The Impervious Cover Model, Revisited (Again)

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The ICM, Revisited, Again

- The Evolution of the ICM, 1979 to 2017
- The Strength of the Evidence
- Utility of Other Watershed Indicators
- Limitations of the ICM
- Implications for Managers and Planners

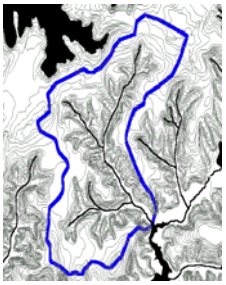
"After having considered that covering the ground of the city with building and pavements, which carry off most of the rain, and prevent its soaking into the Earth and renewing and purifying the Springs, whence the water of wells must gradually grow worse and be unfit for use, as I find has happened in all old cities of Europe

I recommend at the end of the first hundred years, if not done before, the...city employ a hundred thousand pounds in bringing by pipes water so as to supply the inhabitants."

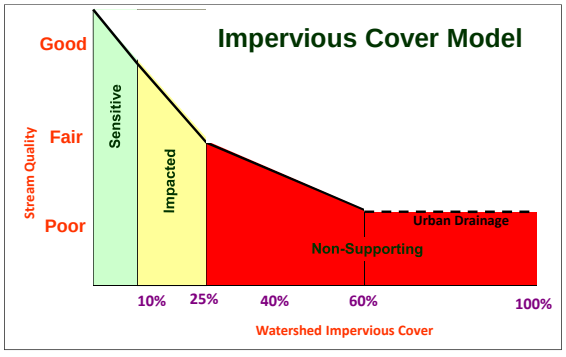
Ben Franklin, Will. Philadelphia. 1790

Urbanization and Stream Quality: A Short History

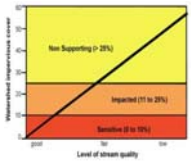
- 1979 First paper: Richard Klien
- 1994 CWP Introduces the ICM
- 1999 CWP ICM and Urban Watershed Planning and Better Site Design
- 2000-2008 Explosion of Research on IC and Stream Gradients Across World (Urban Stream Syndrome)
- 2009 ICM Revisited –Revised Model Proposed
- 2010: Major Improvements in Measuring IC Cover at Watershed Scale but not much gradient research



The original 1994 model



Assumptions of the ICM



Applies to 1st to 3rd order streams

IC association does not always imply IC causation

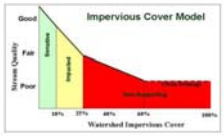
Continuous decline rather than sharp thresholds

Initial diagnosis rather than final classification

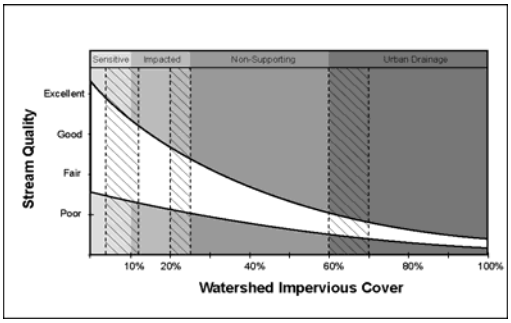
ICM Disclaimer

"ICM predictions are general, and may not fully apply to every stream. Factors such as stream gradient, stream order, stream type, age of subwatershed development, prior land use, past management practices can and will make some streams depart from these predictions"

Must be 18 or older to enter. Not valid in TX, UT and AK. APR of 6.15%. Not everyone qualifies for special financing. Offer may restricted due to Acts of God. You can never win. CSN not liable for any damages, we don't have any $ even if we are



The Revised ICM: 2009



ICM Haters and Lovers

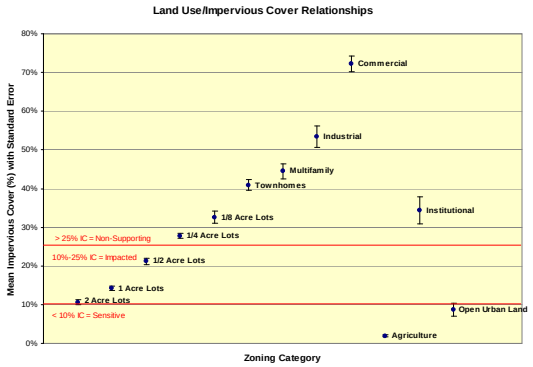
Haters

- Land use planners
- Smart growth advocates
- Water quality regulators
- Stormwater engineers
- Green Infrastructure types
- Builders and developers
- Scientists
- Elected officials

Lovers

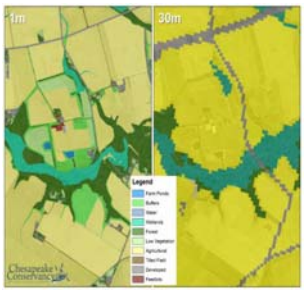
- Opponents of land development
- Rural watershed groups
- Geographers and GIS mappers
- Trout and salmon managers
- Lawyers
- My mother

Impervious Cover as Car Habitat



Progress in Measuring IC

- Incredible progress in mapping IC in last 30 years
- Cover Resolution: 1 meter scale
- Fuzziness in defining TC an IC at the rural exurban boundary



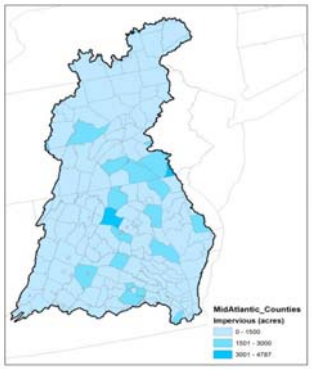
Measuring IC in the Bay Watershed
More Resolution = More Acres

Chesapeake Bay Watershed IC and PC Area Estimates (2016)		
Measurement Technique	Impervious Cover (acres)	Pervious Cover (acres)
Landsat (30m)	**809,311**	**2,341,555**
Multiple Models	**1,269,018**	**3,398,701**
Hi Resolution Data (1m)	**1,702,837**	**3,197,456 ***

Source: CBP (2017) and Peter Claggett
* New land use category "mixed open" reduces PC

Increase in Impervious Surfaces by 2025

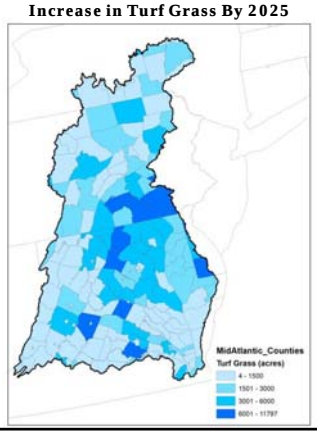
Current Zoning Scenario



Source: CBP, 2017

14

Increase in Turf Grass By 2025



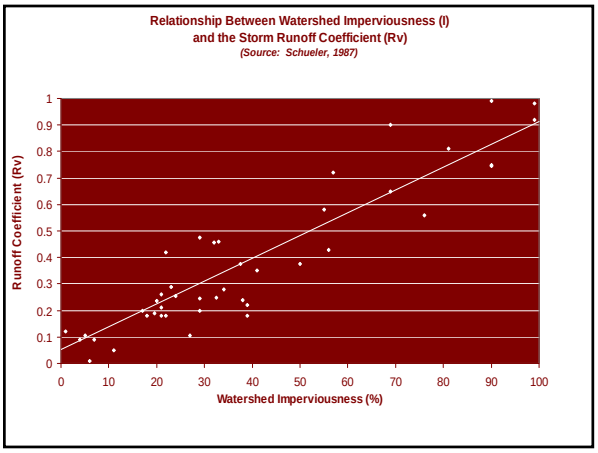
Current Zoning Scenario

Source: CBP, 2017

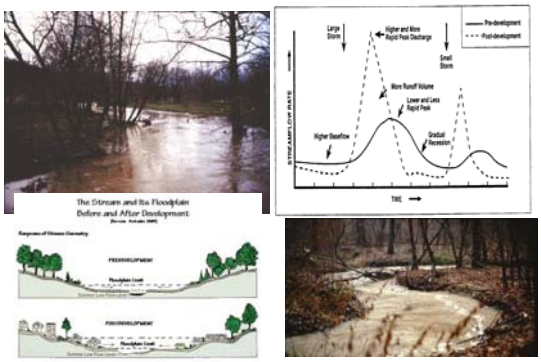
15

Hydrological Indicators

- Increased stormwater runoff
- Increased frequency of flooding
- Floodplain expansion
- Diminished dry weather base flow?
- Increased bank full flooding



Strong Links IC and Urban Hydrology



Stream Corridor Integrity

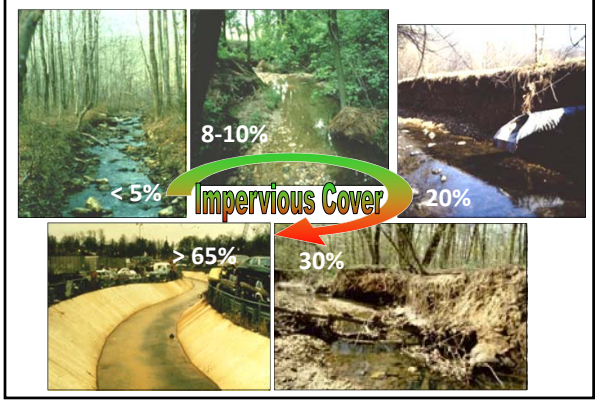
- Loss of headwater streams
- Increased "connectivity" via ditches and storm drain pipes
- Floodplain encroachment
- Loss of intact riparian buffer
- Stream interruption
- Increased number of crossings/fish barriers
- Disconnection between stream and palustrine wetlands
- Poor riparian forest health and spread of invasive plant species

Ditch and Storm Drain Connectivity

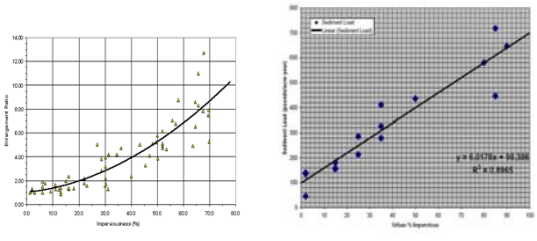
Changes in Stream Geomorphology *

- IC is generally predictive in determining the severity of bank erosion, but lousy as to its timing and exact location
- Channel enlargement and instability
- Increased stream bank erosion and downstream sediment delivery from headwater streams
- But significant potential for bank or floodplain sediment storage in larger streams and rivers
- Legacy sediments in the headwaters confound the issue a bit

IC and Stream Habitat



Channel Enlargement as a Function of Impervious Cover



Sediment Delivery from Urban Streams

- Bank erosion accounted for an average of 70% of annual sediment yield in 18 small watersheds in Baltimore County, MD.
- 57% of the measured erosion was from legacy sediments
- Headwater stream network is the source of most of the measured erosion
- Findings consistent with other geomorphic research
- **Source:** Donovan et al, 2015

Decline in Stream Habitat Indicators

- Declining stream habitat scores
- Decline in large woody debris
- Changes in organic carbon dynamics
- Stream warming
- Loss of pool-riffle structure
- Embeddedness and substrate biofilms

Stream warming

IC increases summer stream temps during dry weather by about 1 degree F per 10% increment of IC

Reflects urban heat island and pavement heating

Some temp spikes during summer thunderstorms (Rice et al, 2011)

Stormwater ponds further enhance stream warming

Water quality indicators

- Increased salinity
- Violations of bacteria standards
- Nutrients and eutrophication
- Aquatic life toxicity
- Urban pesticides
- Trace metals (Cu, Pb, Zn, Hg)
- Sediment PAH contamination
- Trash and debris loads

Headline: Different Types of IC Generate Specific Pollutants

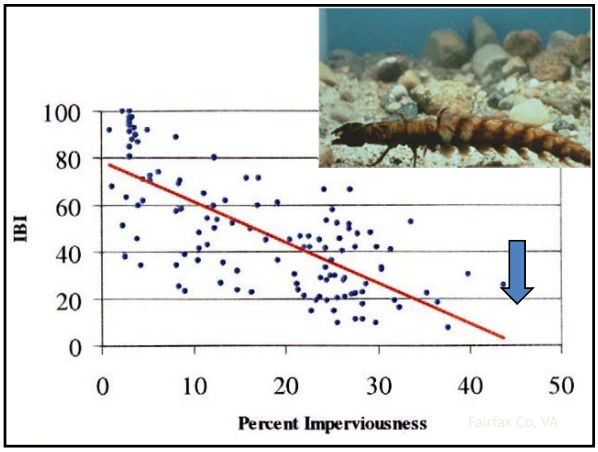
- **Chlorides**: streets and highways
- **DIC, pH and Cl**: Concrete
- **DOC**: streets with canopy (hydrophobic/petroleum)
- **Metals:** streets, rooftops
- **PAH**: Parking lots and street dirt (especially seal coats)

References: Moore et al, 2017, Corsi et al, 2015, McElmurry et al, 2014, Kaushal et al, 2005, Clark et al, 2011

Urban toxics exert many strong impacts on humans and the environment

Aquatic Diversity Indicators

- Aquatic Insects
- Sensitive Insects
- Fish Diversity Scores
- Trout and Salmon
- Floodplain Plant Diversity
- Amphibian Diversity



Pervious cover is not very descriptive term and does not capture the different hydrologic response and pollutant export of its component parts

34

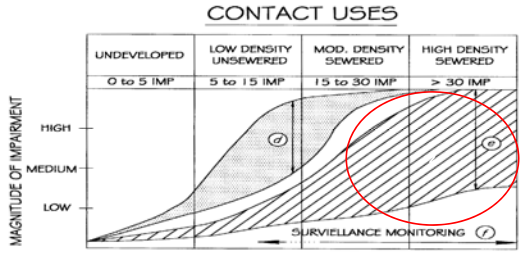
Limitations of the ICM

- Not real good with some indicators, especially those influenced by urban pipe infrastructure
- ICM not yet capable of predicting the effect of BMP treatment
- Major increases in IC and PC over time as mapping became more precise and finer grained

ICM Is Not Helpful in Isolating the Causes of the Decline in Aquatic Biodiversity

- ICM correctly predicts John is dead, but is silent about who killed him
- A lot of potential suspects –
  - new generation of urban insecticides, chlorides, PAHs
  - Water temperature
  - Habitat degradation
  - Something else?

ICM Is Not Really Helpful to Manage for Water Contact Recreation



Can BMPs Defeat the ICM ?

Issue: the effect of stormwater practices in defeating the ICM is the most important– and unanswered – question in watershed research today

Problem: Extremely hard to measure effect because of watershed variability and differences in degree of watershed treatment

Research: debate has raged for three decades, but little definitive sub-watershed evidence to show the effect of BMP treatment (Berry Brook, NH)

A very hard subwatershed experiment to get right

The Many Tools to Mitigate the ICM	
Planning and Zoning Tools	*Engineering Tools*
• Better Site Design • **Large-lot Zoning** • Site-based IC Caps • Watershed-based IC Caps • Development Intensification • **Watershed-based Zoning** • Extreme Land Conservation	• **Enhanced Stormwater Treatment Criteria for Runoff Reduction** • Watershed Restoration Plans and Stormwater Retrofits • Stream and Floodplain Restoration
Regulatory Tools	*Economic Tools*
• Anti-Degradation Provisions • **IC-Based TMDLs** • **Watershed-Based MS4 Permits with IC Treatment or Load Reduction Requirements**	• IC-Based Utilities • Public Private Partnerships • IC Mitigation Fees

Questions and Comments