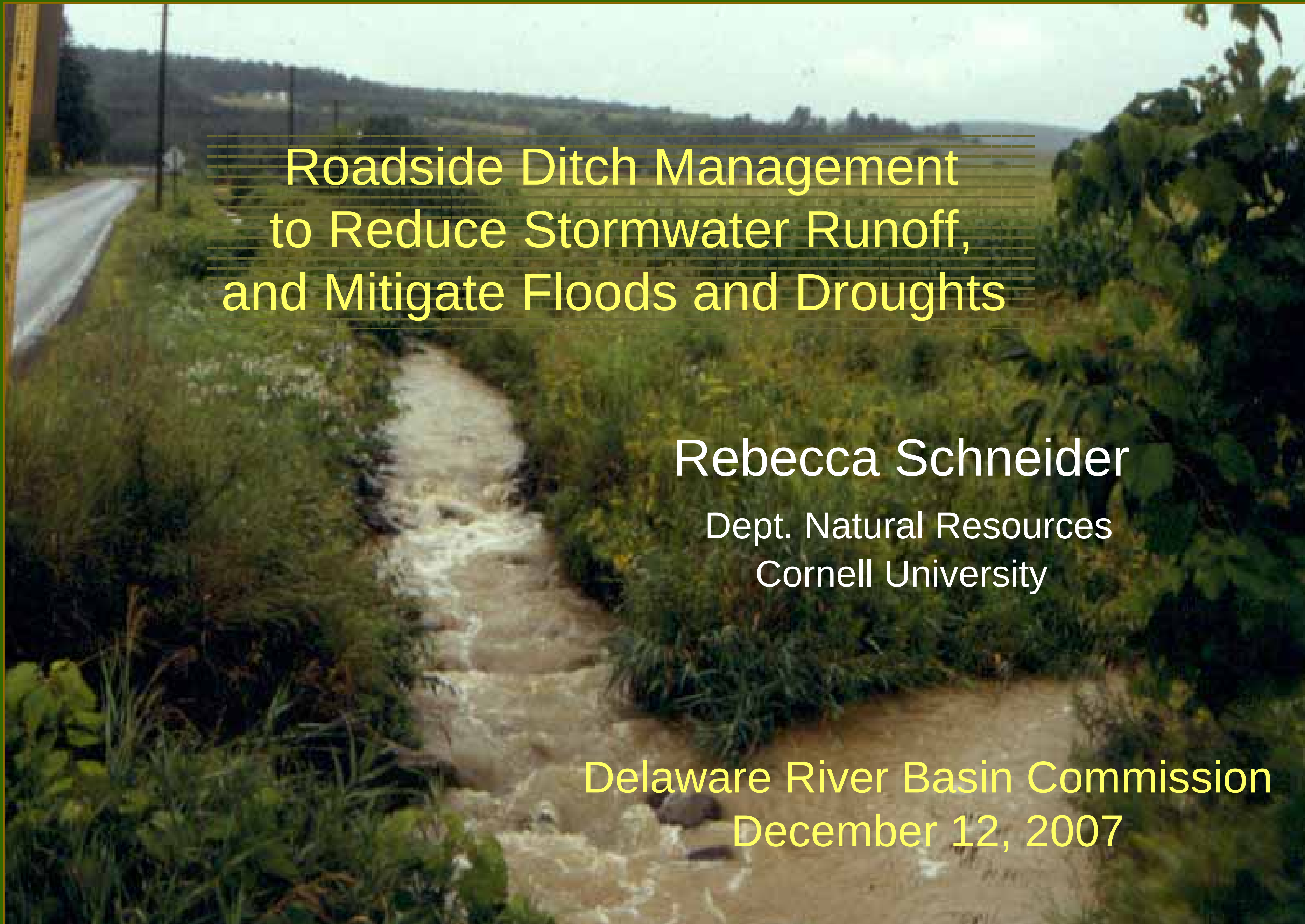


Roadside Ditch Management to Reduce Stormwater Runoff, and Mitigate Floods and Droughts

Rebecca Schneider

Dept. Natural Resources
Cornell University

Delaware River Basin Commission
December 12, 2007

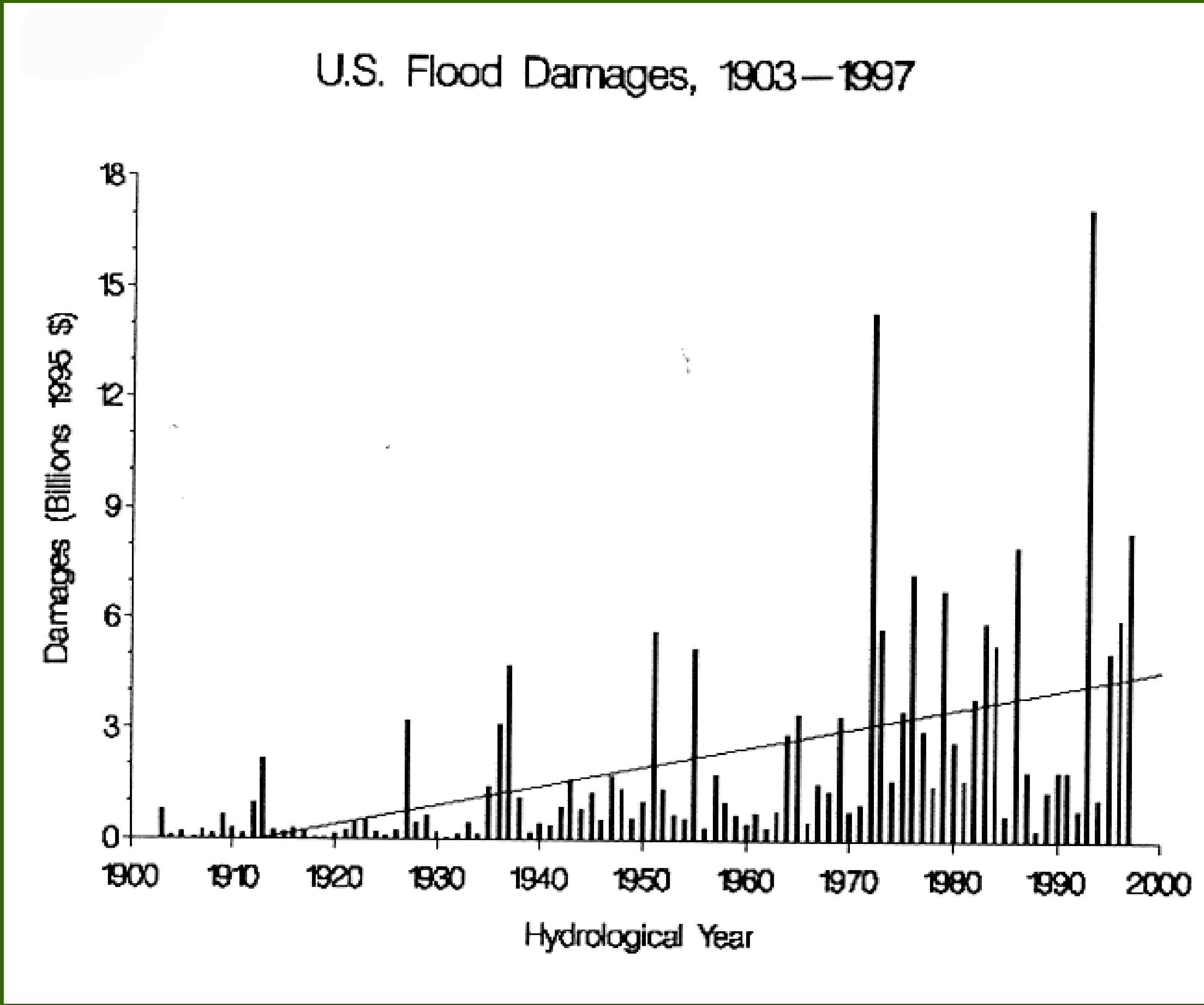
Talk Outline

1. Flood statistics

2. Causes of flood damage –
   - i - climate change
   - ii - watershed management

4. Ditch research project

5. Ditch management recommendations



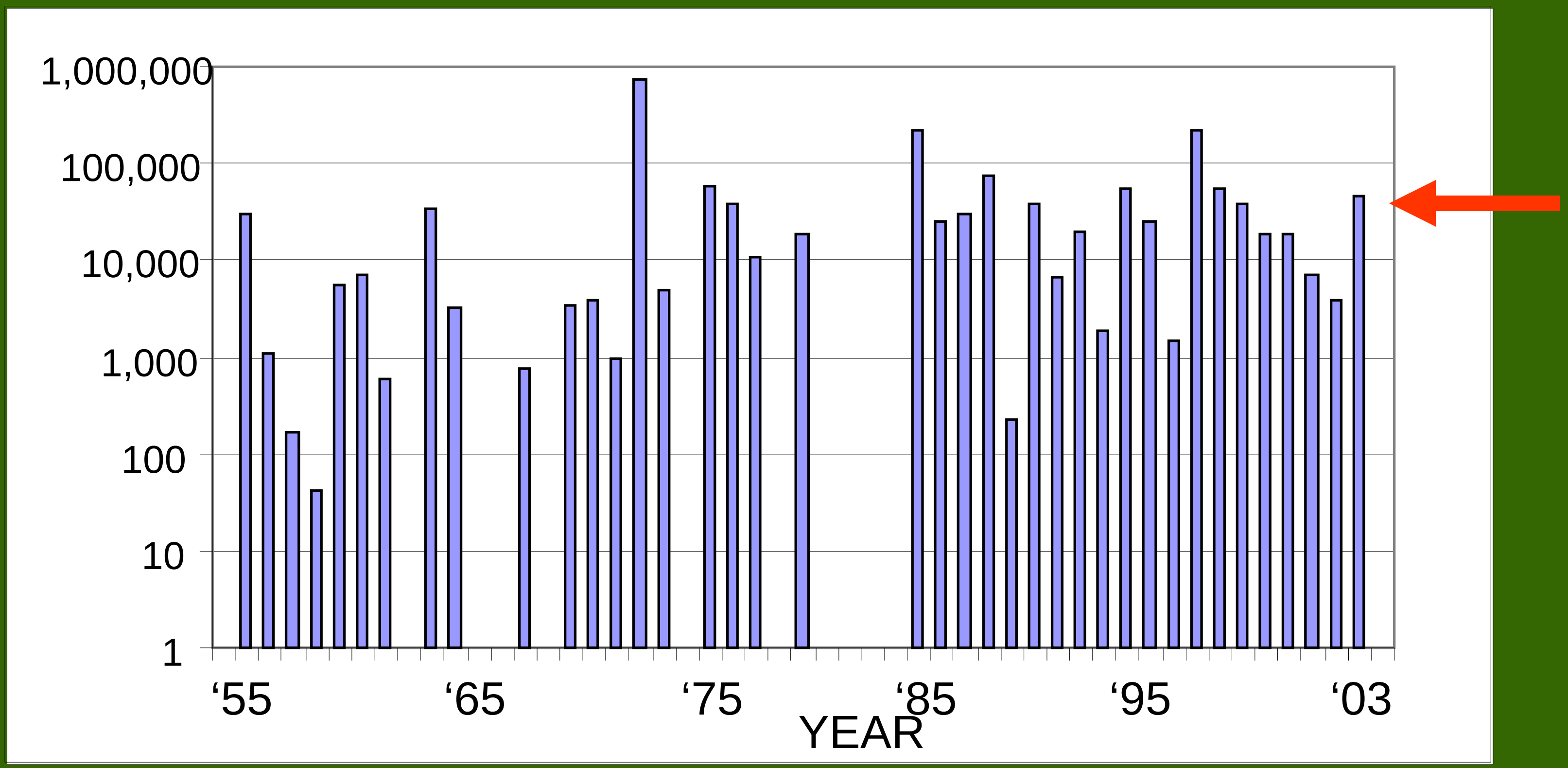
From Kunkel et al. 1999, Bull. Am. Met. Soc.


April 16, 2007, NY

Bring it closer to home ….

What floods cost in New York annually.

In thousands of
current dollars



2006 – $54.8 million

Flood damage estimates in U.S., 2002
R. Pielke, M. Downton, Z. Barnard-Miller
Boulder, CO. www.flooddamagedata.org

Talk Outline

1. Flood statistics

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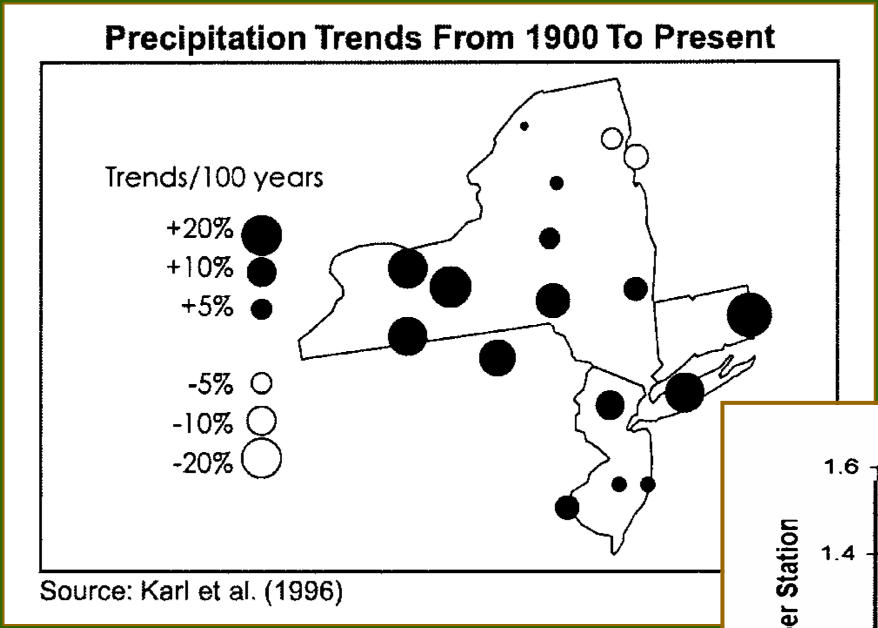
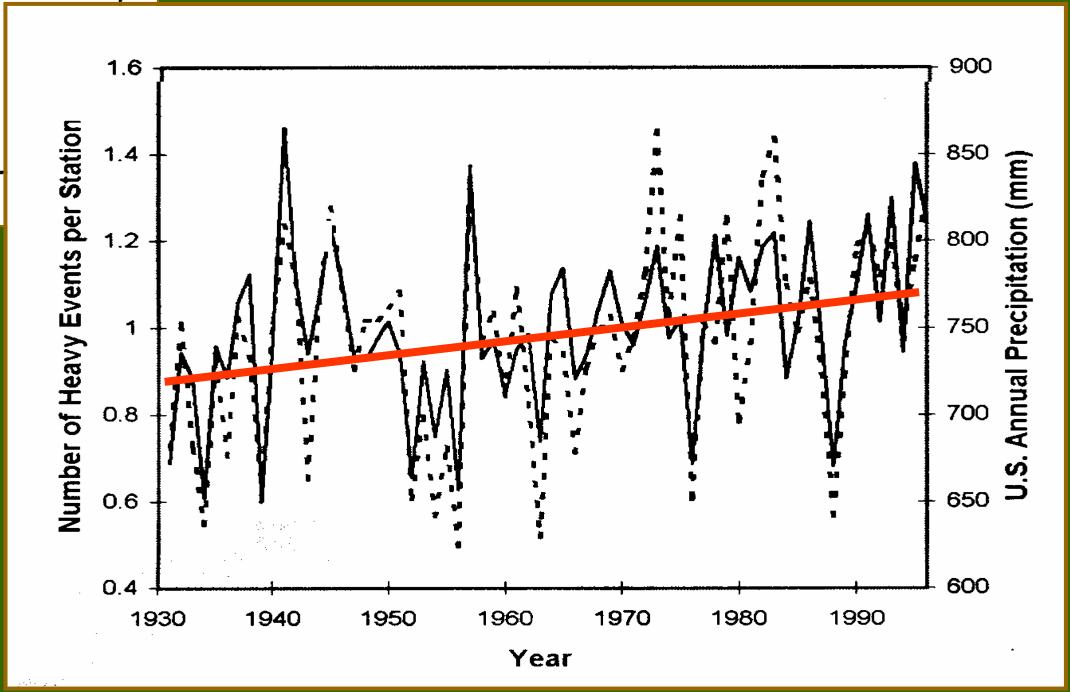
Factor #1:
Changes in Precipitation Patterns – Northeastern U.S.



http://yosemite.epa.gov/oar/globalwarming.nsf/content/us-newyork.html



(From Kunkel et al. 1999, Bulletin of American Meteorological Society)

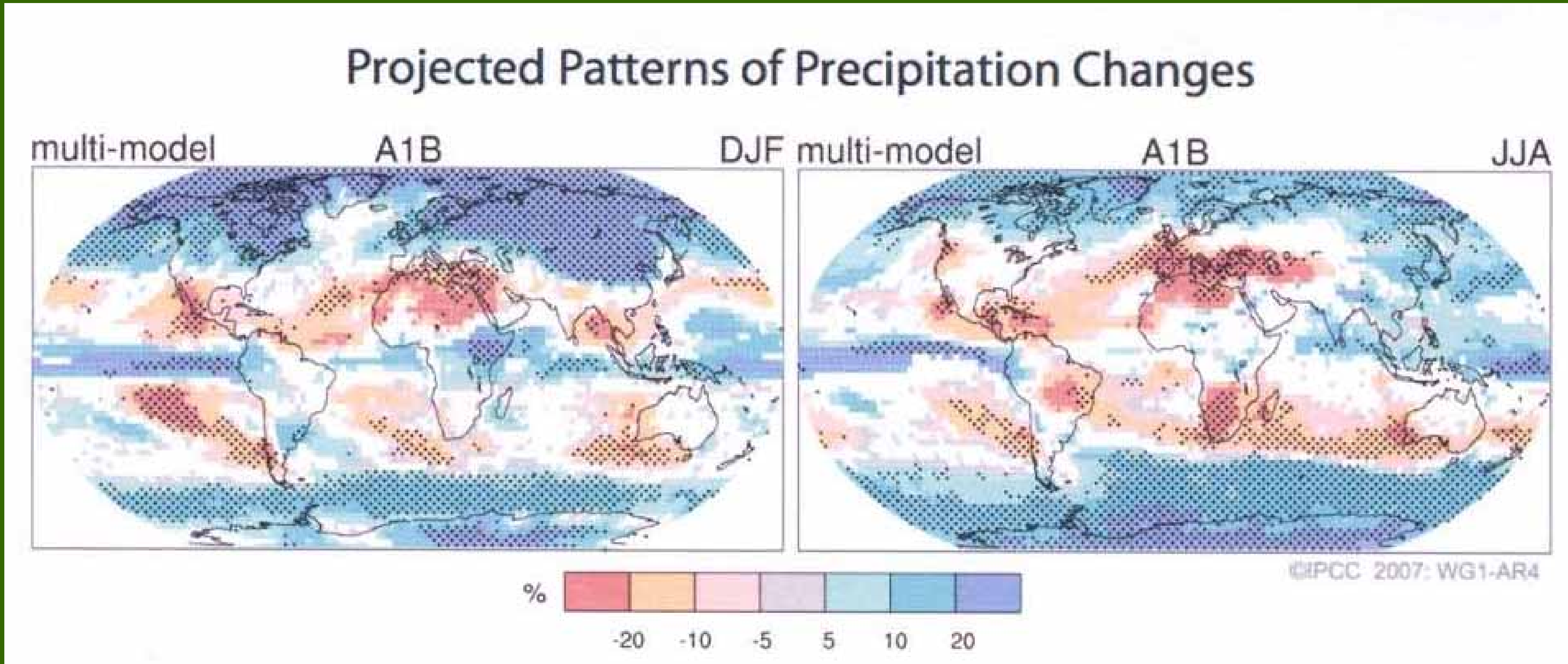
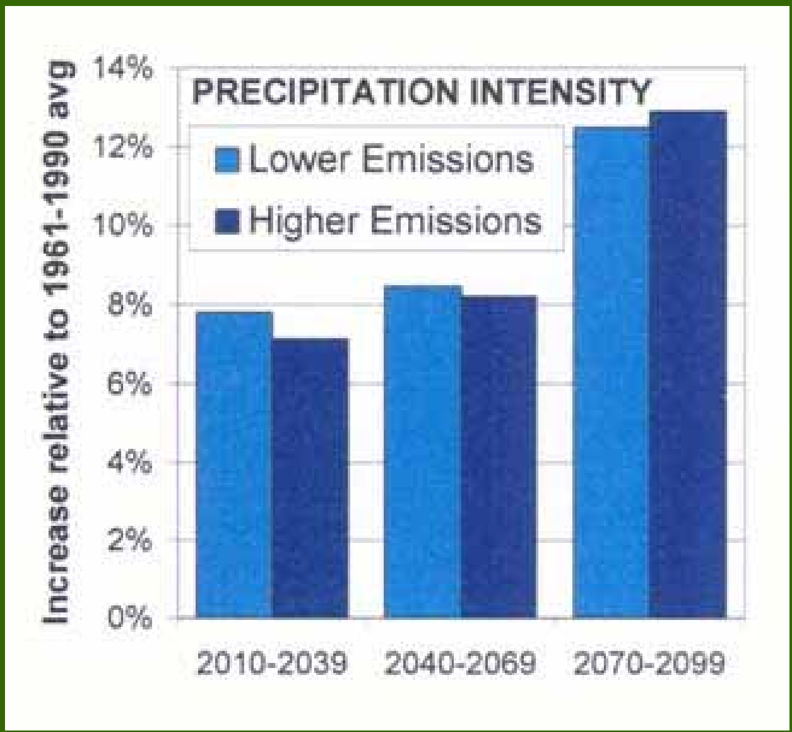


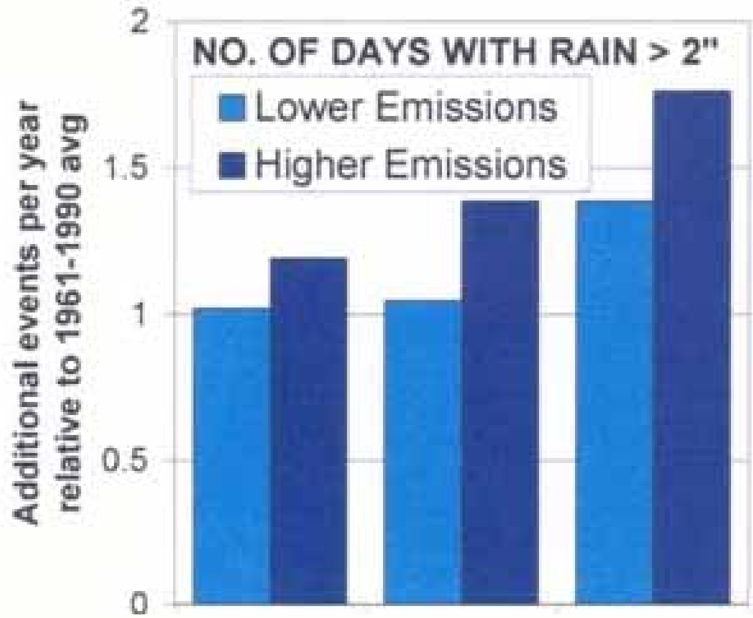
FIGURE SPM-6. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

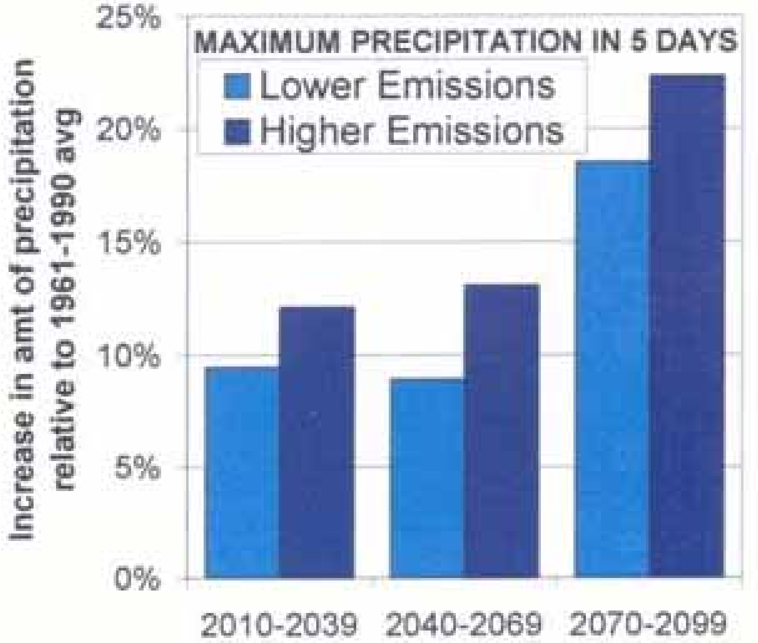
From IPCC, Feb. 2, 2007

Northeastern U.S. Climate – Future directions



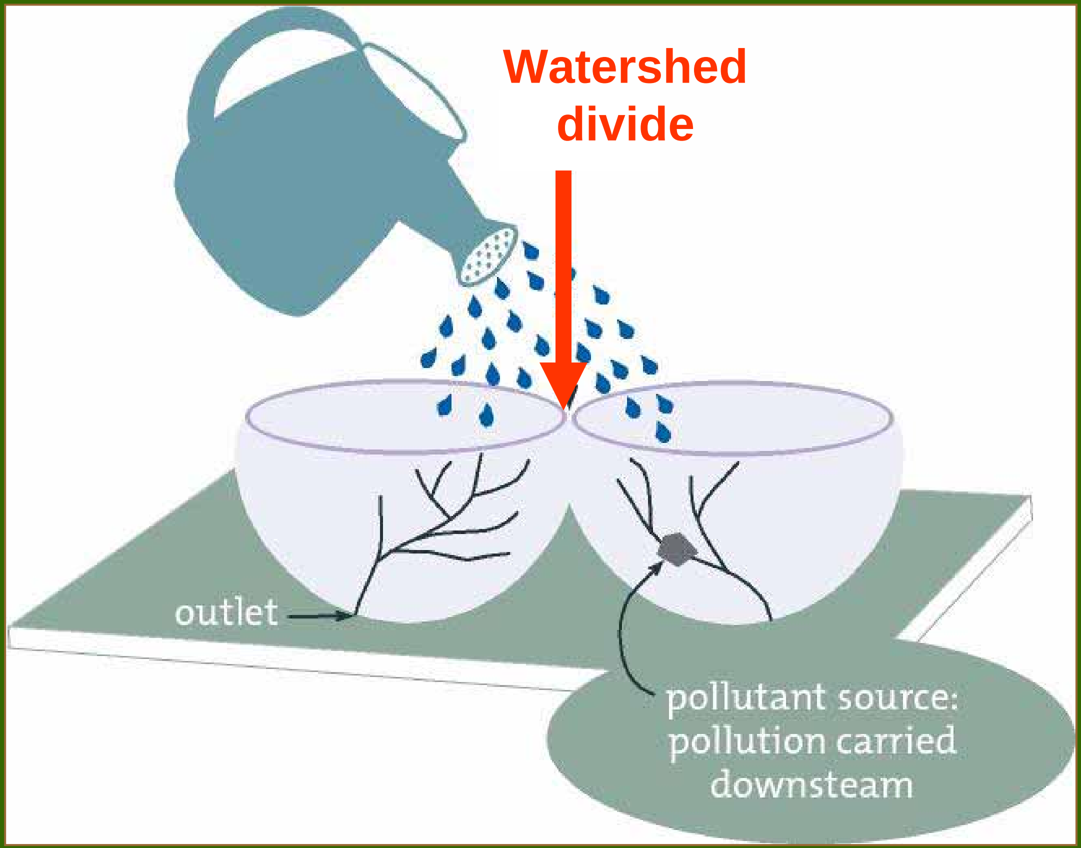
2006 Union of Concerned Scientists
http://www.northeastclimateimpacts.org





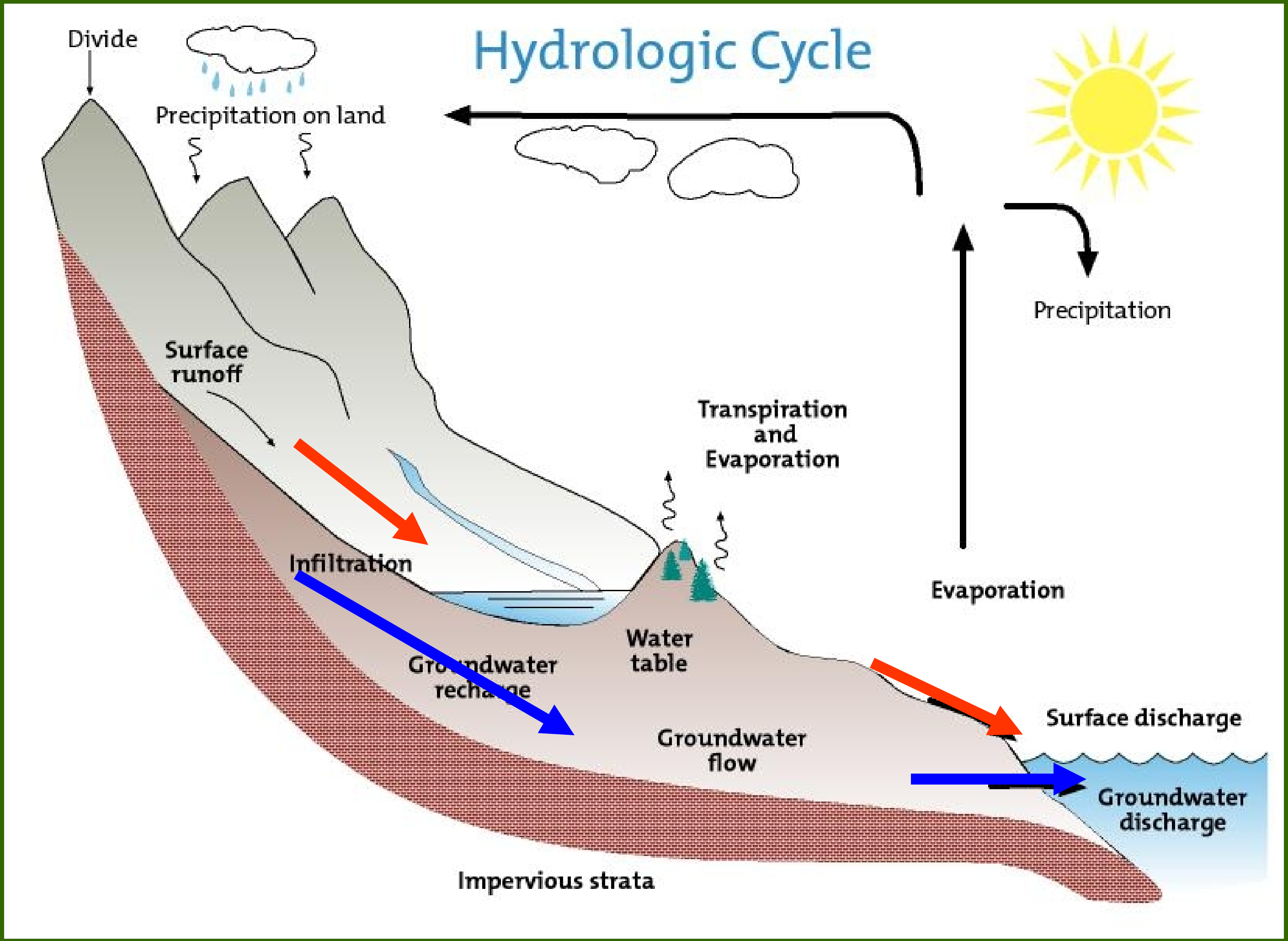
#1 Climatic Changes

Factor # 2: Poor Watershed Management

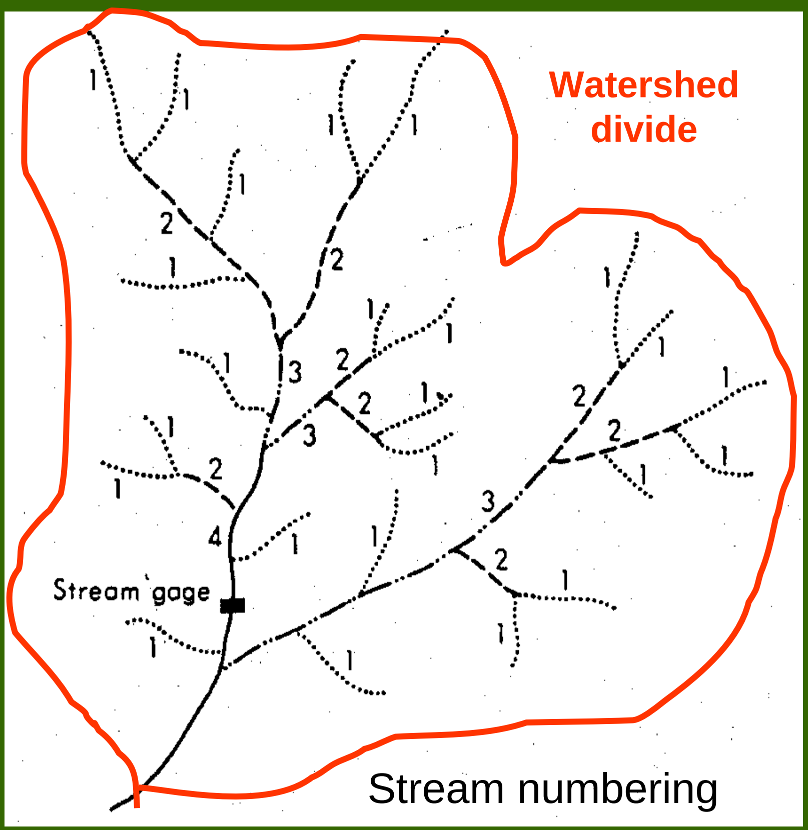


Watershed: all of the area which captures rainfall and contributes to stream flow, i.e. the "bowl".

Balance between precipitation, runoff →, infiltration → , and evapo-transpiration

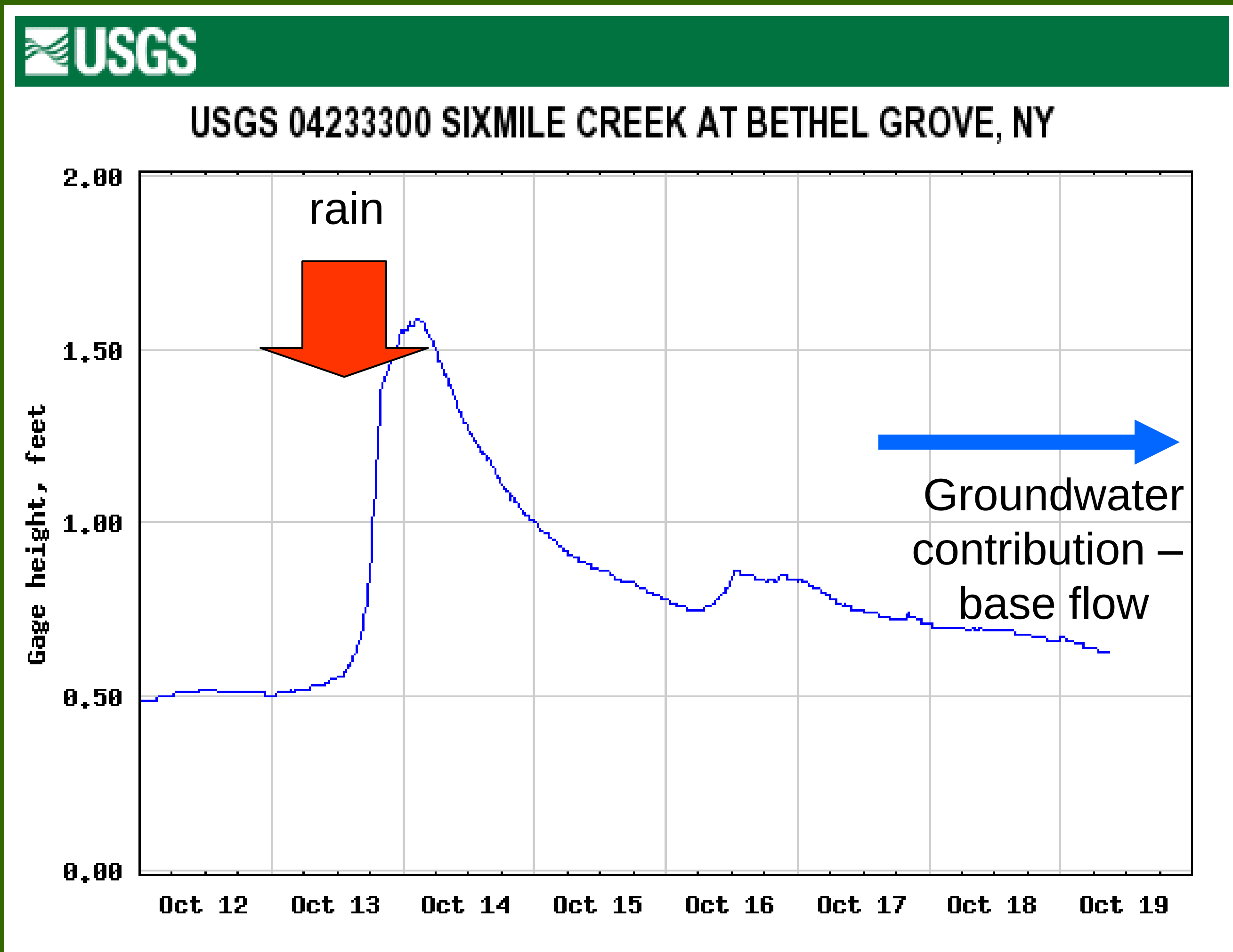


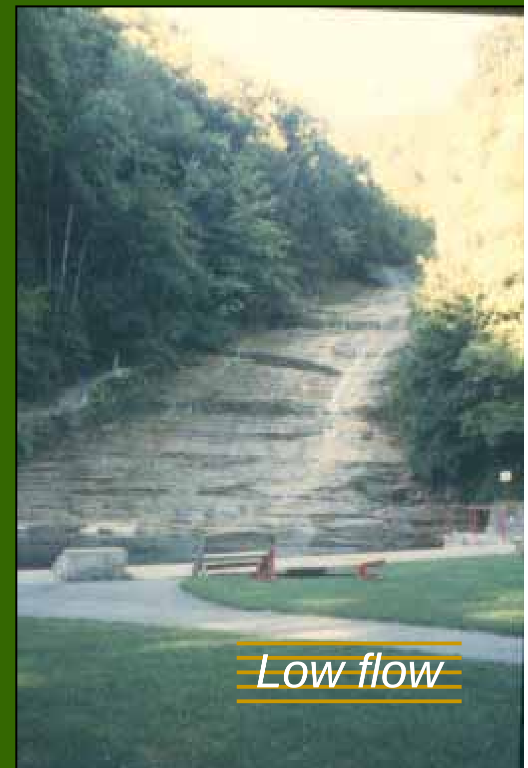
Cross-section of a watershed



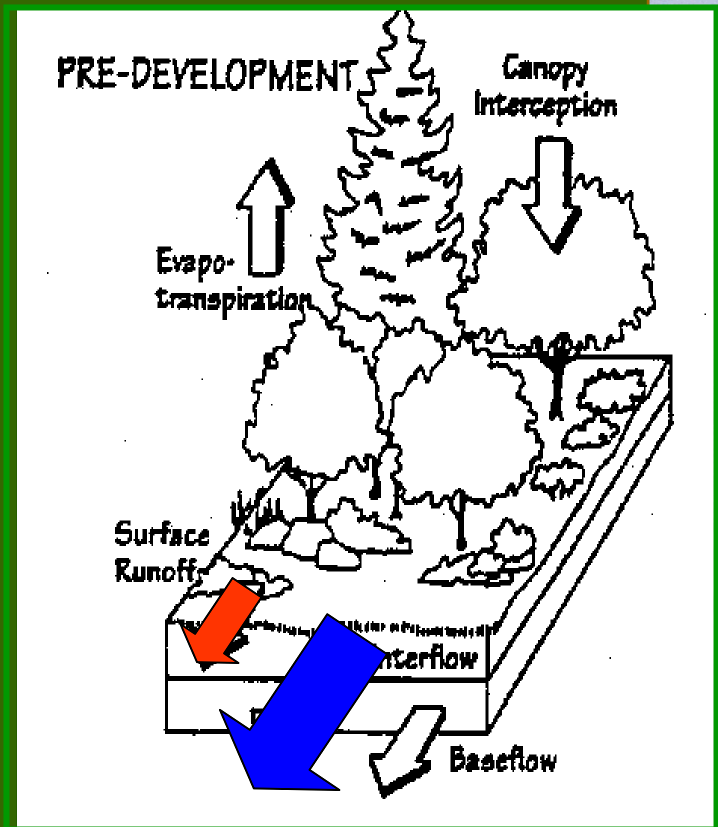
Overland runoff via stream channel networks

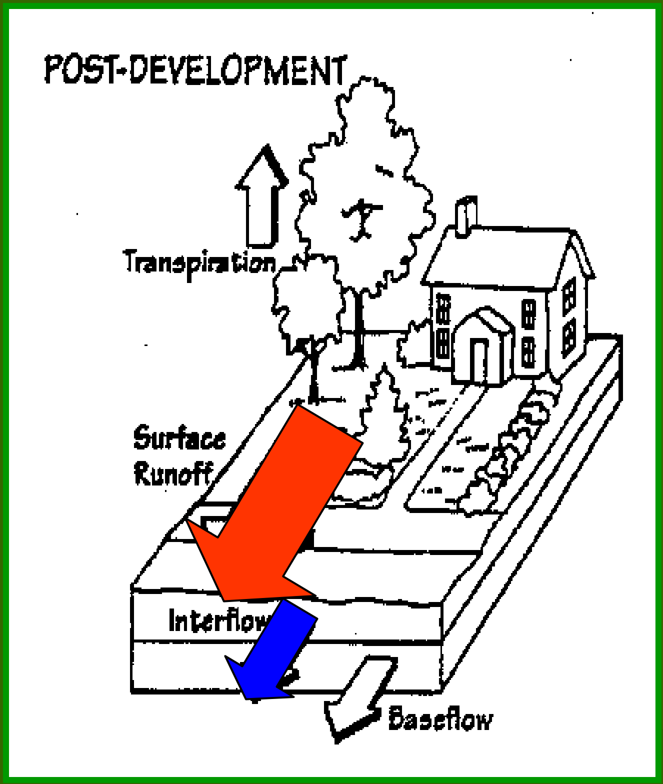
Photo: Y. Arthus Bertrand





Natural stream flow patterns


PRE-DEVELOPMENT
Canopy
Interception
Evapo-
transpiration
Surface
Runoff
Baseflow



Impervious Surfaces:

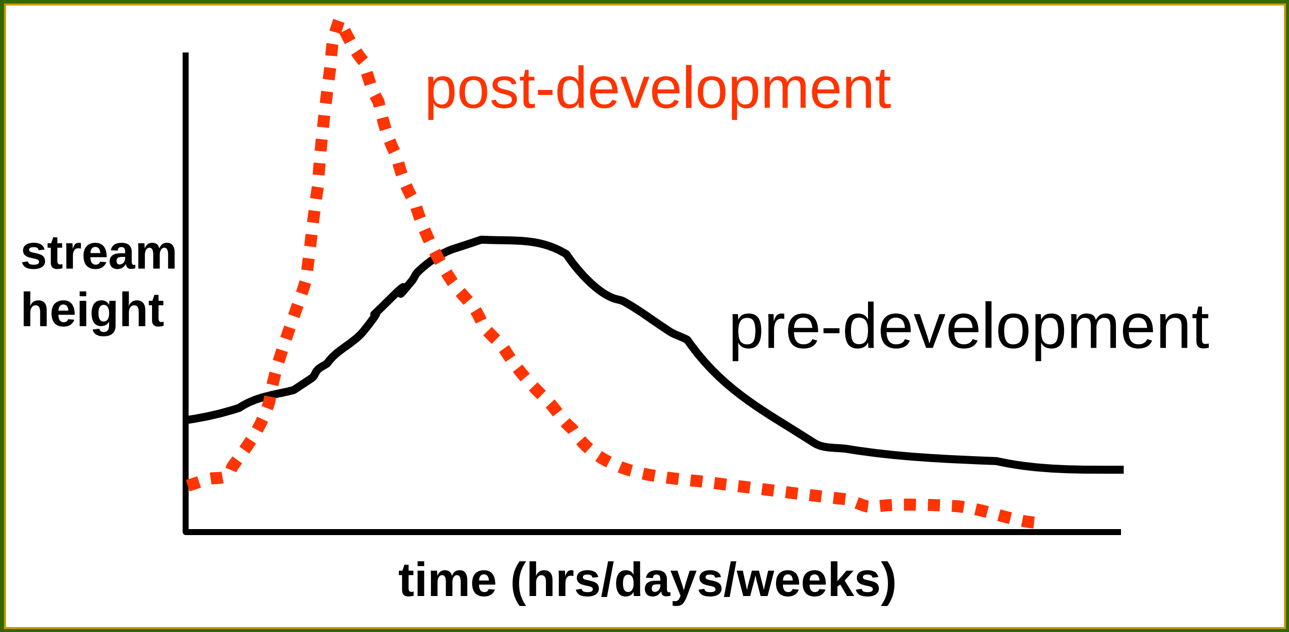
- Rooftops
- Parking lots
- Driveways

Compacted Soils:

- Lawns,
- Crop fields

Impervious surfaces impact the natural patterns of flow:

- ⬆ in **frequency and magnitude of floods**
- ⬆ in **summer droughts**
- degraded water quality – ⬆ erosion
- loss of diversity of fish and aquatic animals



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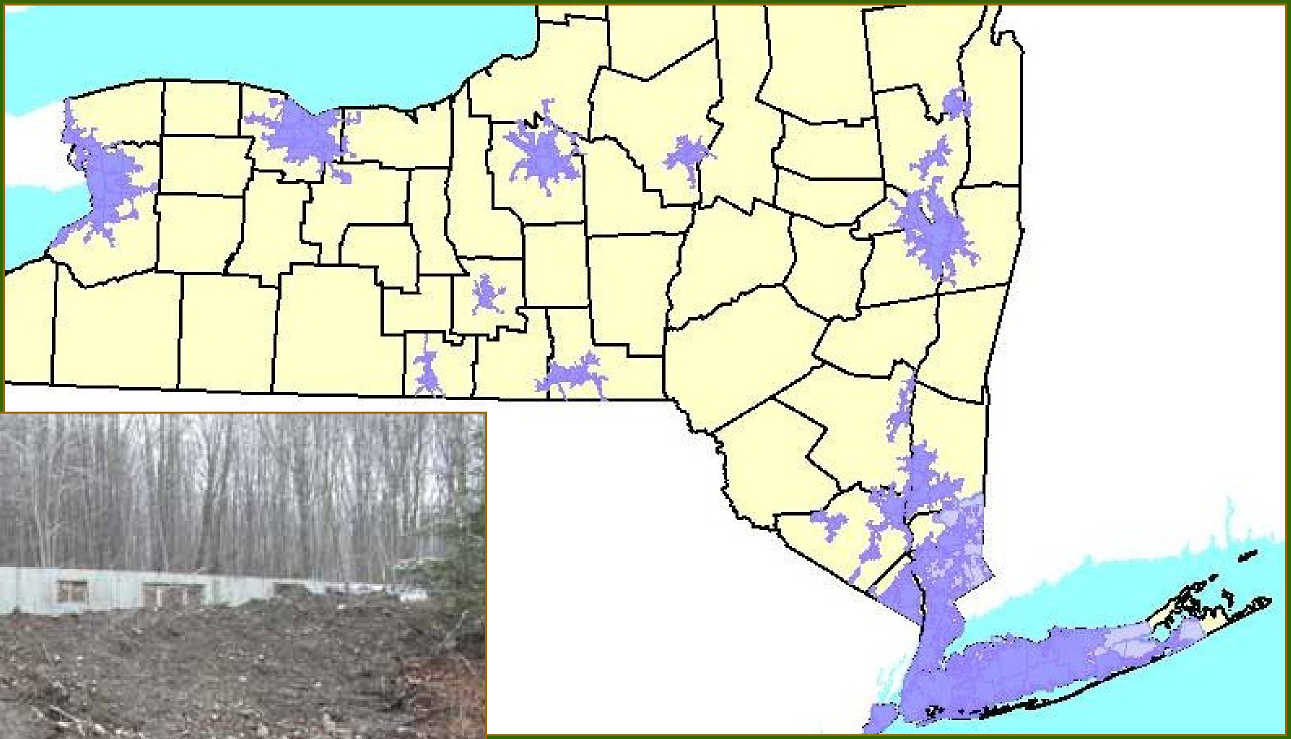
E.P.A. Phase II Stormwater Regulations 2003

For 450 towns in New York – Municipal Separate Storm Sewer Systems



Main focus is on construction activities

Rt. 89, Tompkins Co., Feb 2006

Roadside Ditches – the unrecognized factor in stormwater runoff management

Managed by highway staff to prevent
road flooding and traffic accidents

→ rarely linked to watershed mgmt issues

Roadside Ditches Program Contributors

Principal Investigators:

Rebecca Schneider, Dept. Natural Resources
Todd Walters, Dept. Biological & Envir. Eng.
Art Lembo, Steve DeGloria, Dept. Crops & Soils

Collaborators:

Sharon Anderson, Cayuga Lake Watershed Network
Lynn Irwin, Cornell Local Roads Program
Nancy Trautmann, Dept. Natural Resources
Eric Halstead, Town of Candor Highway Dept.

Sponsors:

U.S.D.A. CSREES, Cornell University – CALS (2004-2007)

Cornell's Roadside Ditch Program

RESEARCH Objectives:

1) How do different ditch management practices affect the quantity and type of materials moving into streams (TSS, bedload, dissolved chemicals, water)?

2) What percentage of the total stream load and flow is contributed by the network of ditches in a watershed?

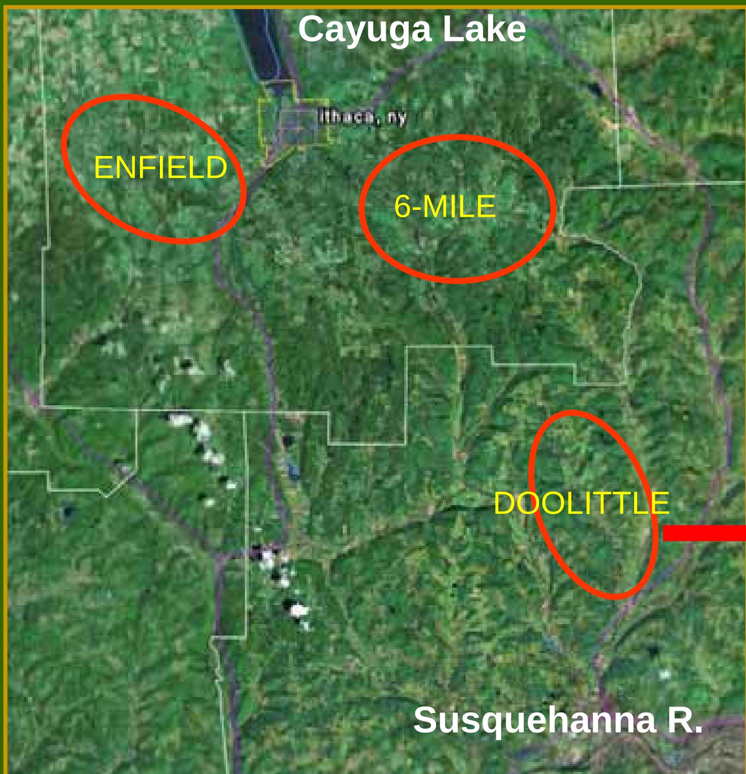
3) Develop a model that estimates ditch loadings based on internal and/ or external land use characteristics?

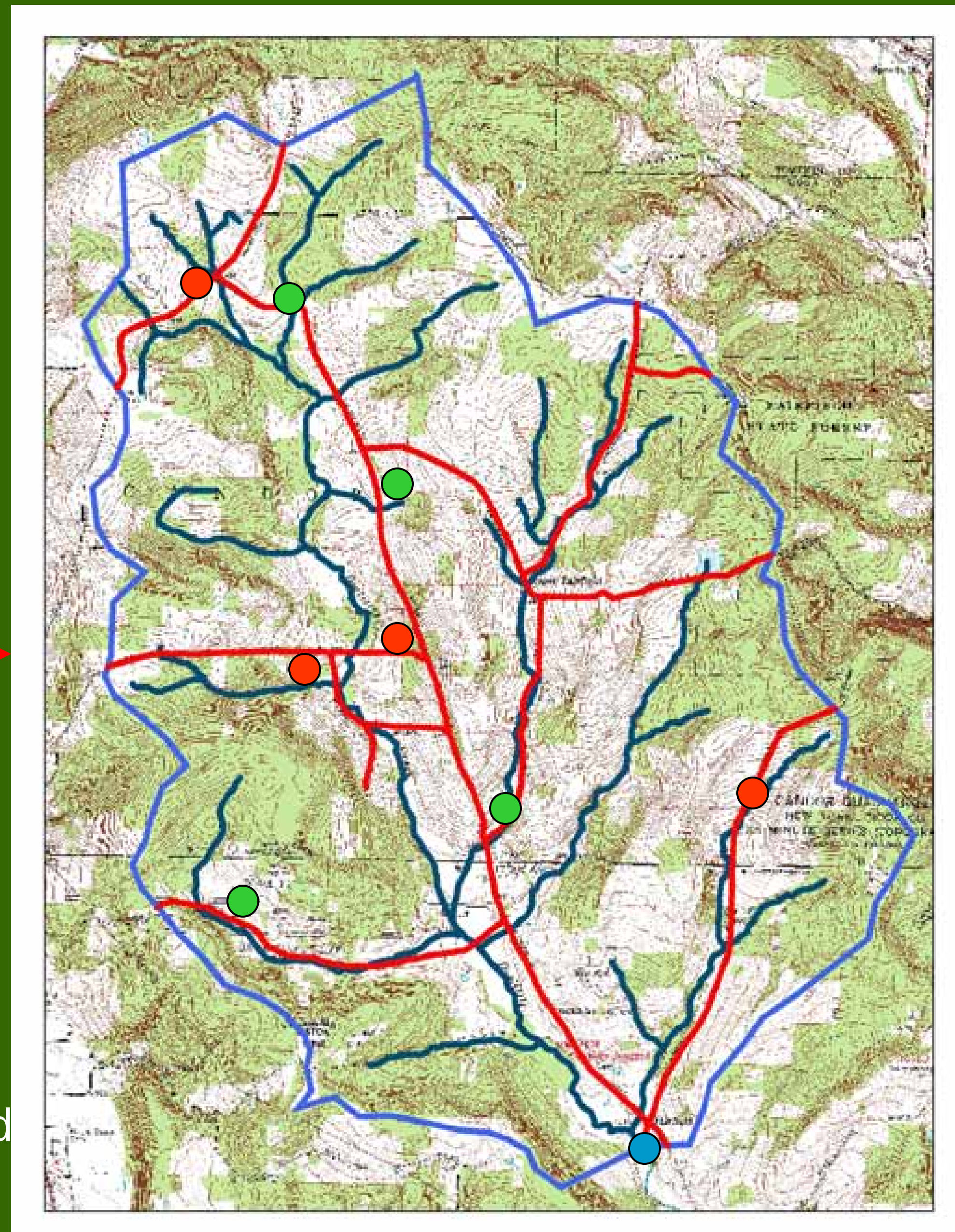
EXTENSION Objectives:

1) Build awareness of the issue and alternative management practices for town highway staff and town planners.

2) Educate youth about ditches and how they affect streams.

Research Study Sites





Monitoring Stations

- vegetated
- stream
- scraped, exposed

- road
- stream
- watershed divide

VEGETATED

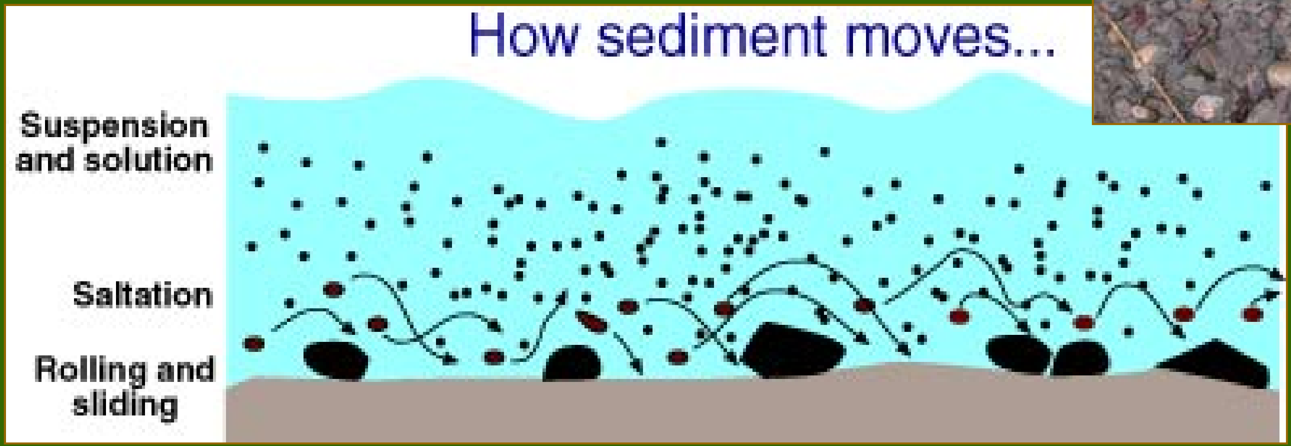
EXPOSED, SCRAPED

Research

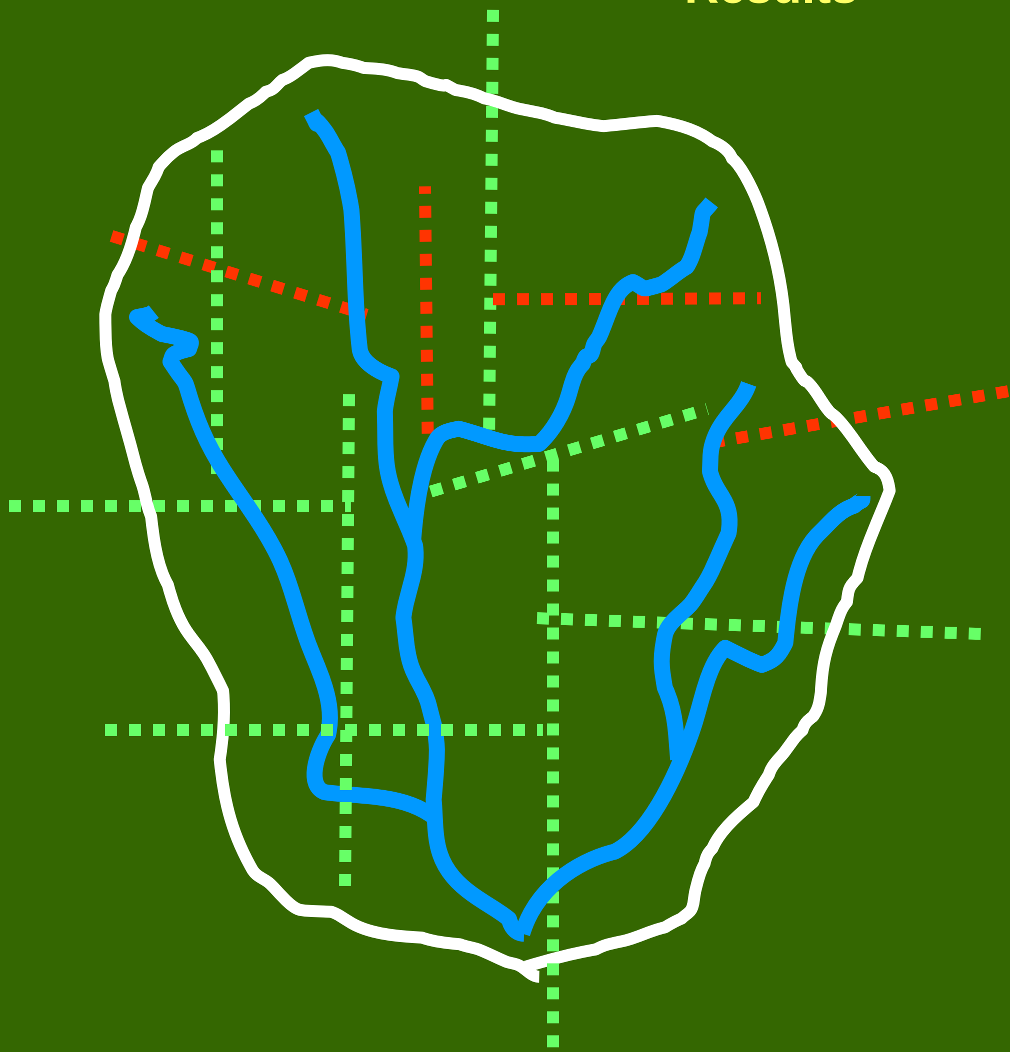
1) Map:
- ditch lengths,
- mgmt types
- connections to streams

2) Monitor:
- Total water flow
- Suspended sediment
- Dissolved chemicals

- Bedload sediment



Results



Enfield Creek

Divide 56 km ^{2} in size

Stream length 88 km

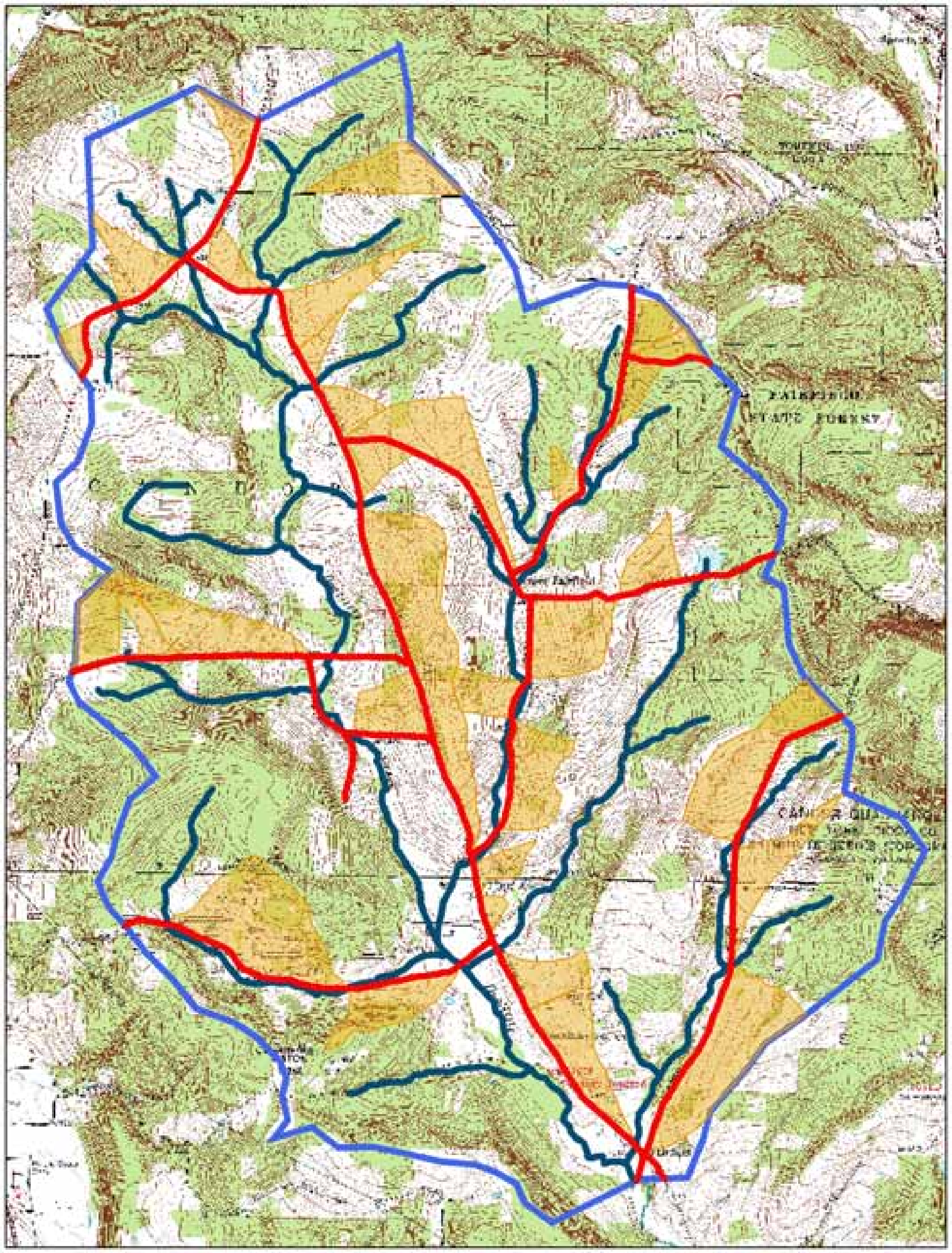
Road length 87 km

Ditches: 142 km
70% linked to stream, largely in 1st order, headwaters.

Stream Channel Density
1.6 km^{-1} ↑ to 4.1 km^{-1}

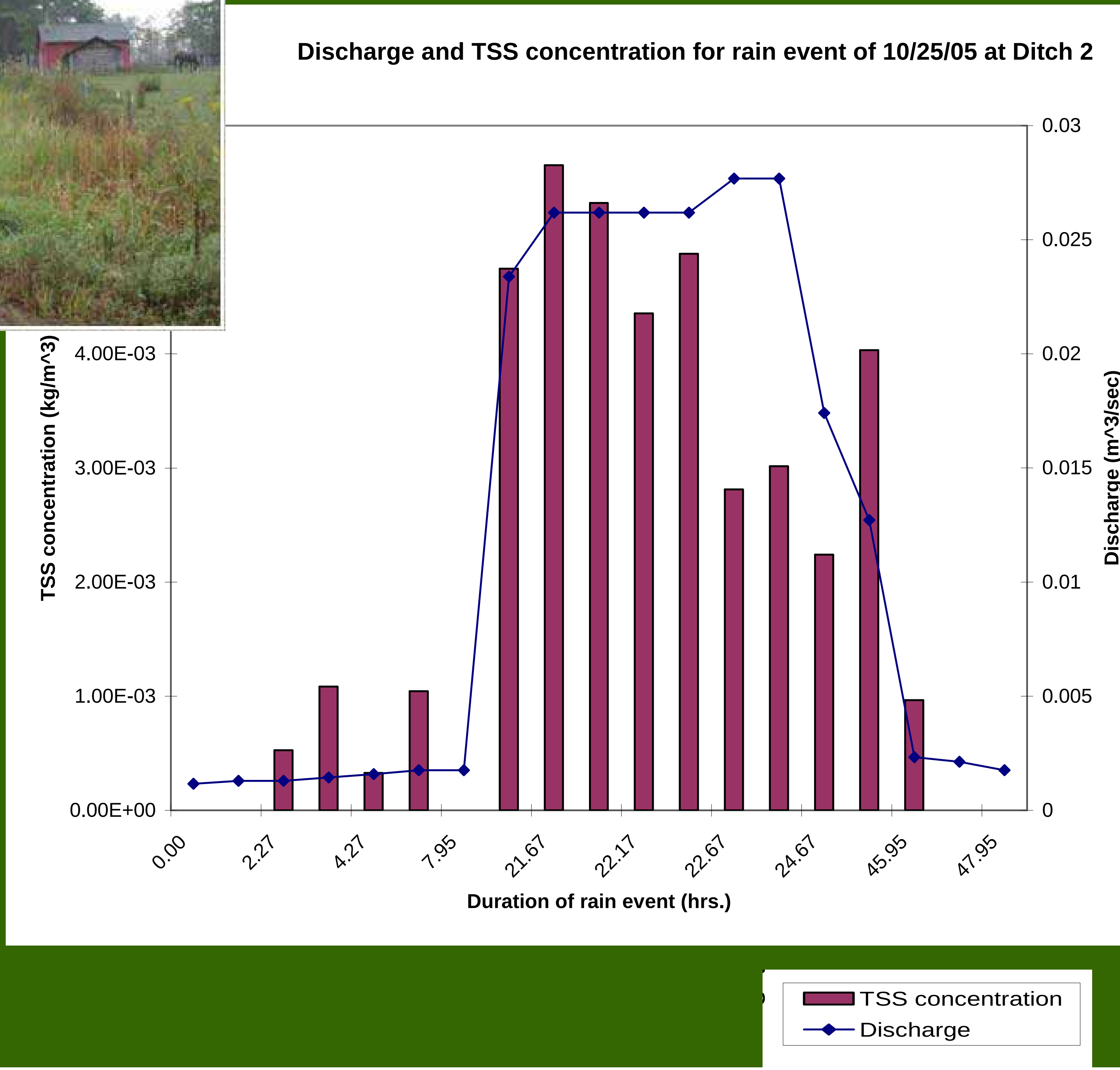
Vegetated

Scraped, exposed



Approximately 25% of the surface runoff from the entire Doolittle Watershed is potentially intercepted and diverted by ditches.

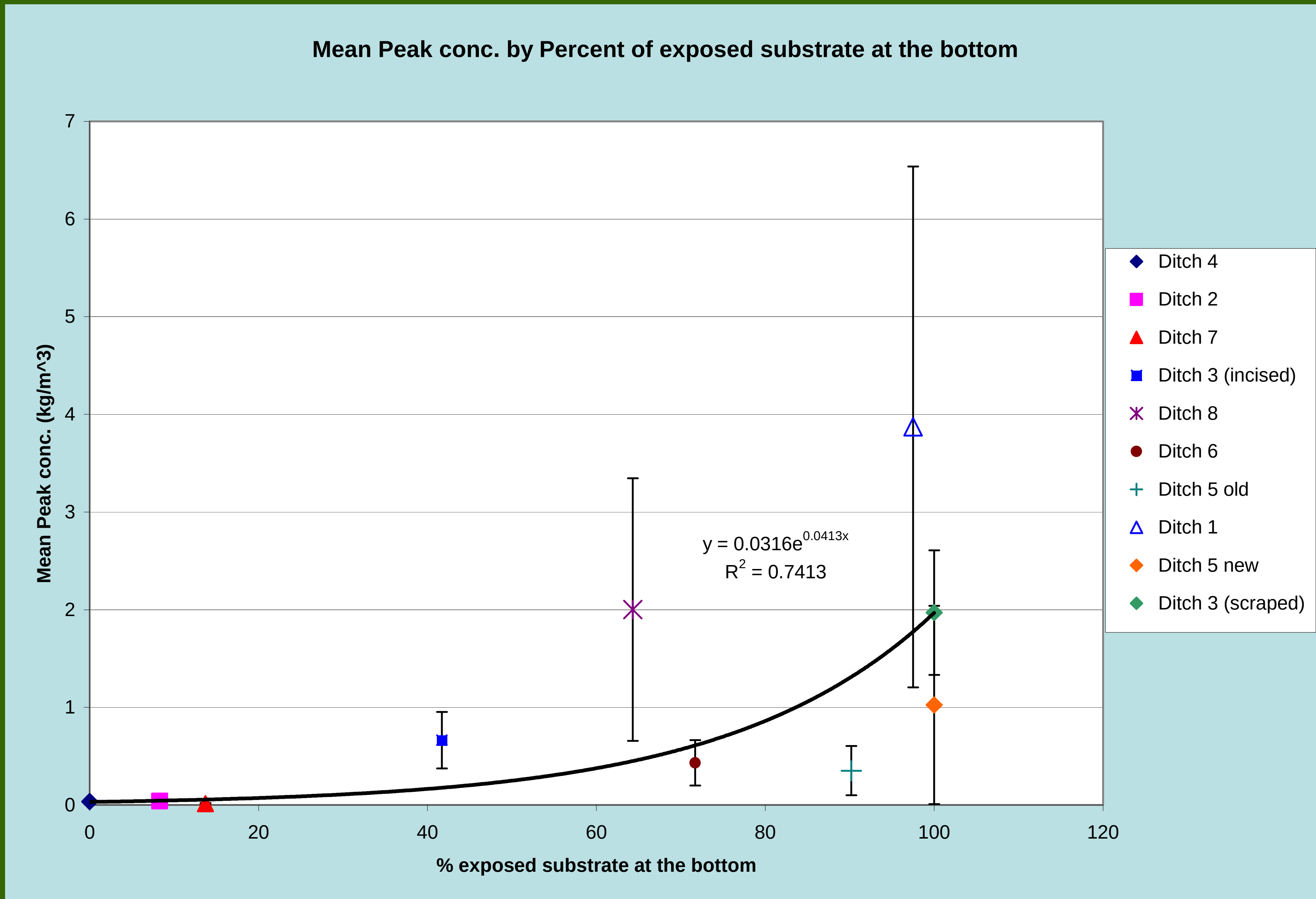
Ditch drainage basins



Discharge and TSS concentration for rain event of 10/25/05 at Ditch 2
TSS concentration (kg/m^3)
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
0.03
0.025
0.02
0.015
0.01
0.005
0
Discharge (m^3/sec)
0.00
2.27
4.27
7.95
21.67
22.17
22.67
24.67
45.95
47.95
Duration of rain event (hrs.)
TSS concentration
Discharge


DANGER


1 2 3 4 5 6 7 8 9 10 11 12
10/23/05 site 1 14:12



Mean Peak conc. by Percent of exposed substrate at the bottom
Mean Peak conc. (kg/m^3)
% exposed substrate at the bottom
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
y = 0.0316e^0.0413x
R^2 = 0.7413
Ditch 4
Ditch 2
Ditch 7
Ditch 3 (incised)
Ditch 8
Ditch 6
Ditch 5 old
Ditch 1
Ditch 5 new
Ditch 3 (scraped)

Summary of Chemicals Transported in Ditches

Dissolved Chemical Loads

	Element	Total load (kg)
Nutrients	Ortho-Phosphates	1.43
	Total P	83.43
	$NO_3^- + NO_2^-$	21.43
Trace Metals	Al	22.64
	Mn	1.48
	Fe	52.27
	Ni	6.39
	Cu	1.28
	Pb	0.25
	Cr	3.79
	Zn	2.90
Cations	Na^+	11,100.58
	Mg^{2+}	737.39
	K^+	75.78
	Ca^{2+}	3,205.36
Anions	As^{3-}	0.16

A diversity of chemicals dissolved in the water and adsorbed on the sediment particles are transported by ditches downstream.

De-icers

Increased salinization of fresh water in the northeastern United States

Sujay S. Kaushal*†‡, Peter M. Groffman*, Gene E. Likens*‡, Kenneth T. Belt§, William P. Stack¶, Victoria R. Kelly*, Lawrence E. Band‖, and Gary T. Fisher**

*Institute of Ecosystem Studies, Box AB Route 44A, Millbrook, NY 12545; §U.S. Department of Agriculture Forest Service, Northeastern Research Station, University of Maryland Baltimore County, Baltimore, MD 21227; ¶Baltimore Department of Public Works, 3001 Druid Park Drive, Baltimore, MD 21215; ‖Department of Geography, University of North Carolina, Chapel Hill, NC 27599; and **U.S. Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237

Contributed by Gene E. Likens, August 4, 2005

Chloride concentrations are increasing at a rate that threatens the availability of fresh water in the northeastern United States. Increases in roadways and deicer use are now salinizing fresh waters, degrading habitat for aquatic organisms, and impacting large supplies of drinking water for humans throughout the region. We observed chloride concentrations of up to 25% of the concentration of seawater in streams of Maryland, New York, and New Hampshire during winters, and chloride concentrations remaining up to 100 times greater than unimpacted forest streams during summers. Mean annual chloride concentration increased as a function of impervious surface and exceeded tolerance for freshwater life in suburban and urban watersheds. Our analysis shows that if salinity were to continue to increase at its present rate due to changes in impervious surface coverage and current management practices, many surface waters in the northeastern United States would not be potable for human consumption and would become toxic to freshwater life within the next century.

impervious surfaces | land use change

For many years, salinization of fresh water related to agricultural practices has been recognized as an environmental problem in arid and semiarid environments throughout the world (1). Long-term salinization of surface waters associated with increasing coverage by roadways and suburban and urban development has been less considered, although previous research has documented sharp increases in concentrations of sodium and chloride in aquatic systems of the rural northeastern United States over decades due to the use of road salt (2–5). Our analysis shows that baseline salinity is now increasing at a regional scale in the northeastern United States toward thresholds beyond which significant changes in ecological communities and ecosystem functions can be expected.

Salinization refers to an increase in the concentration of total dissolved solids in water and can often be detected by an increase in chloride, an important anion of many salts. In the northeastern United States, chloride derived from salt is commonly associated with runoff from roads at latitudes above ≈39°N, particularly during winter. Concentrations of chloride in soils as low as 30 mg/liter have been found to damage land plants, which typically occur in close proximity to roads (6). Increased chloride concentrations in surface waters, however, can be propagated a substantial distance from roadways, leading to more widespread effects on water quality. Increases in salinity up to 1,000 mg/liter can have lethal and sublethal effects on aquatic plants and invertebrates (7), and chronic concentrations of chloride as low as 250 mg/liter have been recognized as harmful to freshwater life and not potable for human consumption (6, 8). Water with chloride concentrations >250 mg/liter can impart a salty taste and also contain elevated concentrations of sodium and toxic impurities from road salt (9), which are of concern to human health. Road salt is currently not regulated as a primary contaminant to fresh waters of the United States, although a recommended limit exists (8). Regulation of road salt was recently considered by the Canadian government after much controversy (6).

Relatively little is known regarding the relationship between widespread increases in suburban and urban development and long-term changes in baseline salinity across regions of the United States. Impervious surfaces now cover >112,610 km² in the United States, an area equivalent to the state of Ohio (10). The amount of impervious surface coverage within the United States is expected to increase sharply with >16,093 km of new roads and 1 million single-family homes being created during the present decade (10). The rate of land-use change may be particularly high in segments of watersheds near surface waters such as streams, rivers, and lakes. As coverage by impervious surfaces increases, aquatic systems can receive increased and pulsed applications of salt, which can accumulate to unsafe levels in ground and surface waters over time (6).

Methods

Rural Sites. We investigated the rate of salinization and increases in the baseline concentration of chloride in inland waters by using long-term data from streams and rivers draining rural watersheds in three locations of the northeastern United States: Baltimore County (Maryland), the Hudson River Valley (New York), and the White Mountains (New Hampshire). Rural sites in these areas have experienced relatively small changes in population growth but contain a low density of roads within their watersheds. The sites in Maryland drain into drinking-water supply reservoirs for Baltimore City and have been monitored over the decades by the municipal government. The sites in the Hudson River Valley have been monitored by the Institute of Ecosystem Studies and the U.S. Geological Survey (2), and the sites in New Hampshire are part of the Hubbard Brook Ecosystem Study (3, 11).

Baltimore Metropolitan Area. Within the Baltimore metropolitan area, we explored long-term changes in chloride concentrations across a broader gradient of land use to determine an empirical relationship between salinization and increasing coverage by impervious surface. The Baltimore metropolitan watersheds drain into the Chesapeake Bay and represent one of the most rapidly developing areas of the northeastern United States. In this region, coverage by impervious surface increased by ≈39% from 1986 to 2000 (12). Streams draining forest, agricultural, suburban, and urban watersheds were sampled as part of the National Science Foundation-supported Baltimore Long Term Ecological Research (LTER) project. Samples were collected weekly from 1998 to 2003 without regard to flow conditions (no

Abbreviation: LTER, Long Term Ecological Research.

†Present address: University of Maryland Center for Environmental Science, Appalachian Laboratory, Frostburg, MD 21532.

‡To whom correspondence may be addressed. E-mail: likensg@ecostudies.org or skaushal@al.umces.edu.

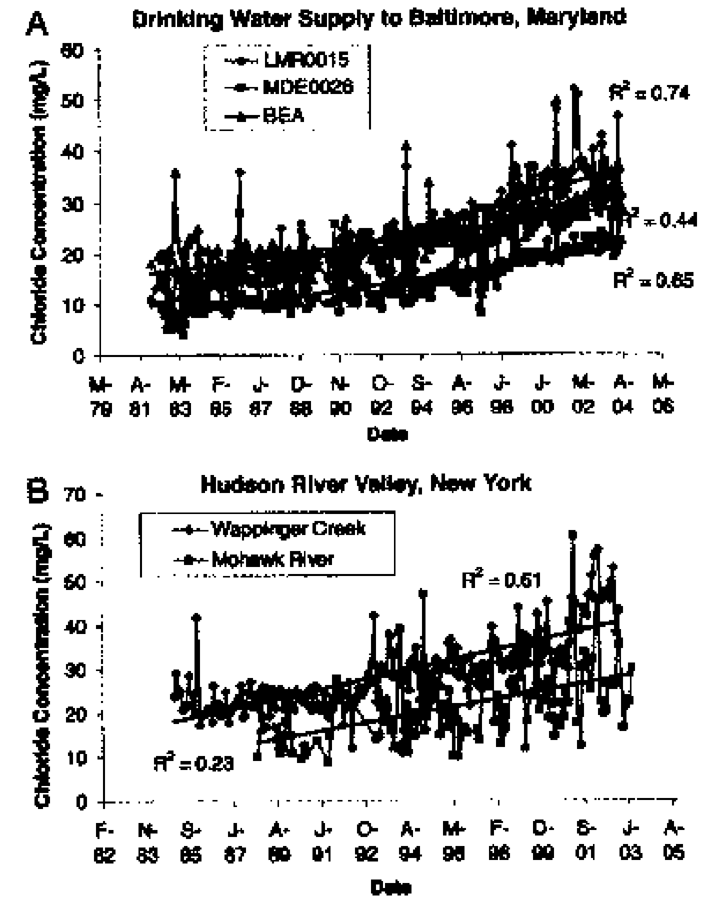


Fig. 1. Examples of significant, long-term increases in baseline concentration of chloride for streams and rivers of the northeastern United States. The R^2 values are given for linear regressions. All streams and rivers are located in rural areas but contain roads within their watersheds. (*A*) LMR0015 (Little Morgan Run), MDE0026 (Middle Run), and BEA (Beaver Run) are sampling stations for tributaries to Liberty Reservoir, a drinking water supply for Baltimore. (*B*) Wappinger Creek and the Mohawk River are tributaries to the Hudson River in the Hudson River Valley. (*C*) The streams in the White Mountains drain into Mirror Lake; one is located near an interstate highway in the Hubbard Brook Valley, and the forested reference stream is watershed 6 of the Hubbard Brook Experimental Forest (10).

Significant quantities of bedload transport move in scraped and exposed ditches.

Roadside Ditch Impacts

a) mechanism for increased land-water linkages
b) conduit for rapid runoff
c) internal source of sediment and other contaminants

d) Potential influence on stream erosion.

Ditch influence on erosion?

Extension to New York Stakeholders

- MS4 Town Highway Staff and Local Governments
  45 Regional Workshops to over 2000 highway staff and local government officials.

- K-12 education – Workshops, Activities for mapping ditches using GPS (*Global Positioning System)*
  Interactive Web site

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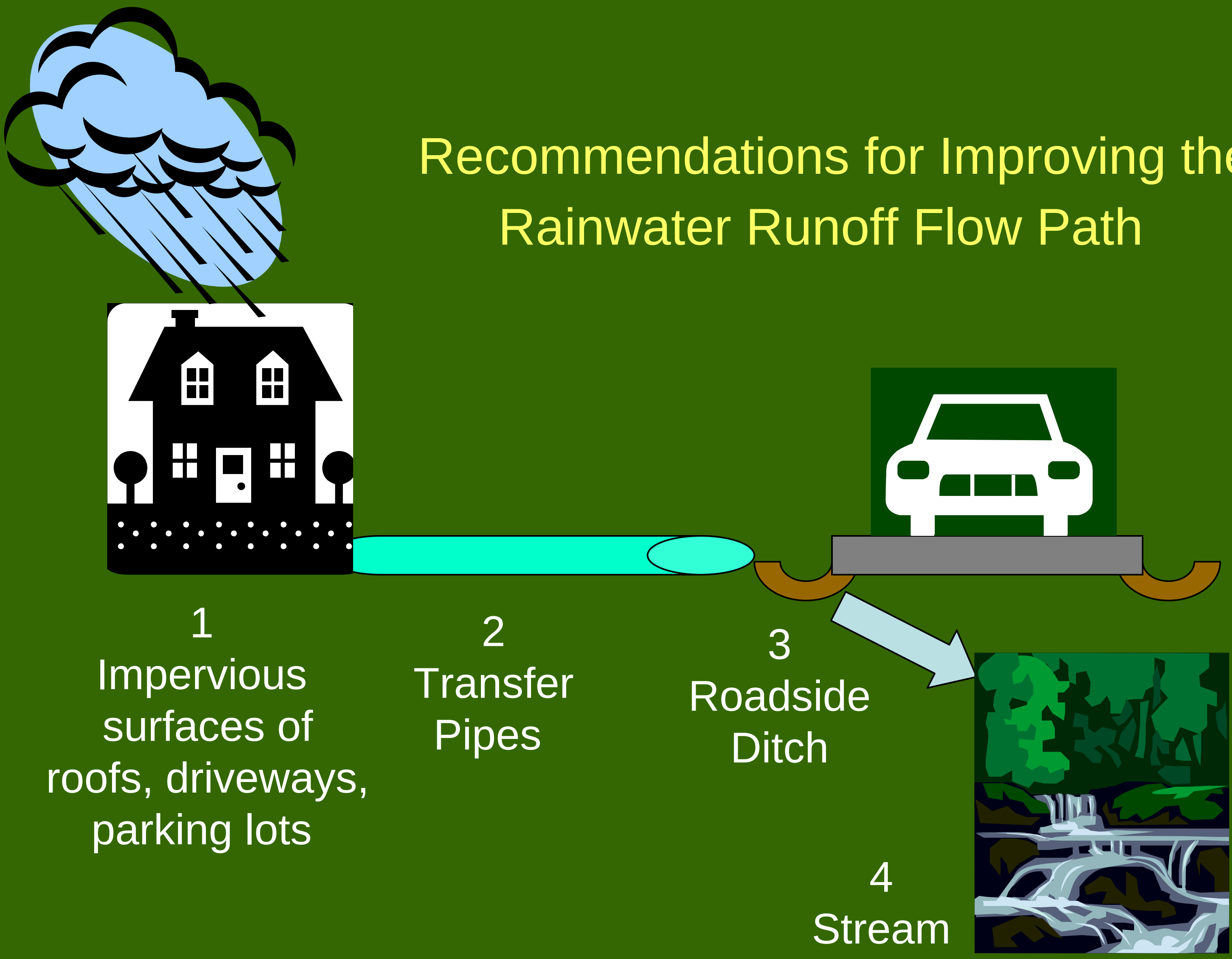
Recommendations for Improving the Rainwater Runoff Flow Path



Recommendation (1) :

Where possible, replace impervious surfaces with permeable pavements.

Recommendation (1)

For Croplands:
- Improve soil infiltration using mulches, cover crops

Recommendation (2) :

Disconnect house runoff from roadside ditches.

(required by NYS building code)

Recommendation (2):

Use rain gardens, rain barrels, and low-lying depressions to capture rain from rooftops.

Recommendation (3) :
Don't scrape ditches and leave them exposed to erosion during storm events.

Recommendation (3):

- Use hydroseeding immediately after ditching
- Hydroseed early in the season to allow sufficient growing time, and not immediately before rain.

- If scraping is necessary, do it in patches with vegetated strips left downslope to capture sediments.

Recommendation (4)

- Disconnect ditches from streams.
- Use infiltration basins or detention ponds that allows for groundwater recharge.

Acknowledgments:
USDA CSREES, Cornell (funding); Cayuga Lake Watershed Network,
Town of Candor and Enfield Highway Depts., City of Ithaca Planning Dept.

Questions?

Stormwater management is risky business.