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The Value of Source Water Protection

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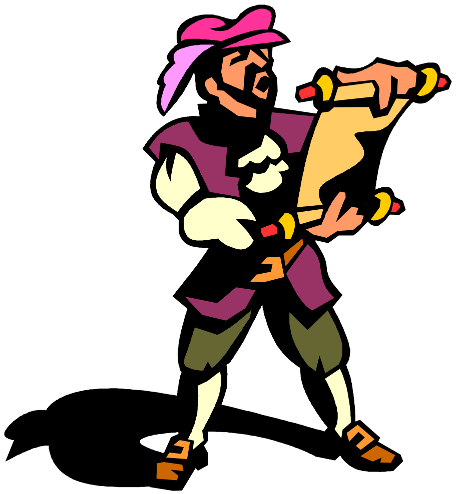
The Cadmus Group, Inc., Waltham, MA

For Battenkill Conservancy – February 28, 2016

Early Source Water Protection Program

- *"There shall be no man or woman dare to wash nay unclean linen, wash clothes,...nor rinse or make clean any kettle, pot, or pan or any suchlike vessel within twenty feet of the old well or new pump. Nor shall anyone aforesaid, within less than a quarter mile of the fort, dare to do the necessities of nature, since by these unmanly, slothful, and loathsome immodesties, the whole fort may be choked and poisoned."*

  Governor Gage of Virginia, Proclamation for Jamestown, VA (1610)



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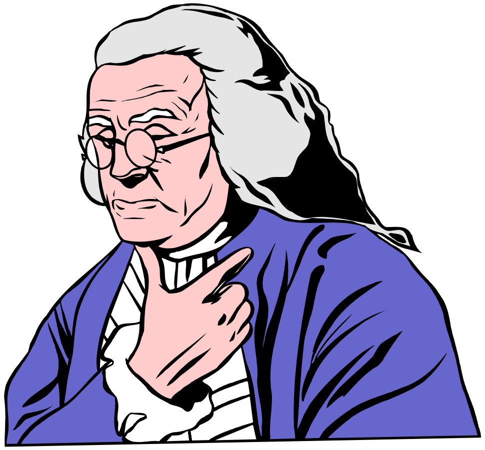
Quotes from **Benjamin Franklin**



- “When the well’s dry, we know the worth of water”, __ Benjamin Franklin, Poor Richard’s Almanac, 1746

- “An ounce of prevention is worth a pound of cure”, __ Benjamin Franklin

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Objectives

- Examine hydrologic responses from land use changes
- Discuss association of contaminants and land use
- Issues with urban stormwater
- Issues related to sediment and nutrients
- Develop and implement preventive and mitigating approaches through land use control to protect drinking water sources

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Hydrologic Responses to Land Use Changes

- Evolution of nature hydrologic regimes
  - Climatic conditions
  - Geology and soils
  - Vegetation
  - Event frequency (high and low)
  - Time

Hydrologic Responses to Land Use Changes

- Hydrologic cycle
  - Precipitation
  - Infiltration and percolation
  - Ground water storage and flow
  - Evapotranspiration
  - Runoff
  - Streamflow
    - Stormflow
    - Interflow
    - Baseflow

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Natural Conditions

Courtesy May, U of W

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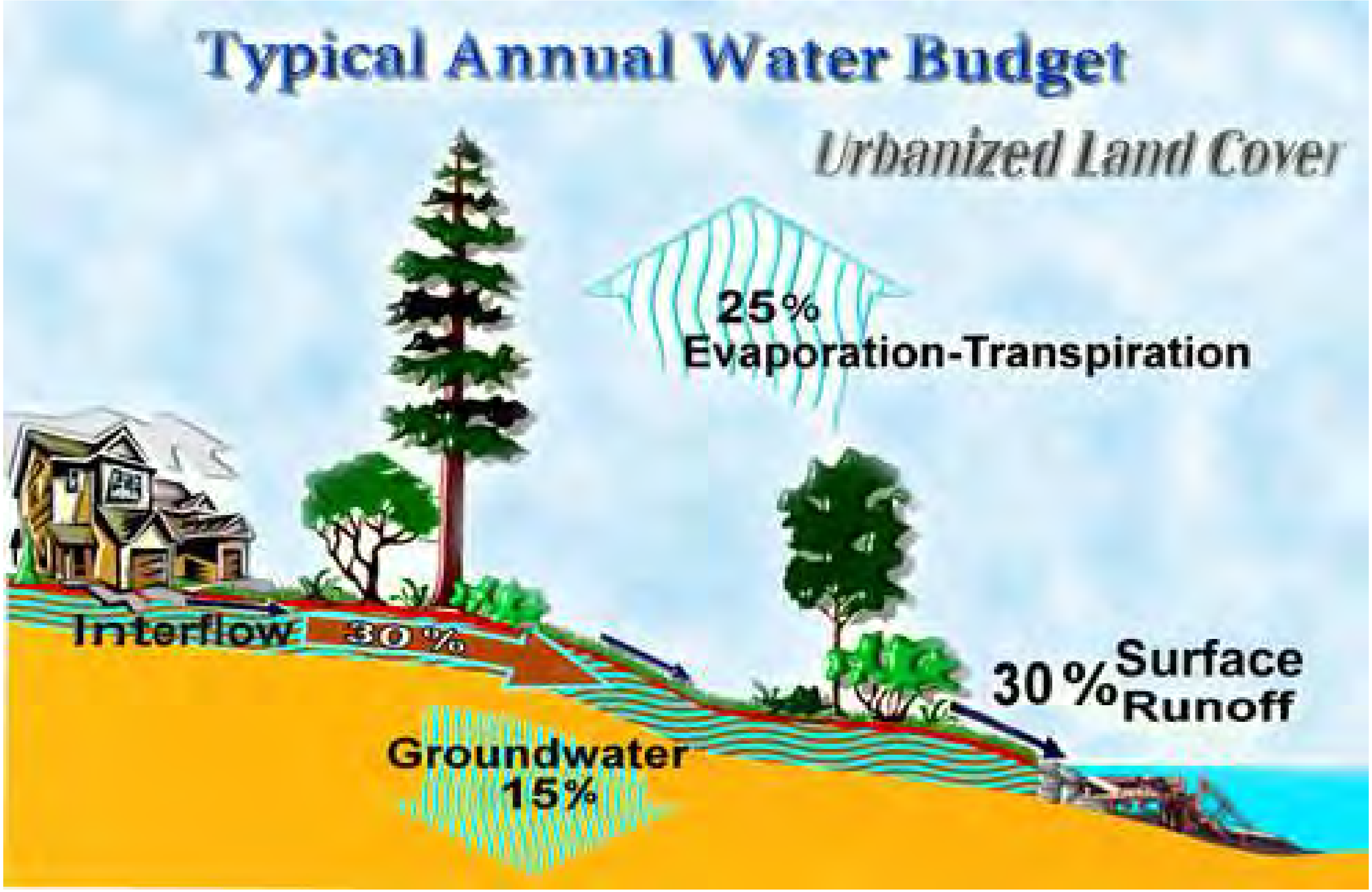
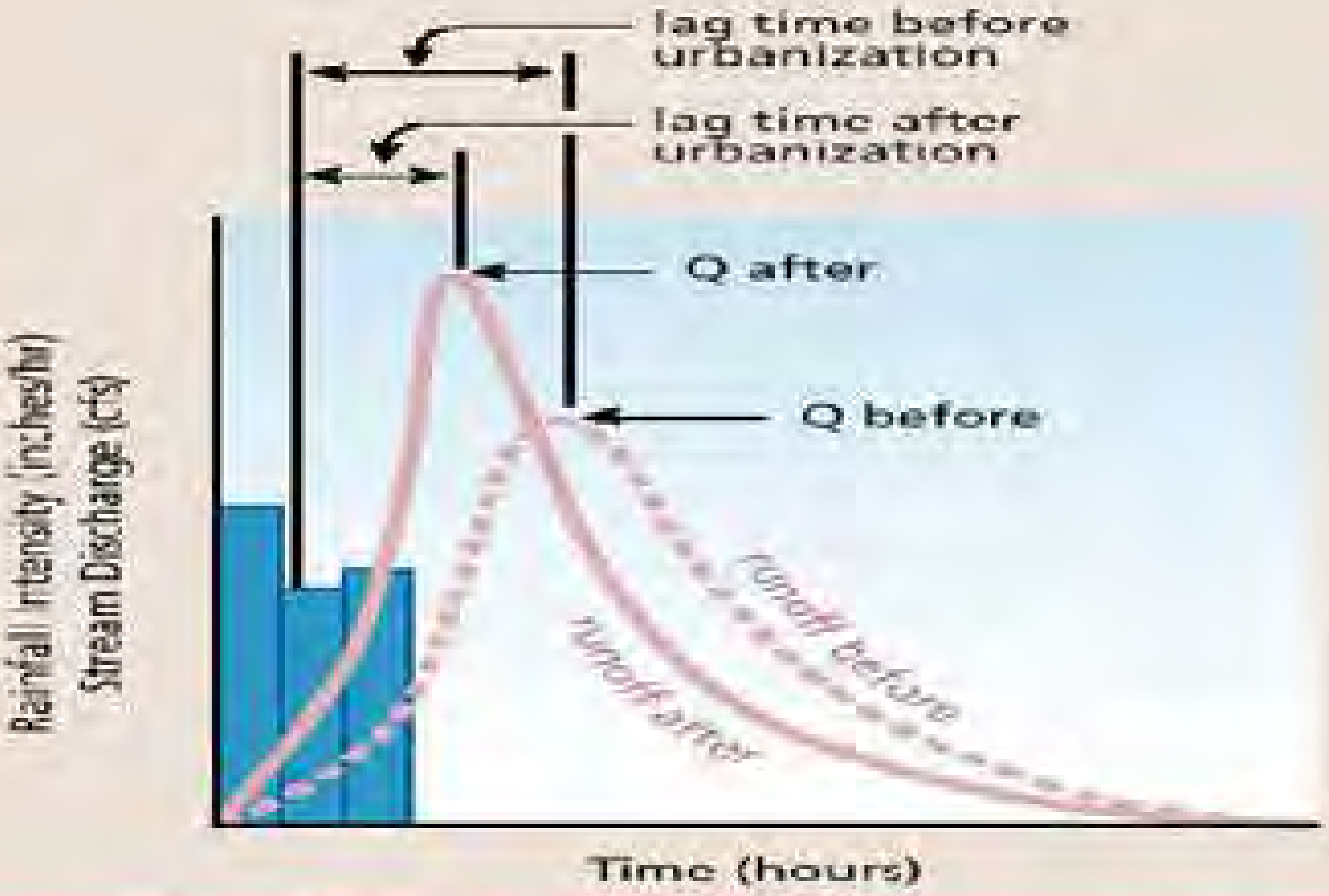
Developed Conditions



Hydrologic Responses to Land Use Changes



A comparison of hydrographs before and after urbanization (blue bars indicate rainfall rate and timing). The discharge curve is higher and steeper for urban streams than for non-urbanized streams due to faster and greater runoff.

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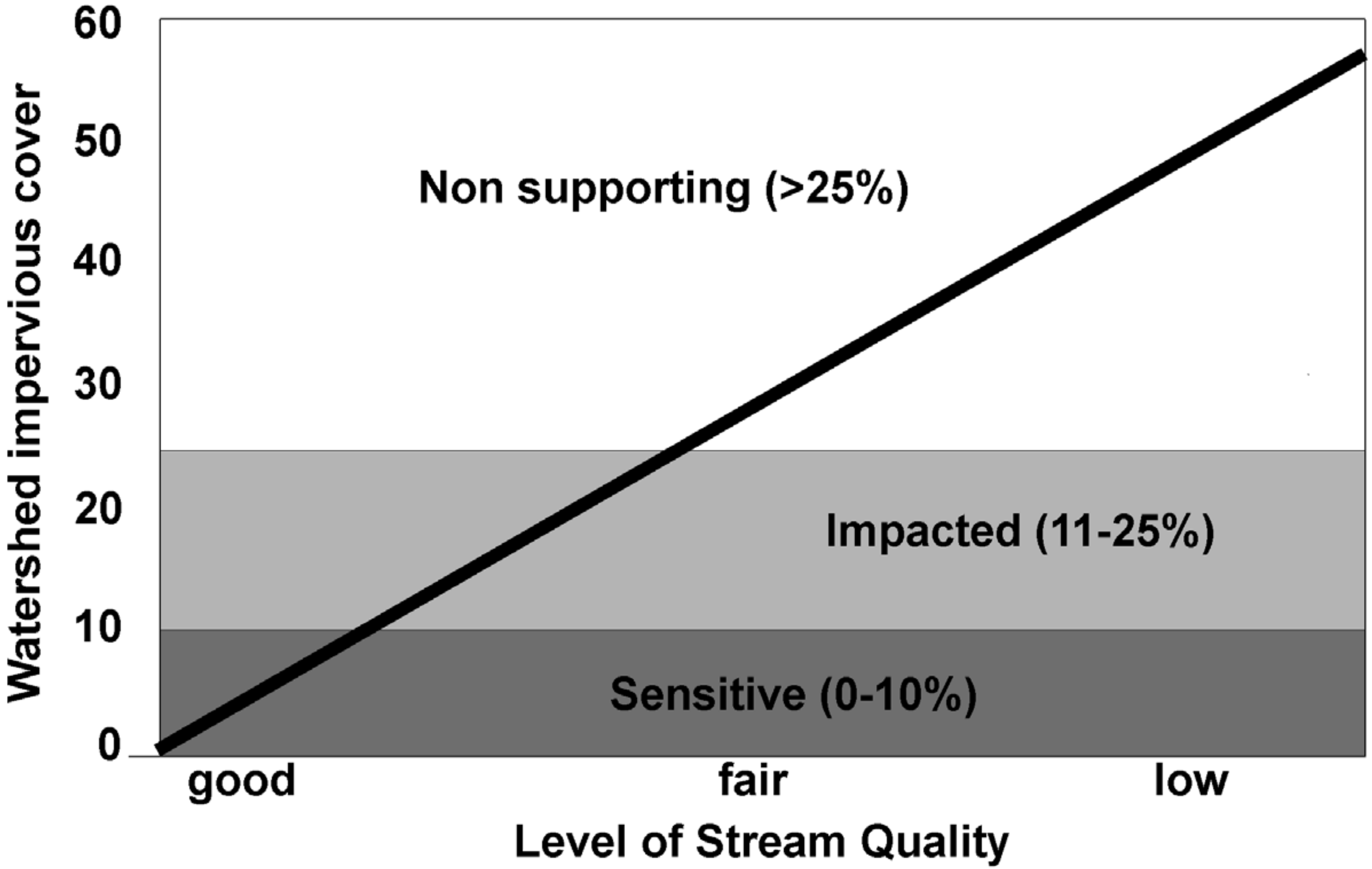
Relationship Between Impervious Cover and Stream Quality



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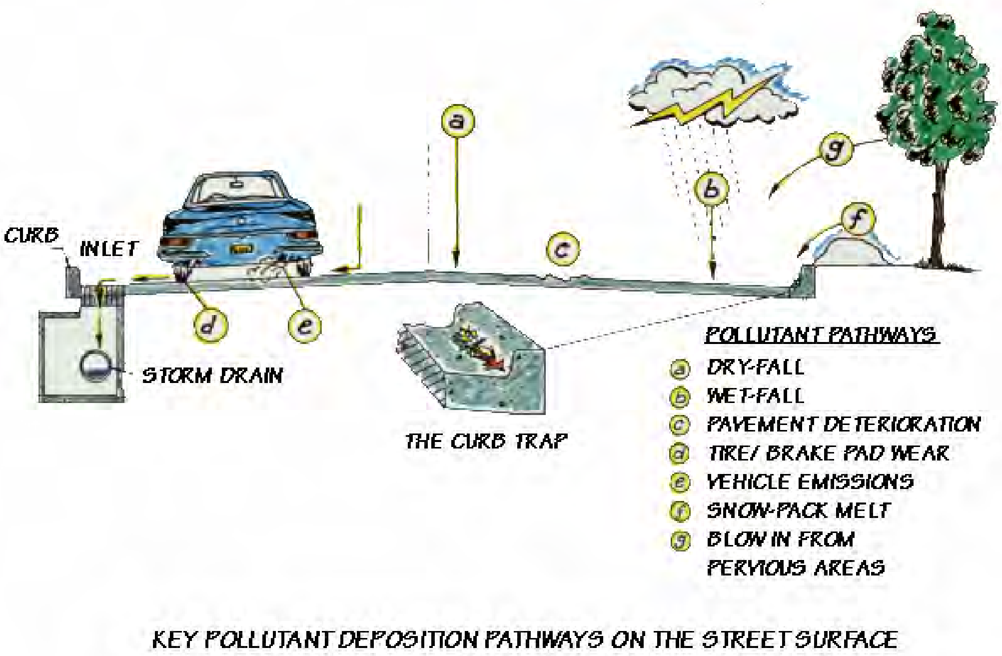
Land Based Contaminants – Surface Runoff

- Source areas
  - Auto recycling
  - Commercial parking lots
  - Fleet storage areas
  - Industrial rooftops
  - Landscaping/nursery
  - Industrial (outdoor storage or unloading)
  - Vehicle service and maintenance
  - Vehicle washing/steam cleaning

  - Agricultural practices
  - Forest harvesting

Land Based Contaminants – Urban Stormwater



Land Based Contaminants – Urban Stormwater

- Typical pollutants
  - Suspended solids/sediments
  - Nutrients (nitrogen and phosphorus)
  - Metals (copper, zinc, lead, and cadmium)
  - Oil and grease
  - Bacteria
  - Pesticides and herbicides
  - Temperature

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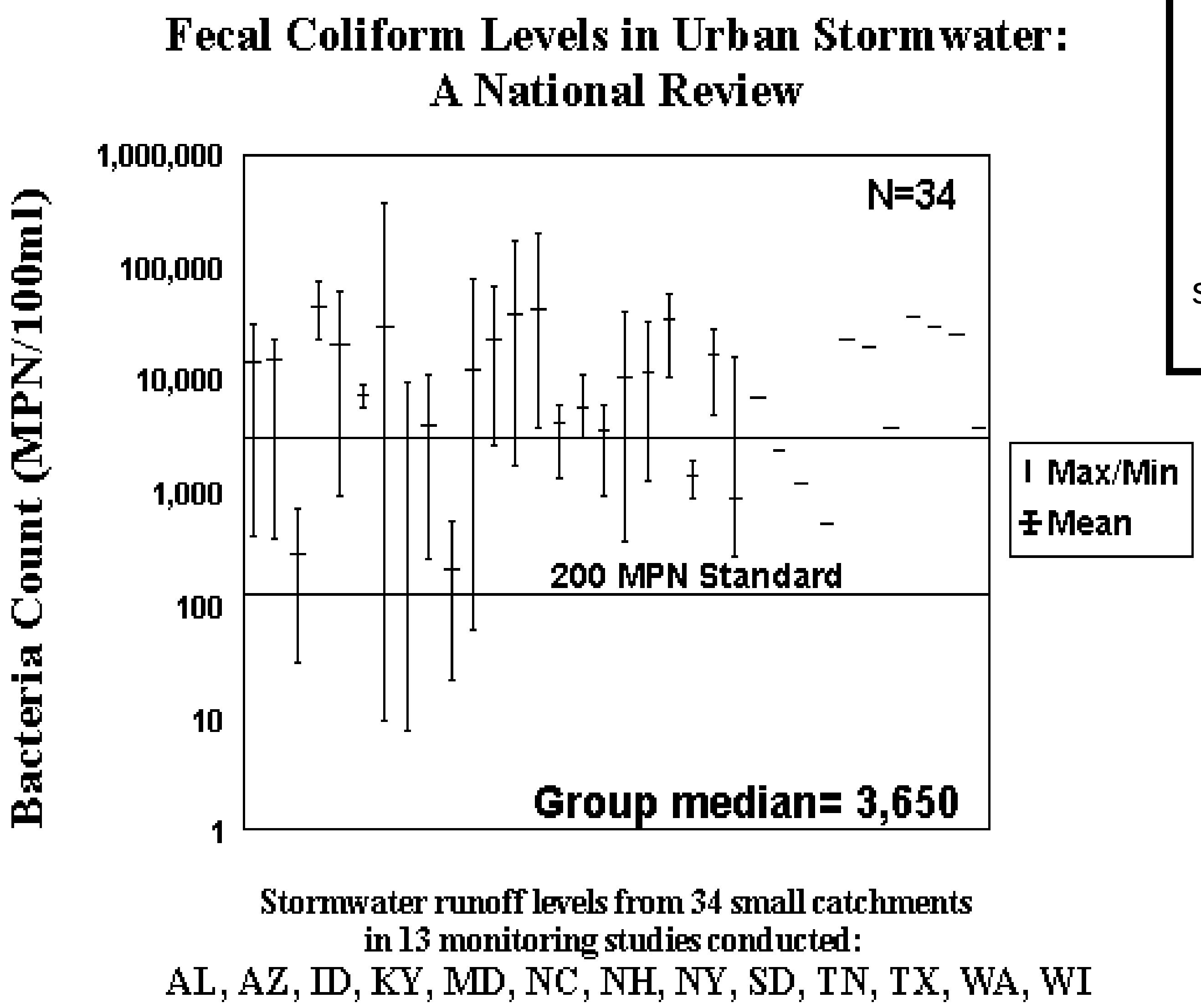
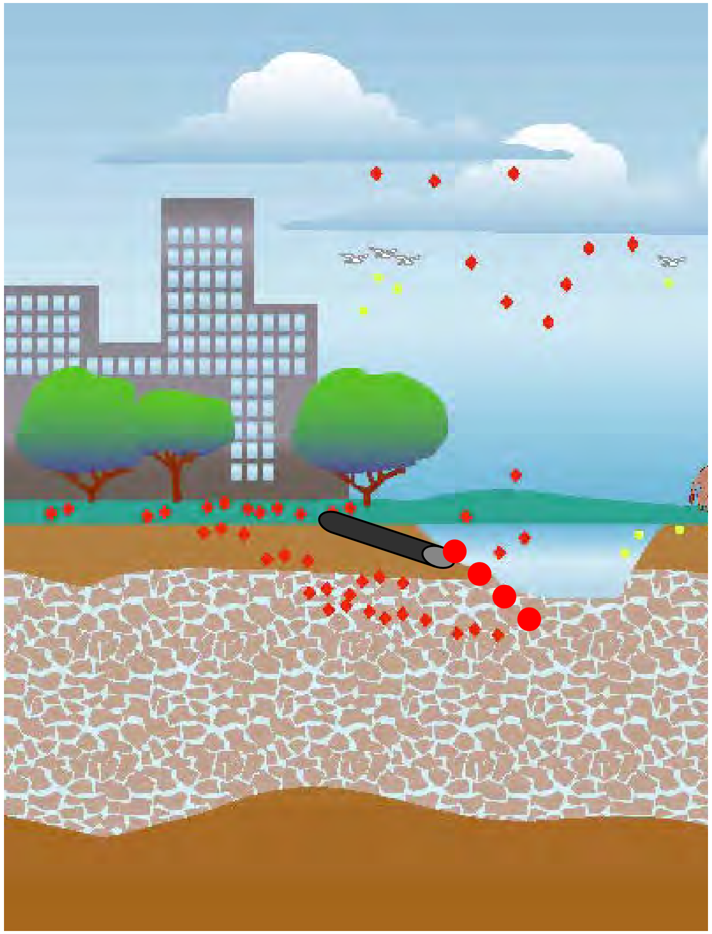
Studies of fecal coliform levels have found much higher levels in urban stormwater runoff than the standard accepted levels.



Land Based Contaminants – Wastewater Discharge

- Sources
  - Publicly Owned Treatment Works (POTWs)
  - Commercial activities (direct and indirect)
  - Industrial activities (direct and indirect)
  - Landfills
  - Mining operations

Land Based Contaminants – Wastewater Discharge



- Direct discharge to waterbodies
- Overflows
- Pretreatment requirements
- Treatment technologies

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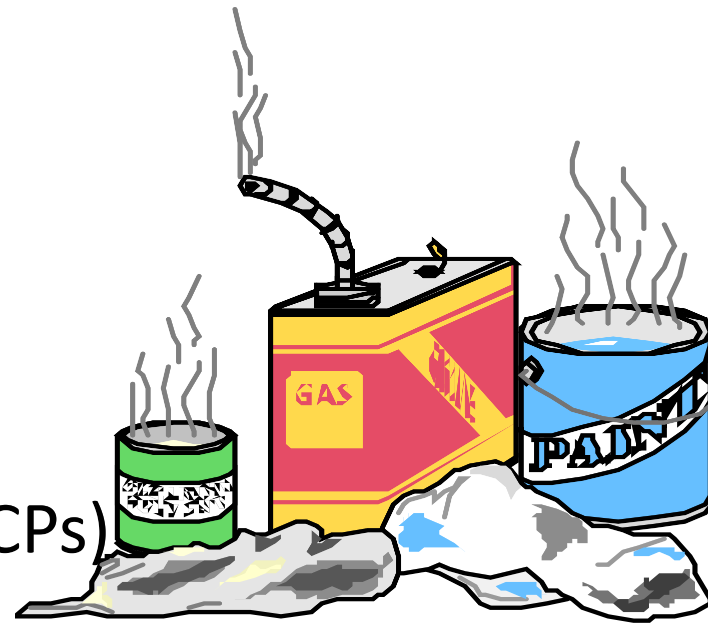
Land Based Contaminants – Wastewater Discharge

- Types of Contaminants
  - Volatile organic chemicals (VOCs)
  - Inorganic chemicals (IOCs)
  - Synthetic organic chemicals (SOCs)
  - Microbiological
  - Emerging contaminants (PPCPs)



Land Based Contaminants – Sediment and Nutrients

Land Based Contaminants – Sediment and Nutrients

- Nutrient pollution, especially from nitrogen and phosphorus, has consistently ranked as one of the top causes of degradation in some U.S. waters for more than a decade. Excess nitrogen and phosphorus lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that make people sick.

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Land Based Contaminants – Sediment and Nutrients

Table 12 Export coefficient (EC) summary for nitrogen and phosphorus (Reckhow et al., 1980; Johnes, 1996; Worrall & Burt, 1999; Bernald et al., 2003)

Crop code	SWAT_ID	Details	N EC (kg/ha/y)	P EC (kg/ha/y)
FRSE	Forest-Evergreen	Forest	1.8	0.11
FRSD	Forest-Deciduous	Forest	1.8	0.11
FRST	Forest-Mixed	Forest	1.8	0.11
RNGB	Range-Brush	Forest	1.8	0.11
RNGE	Range-Grasses	Forest	1.8	0.11
ORCD	Orchard	Orchard	4.8	3.6
RI_R	Rice Irrigated	Rice_double	33.6	10.8
Rice	Rice	Rice	16.8	5.4
WWHT	Winter wheat	Wheat	16.8	3.6
CORN	Corn	Corn	26.4	12
AC_R	AGRC Irrigated	Wheat+Corn	43.2	15.6
AGRL	Agricultural Land-Generic		16.8	5.4

Drinking Water Issues Related to Excessive Nutrients

- Total Organic Carbon
- Disinfection Byproducts

- Cyanobacteria and Algae
- Toxins and Taste & Odor

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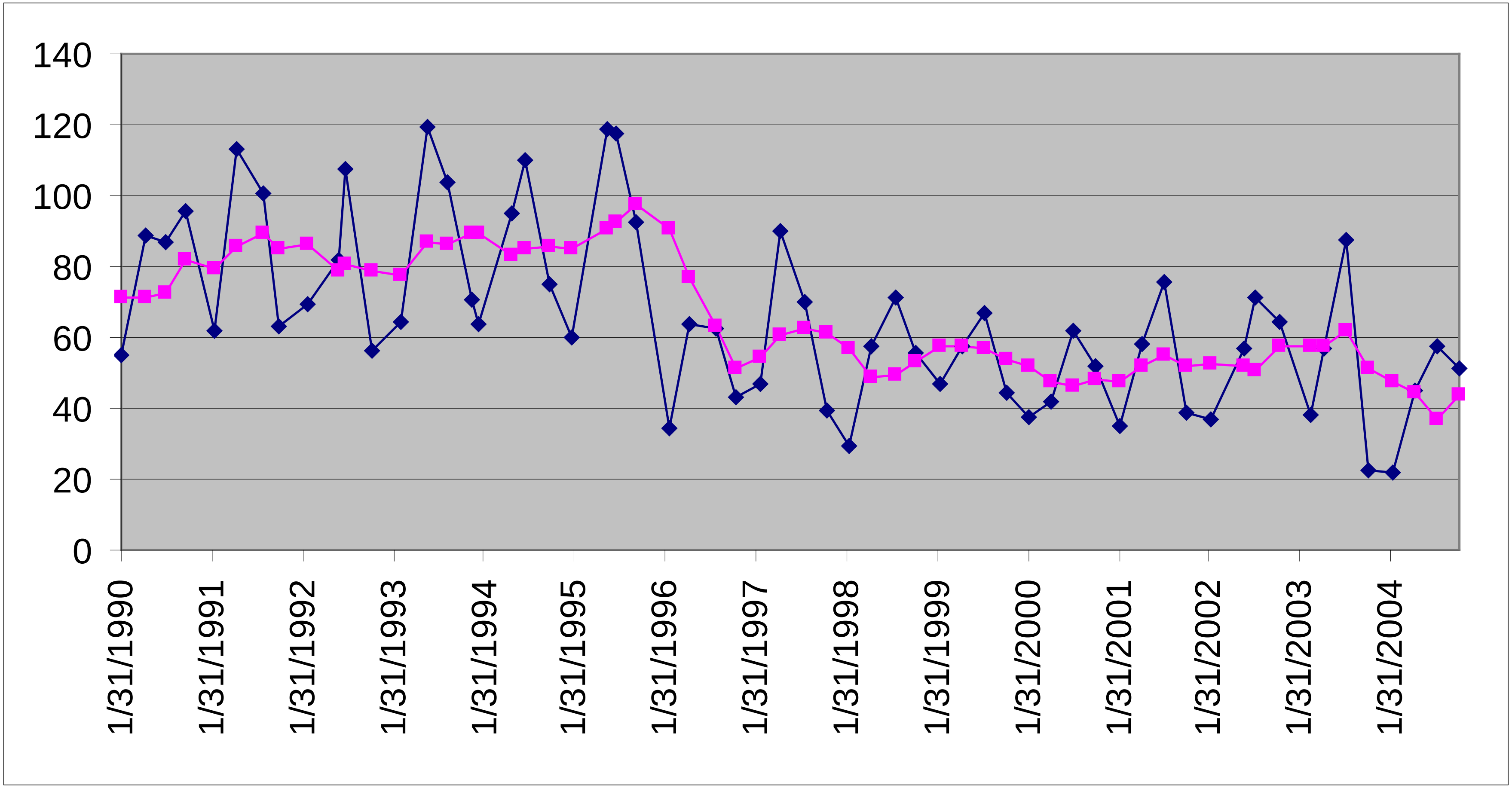
Drinking Water Issues Related to Excessive Nutrients



TTHMs

Important Cyanotoxins

Name	Effect	Reaction t	Comments
Microcystins (MC)	Hepatotoxin	Hours-Days	acute/chronic liver tumors/cancer
Nodularins	Hepatotoxin	Hours-Days	estuaries, brackish
Cylindrospermopsin	Hepatotoxin	Hours-Days	invasive
Anatoxin *a* (ATX)	Neurotoxin	Fast acting (min)	pets & birds
Saxitoxin (STX)	Neurotoxin	Fast acting (min)	cf. red tide
BMAA	Neurotoxin	Fast/Long-term?	Neurological Disorders

BMAA - beta-Methylamino-L-alanine

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Drinking Water Issues Related to Excessive Nutrients

Cause the most common taste and odor problems in water

Chemical cause	Taste/odor	Origin
Geosmin	earthy or grassy odors	Produced by actinomycetes, blue-green algae, and green algae.
2-Methylisoborneol (MIB)	musty odor	Produced by actinomycetes and blue-green algae.
2t, 4c, 7c-decatrienal	fishy odor	Produced by blue-green algae.

Drinking Water Issues Related to Excessive Nutrients

- Contributors to nitrogen and phosphorus pollution:
  - Overusing fertilizer (residential and agricultural usage)
  - Rainfall flowing over cropland, animal feeding operations and pastures, picking up animal waste and depositing it in water bodies
  - Rainfall flowing over urban and suburban areas where stormwater management is not implemented(e.g., parking lots, lawns, rooftops, roads)
  - Discharge of nitrogen and phosphorus from wastewater treatment plants
  - Overflow from septic systems

Conditions Where Nitrate Contamination Is Likely

A localized "above-normal" nitrate load occurs in excess of natural denitrifying capacity of the area.

- Excessive fertilizer applied to a field or yard (e.g., crop-yield competition).

Conditions Where Nitrate Contamination Is Likely

A localized “above-normal” nitrate load occurs in excess of natural denitrifying capacity of the area.

- Feedlots and waste lagoons

Preventive and Mitigating Approaches to Protect Source Water

- Land use management
  - Preserve or restore original hydrologic regimes
  - Moderate impacts from land use changes on hydrologic regimes
  - Eliminate the probability of contaminant release into the environment and source water
- Pollution prevention
  - Minimize release of contaminants from existing establishments and land use through control measures

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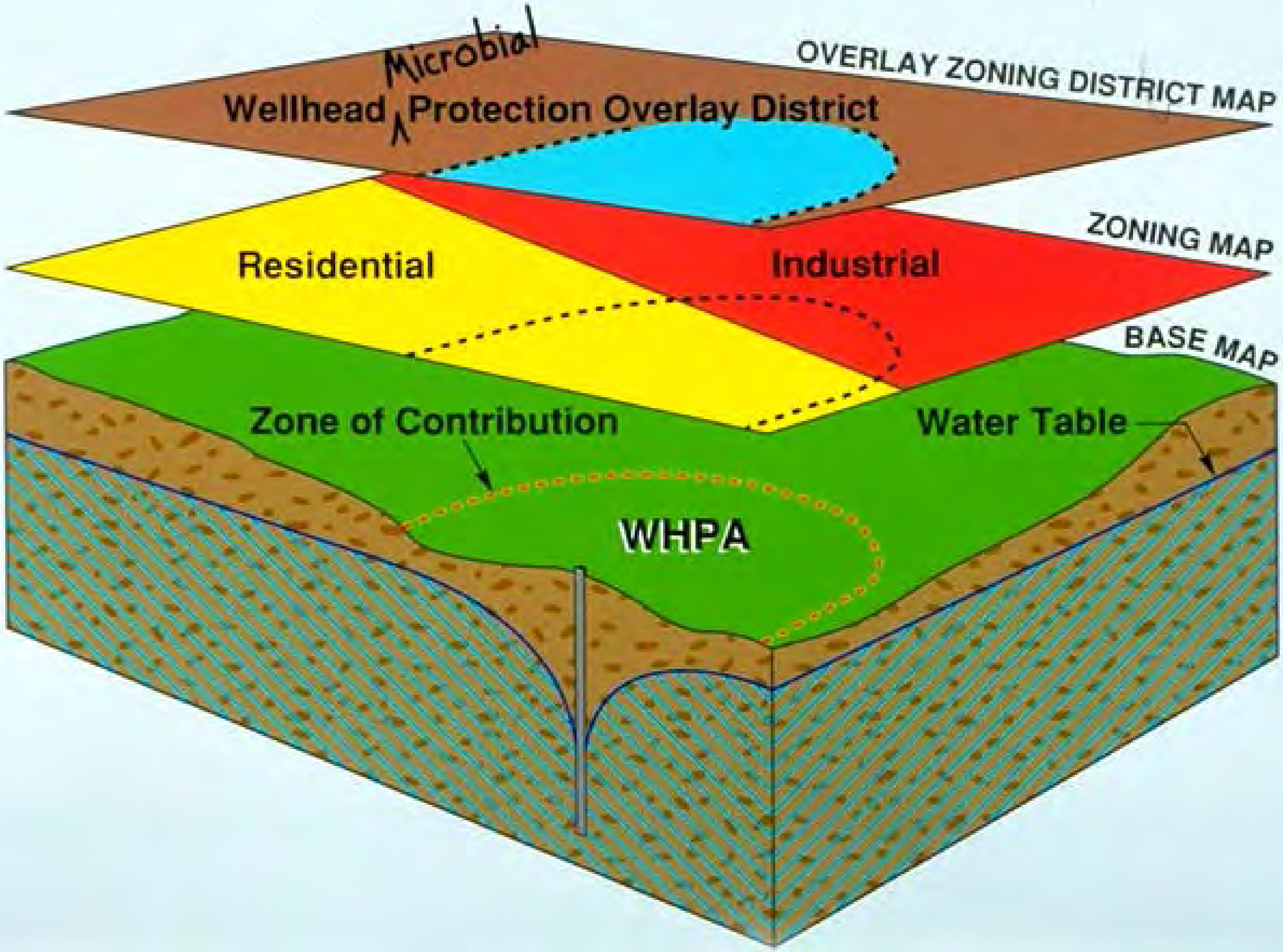
Land Use Management

- Subdivision growth controls
- Zoning
- Land purchase
- Acquisition of development rights
- Land use prohibitions

Subdivision Growth Controls

- Primary purpose is to control division of land into lots suitable for building
- Can protect drinking water supplies from
  - Septic system effluent
  - Storm water runoff

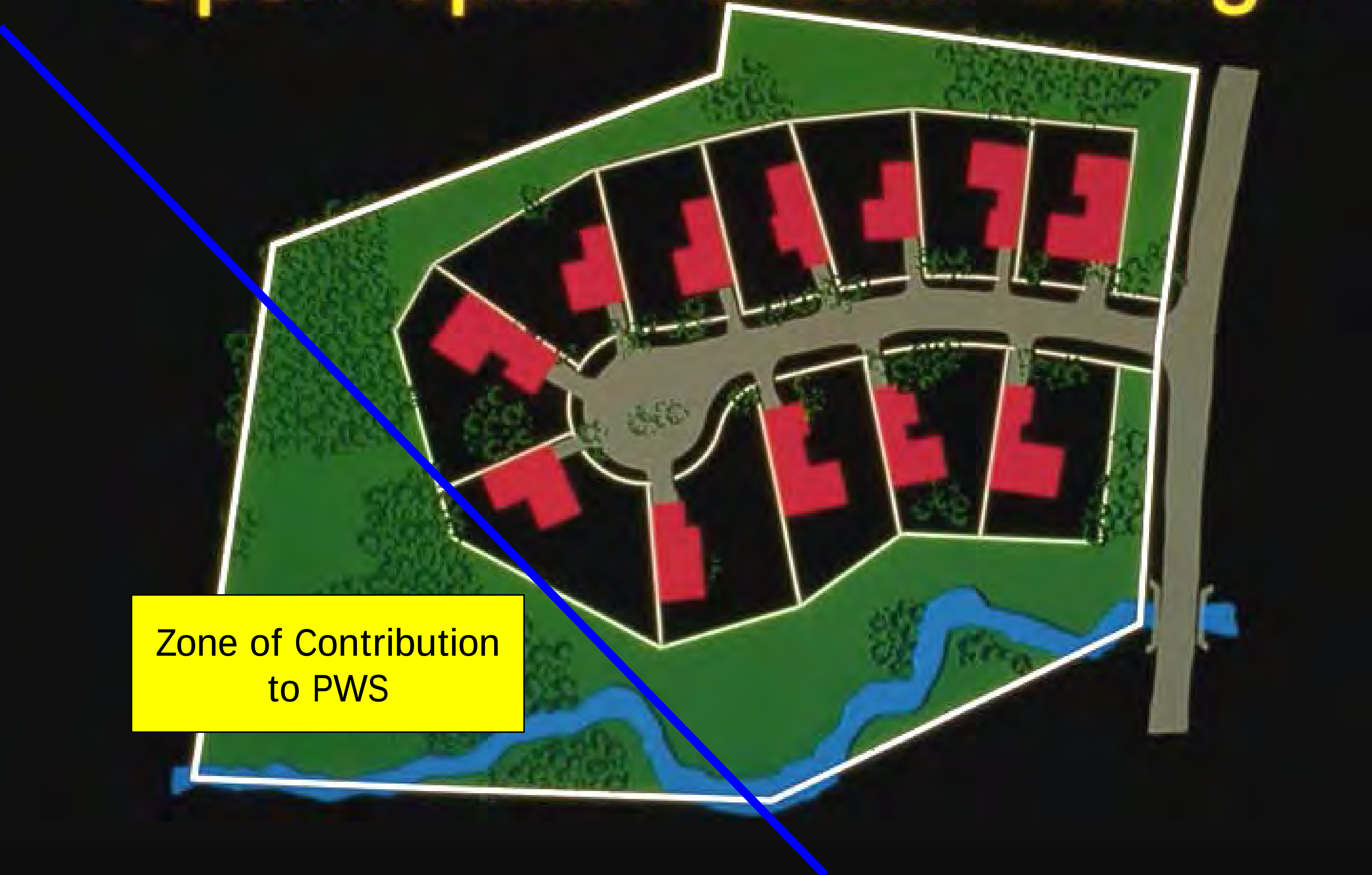
Overlay Zoning District



Cluster and Planned Unit Development

- Cluster development
  - More development in less space
  - Encourages greater protected space
- Planned unit development
  - Diverse land uses in contained land area
  - Reduces infrastructure costs

Open Space Cluster Design

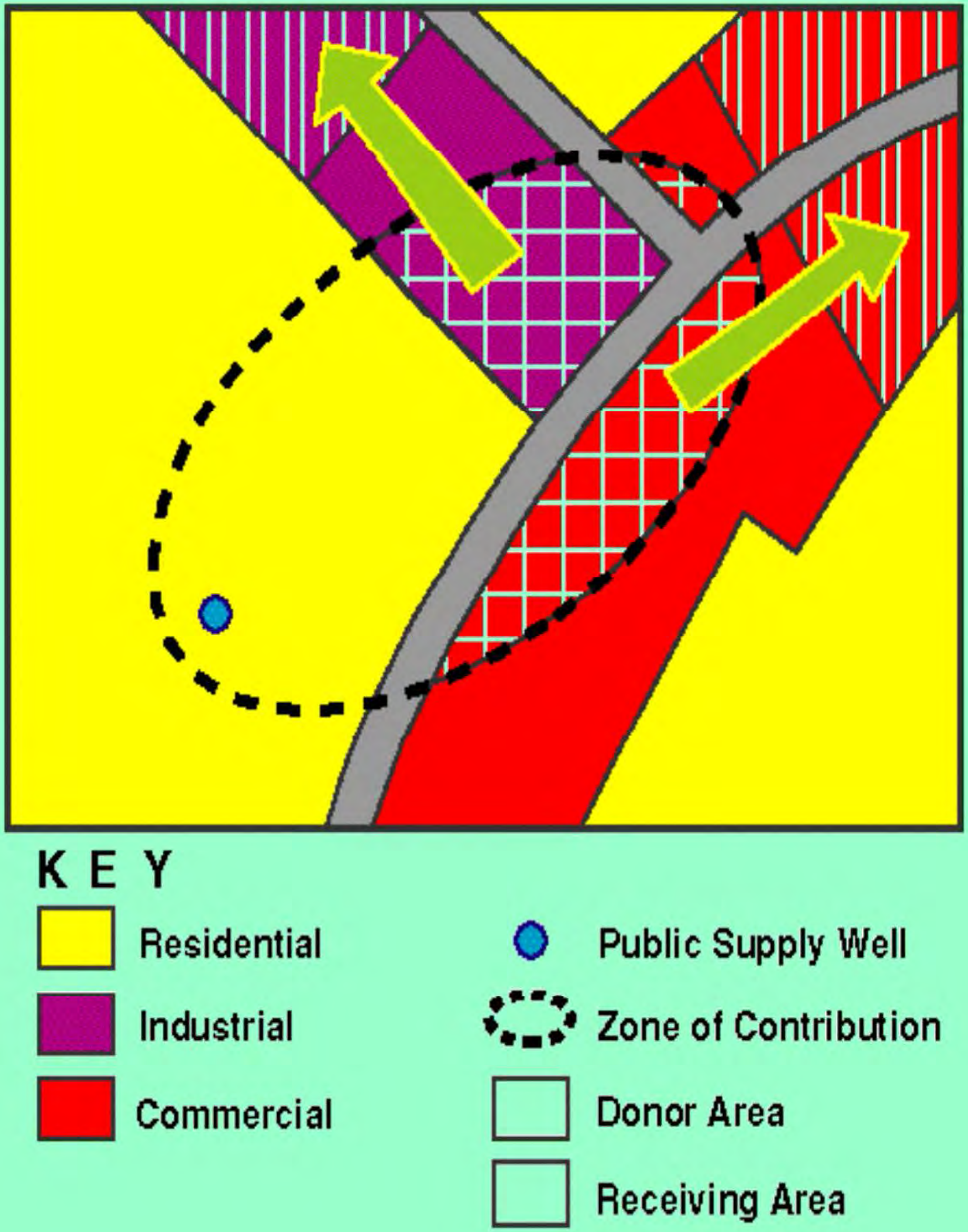


Land Purchase and Development Rights

- Land purchases
- Conservation easements
- Land trusts and conservancies

Transfer of Development Rights

- Land owner can separate right to develop the land from other rights associated with the land
  - Rights can be sold, given away, limited (intentionally or by regulation) **OR**
  - Rights can be transferred


K E Y
Residential
Industrial
Commercial
Public Supply Well
Zone of Contribution
Donor Area
Receiving Area

Land Use Prohibitions

Value of Watershed Protection

Background

- Forests protect land and produce water of high quality (through natural processes / ecosystem services)
- About two-thirds of the runoff in the lower 48 states comes from forested areas
- Many water utilities have use land acquisition to maintain and restore forests to protect their source water
- With proper management, forested watersheds are associated with lower treatment costs = a part of a sustainable water management portfolio

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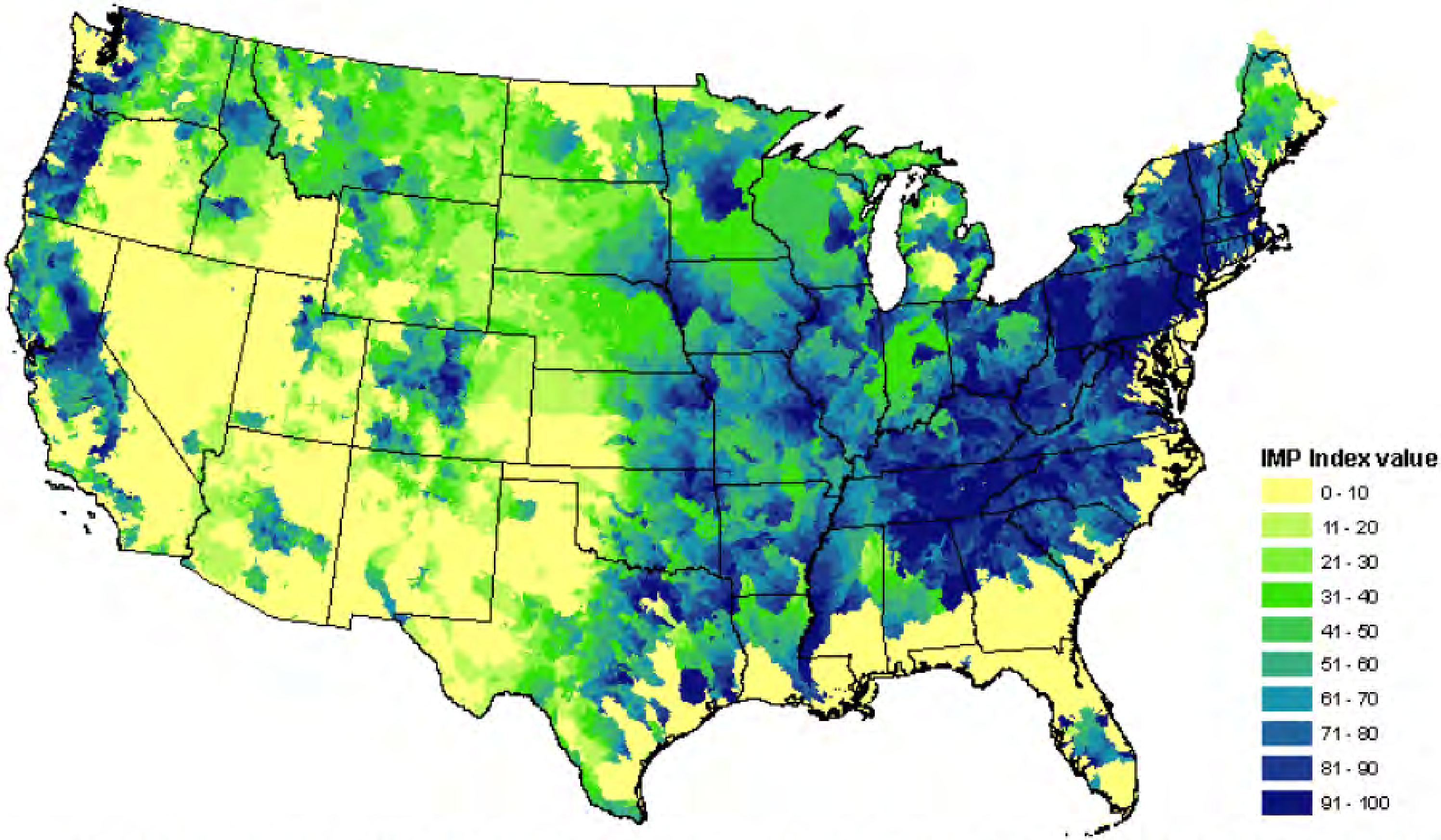
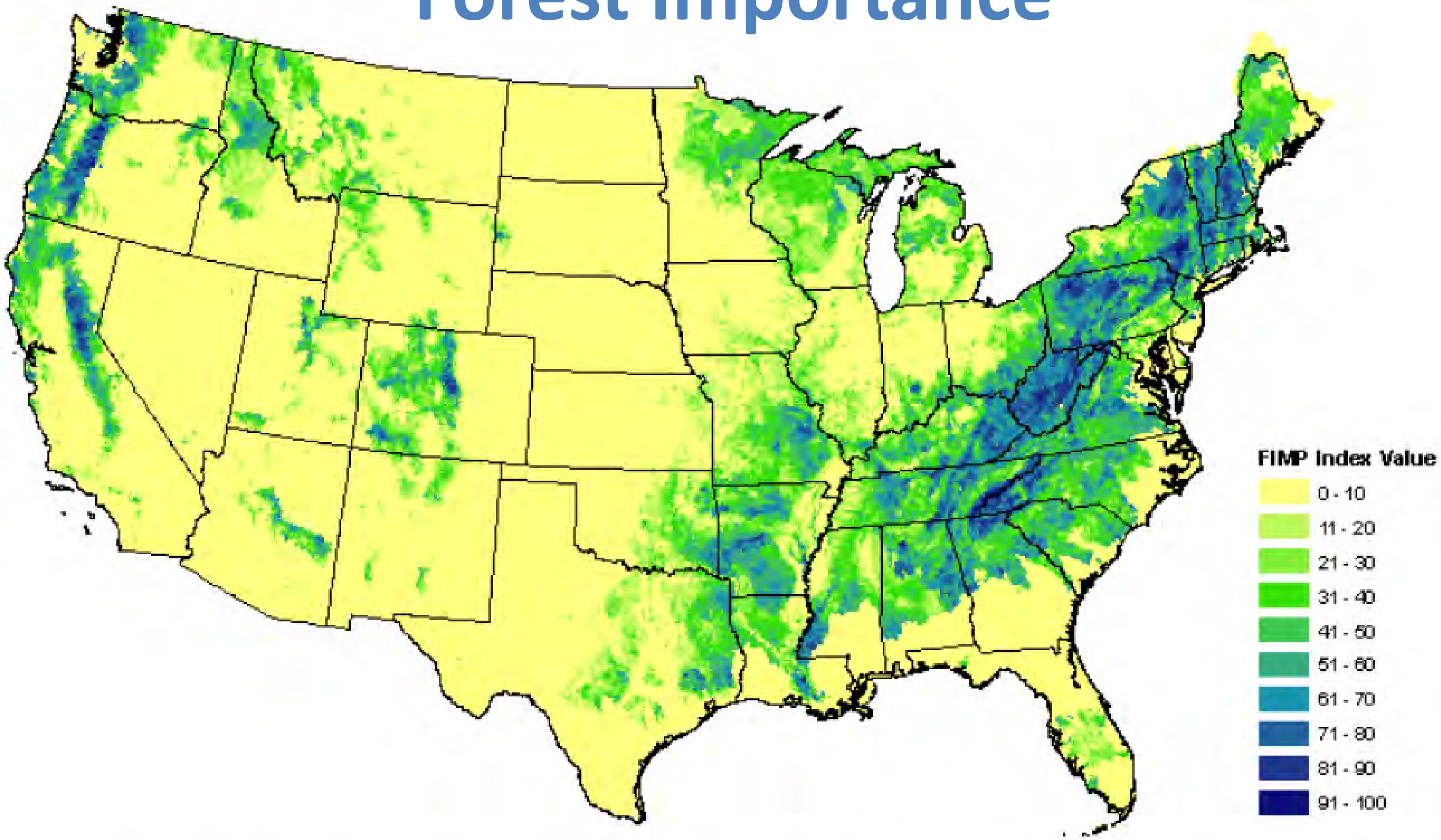
Surface Drinking Water Importance



SURFACE DRINKING WATER IMPORTANCE INDEX, IMP. AREAS WITH HIGHER (BLUE) VALUES REPRESENT AREAS MOST IMPORTANT FOR SURFACE DRINKING WATER.

Credit: Travis Warziniack, USFS

Forest Importance



THE INDEX OF FOREST IMPORTANCE TO SURFACE DRINKING WATER, ***FIMPN***, IDENTIFIES THOSE SUB-WATERSHEDS WHERE FOREST LANDS ARE MOST IMPORTANT IN PROTECTING SURFACE DRINKING WATER.

Credit: Travis Warziniack, USFS

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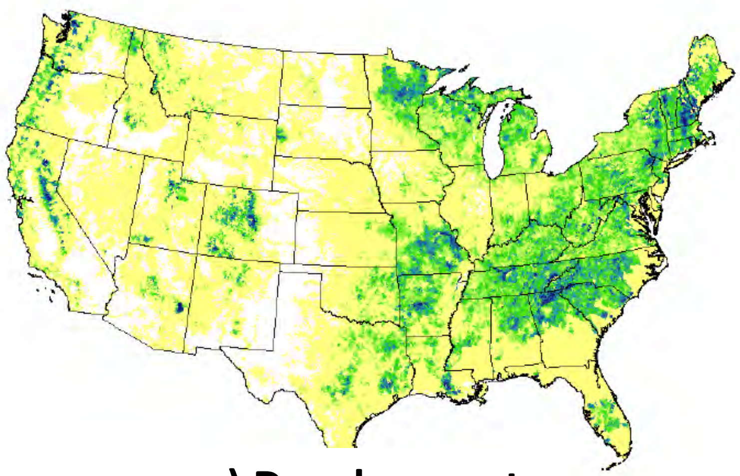
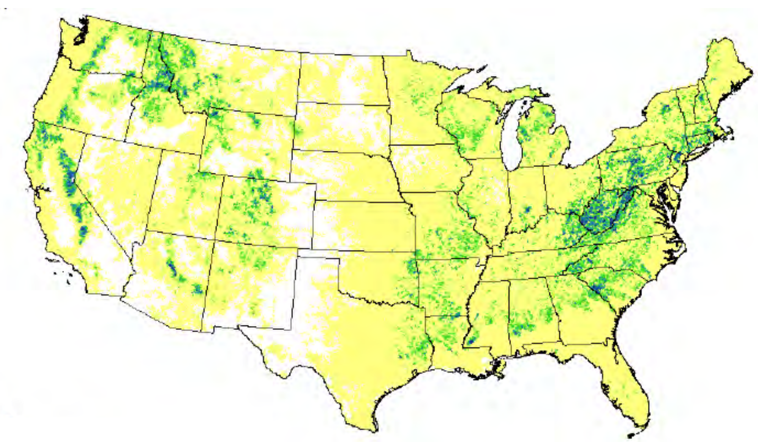
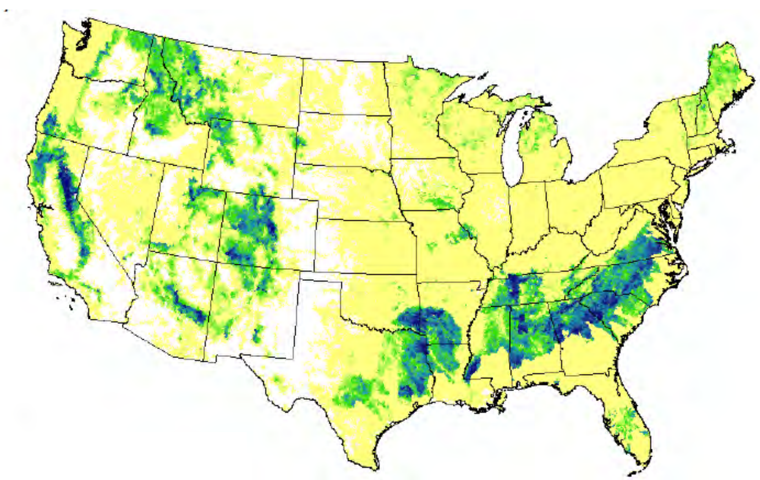


a) Development



b) Insects and disease



c) Fire

Forests Are Not Healthy

Credit: Travis Warziniack, USFS

Watershed Protection

Past works

- The Trust for Public Land (TPL), in partnership with American Water Works Association (AWWA), looked at land conservation as a source water protection (SWP) strategy (published in the 1997 version of "Protecting the Source"
- In 2004, TPL and AWWA published an updated version of the "Protecting the Source" that revisited some of the ideas in the 1997 publication
  - Drawing on a dataset of 27 water systems
  - Found that the more forest cover in a watershed, the lower the treatment costs
  - About 50 to 55 percent of the variation in treatment costs can be explained by the percent of forest cover
  - For every 10 percent increase in forest cover, treatment and chemical costs decreased about 20 percent (up to about 60 percent forest cover)

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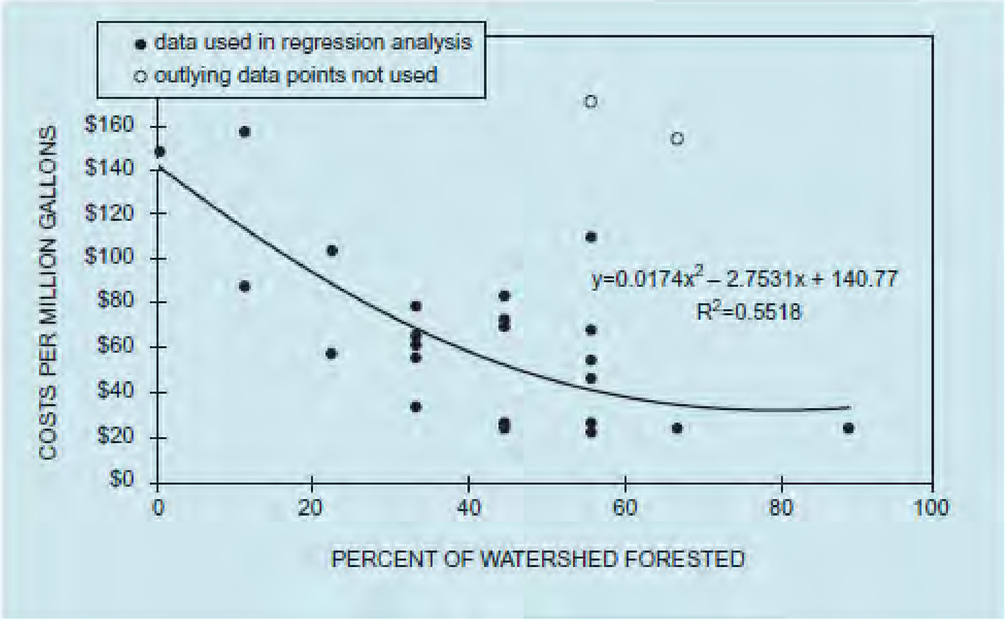
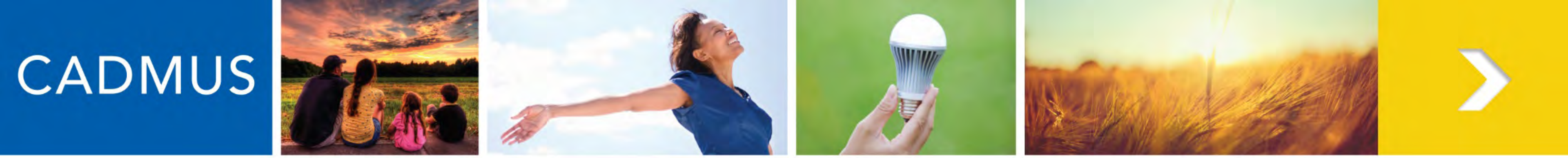
Watershed Protection

Past works (continue)

- The 2004 TPL and AWWA study suffered from
  - Small sample size (n = 27)
  - Other factors that introduce variability (treatment practices and economy of scale)





Watershed Protection

Past works (continue)

- In 2008, TPL, with support from EPA, USFS, and U. of Massachusetts, prepared a white paper on "Statistical Analysis of Drinking Water Treatment Plant Costs, Source Water Quality, and Land Cover Characteristics" with the following findings:
  - Land cover characteristics are association with the source water quality (e.g., increase of agriculture and urban land cover related to increase turbidity)
  - Increase total organic carbons (TOC) is associated with decreased percent forest cover
  - Increase treatment cost is associated with increased TOC
  - Weak relationships because of high variability within dataset

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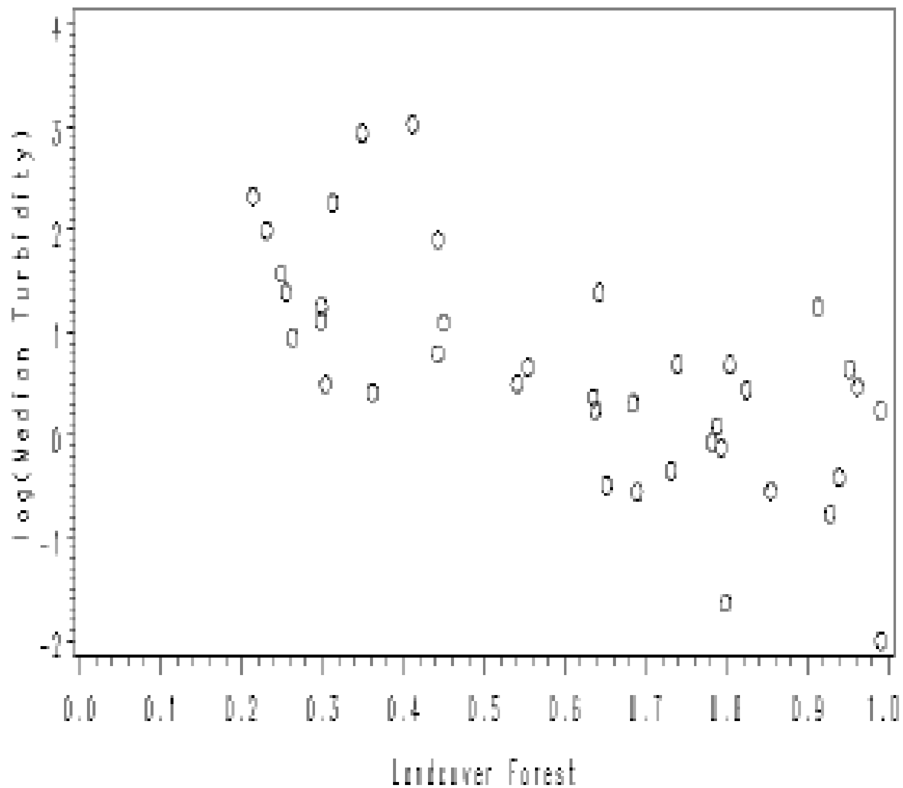
Watershed Protection

Past works (continue)

- Observations
  - Forest cover and turbidity



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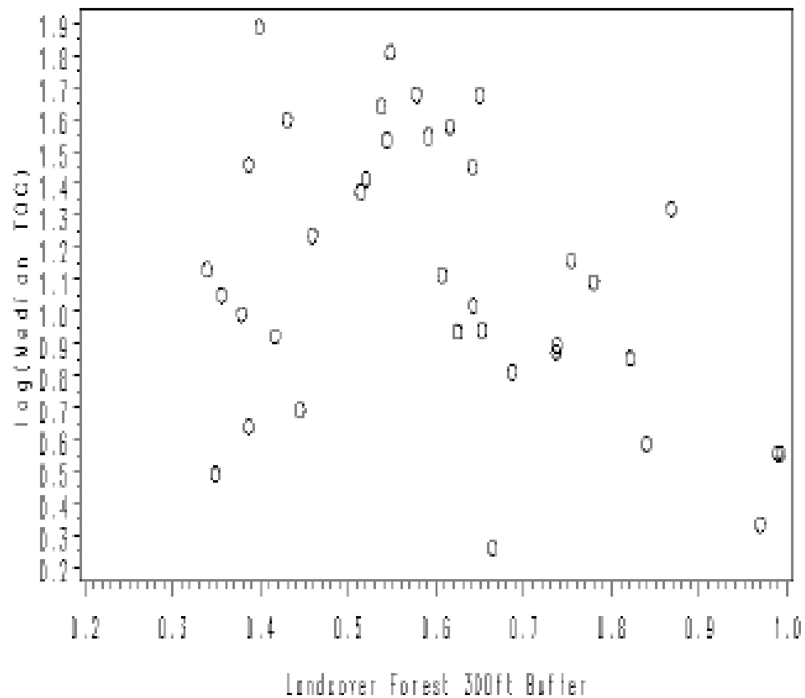
Watershed Protection

Past works (continue)

- Observations
  - Forest cover and TOC
  - Eco-region dependency (e.g., deciduous temperate forest => high TOC)



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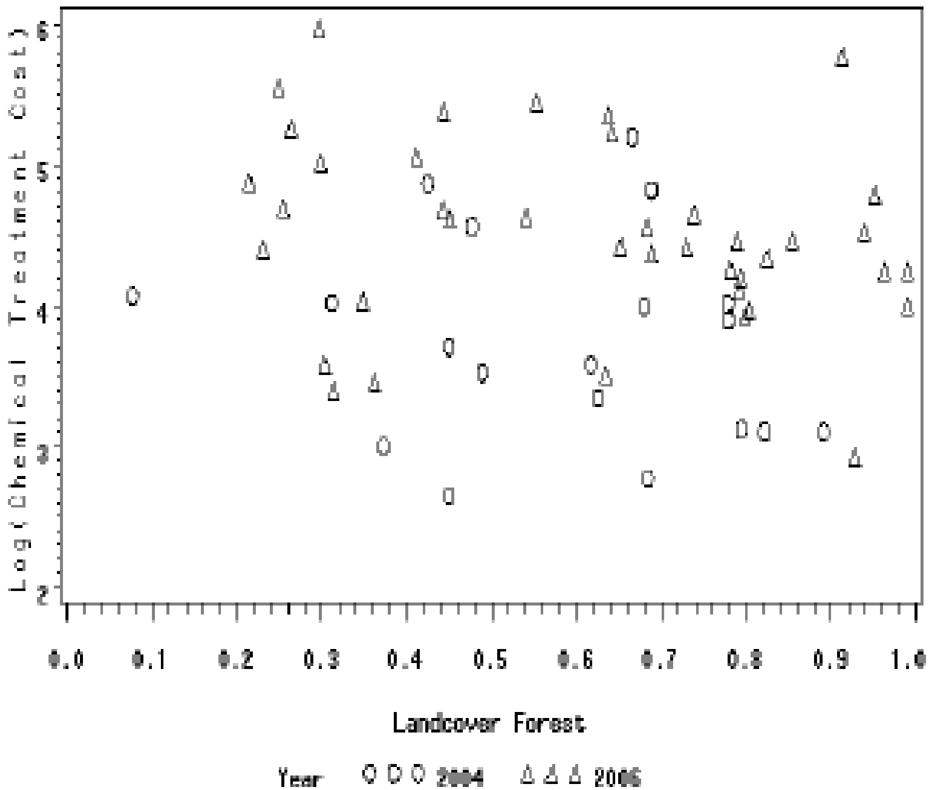
Watershed Protection

Past works (continue)

- Observations
  - Forest cover and treatment costs



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Past works (continue)

- Remarks from 2008 TPL white paper:
  - Reporting and accounting procedures regarding capital versus operation and maintenance (O&M) costs vary among water systems.
  - Diversity in the sequences of treatment and types of chemicals used by water systems may have a confounding effect on the analysis.
  - Raw water sampling methods differ (e.g., systematic/fixed frequency sampling versus event-based/random sampling) and may increase data variability.
  - Varying quality of water at the intakes (e.g., whether the system is drawing from a river/stream versus from a reservoir/lake) with different residence times, storage capacities, and operational flexibility add more variability to the analysis.

Watershed Protection

Past works (continue)

- Remarks from 2008 TPL white paper (continue):
  - Water systems are located in many different eco-regions, and the analysis did not account for regional differences in climate, soil, and geology.
  - Land cover statistics do not capture the effects of location of specific land cover types and relative loading rates in each watershed, which may greatly affect the water quality.
  - Water treatment facilities often over-treat their raw water beyond required standards as a precaution.
  - The costs of chemicals vary widely for drinking water treatment due to differences in chemicals used, economies of scale, bulk pricing, and regional pricing.

Watershed Protection

Past works (continue)

- 2014 JAWWA article by Gartner et al. cited:
  - Winiecki (2012) – n=6, 1 to 27 ratio of protection vs. treatment.
  - New York City SWP initiative – 1 to 4 or 5 ratio of protection vs. treatment.

- Other examples:
  - Remsen, Iowa (grassland)
    - Denitrification plants – about $3M over 30 years
    - Land purchase – about $0.025M over 30 years
    - 1 to 120 ratio of protection vs. treatment

Watershed Protection

Current effort

- Joint effort
  - U.S. Forest Service – Dr. Travis Warziniack
  - American Water Works Association Source Water Protection Committee (chair – Dr. Robert Morgan)
  - U.S. Endowment for Forestry and Communities
  - The Cadmus Group, Inc.
  - Numerous participating utilities – including Rivanna Water and Sewer Authority, Central Arkansas Water, Eugene Water & Electric Board

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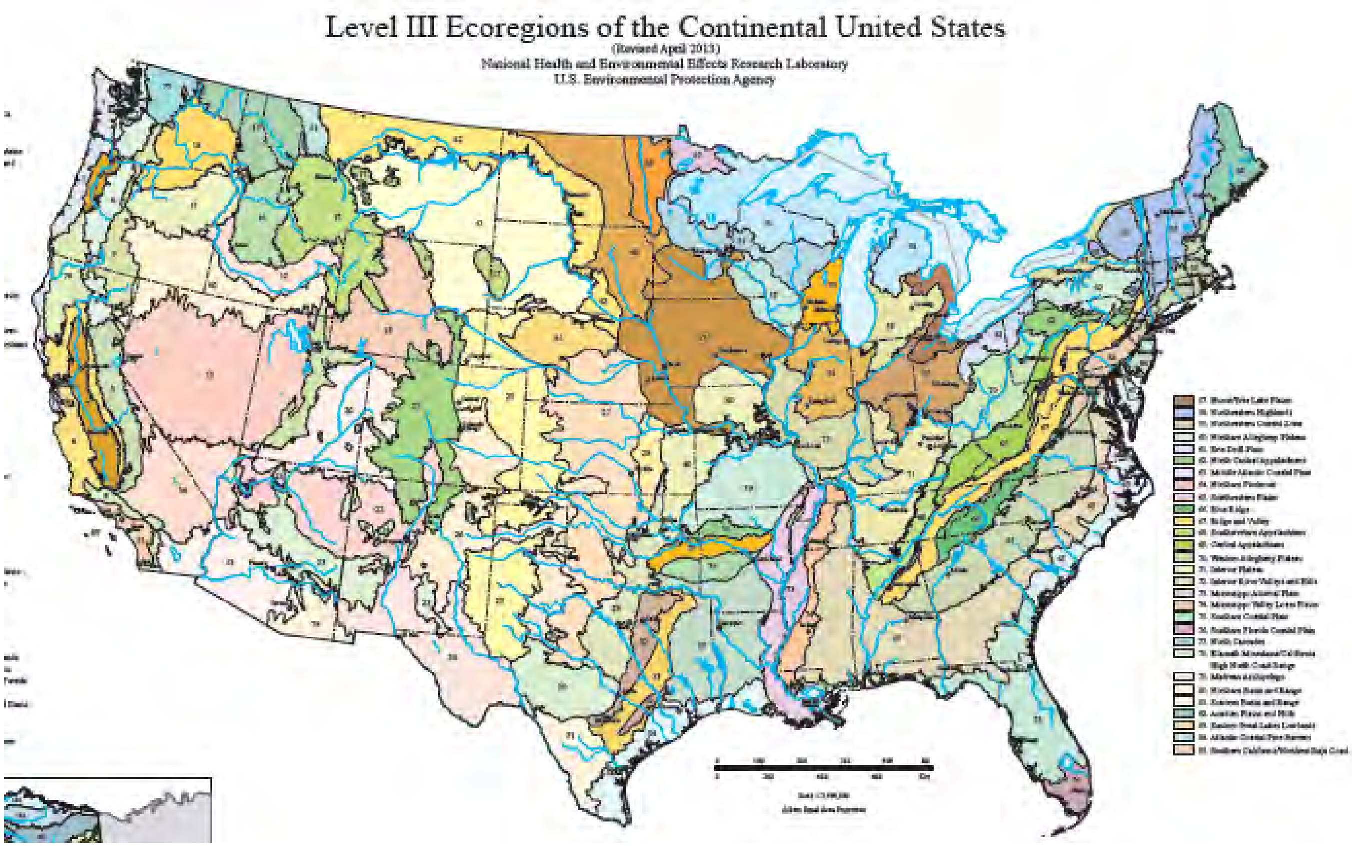
Current effort

- Ecoregions were used to target water systems



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Watershed Protection

Current effort

- Working with AWWA SWP Committee members and Dr. Warziniack, a comprehensive survey instrument was developed
  - Water Supplier Contact Information
  - Location of Intake and Associated WTP
  - Source Water
  - Water Quality
  - Treatment
  - General

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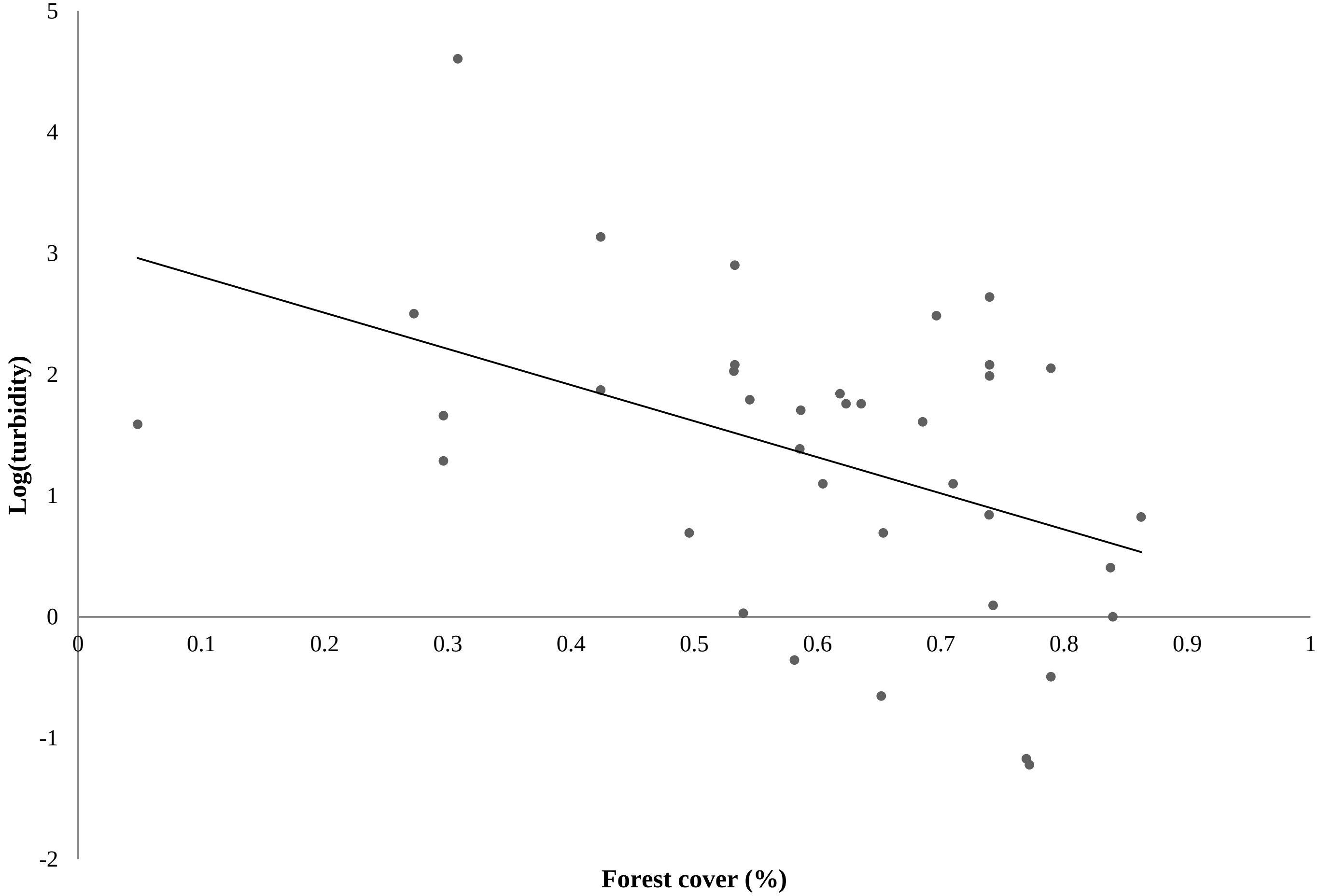
Watershed Protection

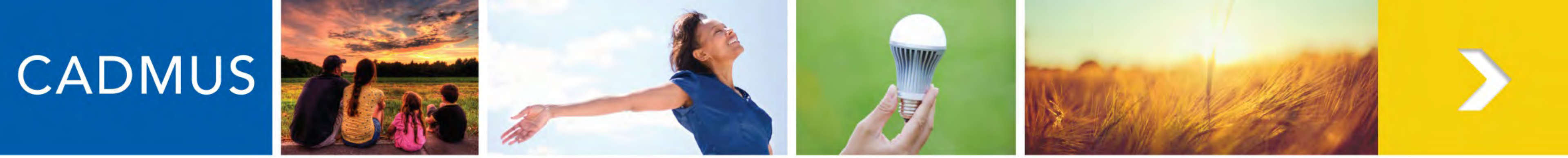
Current effort

- Survey was deployed by AWWA from late-October through mid-December 2014. (n = 14)
- The group followed up with a greatly shortened survey on February 11, 2015, with a closing date of March 2, 2015. (outcome is being compiled) (n = 16)
- PURPOSE – to quantify the relationship among watershed health (as indicated by forest cover), water quality (as depicted by water quality data at water utility intakes), and water treatment costs (as represented by water treatment expenditures linked to turbidity, total organic carbon, and total suspended solids removal).

Watershed Protection and Treatment Costs

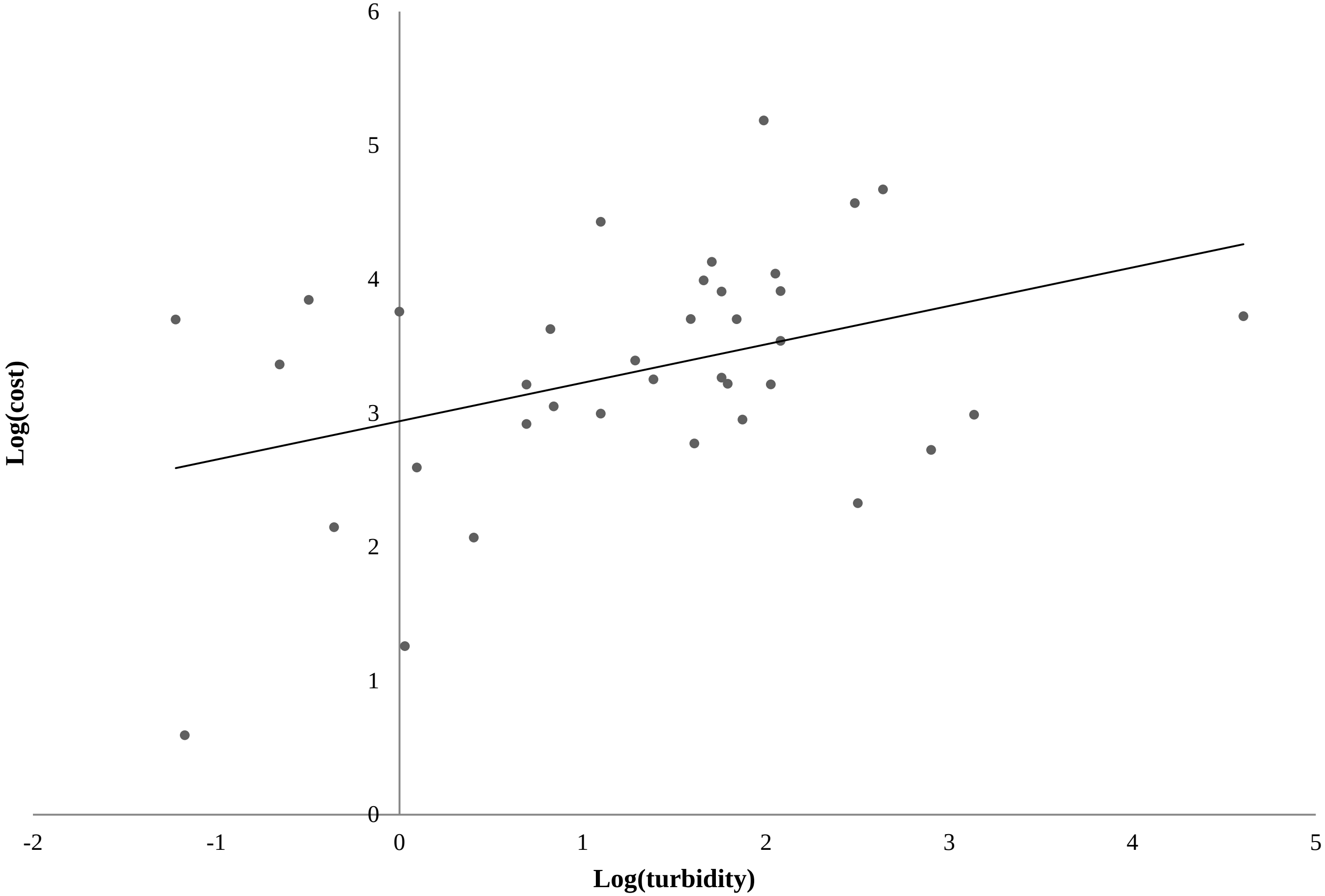
Current effort





Watershed Protection and Treatment Costs

Current effort



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Watershed Protection and Treatment Costs

Current effort (preliminary results)

- 1% decrease in forest cover (to development) → 3.9% increase in turbidity
- 1% increase in turbidity → 0.19% increase in treatment costs
- For the systems involved in the study – an average plant that produces 19.3 mgd and has chemical costs of $105 per million gallons of water – a conversion of 10% of the watershed from forest cover to developed area increases chemical treatment costs by $65,000 per year. [With a discount rate of 3%, the present value of this cost over 30 years is about $1.3 million.]

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Watershed Protection and Treatment Costs

Summary

- As suggested by the TPL studies, an increase in forested land in a drinking water supply watershed is associated with a decrease in water treatment costs, and vice versa.
- Nevertheless, as noted in the TPL studies and the ongoing AWWA/USEFC project, collecting comprehensive data to quantify the relationships among forest coverage, water quality, and water treatment cost is not trivial.
- Under the right circumstances, SWP effort (as a preventive and sustainable approach) yields savings in treatment.

Thank You!

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