The Impervious Cover Model Revisited: review of recent ICM research

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Symposium on Urbanization and Stream Ecology

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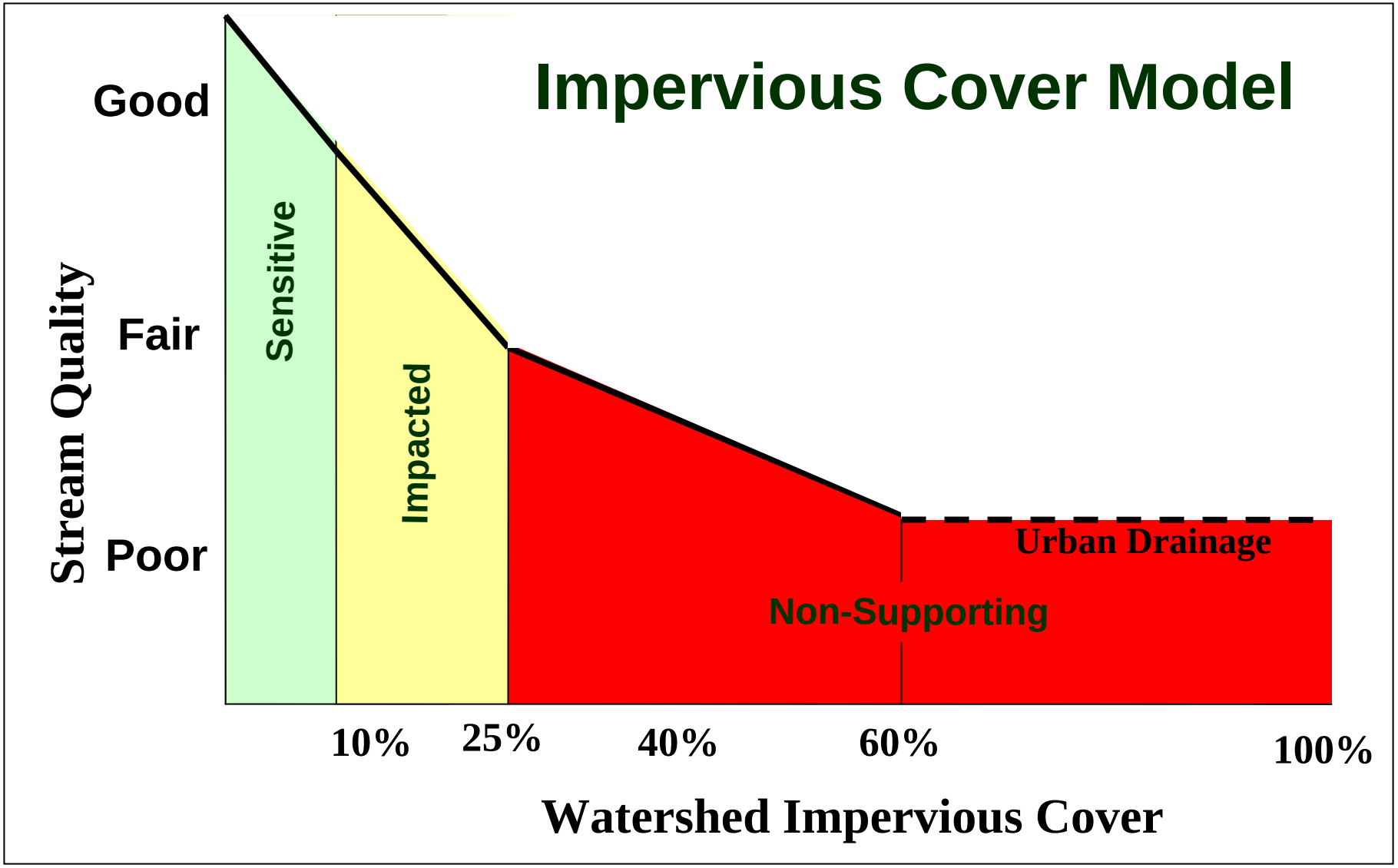
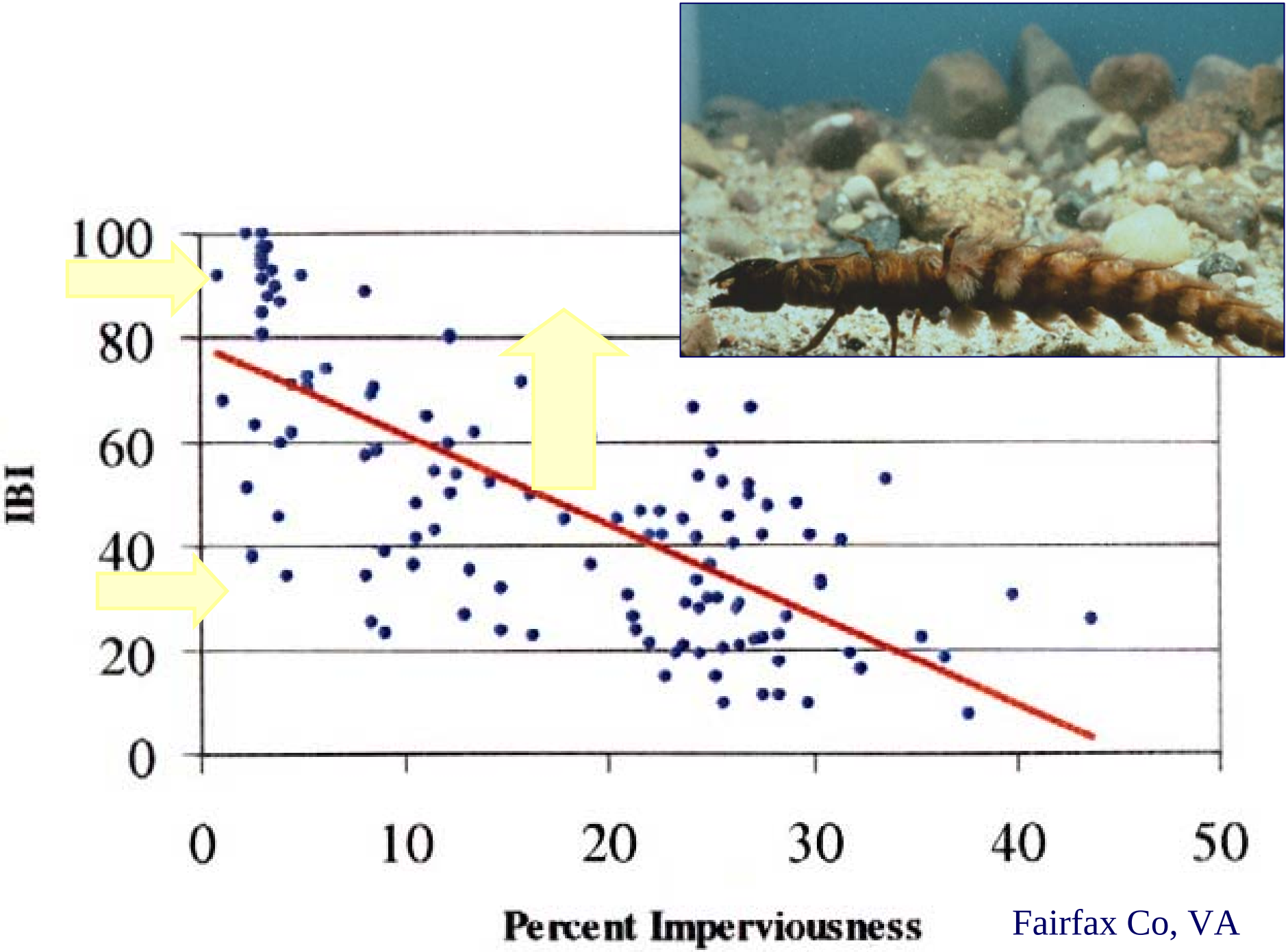
Original ICM developed based on 200+ reports and papers





Fairfax Co, VA

The Inexorable Growth of Impervious Cover

- Elvidge et al (2004): 112,665 km2 of IC created as of 2005

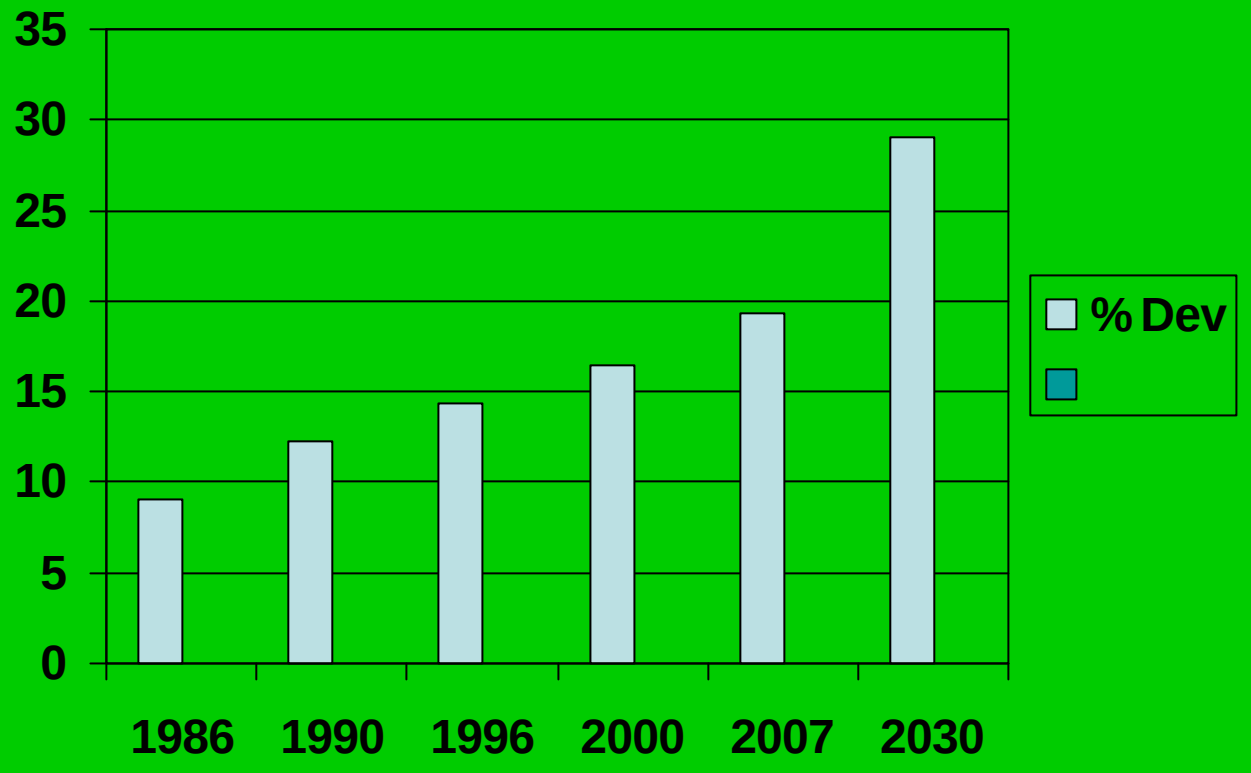
- Beach (2002): As much as 100,000 km2 more IC will be created by 2025

- Nelson (2004): As much as 127,250 km2 more IC will be created by 2030

- Exum at al (2006): At least 14% of 8 SE states had exceeded 5% IC as of 2000

- As much as 10 to 15% of US streams and rivers at risk

Development is creeping up on us, and will defeat our efforts, if we don't get our act together soon



76,800 acres of impervious cover and 232,500 acres of turf cover created each year, or nearly 1% of Chesapeake Bay watershed per year --- Jantz et al (2005)

Translating ICM Science into Management

- IC is tangible – it can be measured, mapped, traded, reduced, priced, forecast and perhaps mitigated.
- IC (and other metrics) can be used to classify, manage and regulate small watersheds.
- Scientists need to present the simplest model that captures the most variation – we can′t worship at the altar of complexity.

The ICM Revisited: Recent Research

- 65 peer reviewed studies tested the ICM in wide range of ecoregions have been published since 2003

- Based on criteria to be included in the database, 27 studies were excluded, yielding a total of 38 studies

- When researchers sampled multiple indicators within the same study, they were considered as separate entries (e.g., water quality, hydrology, habitat, etc.)

- The final ICM database contained 67 individual entries

The ICM Revisited: Recent Research

Confirming

•Primarily sampled small subwatersheds (1st to 3rd order streams)
•Directly estimated impervious cover
•Tested subwatersheds over a broad range of impervious cover
•Reported a strong linear negative relationship for the indicator with increasing impervious cover
•Showed an initial detectable shift in indicator quality in the 5-15% impervious cover range
•Showed a general shift to fair to poor indicator quality in the 20-30% impervious cover range

Reinforcing - Either did not sample small subwatersheds and test a broad range of impervious cover OR relied on percent urban land or an urban index

Inconclusive - Met most of the criteria for confirming, but reported a mixed, weak, or inconsistent relationship between indicator quality and the metric used to describe urbanization

Contradicting - Met most of the criteria for confirming, but did not show a negative or detectable relationship between urbanization and the indicator category analyzed

The ICM Revisited: Recent Research

- 72% confirm or reinforce the ICM
- 28% are inconclusive or contradicting
- Contradicting studies are located in larger watersheds with legacy problems, and primarily involve dry weather water quality and baseflow
- Strongest support for aquatic insects, fish and individual geomorph. indicators

The ICM Revisited: Recent Research

Distribution of Database Entries With Regard to Freshwater Streams

Indicator	Total	Confirming	Reinforcing	Inconclusive	Contradicting
Hydrology [1]	4	0	0	1	3
Geomorphology	4	3	0	1	0
Habitat	7	3	1	0	3
Water Quality [2]	6	3	0	2	1
Benthic Macros	10	5	4	0	1
Fish	11	1	8	1	1
Composite [3]	2	2	0	0	0
Other [4]	5	1	1	2	1

1 primarily baseflow

2 primarily water quality parameters sampled during dry weather, no studies evaluated stormflow quality

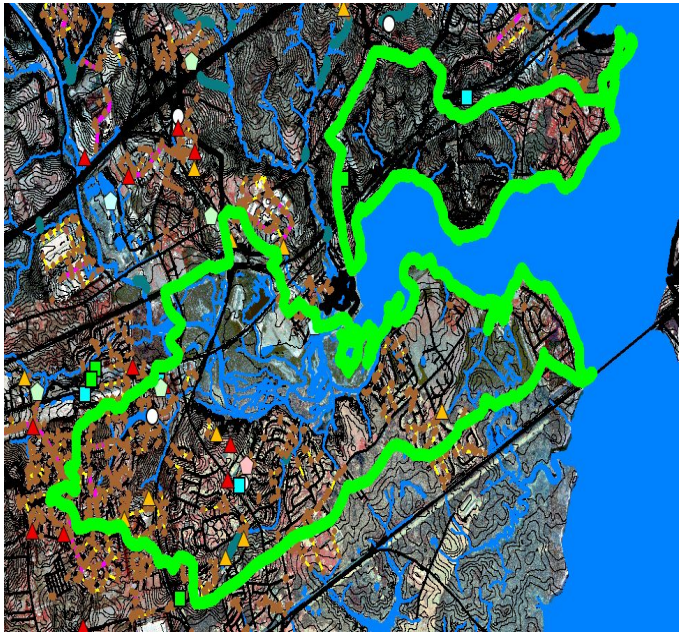
3 combined index measuring habitat, benthic macroinvertebrates and fish

4 other includes sediment quality, algae and amphibian abundance

Impacts are now detected well below the 10% IC threshold.

Impacts of land development are now detected as low as 5 to 10% impervious cover

Research shows that metrics such as watershed forest, turf, wetland or riparian cover predict stream quality better below 10% IC



Riparian forest buffers have a mitigating effect on the ICM

- Riparian forest cover appears to partly mitigate the effect of IC on streams, up to about 15% IC, especially for geomorphic and biodiversity indicators

- Beyond 15%, not much effect

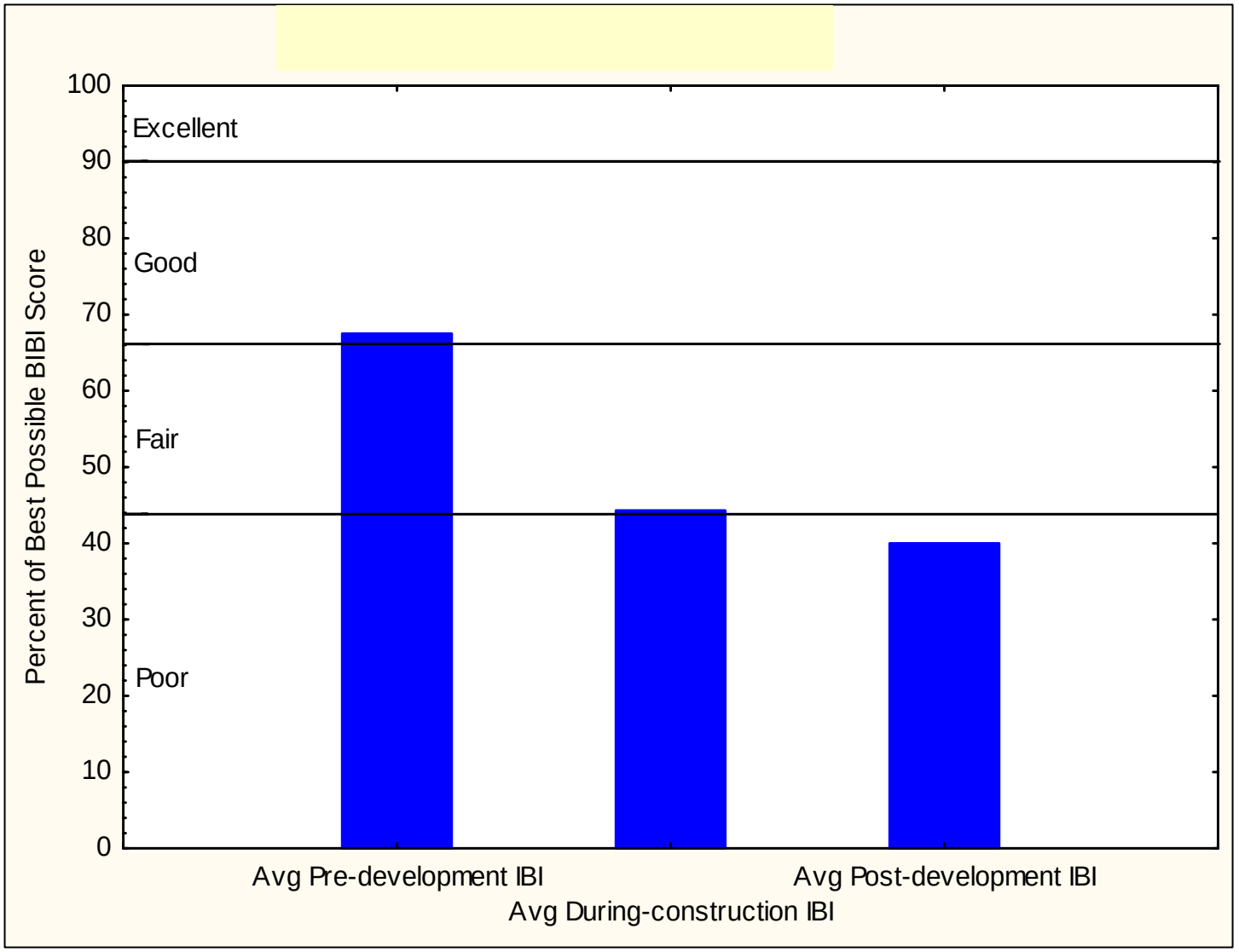
- Subwatershed IC also related to loss of riparian quality

Not Much Effect From Current Watershed Treatment

- Most ICM research was done in regions with at least a moderate degree of development regulation

- The extent or effectiveness of watershed treatment has seldom been measured and is often incomplete

- Can show improvements within the limits of the reformulated ICM


100
90
80
70
60
50
40
30
20
10
0
Excellent
Good
Fair
Poor
Percent of Best Possible BIBI Score
Avg Pre-development IBI
Avg During-construction IBI
Avg Post-development IBI

The ICM doesn't Apply Everywhere

Rocky Mountain Front Range – streams have already been degraded by prior riparian alterations and water diversions in the last 150 years

Reference: Sprague et al, 2006

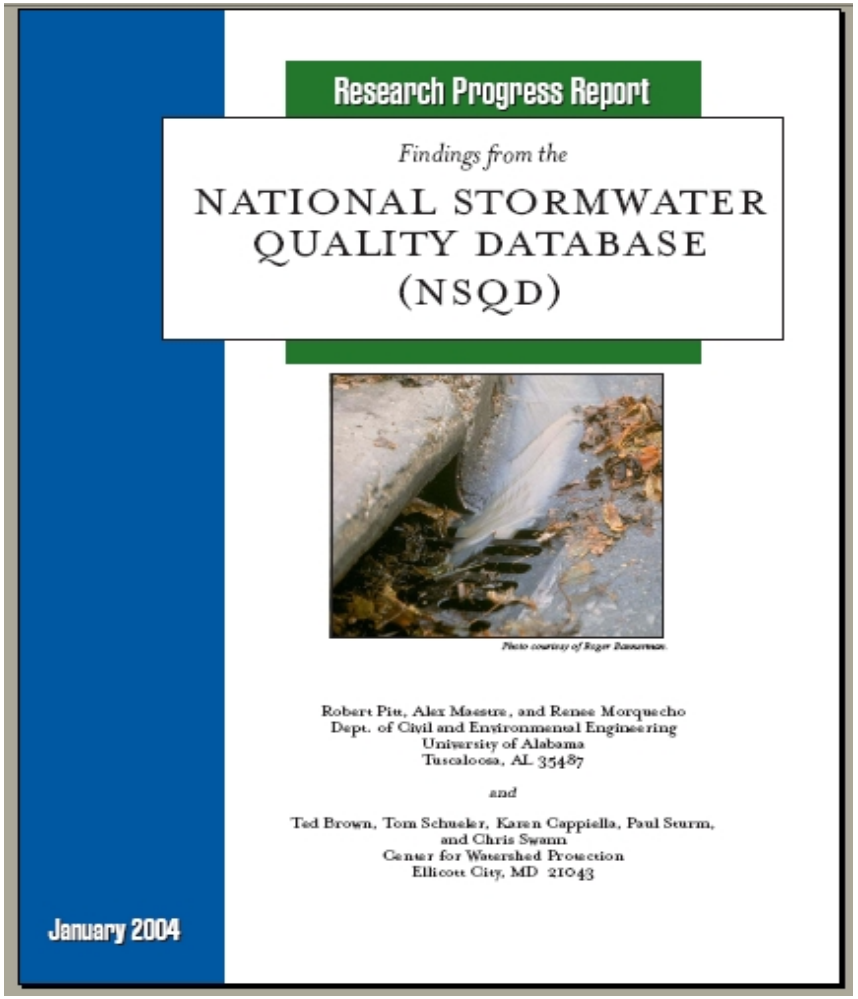
ICM and Water Quality

- Pollutant concentrations do not follow ICM

- Not all IC is the same with respect to pollutant concentration
  - Source areas
  - Land uses
  - Hotspots

- Pollutant loads do conform closely to ICM

- Dry weather WQ does not conform to the ICM



Research Progress Report

Findings from the

NATIONAL STORMWATER QUALITY DATABASE (NSQD)

Photo courtesy of Roger Bannerman

Robert Pitt, Alex Maestre, and Renee Morquecho
Dept. of Civil and Environmental Engineering
University of Alabama
Tuscaloosa, AL 35487

and

Ted Brown, Tom Schueler, Karen Cappiella, Paul Sturm, and Chris Swann
Center for Watershed Protection
Ellicott City, MD 21043

January 2004

✓ The National Stormwater Quality Database, Version 3.0

✓ Developed by University of Alabama and Center for Watershed Protection

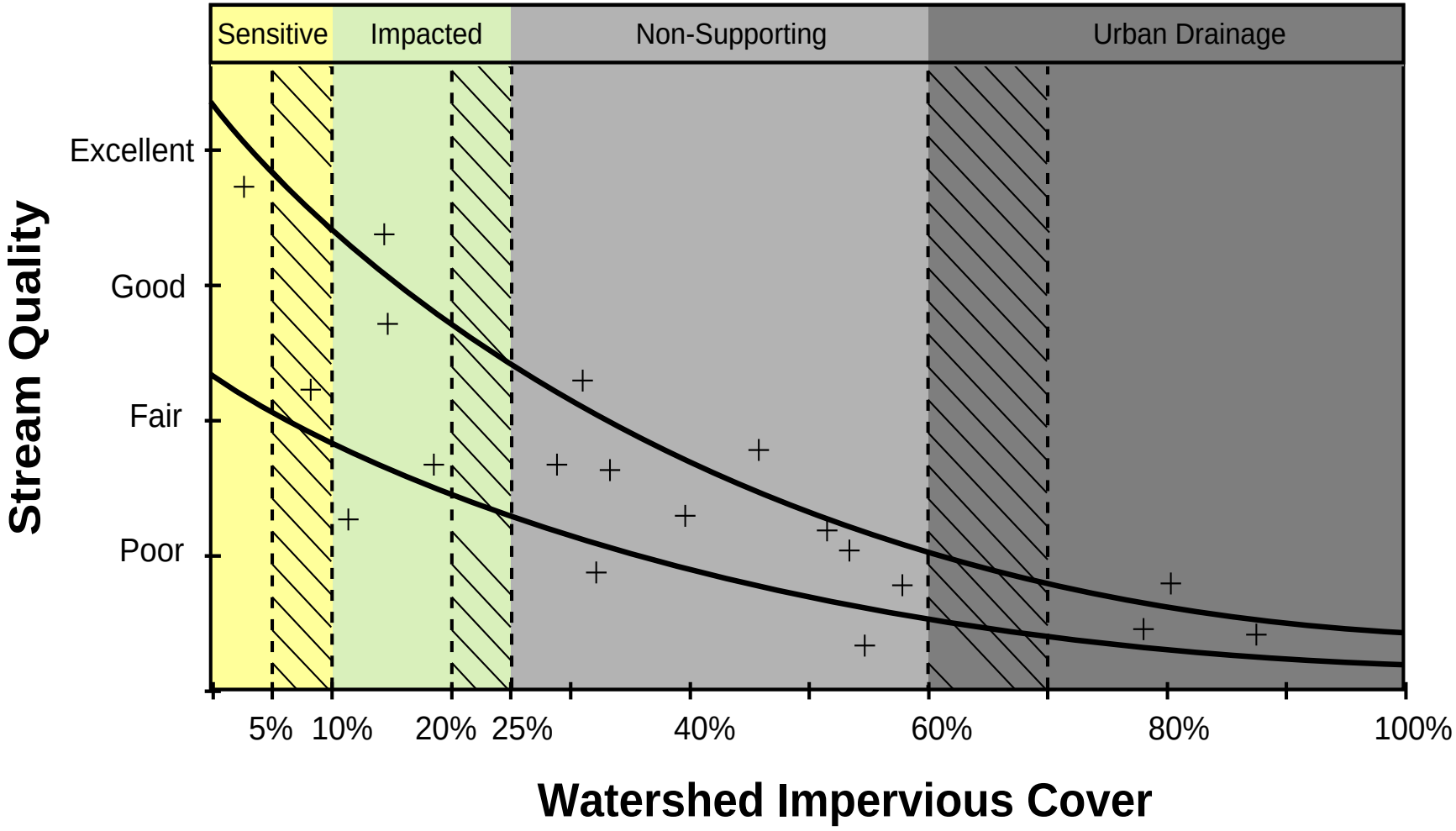
✓ Contains pollutant concentrations for nearly 8000 storm events and 30 parameters

✓ Provides statistical ability to set regional and national benchmarks or action levels to define unacceptable stormwater quality

The Reformulated ICM

- Expresses the impervious cover / stream quality relationship as a cone that is widest at lower impervious cover and progressively narrows at higher impervious cover
- The transition between stream quality conditions is expressed as a band rather than a fixed line
- Represents the observed subwatershed variability and outlines the general range in expected improvement that could be attributed to watershed treatment

The Reformulated ICM (aka “The Cone”)



Caveats and Proper Use of the ICM

- Use should be restricted to 1st to 3rd order alluvial streams with no major point sources of pollutant discharge and no major impoundments or dams

- Stream slope , as measured across the subwatershed should be in the same range for all subwatersheds

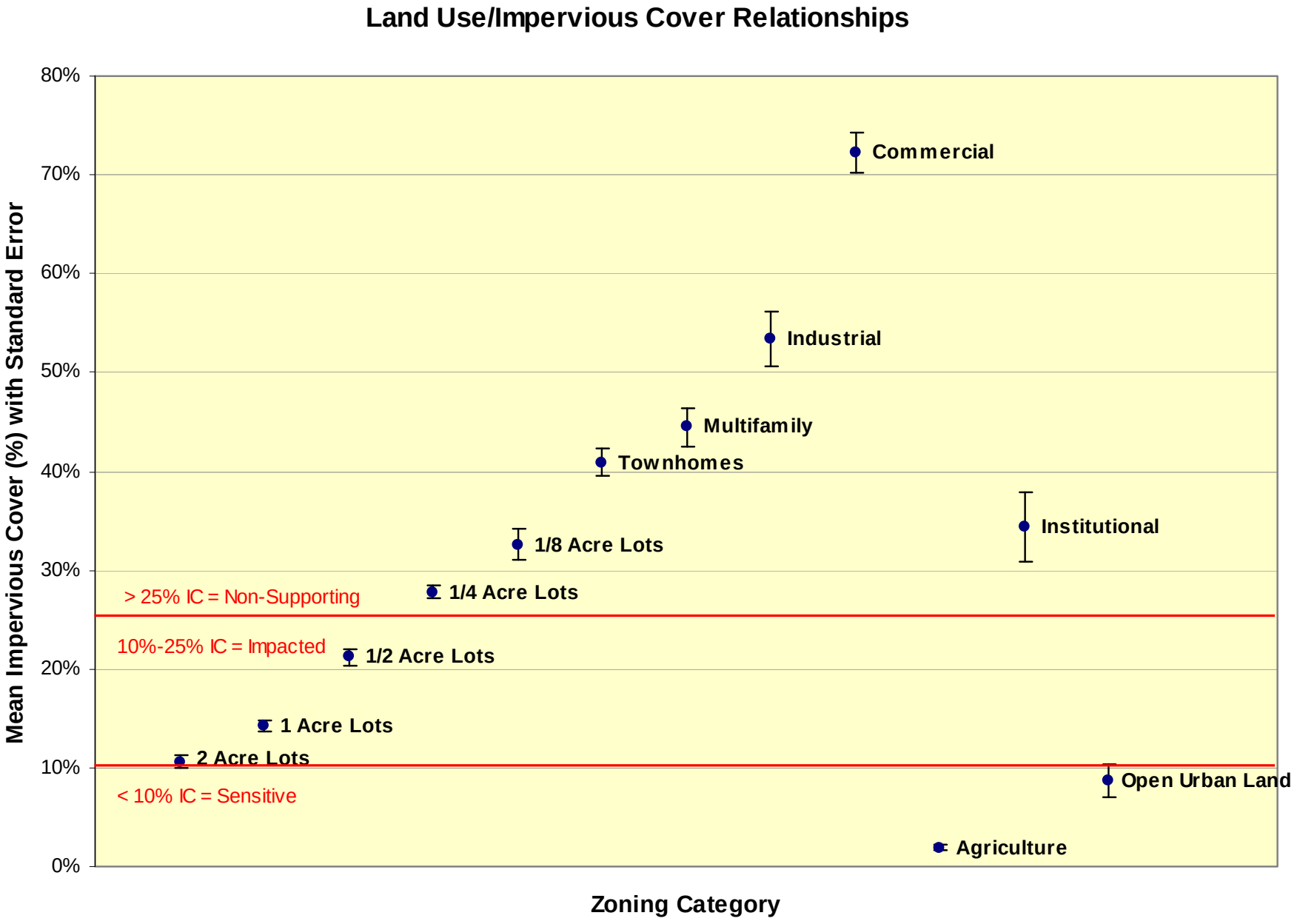
- Management practices in the contributing watershed must be good (e.g. no deforestation, acid mine drainage, major point sources, intensive row crops, etc.)

- Below 10% subwatershed impervious cover, other metrics, such as forest cover, riparian forest cover, road density or crop cover may be more useful than impervious cover in explaining the variability within sensitive subwatersheds

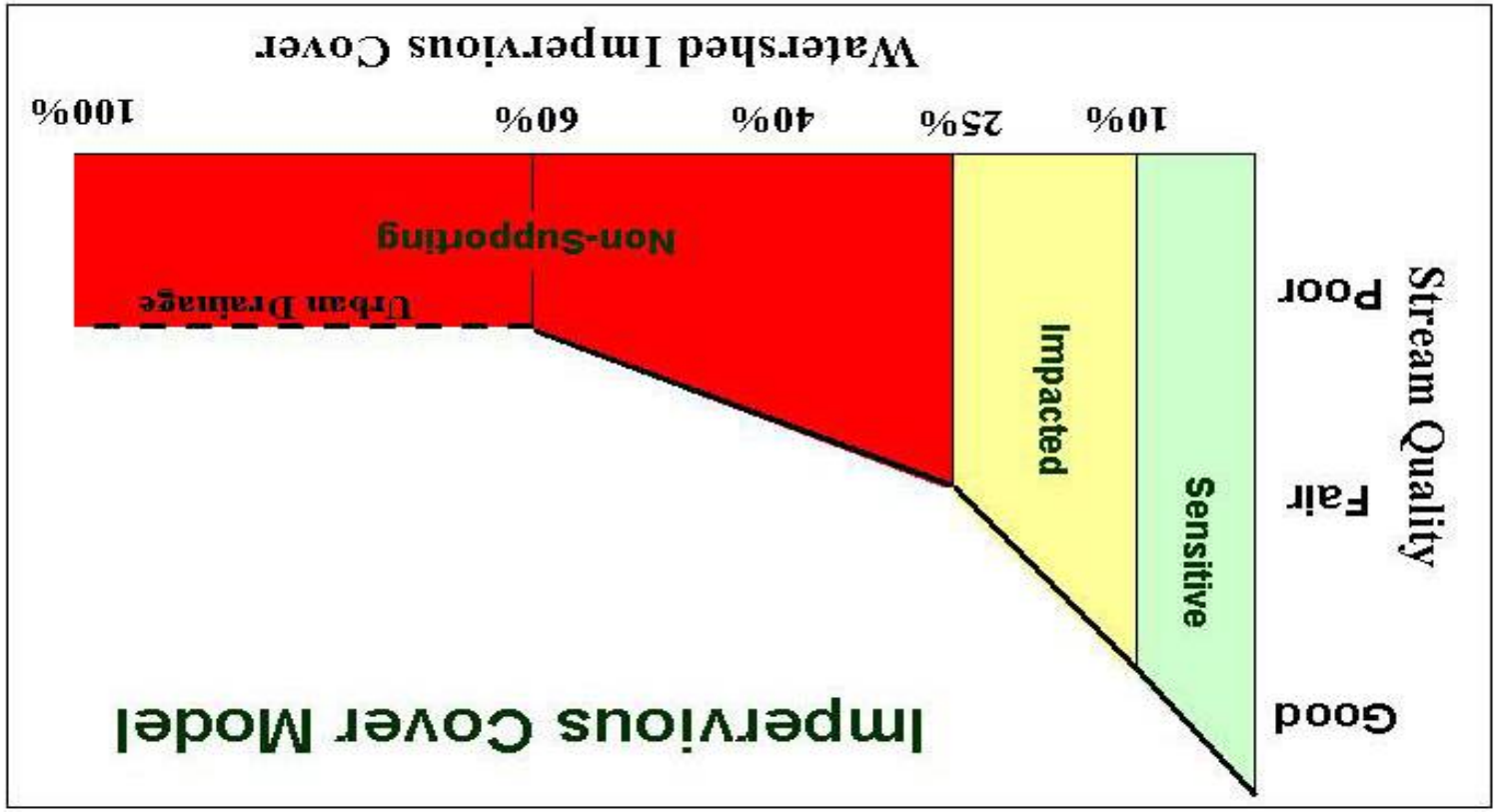
Key Themes

- Why Everybody Hates the ICM
- Setting Realistic Objectives for Urban Waters
- Planning, Engineering, Regulatory and Economic Response to the ICM
- Subwatershed Classification Matters

More Detailed Handout Available


Land Use/Impervious Cover Relationships
Mean Impervious Cover (%) with Standard Error
80%
70%
60%
50%
40%
30%
20%
10%
0%
Commercial
Industrial
Multifamily
Townhomes
Institutional
1/8 Acre Lots
1/4 Acre Lots
> 25% IC = Non-Supporting
10%-25% IC = Impacted
1/2 Acre Lots
1 Acre Lots
2 Acre Lots
< 10% IC = Sensitive
Open Urban Land
Agriculture
Zoning Category

Can we Defeat the Impervious Cover Model?



Setting Realistic Objectives for Impacted Streams

✓ Consistently attain good stream quality indicator scores, emphasizing achieving enough stream function to adequately protect downstream receiving waters from degradation

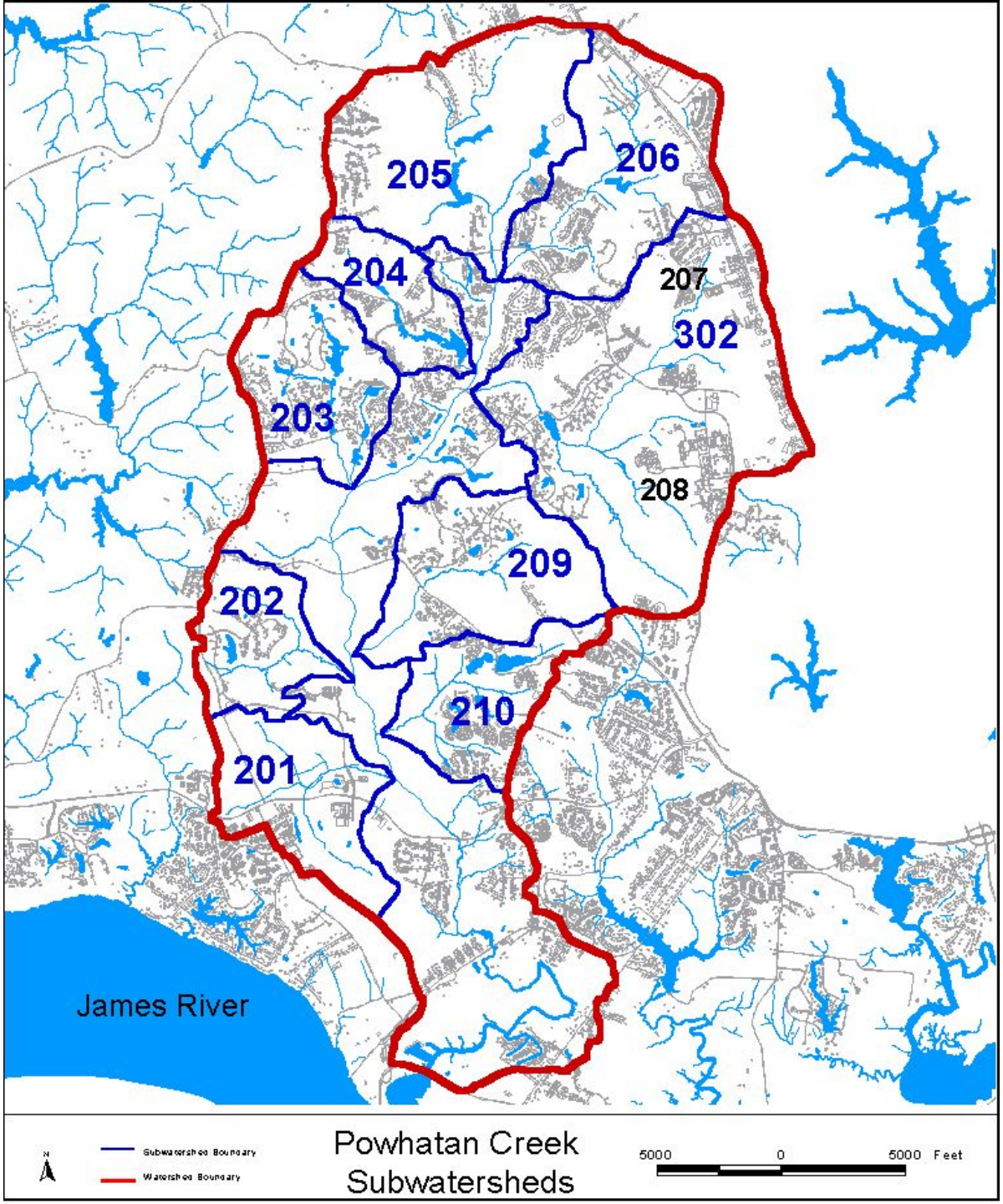
✓ Example Functions: flood storage, instream nutrient processing, biological corridor and relatively stable channels to prevent increased downstream sediment export

Realistic Objectives for Non-Supporting Streams

- ✓ Consistently attain fair to good stream quality indicator scores, which may require selective application of restoration practices
- ✓ Meet bacteria standards during dry weather and trash limits during wet weather
- ✓ Remaining stream corridor is a connected network that allows safe passage for fish and floodwaters

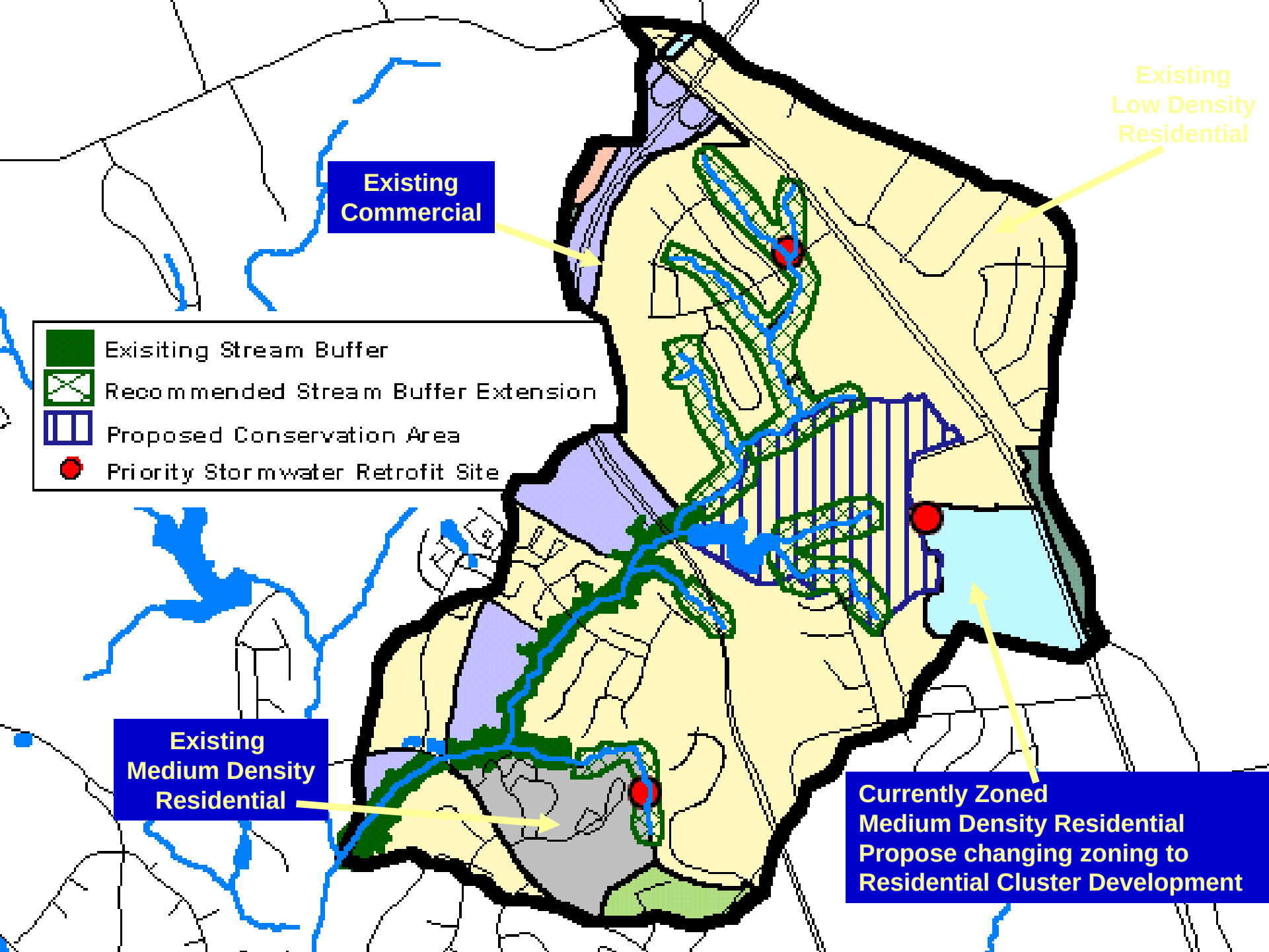
Planning and Zoning Responses to the ICM

- Better Site Design
- Watershed Planning
- Extremely Large Lot Zoning
- Site-Based IC Caps
- Watershed-Based IC Caps
- Development Intensification
- Watershed-Based Zoning Linked to Permits


205
206
204
207
302
203
208
209
202
210
201
James River
N
Subwatershed Boundary
Watershed Boundary
Powhatan Creek
Subwatersheds
5000
0
5000 Feet

Powhatan Creek: Changes in Subwatershed Quality

Classification	1998	2000	2020
Sensitive	6	4	0
Impacted	4	6	9
Non-Supporting	0	0	1


Existing Commercial
Existing Low Density Residential
Exisiting Stream Buffer
Recommended Stream Buffer Extension
Proposed Conservation Area
Priority Stormwater Retrofit Site
Existing Medium Density Residential
Currently Zoned Medium Density Residential Propose changing zoning to Residential Cluster Development

Numerical Performance Objectives to Protect Sensitive Streams

✓ Restrict subwatershed IC to less than 10%*

✓ Retain at least 65% forest or native vegetative cover.

✓ Conservation practices on all croplands and no livestock in streams

✓ Ensure native cover on at least 75% of the riparian network

✓ Limited crossings of stream network that do not impair aquatic movement

- Actual IC cap may range from 5 to 12% depending on antecedent land cover, ecoregion and resource sensitivity

Subwatershed Plans and Permitting

- Measure/Forecast Subwatershed Current and Future Land Cover
- Use ICM to Establish Initial Subwatershed Classification
- Stream Monitoring to Confirm or Modify Classification
- Develop Subwatershed Plans
- Conduct Compliance Monitoring
- Implement Appropriate Practices
- Establish Sentinel Indicator Monitoring

Engineering Responses to the ICM

- Generic Stormwater Treatment Requirements
- Runoff Reduction Performance Criteria
- Special Subwatershed Stormwater Criteria
- Watershed Retrofit and Restoration Practices

Runoff reduction is defined as the total annual runoff volume reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration at small sites

Runoff Reduction Rates (%)

Infiltration	50 to 90
Bioretention	40 to 80
Pervious Pavers	45 to 75
Green Roof	45 to 60
Dry Swale	40 to 60
Rain Tanks/Cisterns	40
Roof Disconnection	25 to 50
Grass Channel	15 to 30
Dry ED Pond	0 to 15
Wet Pond	0
Sand Filter	0

Source: CWP and CSN (2008)

Sensitive: Full Runoff Reduction for all storm events up to the two-year design storm event (3 to 3.5 inches)

Impacted: Full Runoff Reduction for all storm events up to the one year design storm event (2.2 to 2.6 inches).

Non-supporting: Maximize Runoff Reduction up to the 90% or water quality storm (0.8 to 1.4 inches).

Urban Drainage: Maximize Runoff Reduction up to the "first flush" storm (usually about 0.5 inch)

Regulatory Responses to the ICM

- Anti-degradation provisions to protect healthy waters
- Impervious Cover based TMDLs
- Watershed Based Permitting
- Compliance Monitoring

TMDLs and Compliance Monitoring

Impacted: Impervious Cover Based TMDLs to set targets for desired runoff reduction and removal of pollutants of concern

Compliance: Measure IC, IC treated and stream indicators

Non-supporting: Stormwater TMDLs to outline most critical subwatersheds to maximize removal of pollutants of concern.

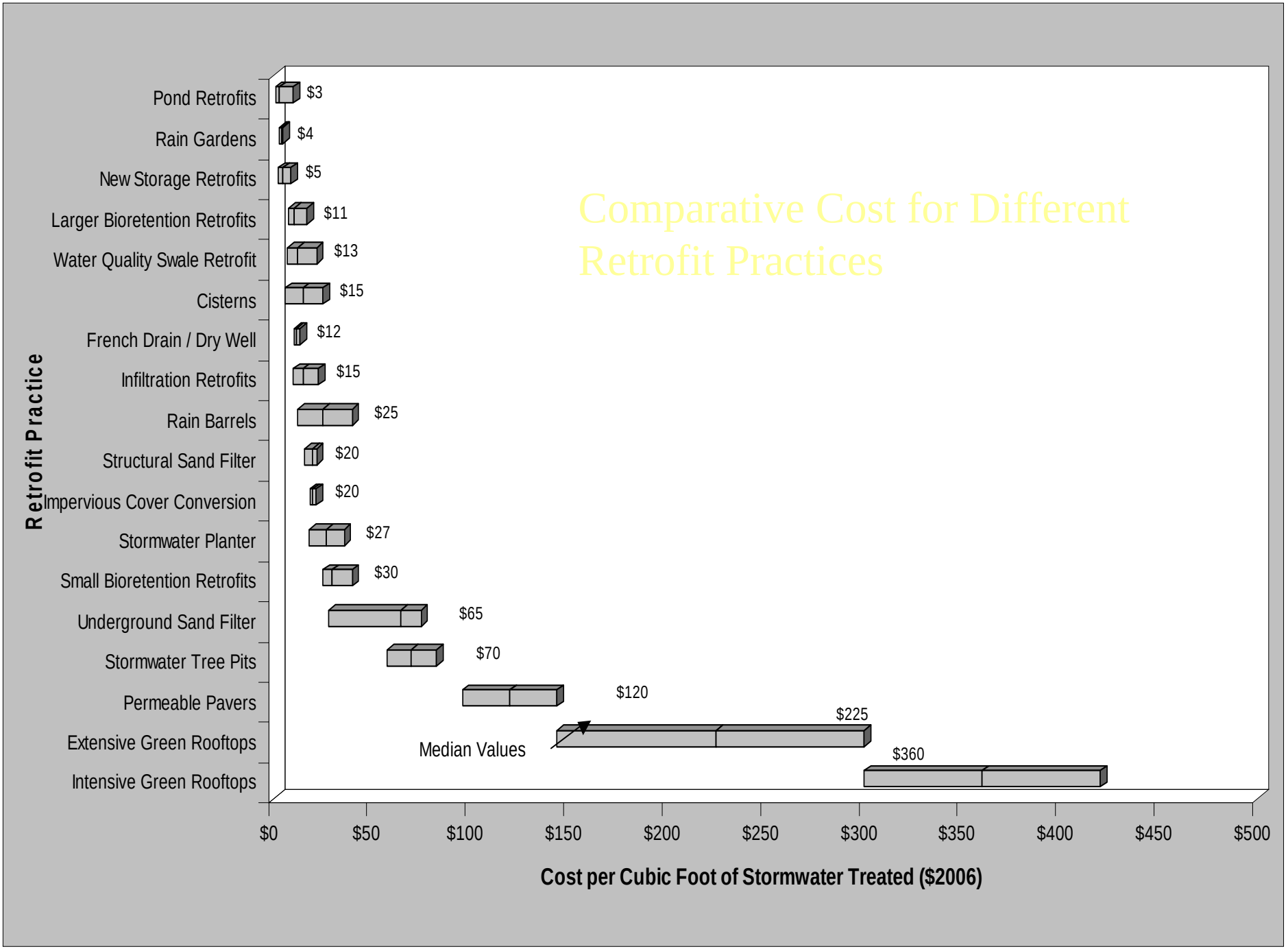
Compliance: Outfall monitoring to define dirty subwatersheds that exceed 75th percentile of stormwate quality

Urban Drainage: Traditional TMDLs to identify and treat dirtiest urban source areas and discharges to maximize removal to downstream receiving waters

Compliance: Source area sampling and inspections to define dirtiest upland source areas and hotspots

Economic Responses to the ICM

- IC-based Stormwater Utilities
- Excess Impervious Cover Fees
- IC Mitigation Fees
- Subwatershed IC Trading
- Economic Incentives for Development Intensification


Comparative Cost for Different Retrofit Practices
Retrofit Practice
Pond Retrofits
Rain Gardens
New Storage Retrofits
Larger Bioretention Retrofits
Water Quality Swale Retrofit
Cisterns
French Drain / Dry Well
Infiltration Retrofits
Rain Barrels
Structural Sand Filter
Impervious Cover Conversion
Stormwater Planter
Small Bioretention Retrofits
Underground Sand Filter
Stormwater Tree Pits
Permeable Pavers
Extensive Green Rooftops
Intensive Green Rooftops
$3
$4
$5
$11
$13
$15
$12
$15
$25
$20
$20
$27
$30
$65
$70
$120
$225
$360
Median Values
$0
$50
$100
$150
$200
$250
$300
$350
$400
$450
$500
Cost per Cubic Foot of Stormwater Treated ($2006)

We Can Only
Recover Our Urban
Waters When We
Align Zoning,
Planning,
Engineering,
Economics and
Regulations at the
Subwatershed Level