperviousness
Channel Stability	Stable	Unstable	Highly Unstable
Aquatic Life Biodiversity	Good/Excellent	Fair/Good	Poor

Figure and Table from Center for Watershed Protection

44



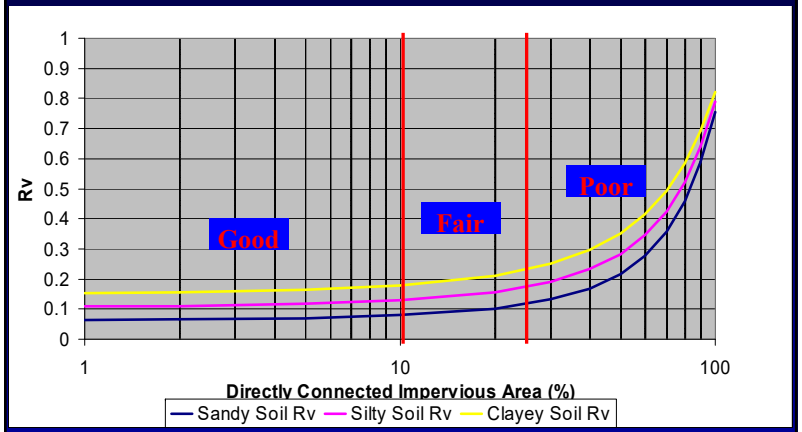




Measuring the development characteristics for an area enables us to model sources of stormwater contaminants and to better develop controls relating to receiving water objectives.

45

Volumetric Runoff Coefficients and Expected Biological Conditions



Based on modeling several hundred neighborhoods representing many land uses in Jefferson Co, AL. Can now calculate the expected effects and magnitude of needed changes to achieve targeted conditions.

46

Conclusions

- We can learn from the past several decades of receiving water investigations
- Problems are site specific and require sequential investigations
- Must use combinations of study components, including:
  - habitat evaluations,
  - rainfall and flow (and snowmelt) monitoring,
  - chemical, and biological monitoring, and
  - toxicity investigations

47

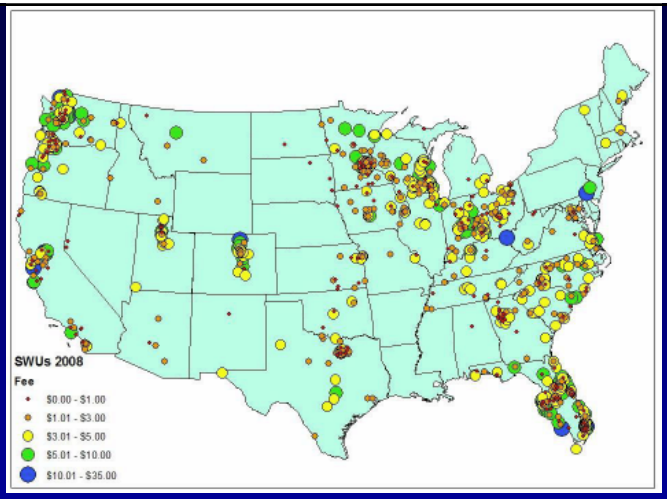
Conclusions (continued)

- Must evaluate both sediment and water in most cases
- All flow phases (dry and wet weather) and seasons (including snowmelt) may be important
- May require extensive and long-term effort to obtain data with small uncertainty
- Need to balance resources with study objectives

48

A couple of last thoughts from the recent National Research Council, National Academy of Science committee report on *Stormwater Management in the United States*:

- Enormous potential for improvements: projections are that about 40% of urban land will be redeveloped by 2030.
- Current program funding for wastewater is much greater than for stormwater, even though there are 5 times more stormwater permitees. Additional resources for program implementation could come from shifting existing programmatic resources. However, securing new levels of public funds will likely be required.



Distribution of stormwater utility fees, $/capita/month (Western Kentucky University Stormwater Utility Survey, Campbell and Back 2008)