The Road Ahead:
Lessons Learned in Managing Stormwater in the Chesapeake Bay

Chaska MN  September 25, 2009
Chesapeake Stormwater Network

Align the local, state, federal and private sectors to solve the Bay stormwater problem through an independent network of concerned stormwater professionals

www.chesapeakestormwater.net
Lessons Learned

1. Tracking the Growth Imprint
2. IC and Stormwater Impacts
3. Runoff Reduction From Roof to Stream
4. Challenges to Shifting to Runoff Reduction
5. Retrofitting Old Impervious Cover
The indigenous stormwater tribes of North America

- Lackaniconas
- Karstians
- Eutrophicicators
- Flatheads
- Redevelophants
- Darkhollers
- Mudsters
- Salmonolos
- Salmonellas
- Aridstas
- Frozenstiffs
- Luckycanucks
A Brief History of Stormwater in the Chesapeake Bay

1600: Not a lot of runoff
1800 - 1900: Lots of Erosion and Mill Ponds
1900 - 1950: Profound Drainage Alteration
1960s: Growth begins in watershed
1980s: Pipe and Pond Era
2008: The emergence of LID, ESD and runoff reduction
Lesson 1: Incremental Growth Over Time Really Adds Up

- Between 1990 to 2000, population increased by 8%, but IC increased by 41%, and turf cover by 80%
- Population expected to grow by 16.5% by 2030
- 75% of land development outside of smart growth areas
- Recession has temporarily slowed growth trends
76,800 acres of impervious cover and 232,500 acres of turf cover created each year, or 0.8% of Bay watershed per year
Lesson 2: It doesn’t take a lot of development to create a major impact
The ICM Revisited: Recent Research

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

- 72% confirm or reinforce the ICM
10,000 Miles of Degraded Streams in Watershed

Impervious Cover:
- < 5%
- 8-10%
- 20%
- > 65%
- 30%
Impacts are now detected well below the 10% IC threshold.

Impacts of land development are now detected as low as 5 to 8% impervious cover *

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

Ecoregions where cropland is the dominant predevelopment land cover often have a higher IC threshold (12 to 15 %) than forested ecoregions.

Recent Finding from USGS

Prior channel modification and sedimentation suspected
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.
Piney Branch - WBPB203A

Avg Pre-development IBI

Avg During-construction IBI

Avg Post-development IBI

0 10 20 30 40 50 60 70 80 90 100

Percent of Best Possible BIBI Score

Excellent

Good

Fair

Poor

Avg Pre-development IBI

Avg During-construction IBI

Avg Post-development IBI
Rehabilitation
Protection
Stewardship

Realistic Restoration Expectations - Booth et al 2004

Region of unlikely outcomes

Stream Health (BIBI score)

Subwatershed Impervious Cover (%)
Lesson 3: We have also reached a clipping point, with respect to turf cover in our watershed
The Clipping Point:
Emergence of Turf Cover
As a Major Bay Ecosystem

<table>
<thead>
<tr>
<th>TURF COVER, BAY WATERSHED 2000</th>
<th>TURF PERCENT OF BAY LAND AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1: 3.82 million acres</td>
<td>Method 1: 9.5%</td>
</tr>
<tr>
<td>Method 2: 3.79 million acres</td>
<td>Method 2: 9.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPARISON TO OTHER BAY LAND USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Crops: 9.2% of watershed</td>
</tr>
<tr>
<td>Pasture: 7.7%</td>
</tr>
<tr>
<td>Hay and Alfalfa: 7.4%</td>
</tr>
<tr>
<td>Wetlands: 3.8%</td>
</tr>
</tbody>
</table>
Distribution of Turf Grass in the Chesapeake Bay Watershed (yr. 2000)

Legend
- US_DetailedStates
- Chesapeake Bay

Counties/cities
Turf grass (acres)
- 0 - 30,000
- 30,001 - 60,000
- 60,001 - 90,000
- 90,001 - 120,000
- 120,001 - 150,000

Map showing the distribution of turf grass in the Chesapeake Bay Watershed, with different shades indicating the amount of turf grass in each county or city.
**Turf Trends in Bay**

- 8.6% annual growth rate for turf in VA from 1972 to 2004

- Per capita turf in VA has nearly doubled from 0.13 to 0.24 acres/resident acres in same period

- Last few decades has seen increase in large lot size

Home lawns comprise about 68% of all turf in 1995, about 75% now
Lawns and Nutrients

Almost 90% of residents have a yard

About 50% to 65% have yard fertilized

Average of two applications per year

50% of fertilizers over-fertilize

• Estimated N Fertilizer Inputs by lawns: 215 million lbs/yr or twice current annual average wastewater and ag loads to Bay
Urban Stormwater Nutrient Loads Are Fast Becoming a Big Slice of the Bay Pie

<table>
<thead>
<tr>
<th>Year</th>
<th>Total N</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>2000</td>
<td>9%</td>
<td>15%</td>
</tr>
<tr>
<td>2005</td>
<td>19%</td>
<td>30%</td>
</tr>
<tr>
<td>2030</td>
<td>??</td>
<td>??</td>
</tr>
</tbody>
</table>

Only Bay nutrient load sector where we are seeing reverse progress in load reductions - source OIG (2007)
Bay Turf Economics

• Spend more than $4.5 billion per year maintaining turf cover.
• Spend more than $600 million/yr on fertilizers and chemicals
• Estimated 6.1 million grass farmers and 50,000 + lawn care laborers
• Homeowners spend equivalent of 60,000 full time jobs maintaining turf
Lesson 4: Our Conventional Stormwater Practices Don’t Do the Job

- Design to the Minimum
- Poor Installation
- No Change in Runoff Volumes
- Pollutant Removal Not a Great Approach
A stormwater outfall is an admission of failure

No mo pipes!
Lesson 5
Our Development Codes Produce Needless Impervious cover, but we have a hard time changing them
Lesson 6: We need to shift away from peak control to runoff volume control
Runoff reduction (RR) is defined as the total volume reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration at small sites.
Runoff Reduction Seeks to Maintain Pre-Development Runoff Coefficient for the Development Site up to a Defined Storm Event
Stormwater Practices Differ Sharply in Ability to Reduce Runoff Volume

- Wet Ponds, ED Ponds and Constructed Wetlands and Filters Reduce Runoff Volumes by zero to 10%
- Bioretention, Infiltration, Dry Swales and Related Practices Reduce Runoff Volumes by 50 to 90%
## Annual Runoff Reduction Rates (%)

<table>
<thead>
<tr>
<th>Method</th>
<th>Reduction Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration</td>
<td>50 to 90</td>
</tr>
<tr>
<td>Bioretention</td>
<td>40 to 80</td>
</tr>
<tr>
<td>Pervious Pavers</td>
<td>45 to 75</td>
</tr>
<tr>
<td>Green Roof</td>
<td>45 to 60</td>
</tr>
<tr>
<td>Dry Swale</td>
<td>40 to 60</td>
</tr>
<tr>
<td>Rain Tanks/Cisterns</td>
<td>40 +</td>
</tr>
<tr>
<td>Roof Disconnection</td>
<td>25 to 50</td>
</tr>
<tr>
<td>Grass Channel</td>
<td>15 to 30</td>
</tr>
<tr>
<td>Dry ED Pond</td>
<td>0 to 15</td>
</tr>
<tr>
<td>Wet Pond</td>
<td>0</td>
</tr>
<tr>
<td>Sand Filter</td>
<td>0</td>
</tr>
</tbody>
</table>

*Source: CWP and CSN (2008)*
4. FROM THE ROOF TO THE STREAM

1. Early ESD Site Assessment
2. Maximize Forest Canopy
3. Conserve Soils and Contours
4. Minimize Impervious Cover
5. Utilize Rooftop Runoff
6. Frontyard Bioretention
7. Dry Swales
8. Linear Wetlands
9. Stream Corridor Management
1. Early Site Assessment

What it is:

ESD plan and map submitted at earliest stage of development review including karst vulnerability, forest conservation, wetlands, soils, steep slopes, drainage, zero-order streams, buffers, sensitive areas, suitable soils, proposed impervious cover, and initial runoff reduction approach

What it replaces:
2. Maximize Forest Canopy

What it is:

What it replaces:

Preservation of Priority Forests and Reforestation of Turf Areas

Property Line to Property Line Clearing and Grubbing
3. Conserve Soils and Natural Contours

What it is: Construction site practices provide greatest possible conservation of original soil structure so that only a small footprint is disturbed around the final hardscape

What it replaces:

- Mass grading
- Soil Compaction
Soil Compost Amendments

- New practice to increase runoff reduction capacity of pervious areas that accept runoff from impervious ones
- Relieves compaction of urban soils and increases infiltration and storage of runoff
4. Minimize Site Impervious Cover

What it is: narrower streets, permeable driveways, clustered development, smaller cul-de-sacs, better pedestrian access, and other site design

What it replaces:

Super-sized lots, streets, sidewalks and cul-de-sacs
Better Site Design

- Reduce Impervious Cover Through Site Design
- Disconnect Impervious Cover
- Protect Site Open Space/Natural Areas
- Low Impact Development
5. Utilize Rooftop Runoff

What it is: a series of practices to capture, disconnect, store, infiltrate or re-use rooftop runoff

What it replaces:

Directly connected roof leaders
BAY WIDE DESIGN SPEC NO. 6

RAIN TANKS AND CISTERNS
Other Options to Handle Rooftop Runoff
6. Front yard Bioretention

What it is:

Grading of front yard to treat roof, lawn and driveway runoff

What it replaces:

Requirements to have positive drainage from house to street
7. Dry Swales

What it is: shallow, well drained bioretention swales along the secondary streets that help reduce runoff volumes

What it replaces:

<table>
<thead>
<tr>
<th>Storm drain inlets</th>
<th>Curb and gutter</th>
<th>Storm drain pipes</th>
</tr>
</thead>
</table>
8. Linear Wetlands

What it is:

What it replaces:

Large Stormwater Detention, Extended Detention or Wet Ponds
9. Stream Corridor Management

What it is:  
Active Reforestation and Restoration of the Stream Corridor

What it replaces:  
Passive (mis) Management of the Stream Corridor
Lesson 7: We still silo stormwater and don’t integrate it with the other seven tools of watershed protection.

The 8 Tools of Watershed Protection:
1. Watershed Planning
2. Land Conservation
3. Aquatic Buffers
4. Better Site Design
5. Erosion & Sediment Control
6. Stormwater Management
7. Non-Stormwater Discharges
8. Watershed Stewardship
Lesson 8: The roof to stream stormwater paradigm requires massive adoption of innovation by a profession that is often conservative.

Source: Diffusion of Innovation, 5th Edition, Everett M. Rogers
Regulations Alone Do Not Foster Innovation

• Training of Designers and Plan Reviewers
• Revised Local Plan Review Process
• Real World Site Testing
• Cost Analysis
• Local Code Changes
• Impervious Cover Mitigation Fees
Lesson 9: New Regulations and Laws are Driving Innovation, but Site Based Tools are Needed to Really Make it Happen

<table>
<thead>
<tr>
<th>1. Post-Development Project &amp; Land Cover Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constants</strong></td>
</tr>
<tr>
<td>Annual Rainfall (inches)</td>
</tr>
<tr>
<td>Target Rainfall Event (inches)</td>
</tr>
<tr>
<td>Phosphorus EMC (mg/L)</td>
</tr>
<tr>
<td>Target Phosphorus Load (lb/acre/yr)</td>
</tr>
<tr>
<td><strong>P</strong></td>
</tr>
<tr>
<td><strong>Land Cover (acres)</strong></td>
</tr>
<tr>
<td>Forest/Open Space -- undisturbed, protected forest/open space</td>
</tr>
<tr>
<td>Managed Turf -- disturbed, graded for yards or other turf to be</td>
</tr>
<tr>
<td>Impervious Cover (all soil types)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

| **Rv Coefficients**                                  |                          |
| Forest/Open Space                                   | A soils | B Soils | C Soils | D Soils | Totals |
|                                                      | 0.02    | 0.03    | 0.04    | 0.05    | 0.05   |
| Managed Turf                                        | 0.15    | 0.20    | 0.22    | 0.25    | 0.25   |
| Impervious Cover                                    | 0.90    | 0.90    | 0.90    | 0.90    | 0.90   |
A step by step approach to comply at a development site

Step 1: Conserve Natural Areas and Soils
- Soil Amendments
- Forest Conservation
- Site Design to Minimize Impervious Area
- Reduce Soil Disturbance

Step 2: Apply ESD Reduction Practices
- Roof Disconnects
- Sheetflow to Cons
- Reforestation
- Soil Amendments
- Permeable pavers

Step 3: Apply Engineered Runoff Reduction Practices
- Bioretention
- Dry Swales
- Green Roofs
- Infiltration
- Traditional STPs

Step 4: Apply Standard Treatment Practices
- Adjust Site loads for Phosphorus treatment

Step 5: Mitigation Fee for balance of unmet P Load

Tv: Treatment Volume for Site
ESD: Environmental Site Design
STP: Stormwater Treatment Practices
### A Lot of Change Going On in the Bay States

<table>
<thead>
<tr>
<th>STATE</th>
<th>Runoff Reduction</th>
<th>Channel Protection</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>Reduce Runoff 1st Inch of Rainfall</td>
<td>No</td>
<td>New Regs New Manual</td>
</tr>
<tr>
<td>DE</td>
<td>Reduce Runoff from 2.4 inches of rainfall</td>
<td>YES</td>
<td>New Regs New Manual</td>
</tr>
<tr>
<td>MD</td>
<td>Reduce Runoff from 1.0 to 2.4 inches of rainfall</td>
<td>YES</td>
<td>New Regs New Manual?</td>
</tr>
<tr>
<td>PA</td>
<td>Reduce Runoff from 1.0 to 2.4 inches of rainfall</td>
<td>YES</td>
<td>2005 Manual</td>
</tr>
<tr>
<td>VA</td>
<td>Reduce Runoff from 1.0 to 2.4 inches of rainfall</td>
<td>YES</td>
<td>New Regs New Manual</td>
</tr>
<tr>
<td>WV</td>
<td>Reduce runoff from 1st Inch of rainfall</td>
<td>No</td>
<td>New Permit New Manual</td>
</tr>
</tbody>
</table>
Need for New Design Tools

• Spreadsheet to count increments of runoff reduction from roof to stream
• CSN/CWP released 14 new design specs
• Focus on better design and installation
Its Still Possible to Do Dumb LID
Defining Treatment Volume

\[ T_v = \left\{ P \times (R_{vI} \times \%I + R_{vT} \times \%T + R_{vF} \times \%F) \times SA \right\}/12 \]

Site Cover Runoff Coefficients

<table>
<thead>
<tr>
<th>Soil Condition</th>
<th>Runoff Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Cover</td>
<td>0.02 to 0.05*</td>
</tr>
<tr>
<td>Disturbed Soils</td>
<td>0.15 to 0.25*</td>
</tr>
<tr>
<td>Impervious Cover</td>
<td>0.95</td>
</tr>
</tbody>
</table>

*Hydrologic Soil Group (HSG)
Forest  A: 0.02  B: 0.03  C: 0.04  D: 0.05
Disturbed A: 0.15  B: 0.20  C: 0.22  D: 0.25

\[ P = \text{rainfall depth for 90th percentile storm} \ 1.0 \ \text{inch} \]
## BIORETENTION DESIGN

<table>
<thead>
<tr>
<th>LEVEL 1 DESIGN</th>
<th>LEVEL 2 DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV= (Rv)(A)</td>
<td>TV= 1.25 (Rv)(A)</td>
</tr>
<tr>
<td>Filter media at least 24” deep</td>
<td>Filter media at least 36” deep</td>
</tr>
<tr>
<td>One form of accepted pretreatment</td>
<td>Two or more forms of accepted pretreatment</td>
</tr>
<tr>
<td>At least 75% plant cover</td>
<td>At least 90% plant cover, including trees.</td>
</tr>
<tr>
<td>One cell design</td>
<td>Two cell design</td>
</tr>
<tr>
<td>Underdrain</td>
<td>Infiltration design or underground stone sump</td>
</tr>
</tbody>
</table>
Draft Bay-wide Design Specifications

- Rooftop Disconnection
- Filter Strips
- Grass Channels
- Soil Amendments
- Green Roofs
- Rain Tanks/Rainwater Harvesting
- Permeable Pavement
- Infiltration
- Bioretention
  - Urban Bioretention
- Dry Swales
- Filtering Practices
- Constructed Wetlands
  - Wet Swales
- Wet Ponds
- Extended Detention Ponds

Drafts available at CSN website: www.chesapeakestormwater.net
Lesson 11: Our Stormwater Practices Need to Be Customized for Unique Terrain and Development Conditions

- Karst
- Coastal plain
- Ultra-urban areas
- Trout waters
- Steep Terrain
Need New and Innovative Sustainable Stormwater Practices for the City

1. Green Roofs
2. Cisterns and Rain Tanks
3. Foundation Planters
4. Permeable Pavers
5. Expanded Tree Pits
6. Regular Bioretention
7. Street Bioretention
8. Soil Restoration
9. Reforestation
10. Sand Filters
Lesson 12: We need a new maintenance model for LID
Lesson 10: The Municipal, Industrial and Construction Permit Programs in the Bay States Need a Major Makeover to Improve Water Quality
<table>
<thead>
<tr>
<th>Core Programs</th>
<th>DC</th>
<th>MD</th>
<th>PA</th>
<th>VA</th>
<th>WV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large MS4 Permits</td>
<td>A-</td>
<td>C-</td>
<td>-</td>
<td>D</td>
<td>-</td>
</tr>
<tr>
<td>Small MS4 Permits</td>
<td>-</td>
<td>F</td>
<td>D</td>
<td>C+</td>
<td>A</td>
</tr>
<tr>
<td>Stormwater Regs</td>
<td>I</td>
<td>B+</td>
<td>I</td>
<td>I</td>
<td>B+</td>
</tr>
<tr>
<td>Stormwater Manual</td>
<td>I</td>
<td>C-</td>
<td>B</td>
<td>A-</td>
<td>I</td>
</tr>
<tr>
<td>MS4 Outreach</td>
<td>B</td>
<td>D</td>
<td>D</td>
<td>B-</td>
<td>B</td>
</tr>
<tr>
<td>Public Outreach</td>
<td>A</td>
<td>D+</td>
<td>F</td>
<td>B</td>
<td>I</td>
</tr>
<tr>
<td>Industrial Permits</td>
<td>D</td>
<td>D</td>
<td>D-</td>
<td>B-</td>
<td>D</td>
</tr>
<tr>
<td>Construction Permits</td>
<td>B+</td>
<td>C-</td>
<td>D+</td>
<td>C-</td>
<td>D</td>
</tr>
<tr>
<td>Permit Enforcement</td>
<td>B+</td>
<td>D</td>
<td>D-</td>
<td>D</td>
<td>D-</td>
</tr>
<tr>
<td>Local/ State Financing</td>
<td>A-</td>
<td>C-</td>
<td>F</td>
<td>C+</td>
<td>D+</td>
</tr>
<tr>
<td><strong>OVERALL GRade</strong></td>
<td>B+</td>
<td>D+</td>
<td>D</td>
<td>C+</td>
<td>C</td>
</tr>
</tbody>
</table>
Lesson 13: We have more than 1.2 million acres of impervious cover discharging untreated stormwater
STRATEGIES TO MAXIMIZE RETROFIT DELIVERY OVER TIME

Percent of Subwatershed Treated

Time (Years)

Demonstration Retrofits

- Install Retrofits on Public Land
- Encourage On-Site Retrofits in Neighborhoods
- Piggyback Retrofits on Municipal Construction Projects
- Require Hotspot Retrofits through Permit Compliance
- Mitigation Retrofits on Private Land
- Subsidize On-Site Retrofits on Private Land
- Trigger Retrofits as Part of Rezoning or Public/Private Partnerships
- Require Stormwater Treatment on Redevelopment Projects
Comparative Cost for Different Retrofit Practices
Lesson 14:
In an era of profound change, we need to align science, engineering, planning, regulations and economics together to effectively implement the changes
Questions ?