Emerging Stormwater Pollutant Reduction Strategies From Another Urban Watershed:

Importing Some Ideas from the Chesapeake Bay
Chesapeake Stormwater Network

Three year old 501(c)(3) organization

Two websites: www.chesapeakestormwater.net
www.cbstp.org

Watershedguy@hotmail.com
Key Themes

- New Stormwater Developments in the Chesapeake Bay Watershed
- Update on the Impervious Cover Model
- Urban Stream Channel Erosion and Mitigation
- Renewed Focus on Stormwater Hotspots
- Turf as a Pollutant Source Area
- The Shift to the Runoff Reduction Paradigm
- Nutrient Accounting and Economics
- New Institutional Structures
Paving the Bay: Land Development Continues Unabated

• Between 1990 to 2000, population increased by 8%, but IC increased by 41%, and turf cover by 80%
• Croplands represent 64% of the loss, forests the remaining 36%
• 75% of land development outside of smart growth areas
Urban 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>
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<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>2009</td>
<td>12%</td>
<td>22%</td>
</tr>
<tr>
<td>2030</td>
<td>??</td>
<td>??</td>
</tr>
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</table>

Urban and suburban runoff is the only Bay nutrient load sector where we are seeing reverse progress in load reductions- source OIG (2007)
New Stormwater Developments in the Chesapeake Bay Watershed

- Once a leader, went to sleep for 20 years
- Poor stormwater scorecard in most states
- More stringent runoff reduction reqmts for new and redevelopment
- New generation MS4 permits
- Bay wide nutrient and sediment TMDL
- Trading and offsets
The Stormwater Tribes of the Chesapeake Bay Watershed

Lotalawnians

Redevelophants

Nipidees

Hotspotanots
The Nipidees: The Existing Development Tribe
The Nipidees: Existing Development Tribe

- Runoff from 5 million acres of impervious cover and turf cover are mostly untreated
- 21 of the 22 Phase 1 NPDES MS4 Stormwater Permits have not been renewed
- More than a thousand permit year backlog with 500 small NPDES MS4 stormwater permits
- Need for numeric and enforceable stormwater permits...retrofitting
Lotalawnians: The New Development Tribe
Lotalawnians:
The New Development Tribe

- Conservatively, an estimated 2.5 million acres of new land development expected in the Bay watershed by year 2030
- New regulations and design manuals are rolling out in all 7 Bay states
- Runoff reduction holds the line, but requires extensive training and local implementation.
- Considerable uncertainty about actual on the ground implementation
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>
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<tbody>
<tr>
<td>DC</td>
<td>YES</td>
<td>NO</td>
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<tr>
<td>EPA</td>
<td>YES</td>
<td>YES</td>
<td>2010</td>
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<td>DE</td>
<td>YES</td>
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<tr>
<td>MD</td>
<td>YES</td>
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<tr>
<td>PA</td>
<td>YES</td>
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<tr>
<td>NY</td>
<td>YES</td>
<td>YES</td>
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</tr>
<tr>
<td>VA</td>
<td>YES</td>
<td>YES</td>
<td>2011</td>
</tr>
<tr>
<td>WV</td>
<td>YES</td>
<td>NO</td>
<td>2009</td>
</tr>
</tbody>
</table>
The Redevelophants:
The Urban Redevelopment Tribe
The Redevelophants: The Urban Redevelopment Tribe

- A million acres of redevelopment possible in the Bay by 2030
- Not much required in the past
- Tougher redevelopment standards should incrementally reduce pollutant loads in many Bay states
- Serious controversy in numerous states
- Economics and smart growth
The Hotspotanots: The Industrial Stormwater Tribe
The Hotspotanots:
The Industrial Stormwater Tribe

- 20,000 permitted industrial sites in bay watershed as of 2005
- 80,000 stormwater hotspots have not filed and/or are not covered by permits
- Compliance, inspections and monitoring are limited to non-existent.
<table>
<thead>
<tr>
<th>Core Programs</th>
<th>DC</th>
<th>MD</th>
<th>PA</th>
<th>VA</th>
<th>WV</th>
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<tr>
<td>Large MS4 Permits</td>
<td>A-</td>
<td>C-</td>
<td>-</td>
<td>D</td>
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<tr>
<td>Small MS4 Permits</td>
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<td>F</td>
<td>D</td>
<td>C+</td>
<td>A</td>
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<tr>
<td>Stormwater Regs</td>
<td>I</td>
<td>B+</td>
<td>I</td>
<td>I</td>
<td>B+</td>
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<tr>
<td>Stormwater Manual</td>
<td>I</td>
<td>C-</td>
<td>B</td>
<td>A-</td>
<td>I</td>
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<tr>
<td>MS4 Outreach</td>
<td>B</td>
<td>D</td>
<td>D</td>
<td>B-</td>
<td>B</td>
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<tr>
<td>Public Outreach</td>
<td>A</td>
<td>D+</td>
<td>F</td>
<td>B</td>
<td>I</td>
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<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>Overall Grade</td>
<td>B+</td>
<td>D+</td>
<td>D</td>
<td>C+</td>
<td>C</td>
</tr>
</tbody>
</table>
Original ICM developed based on 200+ reports and papers
Reformulated ICM - 2009
The ICM Revisited: Recent Research

- 67 peer reviewed studies tested the ICM in wide range of ecoregions have been published since 2003
- 72% confirm or reinforce the ICM
- 28% are inconclusive or contradicting
- Strongest support for aquatic insects, fish and individual geomorph. indicators
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.
ICM and small estuaries and coastal streams

- ICM does apply to coastal streams, small estuaries and tidal coves in the coastal zone.
- Salinity, mummichogs, benthic macros, sediment metals, fecal coliforms, estuarine fish indicators all decline
Ecoregions where cropland is the dominant predevelopment land cover often have a higher IC threshold (12 to 15 %) than forested eco-regions.

Recent Finding from USGS

Prior channel modification and sedimentation suspected.

The Cropland Caveat
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 *

- Stormwater ponds cannot maintain stream quality
- Most ICM research was done in regions with at least a moderate degree of development regulation
- Cross-sectional studies show decline even with high levels of environmental protection
- Can show improvement within the limits of the “cone”
Other ICM Research Headlines

ICM doesn’t apply everywhere... streams in the front range of the Rockies - they have already been degraded by prior riparian alterations and water diversions in the last 150 years.

Reference: Sprague et al, 2006
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.
Urban Stream Channel Erosion and effect on Sediment and Nutrient Delivery

- Clear differences between delivery rates for healthy, degraded and restored urban streams
- Degraded streams have more nutrient delivery from floodplain soils and less internal nutrient processing
- Stream restoration as a practical, cost-effective strategy
Channel Enlargement as a Function of Impervious Cover

Enlargement Ratio as a Function of Impervious Cover

Enlargement Ratio \( \left( \frac{A_{	ext{post}}}{A_{	ext{pre}}} \right) \) as a Function of Imperviousness (%)
**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)
Renewed Focus on Stormwater Hotspots and Pollution Prevention
ICM and Wet Weather Water Quality

Pollutant concentrations do not follow ICM
Not all IC is the same with respect to EMCs source areas land uses hotspots
Pollutant loads do conform closely to ICM
Objectives of the Benchmarking Tool

✓ Takes only a few hours to complete
✓ Identifies correctable stormwater problems
✓ Increases staff awareness about stormwater, watersheds and community stewardship
✓ Leads to action not just paperwork
✓ Create a quantitative scorecard of overall site performance
✓ Distinguish between dirty, clean and green sites
We have Reached the Clipping Point
The Clipping Point: Emergence of Turf Cover As a Major Bay Ecosystem

**TURF COVER, BAY WATERSHED 2000**

Method 1: 3.82 million acres  
Method 2: 3.79 million acres

**TURF As PERCENT OF BAY LAND AREA**

Method 1: 9.5%  
Method 2: 9.5%

**COMPARISON TO OTHER BAY LAND USES**

- Row Crops: 9.2% of watershed  
- Pasture: 7.7%  
- Hay and Alfalfa: 7.4%  
- Wetlands: 3.8%
What do we know about home lawns and nutrients?

About 50% to 65% fertilize their yard

15 to 20% hire lawn care company

Average of two applications per year

50% of homeowners over-fertilize

Estimated N Fertilizer inputs by lawns: 215 million lbs/yr
The Shift to Runoff Reduction

Monitoring indicates that some practices are very effective in reducing the volume of runoff, which sharply increases the mass reduction of nutrients from sites.

Runoff reduction is defined as the total volume reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration.
# Shifting Away from Percent Removal

<table>
<thead>
<tr>
<th>Practice Group</th>
<th>TP (%)</th>
<th>Sol P (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Ponds</td>
<td>20</td>
<td>-3</td>
</tr>
<tr>
<td>Wet Ponds</td>
<td>52</td>
<td>64</td>
</tr>
<tr>
<td>Wetlands</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td>Infiltration*</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Filtering Systems</td>
<td>59</td>
<td>3</td>
</tr>
<tr>
<td>Water Quality Swales*</td>
<td>24</td>
<td>-38</td>
</tr>
</tbody>
</table>

**Total Phosphorus**

![Box plot showing removal efficiency for different stormwater treatment practices.](image)
The Interesting Case of Bioretention

Based on initial data, it looks as if bioretention has zero or negative removal rates
New research provides insights into bioretention design features that boost TN and TP removal

- 2-4 feet media depth
- 3-5% carbon source in media
- Create anoxic bottom layer to promote denitrification
- Increased hydraulic residence time through media (1-2 in/hr)
- Test media to ensure low P-index
### Volumetric Runoff Reduction Achieved by Bioretention

<table>
<thead>
<tr>
<th>Location</th>
<th>% Runoff Reduction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CT</strong></td>
<td>99%</td>
<td>Dietz and Clausen (2006)</td>
</tr>
<tr>
<td><strong>PA</strong></td>
<td>86%</td>
<td>Ermilio (2005)</td>
</tr>
<tr>
<td><strong>FL</strong></td>
<td>98%</td>
<td>Rushton (2002)</td>
</tr>
<tr>
<td><strong>PA</strong></td>
<td>80%</td>
<td>Traver et al (2006)</td>
</tr>
<tr>
<td><strong>AUS</strong></td>
<td>73%</td>
<td>Lloyd et al (2002)</td>
</tr>
<tr>
<td><strong>ONT</strong></td>
<td>40%</td>
<td>Van Seters et al (2006)</td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td>30%</td>
<td>Perez-Perdini et al (2005)</td>
</tr>
<tr>
<td><strong>NC</strong></td>
<td>40 to 60%</td>
<td>Smith and Hunt (2006)</td>
</tr>
<tr>
<td><strong>NC</strong></td>
<td>20 to 29%</td>
<td>Sharkey (2006)</td>
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<tr>
<td><strong>NC</strong></td>
<td>52 to 56%</td>
<td>Hunt et al (2006)</td>
</tr>
<tr>
<td><strong>NC</strong></td>
<td>20 to 50%</td>
<td>Passeport et al (2008)</td>
</tr>
<tr>
<td><strong>MD</strong></td>
<td>52 to 65%</td>
<td>Davis (2008)</td>
</tr>
</tbody>
</table>

Runoff Reduction Estimate: **40 # to 80 **

# underdrain design *infiltration design

Further research documents that bioretention can sharply reduce runoff volumes, which, in turn increases, the **mass** of nutrients which are removed.
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)
<table>
<thead>
<tr>
<th>BIORETENTION DESIGN</th>
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<tbody>
<tr>
<td><strong>LEVEL 1 DESIGN</strong></td>
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<tr>
<td>RR = 40% TP = 55% TN = 64%</td>
</tr>
<tr>
<td>TV = (Rv)(A)</td>
</tr>
<tr>
<td>Filter media at least 24” deep</td>
</tr>
<tr>
<td>One form of accepted pretreatment</td>
</tr>
<tr>
<td>At least 75% plant cover</td>
</tr>
<tr>
<td>One cell design</td>
</tr>
<tr>
<td>Underdrain</td>
</tr>
<tr>
<td>Both: Maximum organic material in media of 5% and hydraulic residence time of 1 inch per hour through media (10% fines)</td>
</tr>
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</table>

We are now in an design era where we can isolate the design features that maximize runoff reduction and mass nutrient removal.
A renewed focus on stormwater economics and accounting

<table>
<thead>
<tr>
<th>Stormwater Management Scenario</th>
<th>Sector</th>
<th>$</th>
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<tbody>
<tr>
<td>New Development, ESD to MEP (2010)</td>
<td>Private</td>
<td>$46,509</td>
</tr>
<tr>
<td>Redevelopment Using ESD (ultra-urban)</td>
<td>Private</td>
<td>$190,938</td>
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<tr>
<td>Storage Retrofits in Urban Watershed</td>
<td>Public</td>
<td>$32,500</td>
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<tr>
<td>Green Street Retrofits, Highly Urban</td>
<td>Public</td>
<td>$167,123</td>
</tr>
<tr>
<td>Stream Restoration, Nutrient Equivalent</td>
<td>Public</td>
<td>$35,600</td>
</tr>
</tbody>
</table>

Source: CSN (2010)
Emergence of New Leaders and Stormwater Institutions

- MS4 Pyscho-therapists
- Private Maintenance Companies
- Regional Stormwater Utilities
- “Three Water” Utilities
- Regional Stormwater Consortia
- Contractor Certification
- Peer-reviewed design specs
- Bay-wide Designer Training Partnership
Questions and Comments