Monitoring Stormwater Best Management Practices: Why Is It Important and What To Monitor

Scott D. Struck, Ph.D.
US EPA, Urban Watershed Management Branch

New Jersey Water Monitoring Workshop
4/20/2006

Outline

- Introduction
- Current Monitoring Practices
- Parameter Selection for Structural BMP Monitoring Programs
- Monitoring Nonstructural BMPs
- Watershed Monitoring
- Case Study: Accotink Creek
- Developing a BMP Effectiveness Monitoring Program

Introduction

What are stormwater best management practices (BMPs)?

BMPs are devices, practices, or methods used to manage stormwater runoff

Problem:

This definition includes widely varying techniques into a single category

Examples of BMPs

- Retention Ponds
- Constructed Wetlands
- Dry basins
- Infiltration BMPs
- Riparian Buffering
- Stream Bank Armoring / Restoration
- Street Sweeping
- Stormwater Reuse
- Rain Gardens
- Rain Barrels
- Filter Strips
- Swales
- Bioinfiltration
- Green-Roof
- Pet Waste Clean-Up
- Product Substitution
- Public Education

Why Should We Monitor BMPs?

- Do they perform as designed?
- Are they improving water quality?
- Can we meet regulatory requirements?
- Are the costs worth the benefits?

Complications of BMP Monitoring

- Variability in stormwater properties
  - Frequency, duration, intensity of rainfall
  - Antecedent conditions
- Variability in associated runoff
  - Land use
  - Season
  - Routing
- Intermittent point sources
- Nonpoint sources
- Sheet flow
- Safe access/equipment safety
- Design for monitoring
- $$$ for rigorous monitoring

Current Monitoring Practices

Four monitoring approaches to assess BMP effectiveness

- Input/output sampling
  - used with new, existing, or retrofitted structural BMPs
- Before/after sampling
  - most often used with nonstructural or other BMPs that lack an inflow/outflow
- Upstream/downstream sampling
  - often used for single BMP effluent or an untreated stormwater input on its receiving stream
- Controlled watershed comparison (rarely used)

Current Monitoring Practices

Thorough water and pollution loading budgets are important to a robust monitoring program

Factors that can lead to over or underestimation of actual BMP efficiencies:

- Inaccurate stormwater flow measurements
- Exclusion of dry-weather flows, groundwater, and direct precipitation (can contribute to both hydraulic and pollutant loading)
- Lack of equipment maintenance and calibration, and the neglect of bypass flows
- Is your sample representative?

Statistical Validation - the most frequently overlooked factor in BMP monitoring programs

What are Structural BMPs

Parameter Selection for Structural BMP Monitoring Programs

Major Parameter Categories

- Chemical
- Physical
- Biological
- Hydrological
- additional contributing factors

Parameter Selection - Chemical Parameters

The most widely applied chemical parameters in BMP monitoring programs:

<u>Nutrients</u>

- Total Kjeldahl Nitrogen (TKN)
- Chemical Oxygen Demand (COD)
- Nitrate + Nitrite Nitrogen (NO2- + NO3-)
- Total Phosphorus (TP)
- Soluble (or ortho-) Phosphorus (SP)

<u>Metals</u>

- Copper (Cu)
- Lead (Pb)
- Zinc (Zn)
- Others?

<u>General</u>

- Biological oxygen demand (BOD)
- Dissolved oxygen (DO)
- pH
- Temperature
- Conductivity

How to measure? Concentrations? EMC's? Loads? Removals?

Parameter Selection – Physical Parameters

- TSS is often the main specified management goal of BMPs. Can act as an indicator for, and can become carriers of, many other chemical pollutants.
- SSC (USGS)?

- Gross solids, such as litter, trash, and other debris (hard to quantify/labor intensive)
- Turbidity, particle size distribution, settling velocity distribution, accumulated sediments, and bed load
- Physical assessment of receiving locations (stream bank erosion, bank incision, other erosive action) and habitat assessment. May be captured in RBP measurements.

Biological Parameters

Considered by some a better indicator of BMP effectiveness than water quality parameters alone especially for long term effectiveness

- Toxicity testing
  - Microtox® toxicity-screening
  - can be costly and may have highly variable results
- In-stream indices
  - analysis of fish
  - benthic macroinvertebrates
  - plant communities
  - usually need reference sites to compare can be quite variable
- Bacteria/microbiological indicators
  - Fecal coliforms, E.coli, Enterococci

Other causes (i.e., disruption of physical habitat, alteration of hydrologic patterns, introduction of non-indigenous biota, and widespread alteration of the landscape) may also impact these indices.

Parameter Selection – Hydrological Parameters

The foundation of a good BMP monitoring program, both baseline and effectiveness, is an accurate and representative measurement of precipitation and stormwater flow data

- antecedent conditions
- pattern of precipitation
- intensities
- precipitation durations and total volumes
- runoff rates and durations
- total volumes into and out of the BMP

Basic Requirements for Collecting, Documenting, and Reporting Precipitation and Stormwater-Flow Measurements by Church *et al*. (1999)

Parameter Selection – Additional Contributing Factors

Often details that contribute to the observed effectiveness of a BMP are often overlooked

Watershed characteristics that may affect BMP performance:

- Watershed area
- Percent imperviousness
- Land-use breakdown
- Soil types / infiltration rates
- BMP design characteristics (not just pre-construction plans)
- Maintenance activities

Key Considerations for Selecting Appropriate Parameters

- *What parameters are required to meet the monitoring program objectives and goals?*
- *What resources are available for completing monitoring objectives?*
- *Do any regulatory or legal requirements apply to the BMP or its receiving waters?*
- *Are existing monitoring data available?*
- *What are the prevailing land uses in the catchment area?*

Key Considerations for Selecting Appropriate Parameters

- *What are the beneficial uses and impairments (if any) of the receiving water?*
- *Are there any parameters that are particularly useful for evaluating the type of BMP being monitored?*
- *Are there any contributing factors that would be useful in interpreting data from the primary parameters selected?*
- *Are the parameters typically monitored constituents?*

Monitoring Nonstructural BMPs

Definition of nonstructural BMPs?

Anything not requiring an engineer to design?

Monitoring Nonstructural BMPs

The most significant hindrance to monitoring nonstructural BMPs is that many of them rely on behavioral change

- How to measure behavioral change?
- Site specific?
  - People's behaviors are shaped by social, educational, economical, and regional factors; therefore, what works in one place, may not be universally effective

Monitoring Nonstructural BMPs

Other Nonstructural BMPs?

- direct measurement (street sweeping and catchbasin cleaning where pollutants are collected and can be weighted)

For “More” Engineered Systems

- the lack of defined inflows and outflows make it difficult to account for changes over time

Solutions?

- Long-term trend monitoring of a downstream, end-of-catchment system, such as in-stream parameters of the receiving water
- Modeling

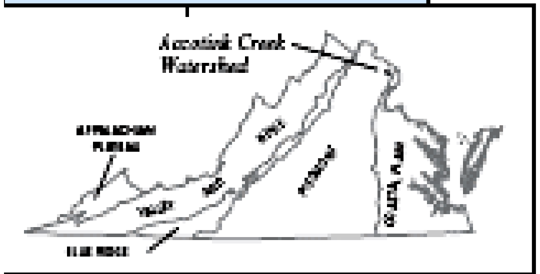
Case Study: Accotink Creek, VA

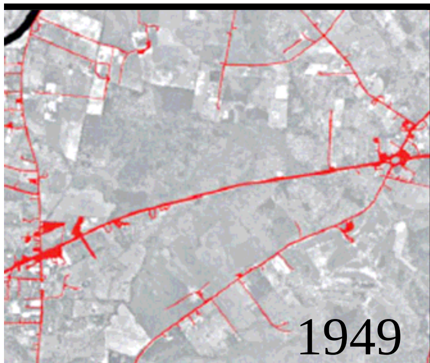
- City of Fairfax, VA
- Restore 1800 Linear Feet of Stream
- Downstream Reach on 303(d) List for Fecal coliform and Benthic Impairment
- Monitor Water Quality Changes

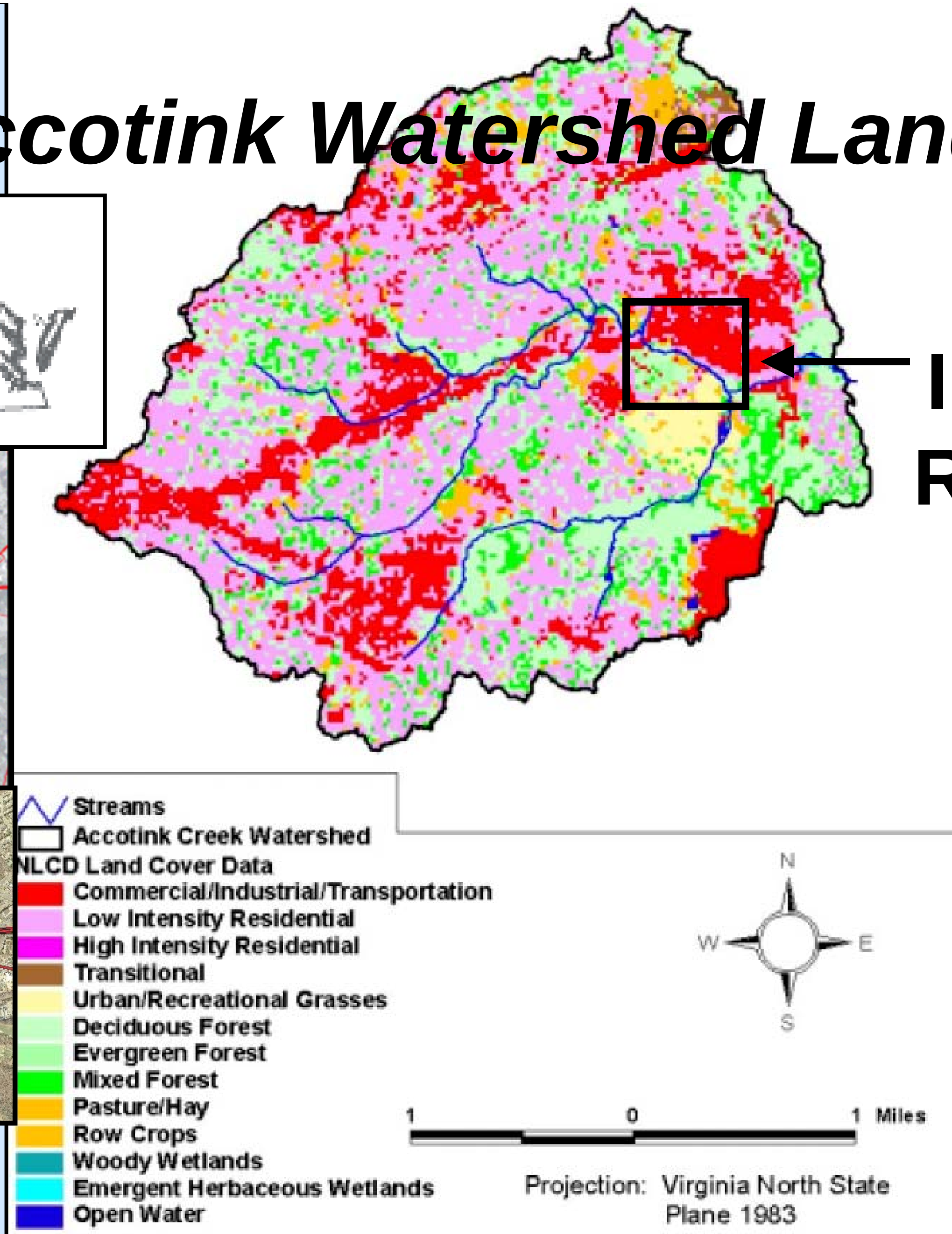
Project Goals

- Restore the stream channel to stable condition
- *Improve low flow habitat conditions*
- *Increase macroinvertebrate density and diversity*
- *Improve fish habitat and density*
- *Meet State WQS for General Benthic Standards (1996) and Fecal coliform (2004)*
- *Decrease sediment loading downstream*

Accotink Watershed Land Use

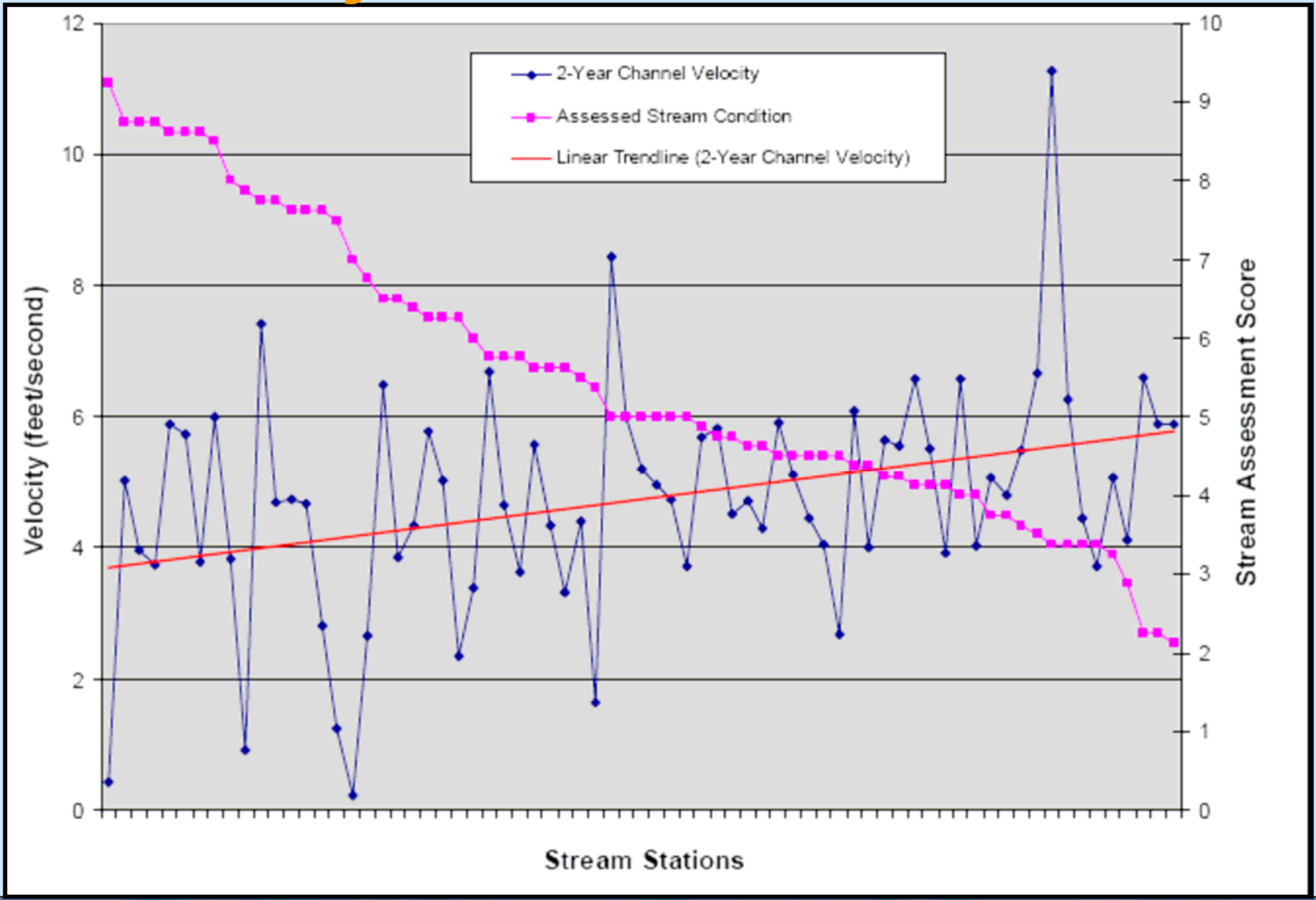






Area of Interest for Restoration

Relationship Between Channel Velocity and Stream Condition

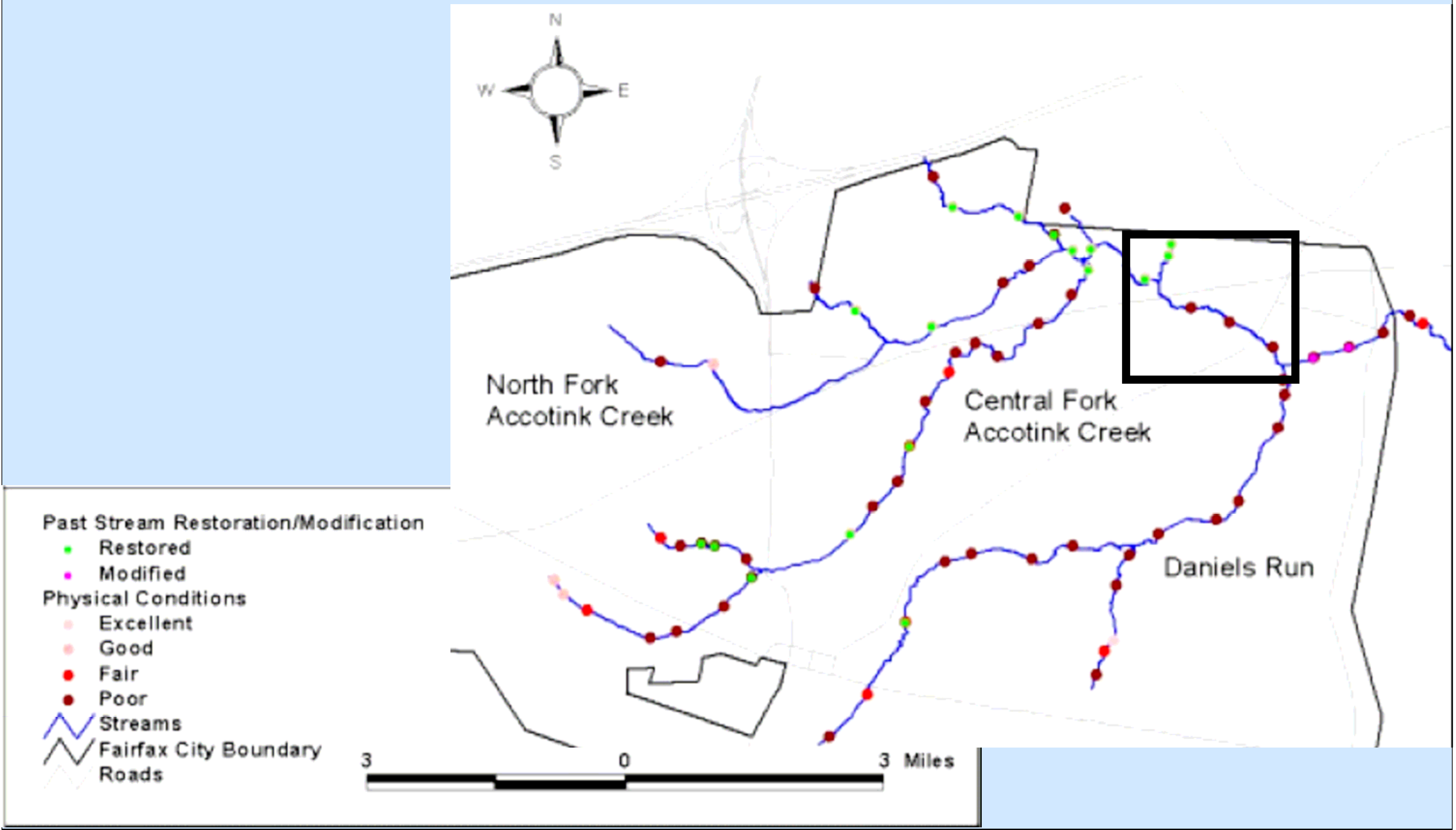


Physical Characteristics of the Streams

- Channel Condition
- Hydrologic Alteration
- Riparian Zone Vegetation
- Vegetative Protection
- Bank Stability

Assessment Score	Stream Length (Feet)	% of Streams
Excellent	300	1
Good	13,730	26
Fair	5,000	9
Poor	34,580	65
Total	**53,610**	**100**

Physical Conditions

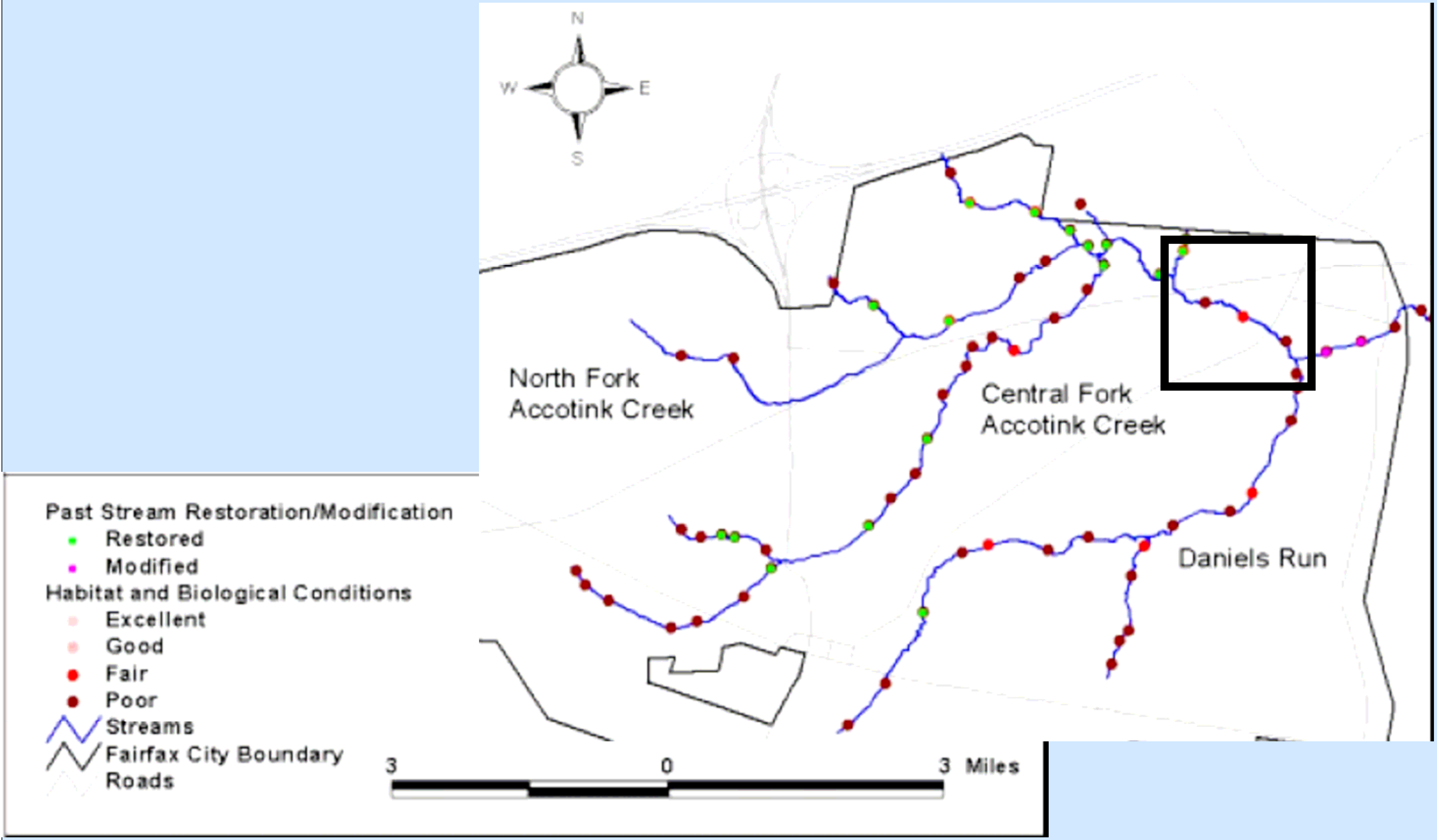


Habitat and Biological Characteristics of the Streams

- Sediment Deposition
- Water Appearance
- Nutrient Enrichment
- Barriers to Fish Movement
- In-Stream Fish Cover
- Pools
- Insect/Invertebrate Habitat
- Canopy Cover
- Riffle Embeddedness
- Macroinvertebrates Observed

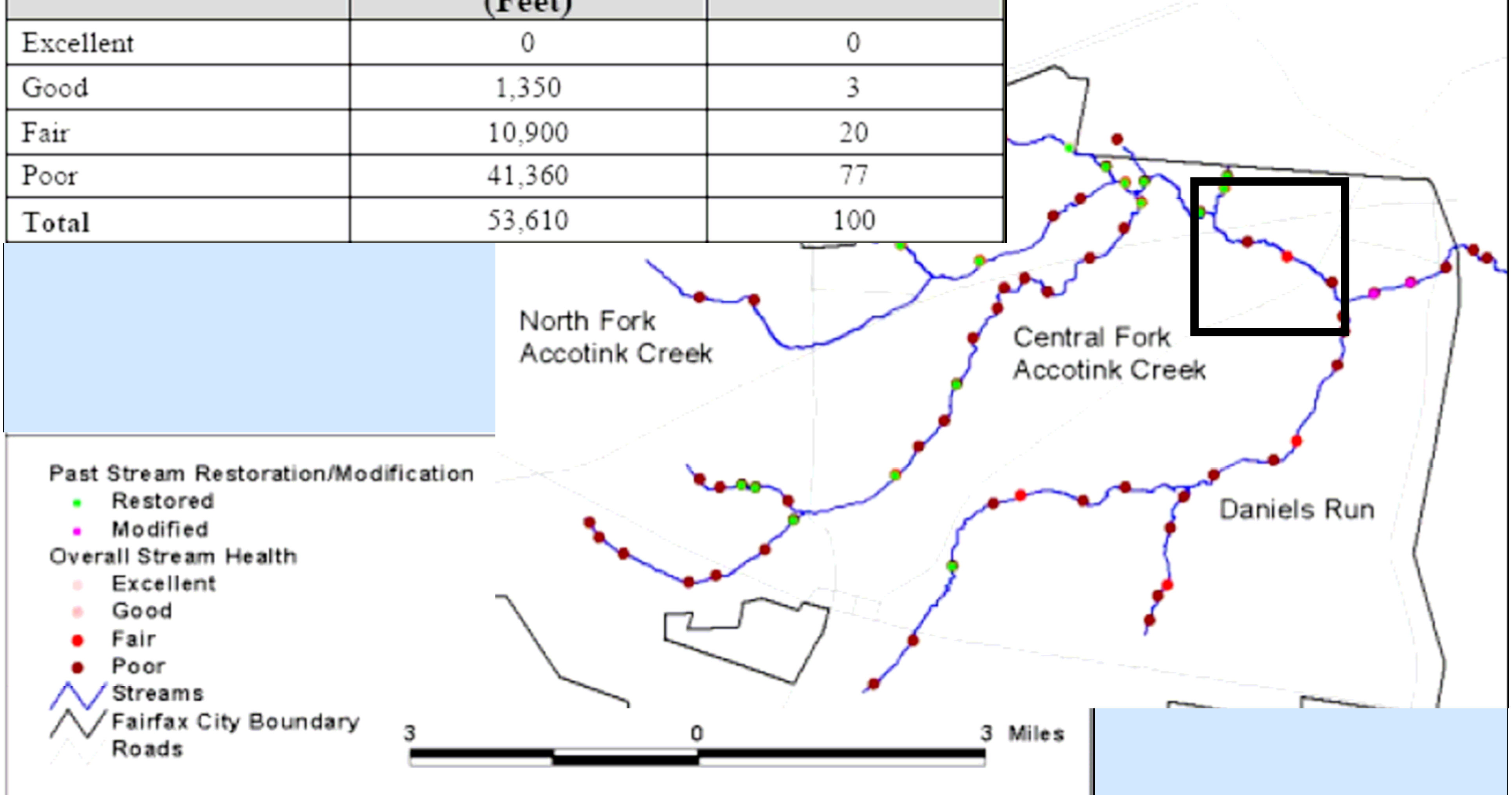
Assessment Score	Stream Length (Feet)	% of Streams
Excellent	0	0
Good	0	0
Fair	10,900	20
Poor	42,710	80
Total	53,610	100

Habitat and Biological Conditions



Overall Stream Health

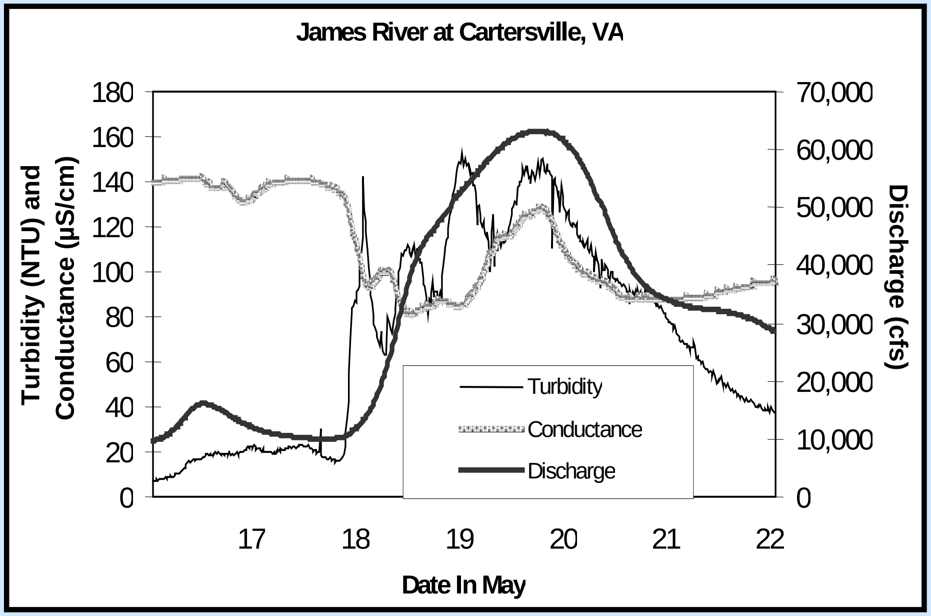
Assessment Score	Stream Length (Feet)	% of Streams
Excellent	0	0
Good	1,350	3
Fair	10,900	20
Poor	41,360	77
Total	53,610	100

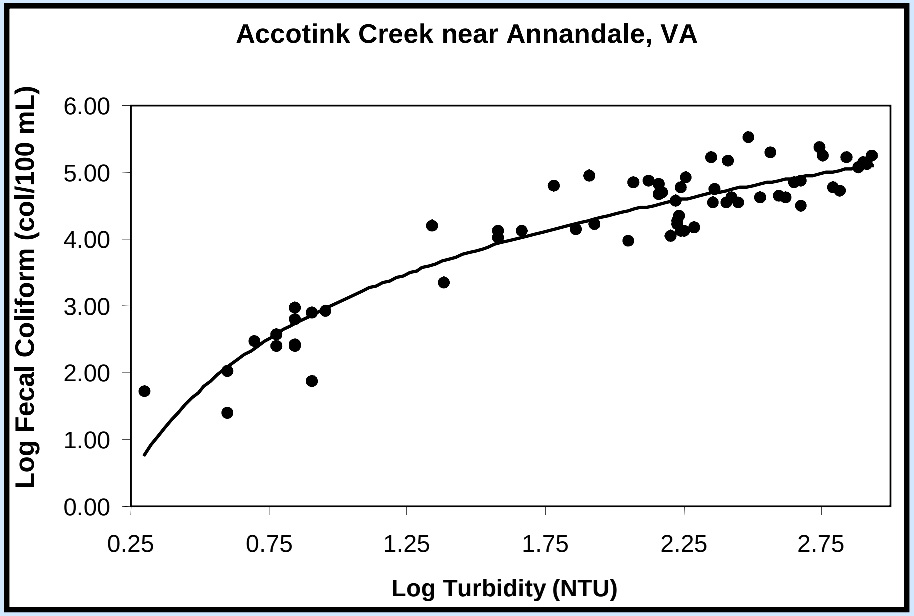


Monitoring of Restoration

Continuous Monitoring

- Use continuous monitoring parameters (i.e. turbidity).
- Regress with descrete WQ parameters (i.e. fecal coliform, suspended sediment)
- Develop concentration estimation curves (similar to water level/flow rating curves)





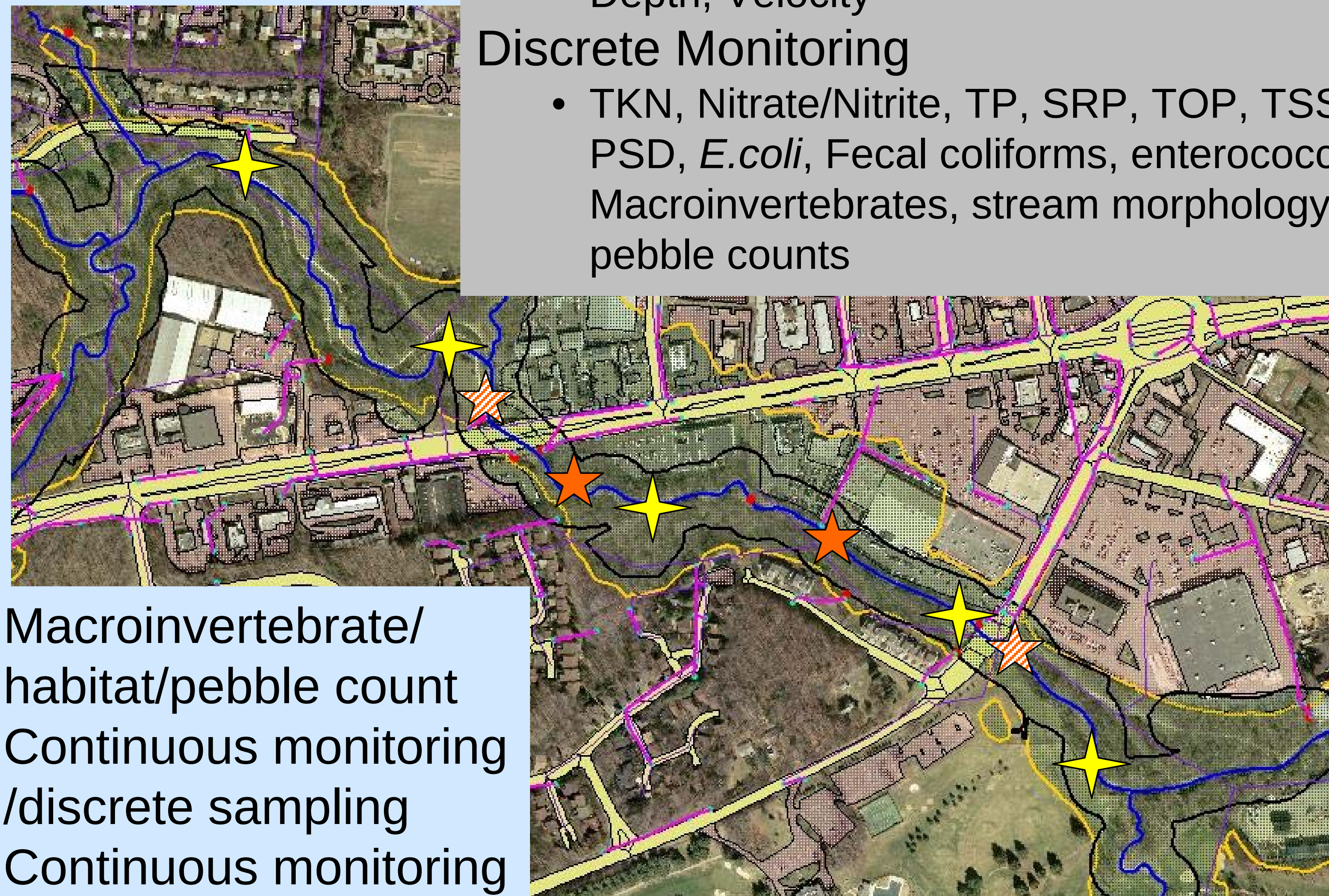
Monitoring

Continuous Monitoring:

- pH, Turbidity, Temp, Conductivity, DO, Depth, Velocity

Discrete Monitoring

- TKN, Nitrate/Nitrite, TP, SRP, TOP, TSS, PSD, *E.coli*, Fecal coliforms, enterococci, Macroinvertebrates, stream morphology, pebble counts



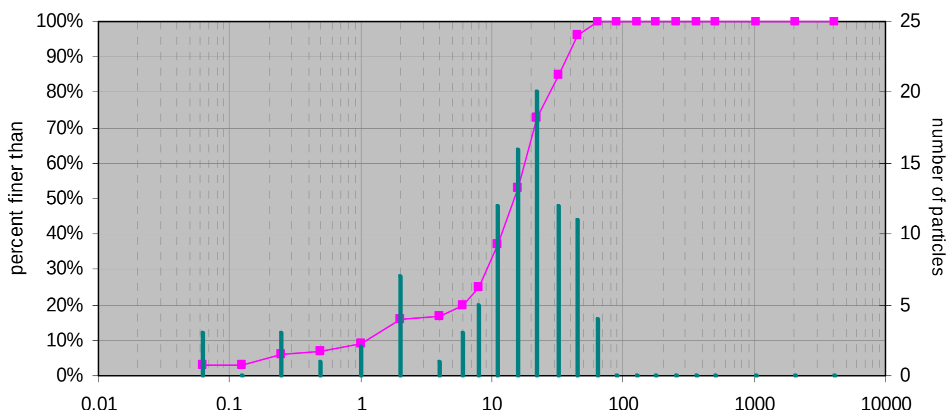
- Macroinvertebrate/ habitat/pebble count
- Continuous monitoring /discrete sampling
- Continuous monitoring

Macroinvertebrate Indices

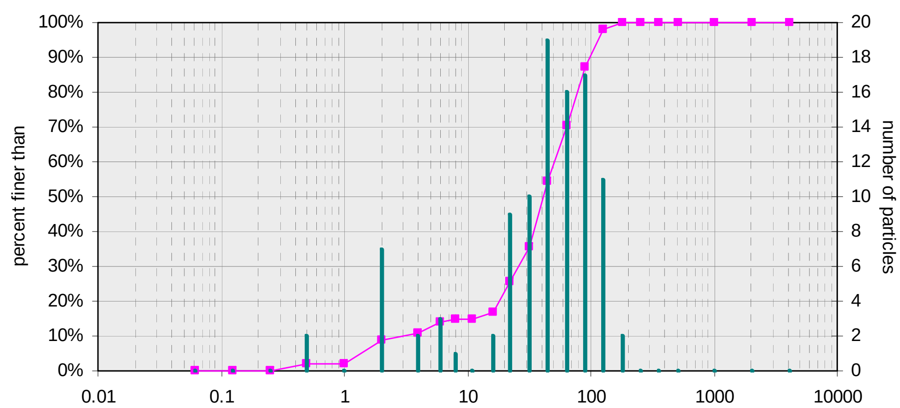
1	VSCI and Metric Scores									
2	StationID	BenSampID	VA SCI Fam	CollDate	VA SCI %Ephem	VA SCI %2 DomTax	VA SCI %Chiro	VA SCI EPTTax	VA SCI %HBI	VA SCI TotTaxa
3	A	110305-1-4A	21.20	11/3/2005	0.00	41.29	33.61	9.09	60.18	22.73
4	A	120705-4-A	21.49	12/7/2005	0.00	71.59	10.09	9.09	58.42	22.73
5	B	110305-1-4-B	29.06	11/3/2005	4.37	60.64	59.82	18.18	60.79	27.27
6	B	120705-4-B	25.06	12/7/2005	0.00	80.28	32.10	9.09	56.28	22.73
7	C	110305-1-4-C	24.31	11/3/2005	0.00	68.94	33.94	9.09	59.78	22.73
8	C	120705-4-C	30.72	12/7/2005	0.00	97.72	38.10	9.09	58.40	40.91
9	D	110305-1-4-D1	23.98	11/3/2005	0.00	31.57	78.99	9.09	58.58	13.64
10	D	110305-1-4-D2	27.82	11/3/2005	0.00	73.99	56.80	9.09	57.41	22.73
11	D	120705-4-D	23.05	12/7/2005	0.00	57.80	42.50	9.09	57.35	13.64
12	D	120705-4-D2	28.12	12/7/2005	0.00	100.00	30.16	9.09	57.15	27.27
13	RUP	120705-4-RUP	28.52	12/7/2005	0.00	94.72	36.13	9.09	59.57	27.27

Sediment Particle Characterization

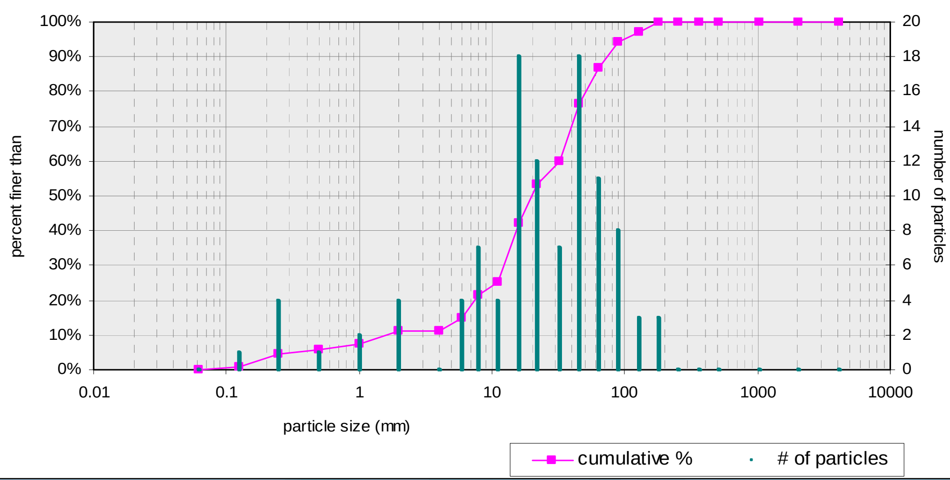
Pebble Count - Site A (Above Lee Hwy)



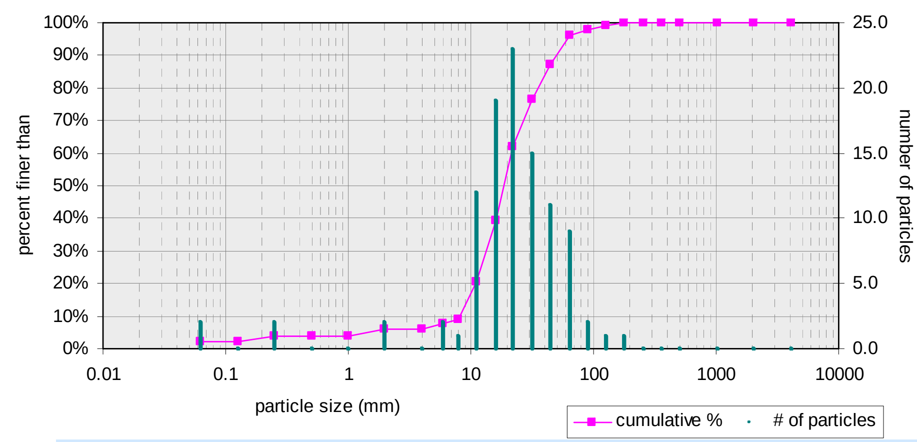
Pebble Count - Site C (First station above Old Lee Hwy)



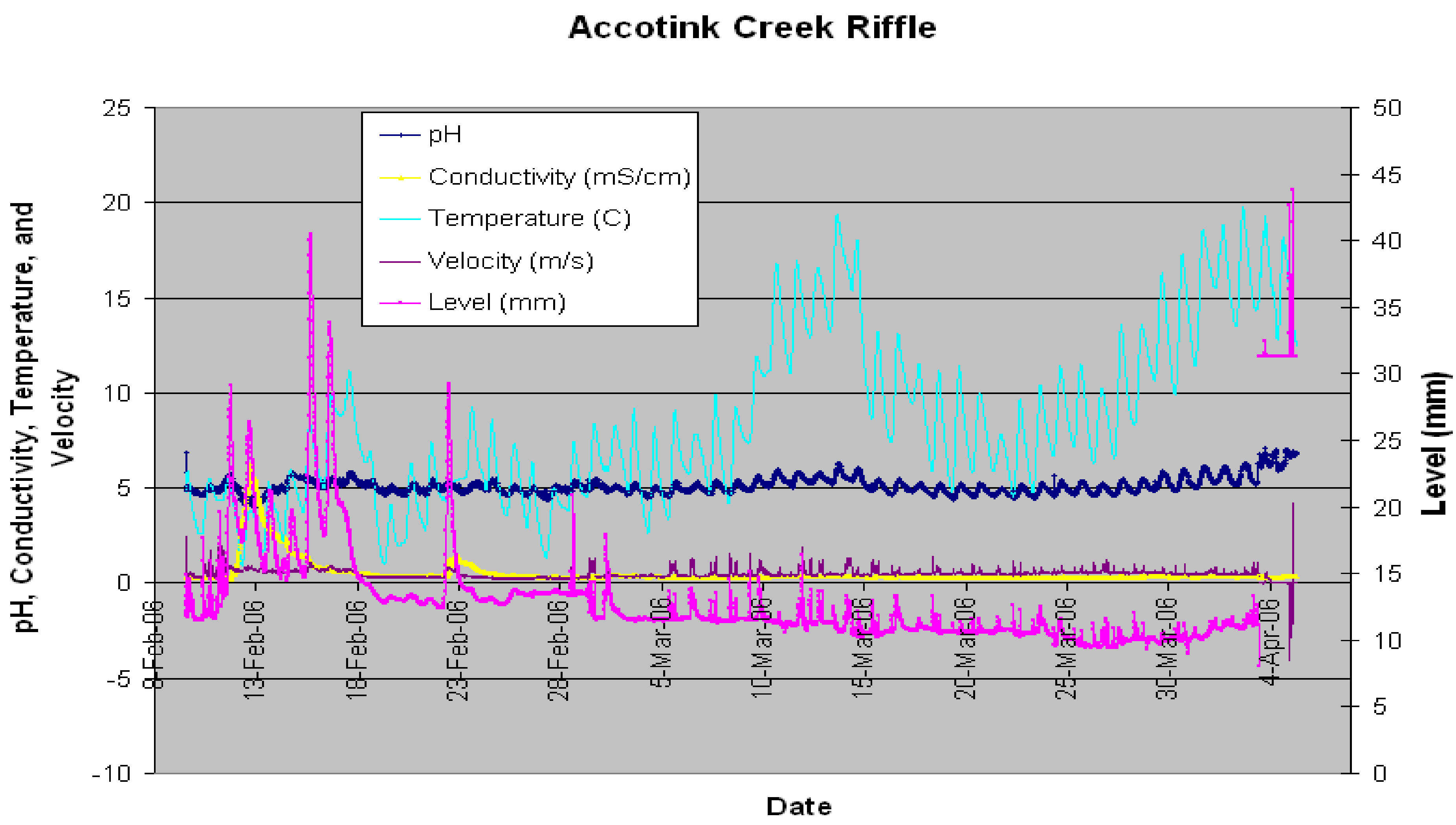
Pebble Count -Site B (Downstream of Lee Hwy)



Pebble Count - Site D (Below Old Lee Hwy)



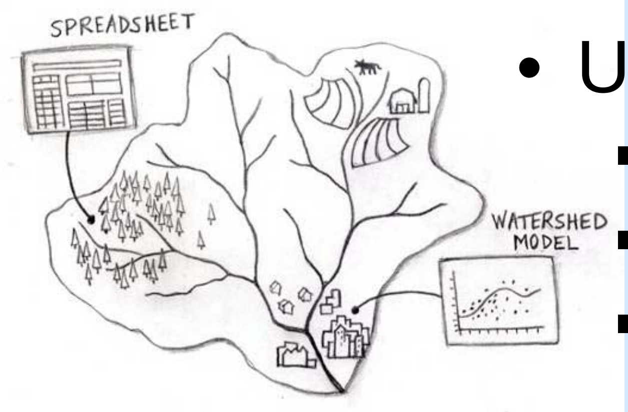
Example of Continuous Data



Watershed Monitoring

Watershed management approaches address local situations but are combined at a larger scale to optimize the maximum benefit for a watershed

- May produce a more accurate measure of the true value of BMP effectiveness
- Relates watershed management to water quality, water quantity, and TMDLs
- Useful for trend monitoring
  - over time
  - designated-use goals
  - water quality standards



Why Do Monitoring Programs Fail?

- Rigorous BMP monitoring programs can become complex quickly. Consequently, many BMP monitoring programs produce insufficient or unsound data, in part due to poor experimental design.

- $$$ to do it right
- Technology issues
- Expertise
- Watershed boundaries generally do not follow planning and policy boundaries

Developing a BMP Effectiveness Monitoring Program

- The Planning Phase
  - Defining Program Goals
  - Collecting Background Informati
  - Identifying Project Resources
  - Formulating Monitoring Objectiv
- The Design Phase
  - Monitoring Approach
  - Parameter and Methods Selecti
  - Hydrologic and Hydraulic Data C
  - Water Quality Data Collection Pr
  - Selection of Equipment and Mat
  - QA/QC Initiatives
  - Quality Assurance Project Plan
- The Implementation Phase
- The Evaluation Phase - Quantifying BMP Efficiency

The Federal Highway Administration's (FHWA) guide "Stormwater best management practices in an ultra-urban setting: selection and monitoring" Report # FHWA-EP-00-002

http://www.fhwa.dot.gov/environment/ultraurb/index.htm


Questions?