

“Re-plumbing” Roadside Ditch Networks for Improving Stream Health

Ditches - The
unrecognized driver
of flooding, water
pollution, and in-
stream erosion and
habitat degradation



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Cornell Local Roads

*NE Transportation and Wildlife Conference
Sept 2016*

Global Impact of Roadside Ditches

Worldwide Road Density

50% of the contiguous US is within 382 meters of a road



Road Density (km / sq km)

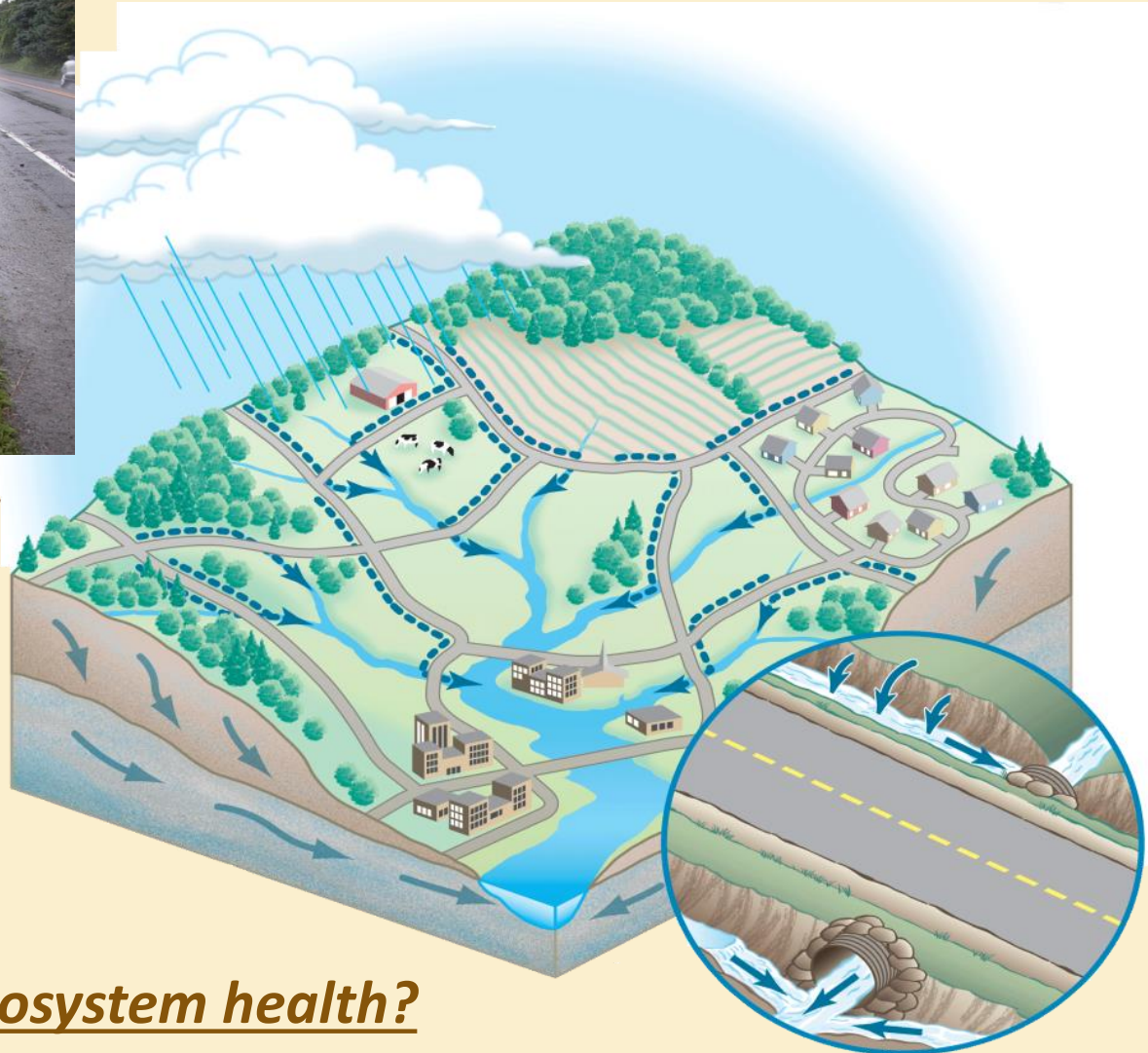


Roadside Drainage Networks



What role do they play in:

- ▣ *Floods?*
- ▣ *Droughts?*
- ▣ *Water pollution?*
- ▣ *Stream and lake ecosystem health?*



Roadside Ditch Team

Faculty:

- **D. Orr, *Cornell Local Roads Program***
- T. Walter, *Dept. Biological and Environmental Engineering*
- D. Buckley, P. Bergholz, *Dept. Crops and Soils*
- R. Marino, R. Howarth, K. Sparks, *Dept. Ecology*

Graduate Students:

- K. Falbo, B. Buchanan, J. Diaz-Robles, J. Archibald,
L. McPhillips, S. Davis, T. Johnson, J. Kimchi (*Undergr*);



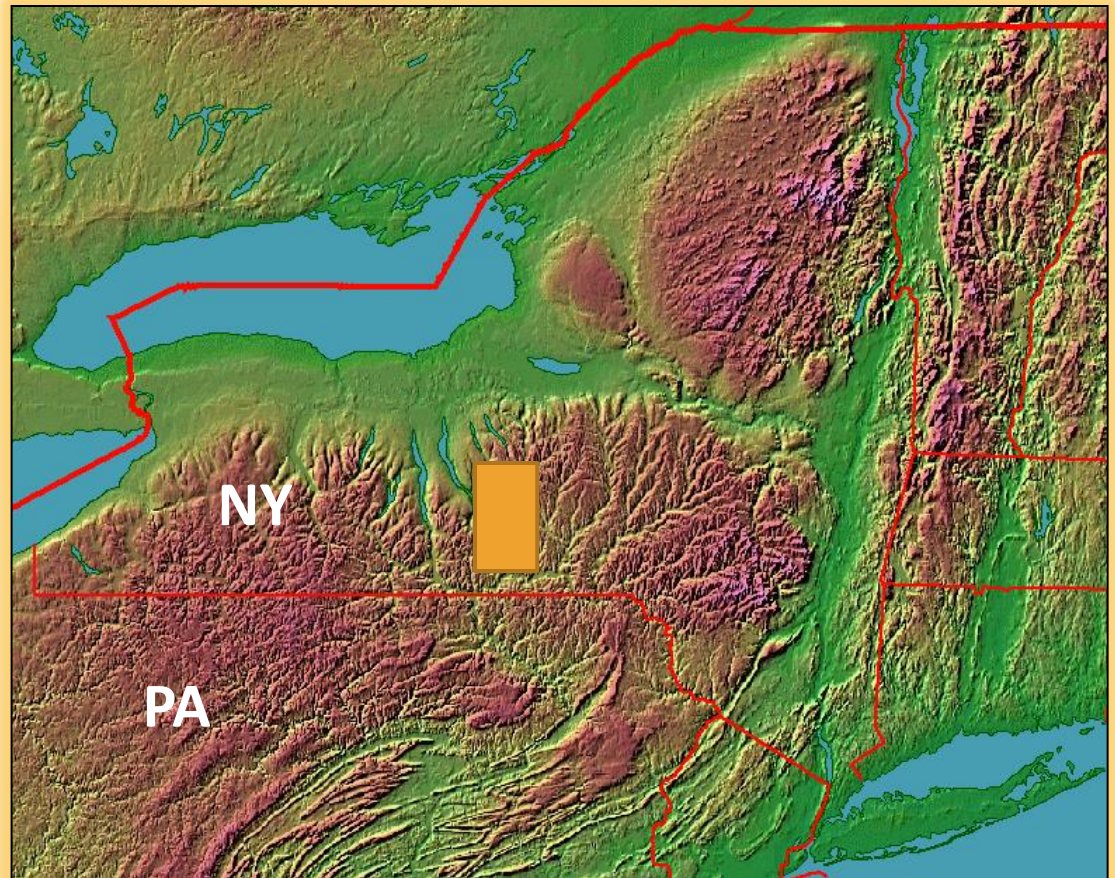
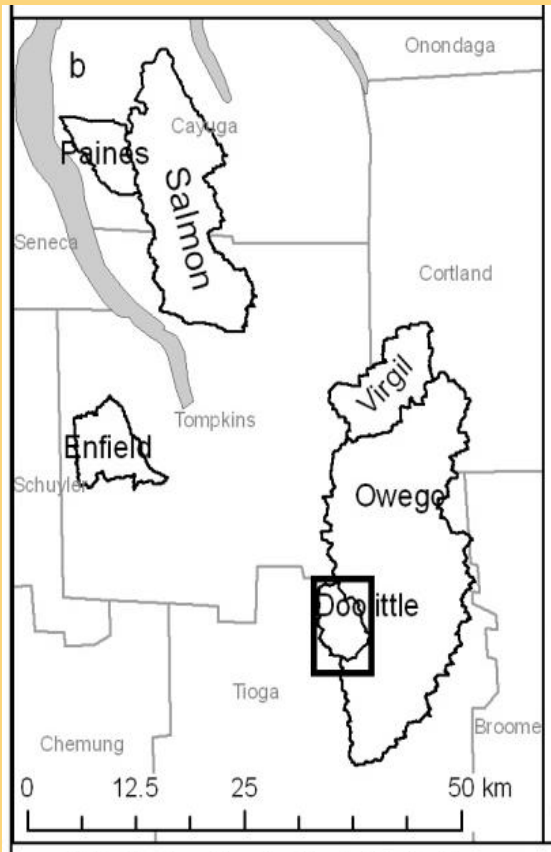
Cornell University



United States Department of Agriculture

National Institute of Food and Agriculture

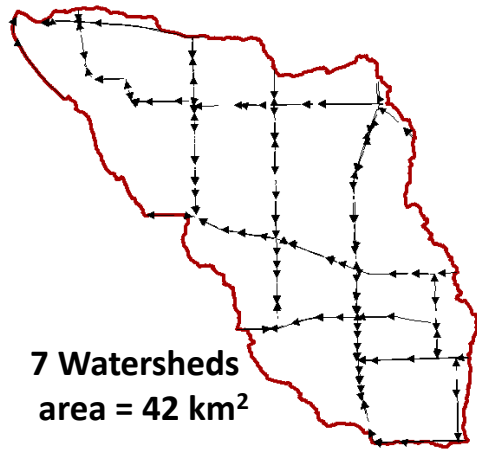
Study Sites



APPROACHES

(1) MONITORING

- ☐ Total water flow
- ☐ Suspended sediment
- ☐ Dissolved chemicals
- ☐ Bedload
- ☐ Fecal coliforms



(2) GPS and ARC-GIS MAPPING

- ☐ Ditch lengths
- ☐ Connections to streams
- ☐ Management types

(3) MODELING

(4) EXTENSION



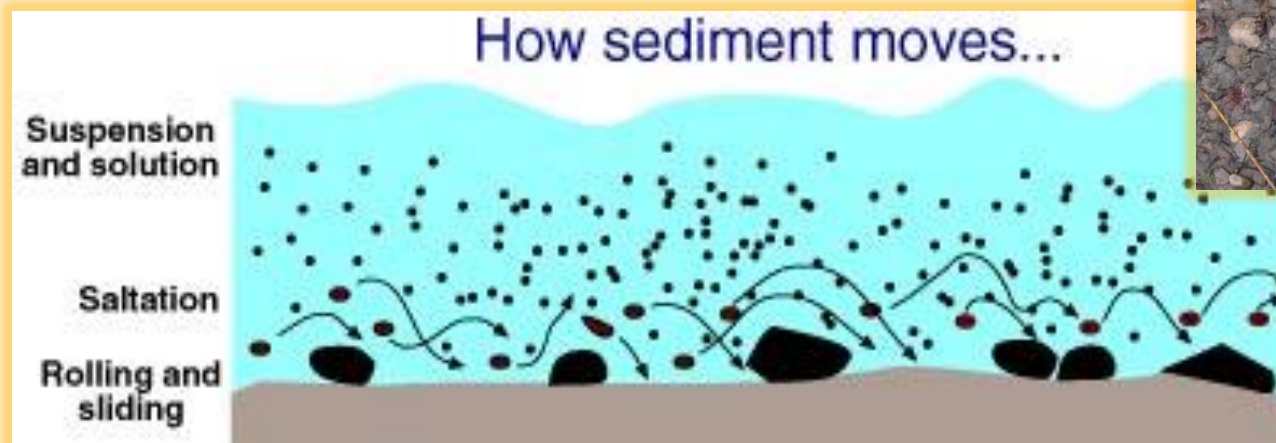
Methods

Monitor

- *Total water flow*
- *Suspended sediment*
- *Dissolved chemicals*



Bedload Transport



Ditch Study Sites



vegetated




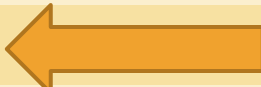



exposed, scraped

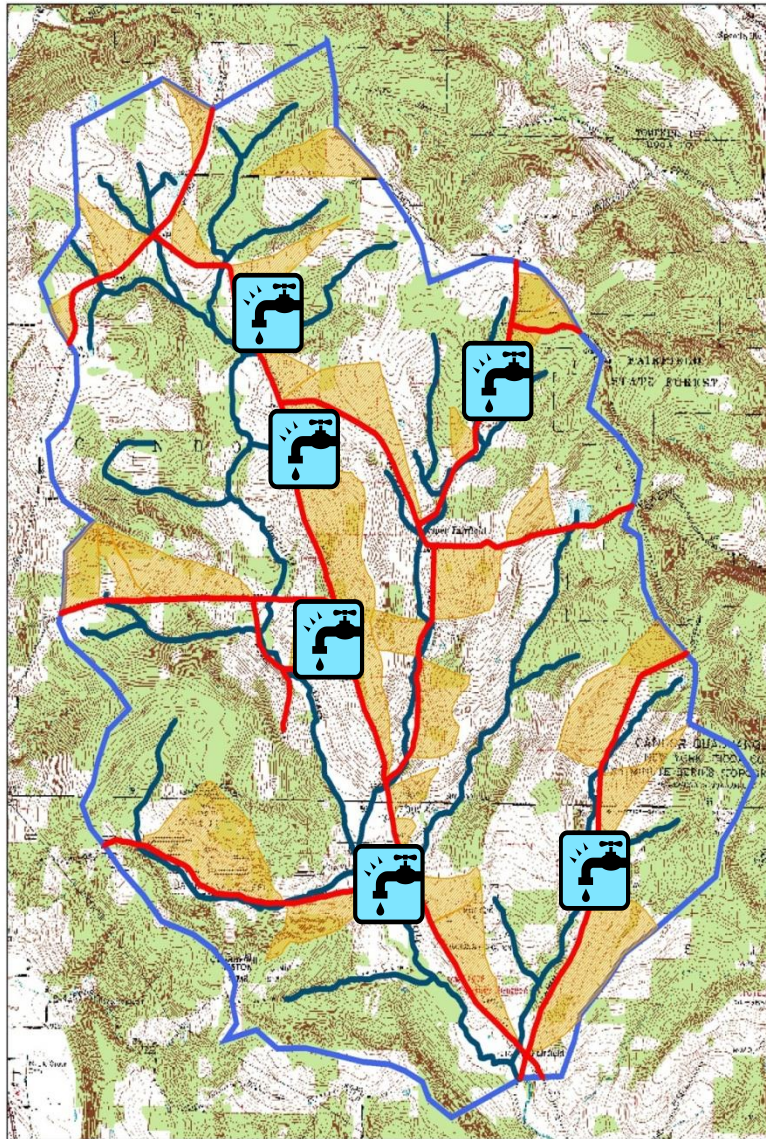
Results - Drainage Mapping

Characteristic

Average value

□ Watershed area	□ 42.3 km ²	
□ Road length	□ 54.3 km	
□ % road surface area of wtshd	□ 0.69 %	
□ Roadside ditch length	□ 81.4 km	
□ Total # of direct connections to strms	□ 94	
□ Total ditch length connected to strms	□ 51.0 km	
□ Area of basins draining to ditches	□ 8.1 km ²	
□ % of watershed draining to ditches	□ 22.3 %	
□ Stream channel length (no ditches)	□ 66.0 km	
□ Stream channel density w/o ditches	□ 1.55 (km/km ²)	
□ Stream channel density with ditches	□ 2.73 (km/km ²)	

Results – Drainage Mapping



Ditch drainage basins potentially intercept ~22 % of the surface runoff and shallow groundwater from each watershed and rapidly shunt it to the nearest stream.



Ditch drainage basins



Stream



Road ditches

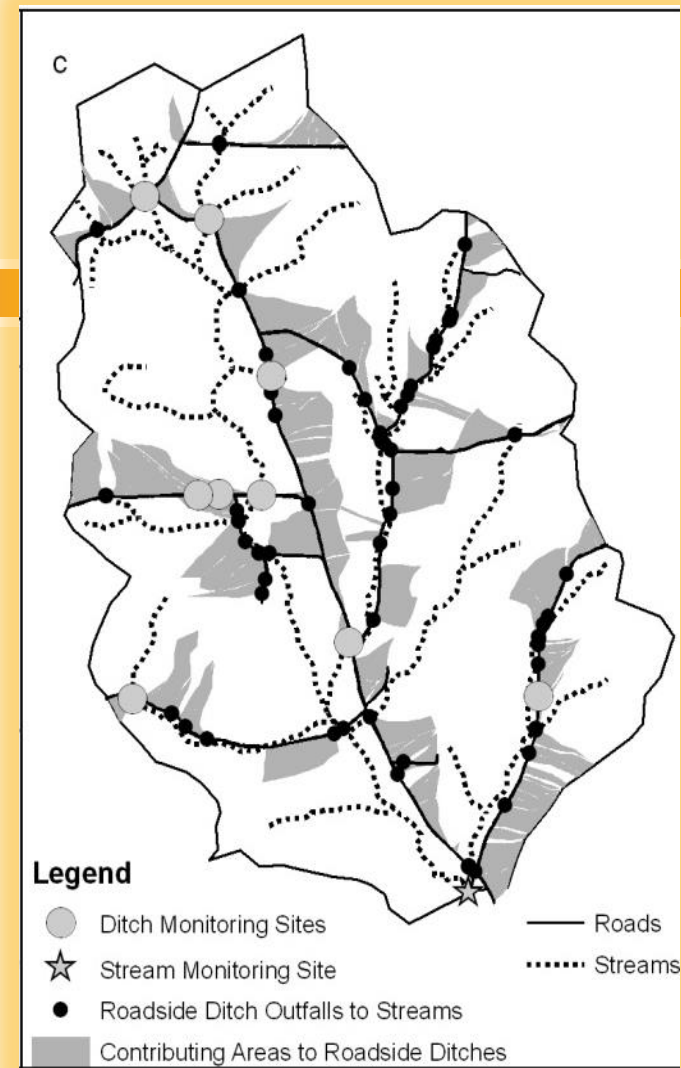


Ditch outflows

Results – Hydrology

Doolittle Creek Watershed

- *8 ditch monitoring stations and Doolittle Crk*
- *10 storms 2005-2006;
1.3 – 12.9 cm total rain/event*
- *Each ditch captured avg of 51% of rainfall in
the ditch's basin*



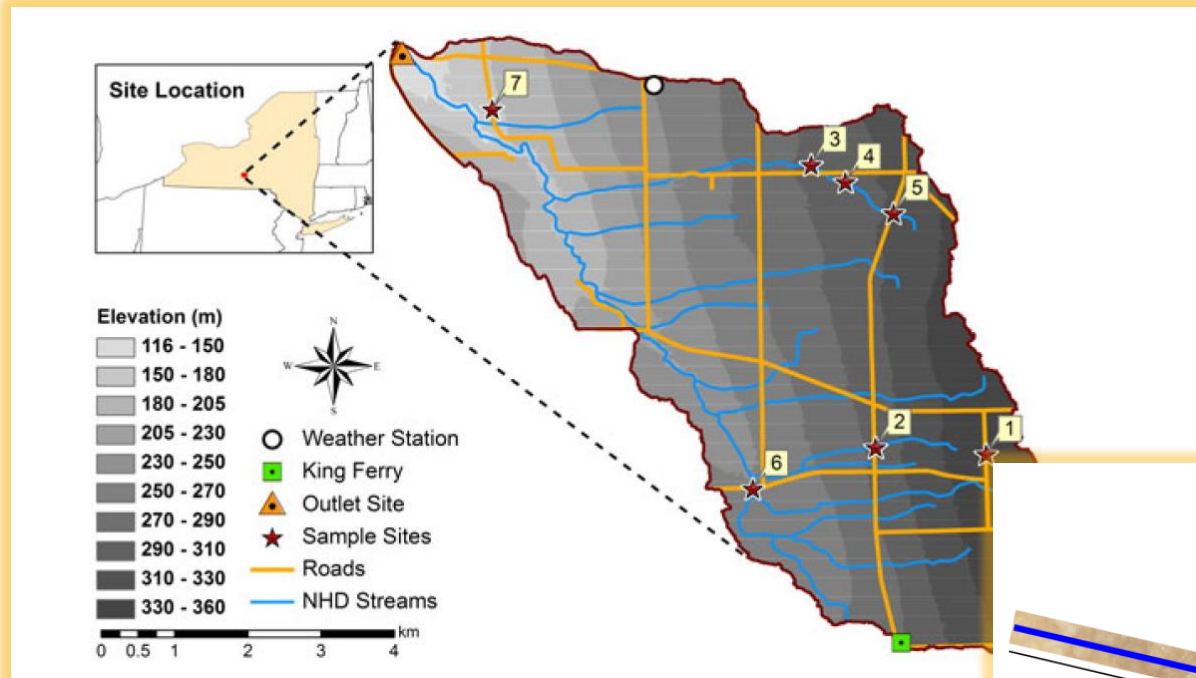
Results – Hydrologic Model

Entire Modeled Ditch Drainage Networks:

- *Doolittle: transported 45,400 m³ water / storm = 3.6% (+/- 1.4%) of incoming precipitation and **19.5%** (+/- 9.7%) of total stream flow measured in each storm*
- *Paine's Creek: **22%** of total stream flow in spring storm event and **29%** of total stream flow in a summer storm event.*

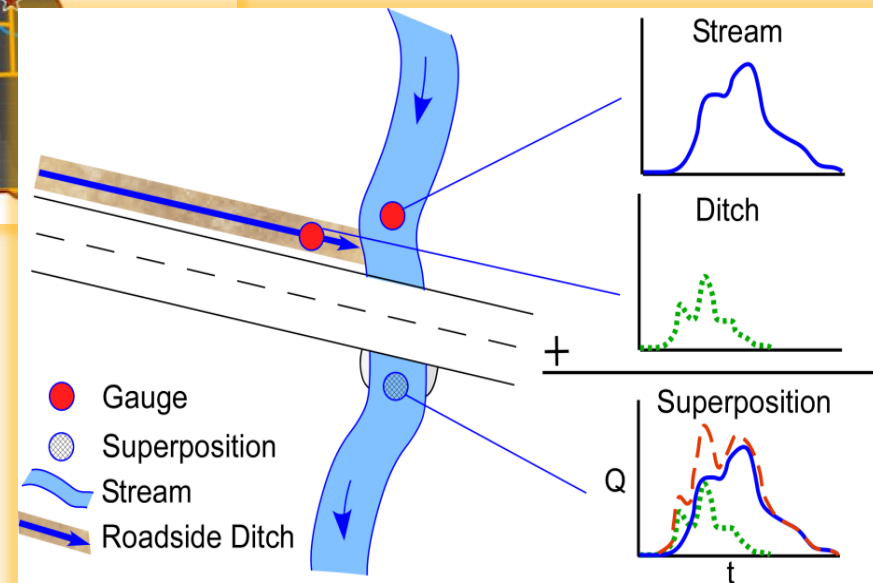
Results - Hydrology

7 ditches
34 storms
2.5 – 40 mm rain
April – Dec. 2009



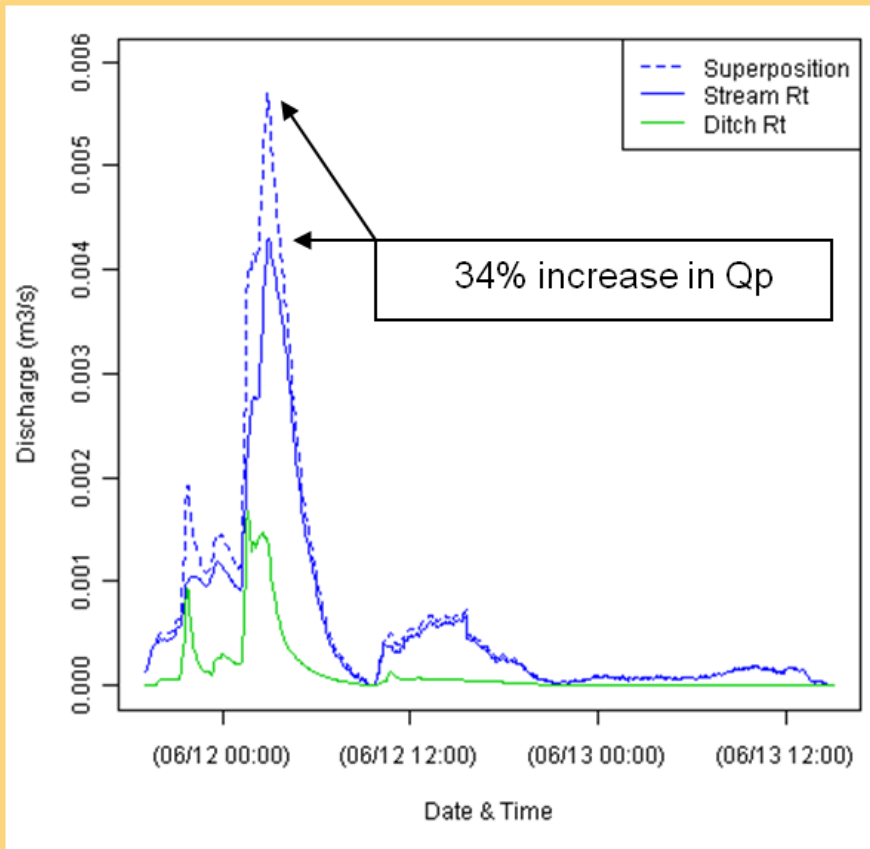
Paine's Creek Watershed

Buchanan et al. 2012

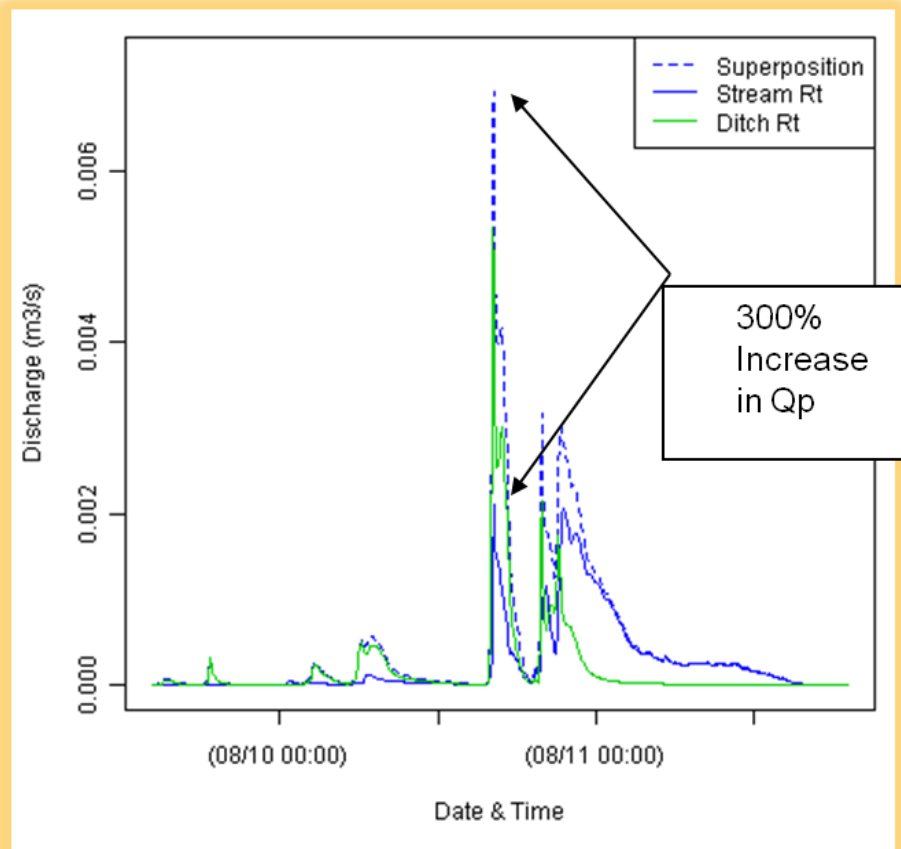


Results – Hydrology

spring

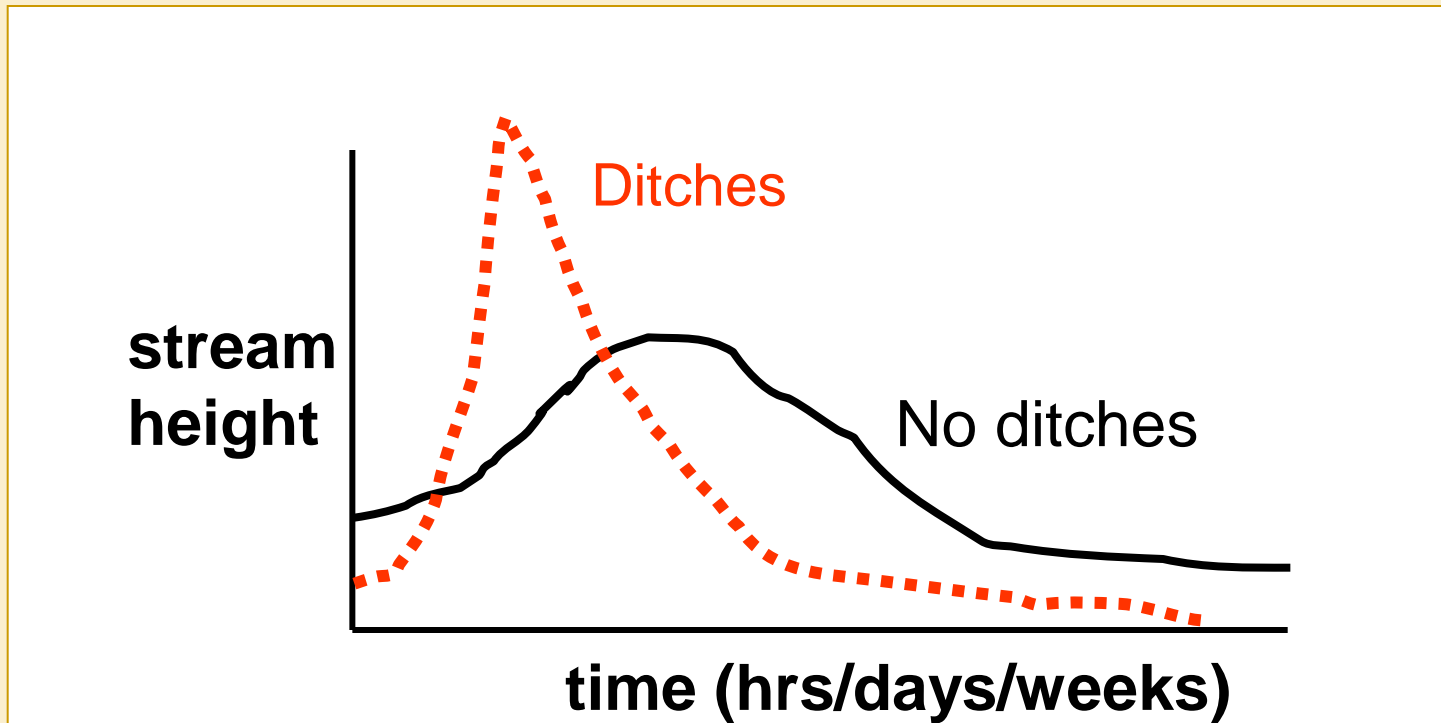


summer



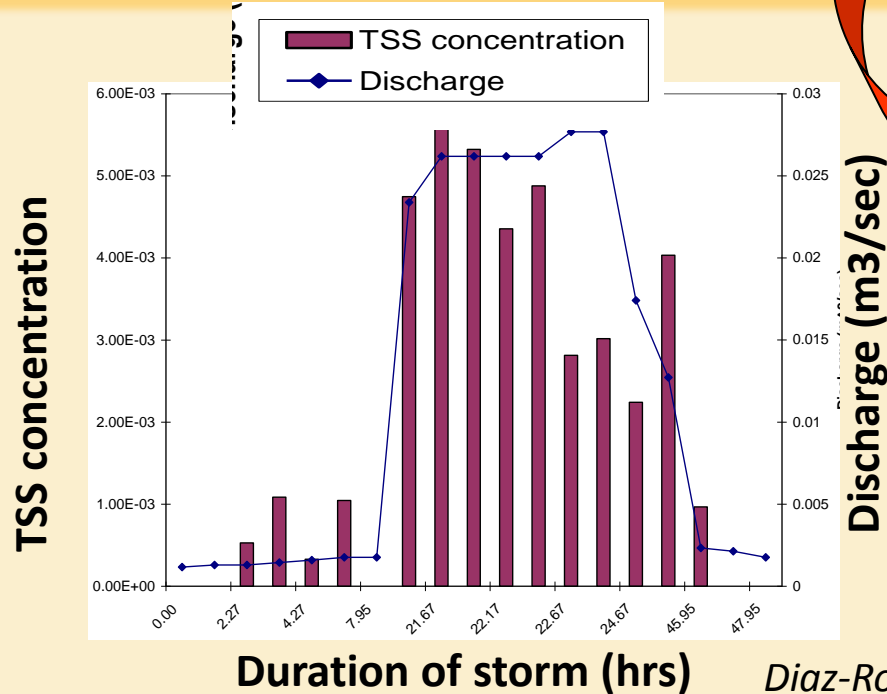
Ditch discharges contribute to increased peak flows (avg 78%) and total flows (avg 57%) in streams. *Buchanan et al. 2012*

Altering the Natural Flow Regime, Aka Environmental Flows



Results – Sediment

Ditches are a source of sediment and associated contaminants to downstream waters, especially when scraped.



Diaz-Robles, 2007



Photo Bill Hecht

Results – Nutrients, Cations

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

	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

Dissolved Chemical Loads over 10 storms

De-icers

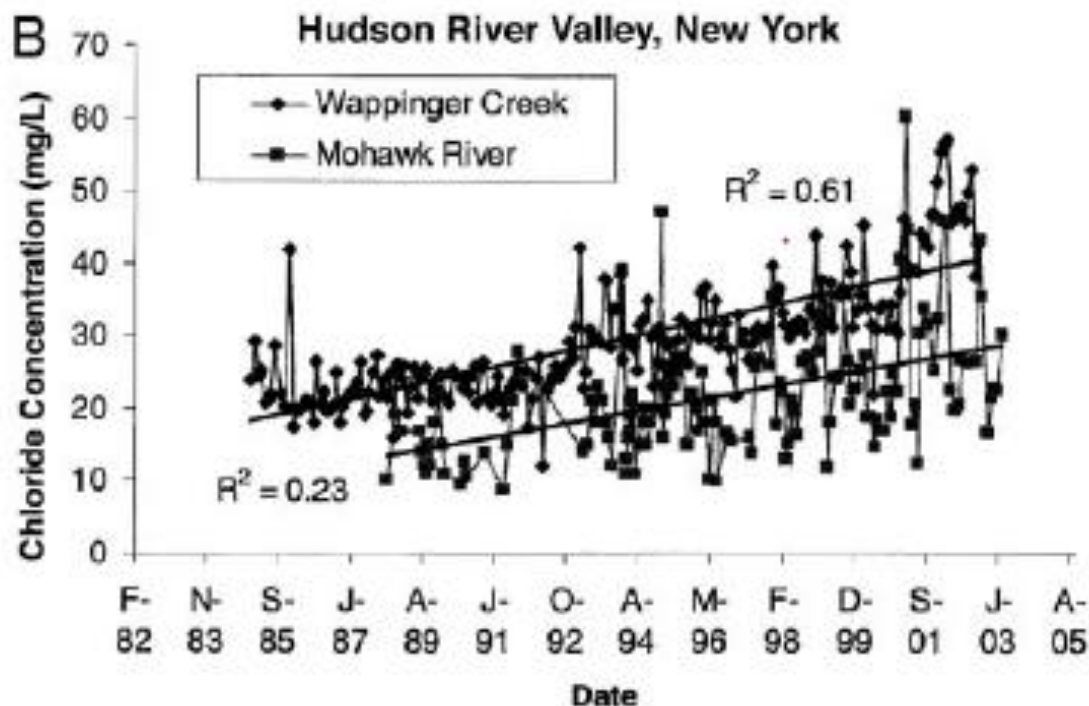
Diaz-Robles 2007

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^{**}

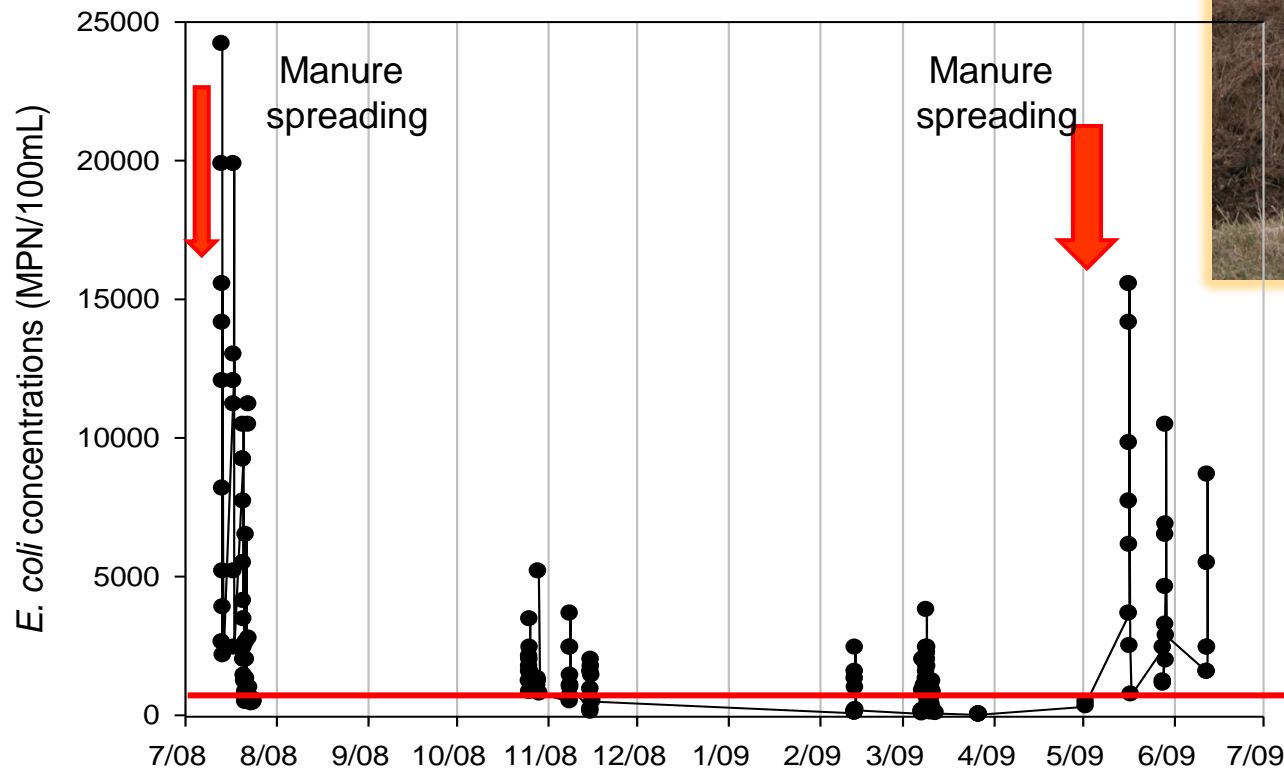
^{*}Institute of Ecosystem Studies, Box AB Route 44A, Millbrook, NY 12545; [§]U.S. Department of Agriculture Forest Service, Northeastern Research Station, University of Maryland Baltimore County, Baltimore, MD 21227; [¶]Baltimore Department of Public Works, 3001 Druid Park Drive, Baltimore, MD 21215; ^{||}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



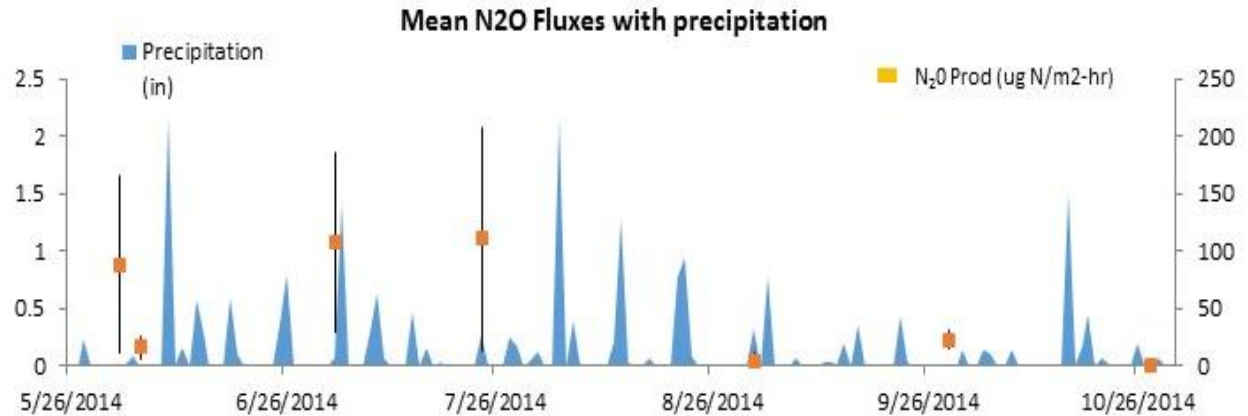
Results - Microbes

Manure spreading, livestock
pasturing ... microbes move via tile
drains to roadside ditches



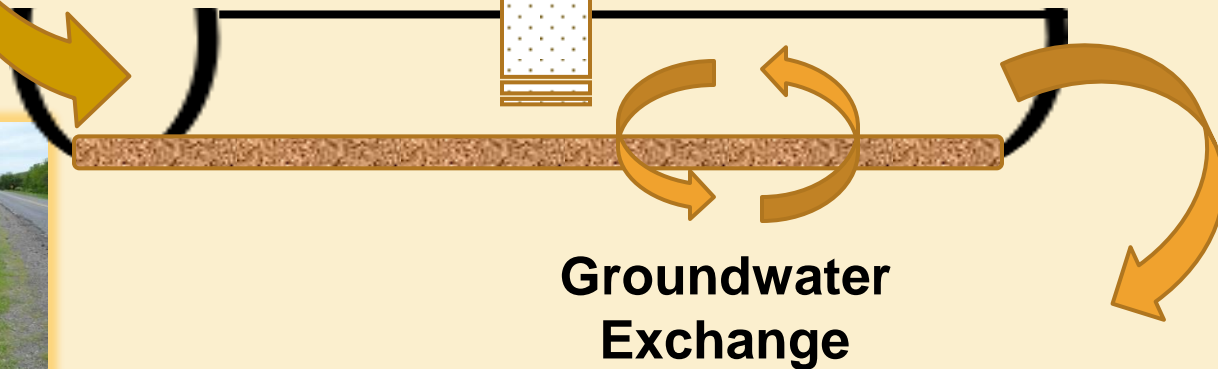
EPA
STD

On-going Research: Conduits/ filters of Nitrogen?



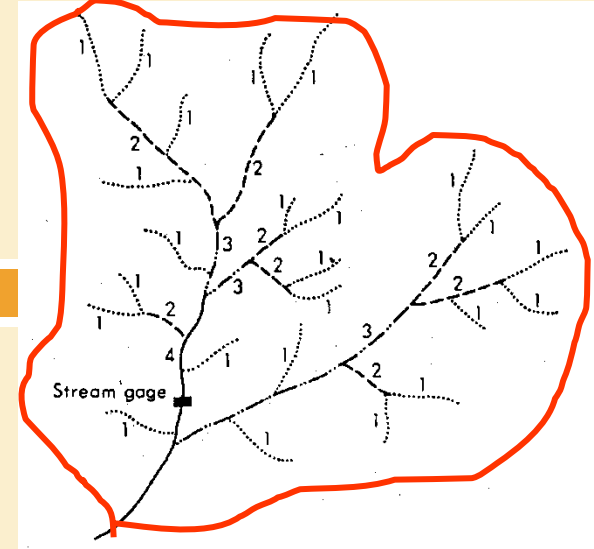
NO_3
~20 mg/l

N_2O
~50 ug/m²-hr



NO_3
~17 mg/l

In-stream Impacts



Upstream / Downstream Movement
via road culverts



<http://www.wellsreserve.org/blog/tags/culvert>

Results – Bedload



Large quantities of gravel, rocks and other bedload move out of ditches and form deltas in the streams.

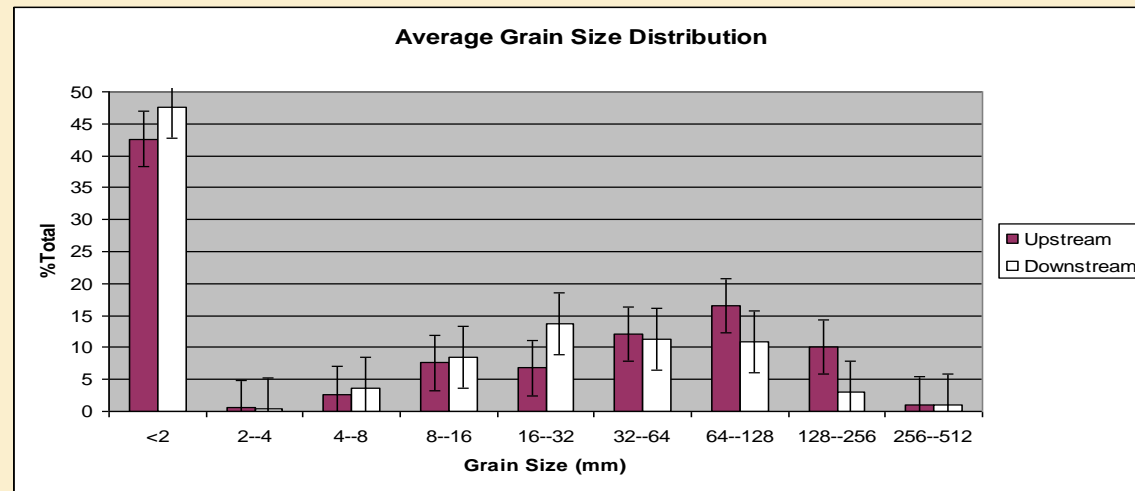
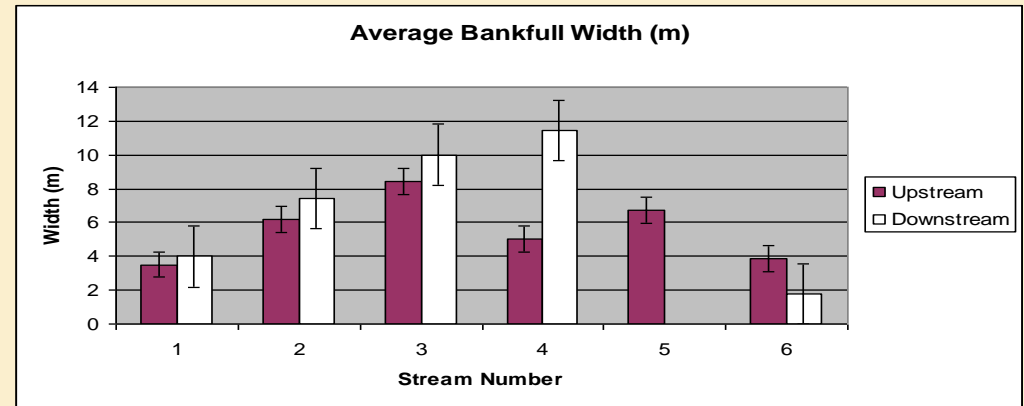
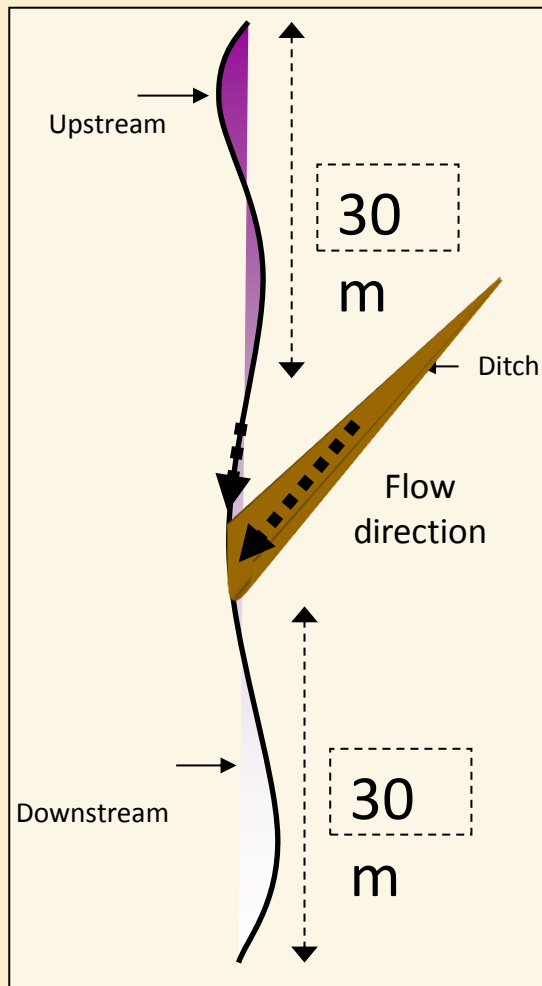


Results – Bedload + Discharge Stream Geomorphology



**High velocity discharges,
bedload deltas
impact stream at ~94
locations in each watershed.**

Results – Hydraulic Radius and Substrate

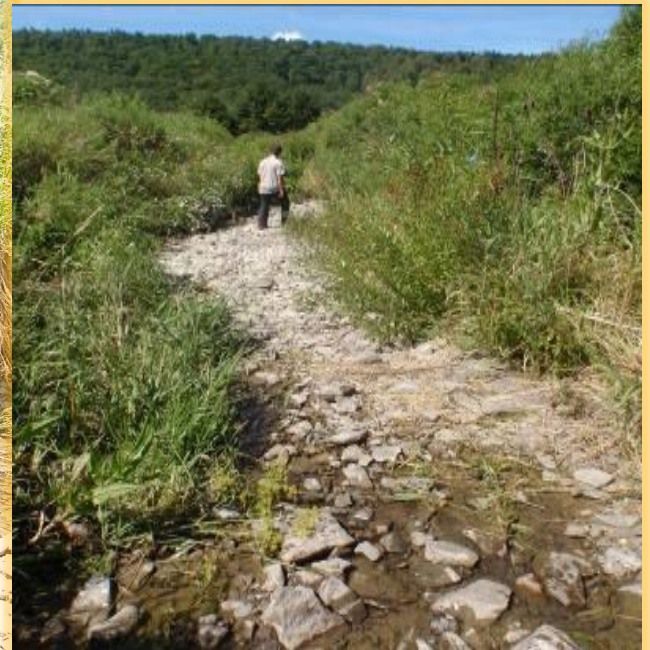


Streams are in chronic disequilibrium with a storm-driven geomorphology

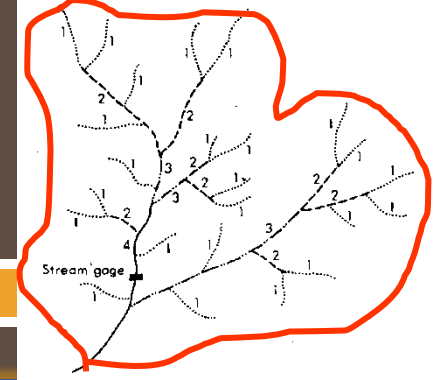


upstream

downstream



Impacts on Stream Health



- Change hydrologic regime – higher floods
- Dry out headwaters
- Increase turbidity, pollution
- Alter geomorphology



Extension Program on Re-plumbing Ditches

- ***Presentations to ~2,500 town highway staff – Cornell Local Roads Highway School, Town govts***
- ***Chesapeake Bay Watershed Conference and Report 2016***



Roadside Ditches

Best Management Practices to Reduce Floods, Droughts, and Water Pollution

We all live in a watershed, and precipitation is the lifeblood of a watershed. When rainfall pounds impervious surfaces and compacted soils, it runs off rapidly instead of percolating down to the groundwater. The runoff can contribute to flooding and carries pollutants that degrade water quality.

Hundreds of miles of ditches criss-cross each watershed. While the ditches drain roads, they also efficiently intercept the runoff from adjacent hillslopes, capturing about 20 percent of the runoff in each watershed. Ditches rapidly shunt the water to streams, where it is discharged, like a high-velocity faucet. Ditches are also conduits of road salts, fertilizers, and viable pathogens from lawns and farms to streams. Unprotected ditches are a significant source of suspended sediment and gravel, turning the streams brown with each storm event. The ditch outputs disturb the natural stream flow and cause erosion along the stream banks.

The end results of these cumulative impacts are:

- increased flooding
- declining groundwater tables
- drier streams and empty wells
- greater streambank erosion
- increased pollution in our drinking water supplies

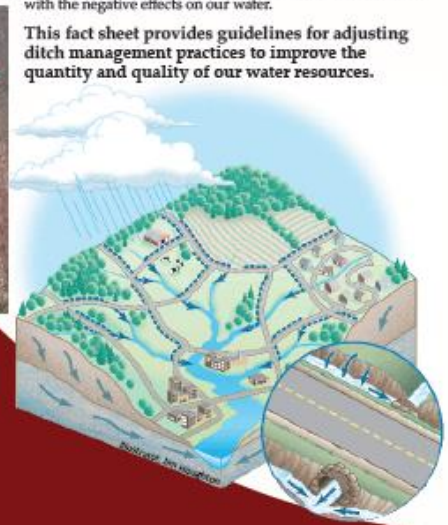
The management practices for roadside ditches, instituted nationwide almost a century ago, have been implemented in large part without considering the impacts on downstream water resources.

Growing water scarcity and anticipated impacts from climate change, however, call for better water stewardship. We need to balance the value that ditches provide in protecting our roadways with the negative effects on our water.

This fact sheet provides guidelines for adjusting ditch management practices to improve the quantity and quality of our water resources.

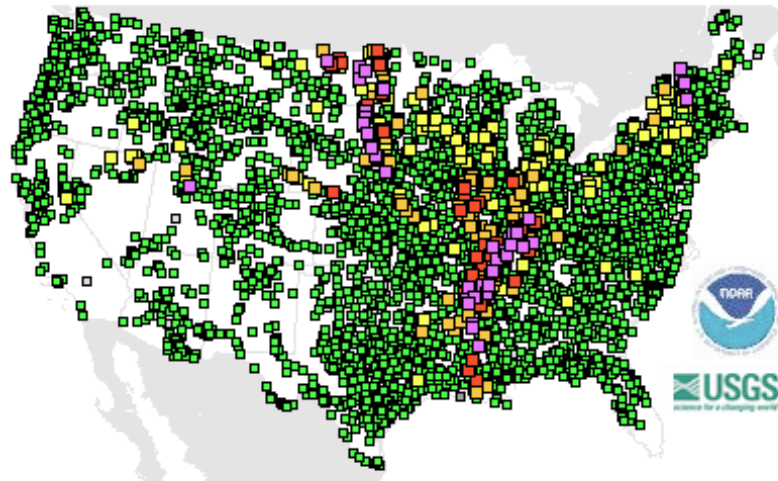


Recent research at Cornell University indicates roadside ditches are a previously unrecognized but critical contributor to flooding and pollution of our waters.



Cornell University

Roadside Ditch Management: Catch and save the rain to buffer the impacts of climate change



4851 Total Gauges
193 Locations in Flood

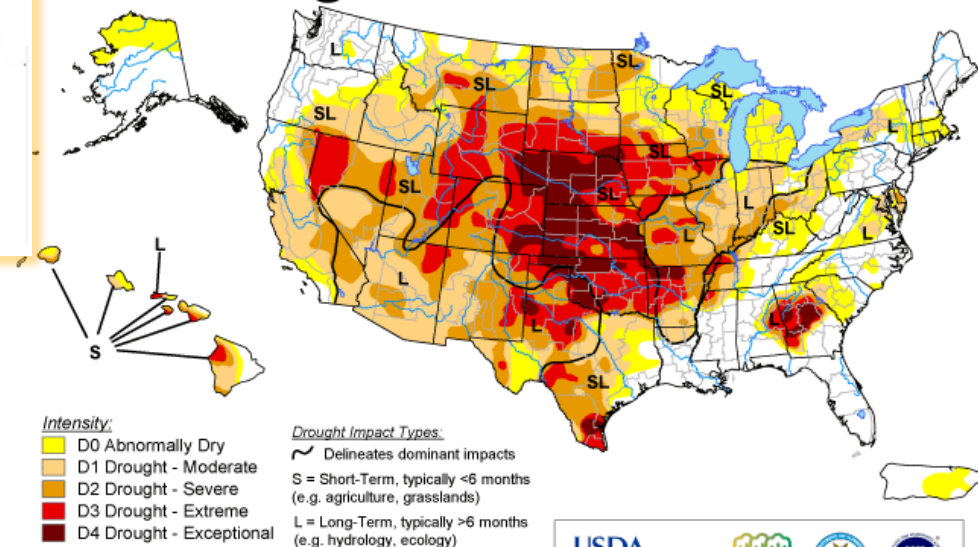
302 Gauges: Observations older than 24 hours
7 Gauges: Out of Service

48 Gauges: Major Flooding
52 Gauges: Moderate Flooding
93 Gauges: Minor Flooding
118 Gauges: Near Flood Stage
4231 Gauges: No Flooding

Last map update: 05/08/2011 at 03:30:40 am EDT / 05/08/2011 07:30:40 UT

2011 Flooding Mississippi R.

U.S. Drought Monitor September 11, 2012 Valid 7 a.m. EDT



Intensity:

D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional

Drought Impact Types:

~ Delineates dominant impacts
S = Short-Term, typically <6 months
(e.g. agriculture, grasslands)
L = Long-Term, typically >6 months
(e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions.
Local conditions may vary. See accompanying text summary
for forecast statements.



Released Thursday, September 13, 2012

Questions?



<http://blogs.cornell.edu/sustainablewaterresourcemanagement/>

Status of NYS Ditch Management

- Avg number of miles of ditches maintained: 60 +/- 145
- 25-49% of HDs reported spending average of 43% of their time spent on ditch maintenance
- 60% HDs report scraping/ cleaning as most common method of ditch maintenance; 11% report mowing as most common method
- How often scraped? 42% of HDs reported 1x/ 2-4 years
- % scraped that are reseeded immediately?
 - 50% HDs reported 0% are reseeded immediately
 - ¼ of ditches reseeded immediately by only 21% of HDs