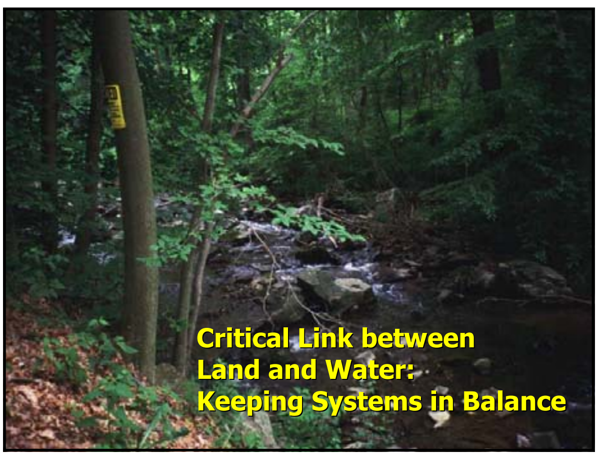
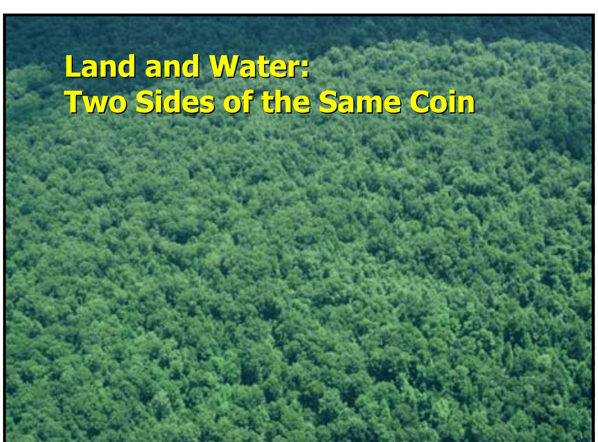
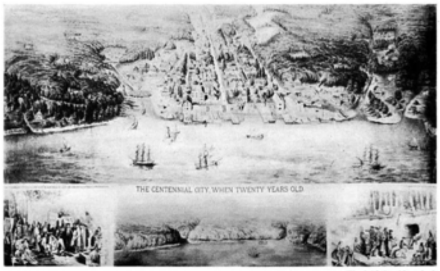
Sustainability in Stormwater Management: Green Infrastructure from the City to the Urban Fringe

Brandywine Conservancy
Environmental Management Center





From Smart Growth. To…

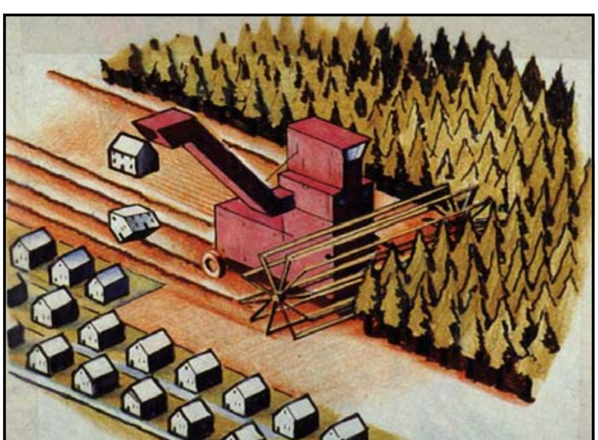


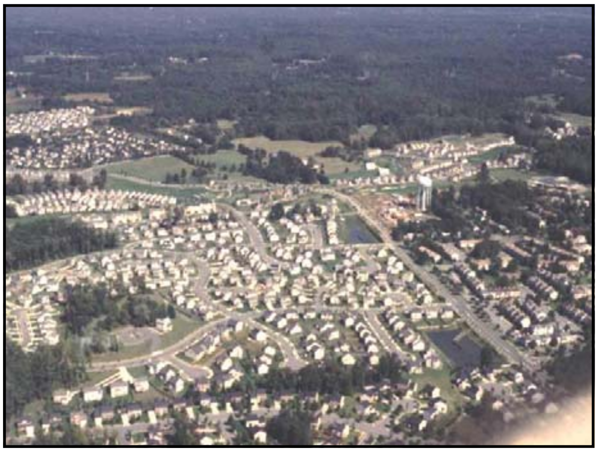
Historical Society of Pennsylvania

PHILADELPHIA IN 1702, ONLY 20 YEARS AFTER PENN'S ARRIVAL

William Penn gave detailed instructions to select a site for a "great towne where it is most navigable, high, dry and healthy; where most ships may ride of deepest draught of water and load and unload without lighterage." The site chosen met these requirements admirably. Philadelphia was named after an ancient city in Asia Minor.

"The only thing new in the world is the history we've forgotten…." Harry Truman



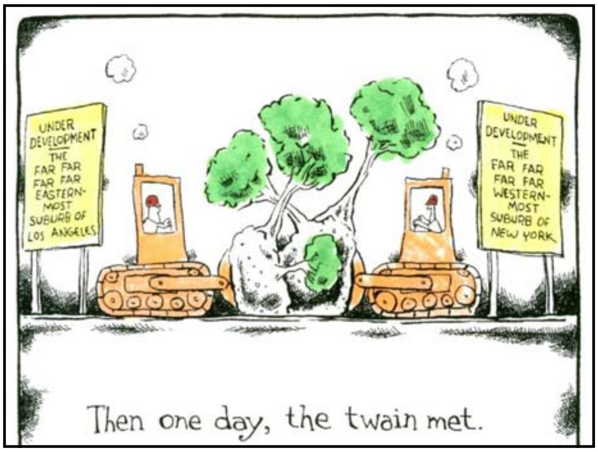


Stormwater Impacts of Conventional Development

- Not just Increased Flooding!
- Increased Runoff Volume
- Decreased Evapotranspiration and Groundwater Recharge
- Increased Frequency of Runoff Events
- Faster Conveyance of Water
- Erosion and Stream Channel Changes
- Decreased Baseflow
- Impacted Aquatic Life
- Pollutants and Temperature Impacts

…Other Impacts of Conventional Development.

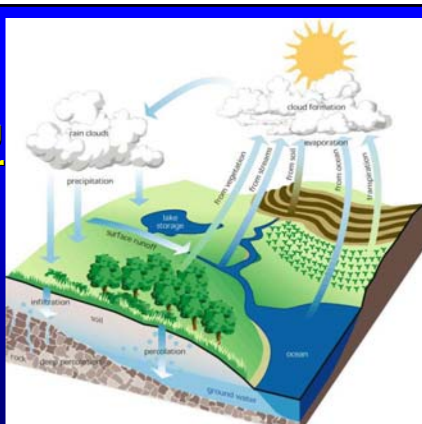
- Habitat Loss/Biodiversity
- Wetlands/Floodplains/Other Water Resources
- Soils/Special Geologic Features
- Air Quality/Microclimate
- Noise
- Historical/Archaeological
- Aesthetics/Scenic
- Quality of Life and Public Health



Impacts:

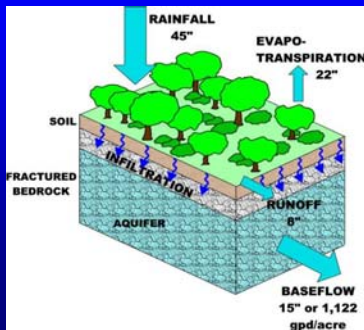
Imbalancing Natural Systems…

Balancing the Water Cycle

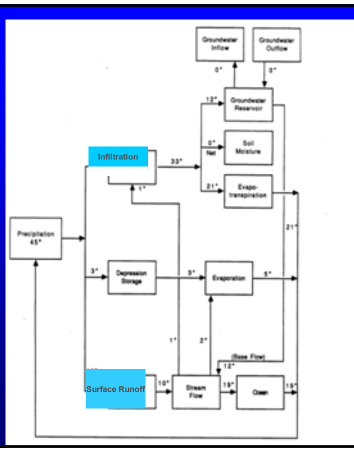


Annual Hydrologic Cycle

For an Average Year



Altered Hydrologic Cycle

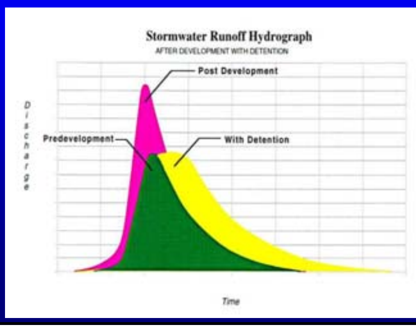


Conventional Stormwater Management

- Controls Peak **Rate** of Runoff to Predevelopment Conditions Usually for Large Design Storms (e.g., 100-year)
- Fails to Control **Volume** of Runoff Maximized in Smaller Storms
- Fails to Control NPS **Pollutant** Loadings also Maximized in Smaller Storms

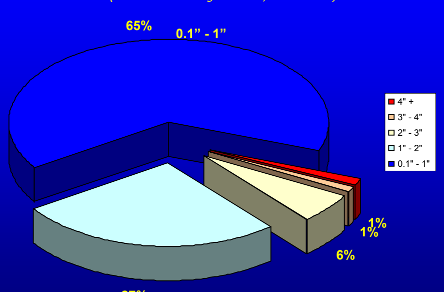
Large storms are important….

We all live downstream….
We haven't understood the basic hydrology of stream and river systems.

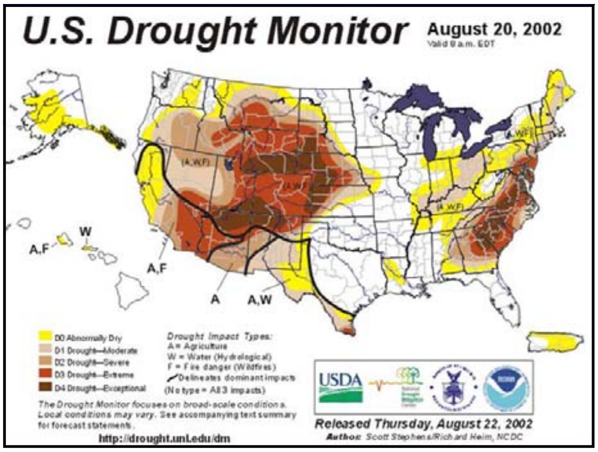


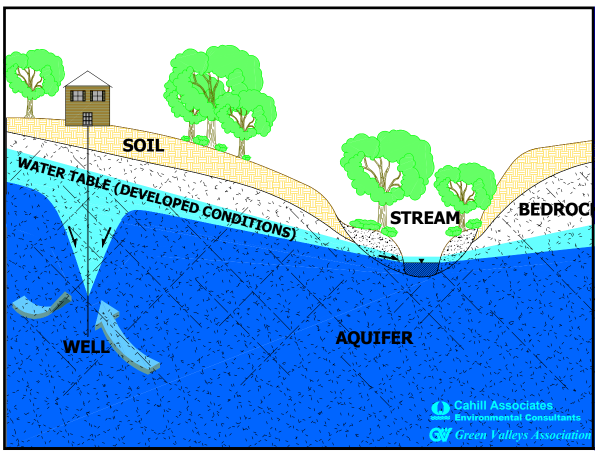
Average Annual Rainfall Volume that Occurs by Storm Magnitude for Harrisburg, PA

(PA State Climatological Office, 1926 - 2003)



Stormwater management has focused only on the largest storms…we haven't paid attention to annual water balance and the reality of smaller storms.



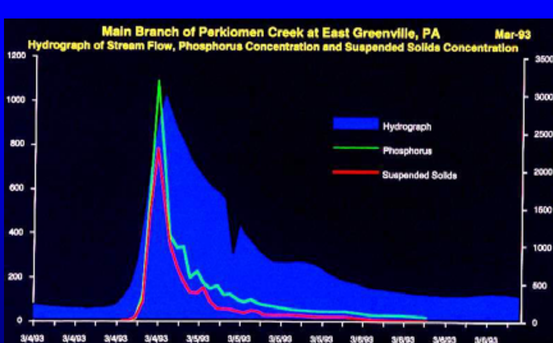


Manage Stormwater as a Valuable Resource… not a Disposal Problem. Volume Control Is Critical….

to Support Stream Baseflow/Low Flow
to Support Wells and Springs
to Support Wetlands
to Minimize Nonpoint Pollutant Loadings
to Minimize Downstream Flooding
to Minimize Stream Morphological Impacts

Water Quality: Nonpoint Source Pollution

- Transported by and dissolved in runoff
- Petroleum Hydrocarbons
- Metals
- Nutrients (Phosphorus and Nitrate)
- Organic matter
- Sediment
- Synthetic Organics (pesticides,herbicides)

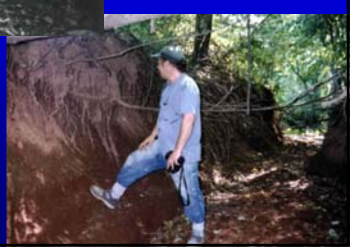


Land Development Impacts on Stream Morphology:

- Major changes to bankfull flow
- Channel widening, downcutting/undercutting, streambed scouring
- Stream bank erosion
- Imbedded substrate with benthic/other aquatic impacts
- Loss of pools, riffles, aquatic habitat

Dry Channels…

Eroded Streambanks…



Land Development Impacts on Stream Ecology:

- Reduced diversity of aquatic insects
- Reduced diversity of fish
- Decline of amphibians
- Degraded wetlands, riparian zones

Loss of Site Vegetation Means Loss of Vegetation Functions (Ecoservices)

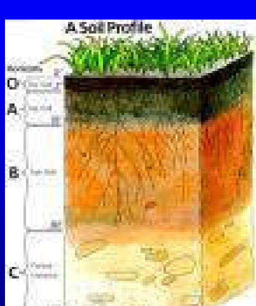
Above Ground:
- Interception/Slowing
- Absorption
- Evaporation/Transpiration

At Ground:
- Temporary Storage
- Quality Filtering

Below Ground:
- Infiltration/Permeation
- Storage
- Quality Filtering/Uptake

Trees as only Perfect BMP

Impacting Essential Living Soil:



Soil Horizons

- Layer of Soil Parallel to Surface
- Properties a function of climate, landscape setting, parent material, biological activity, and other soil forming processes.
- Horizons (A, E, B, C, R, etc)

Image Source: University of Texas, 2002

Common Bulk Density Measurements

Undisturbed Lands Forests & Woodlands 1.03 g/cc	Residential Neighborhoods 1.69 to 1.97 g/cc
Golf Courses; Parks; Athletic Fields 1.69 to 1.97 g/cc	Concrete 2.2 g/cc

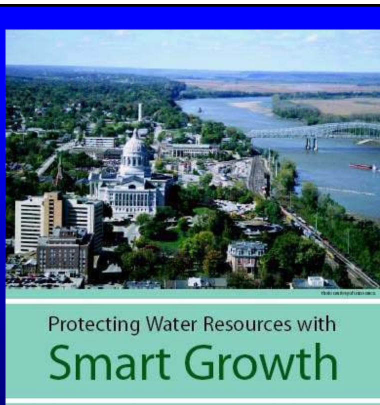
David B. Friedman, District Director Ocean County Soil Conservation District

Sustainability in Stormwater Management:

Get the Watershed Right
Get Each Municipality Right
Get Each Development, Each Site Right

Sustainability:

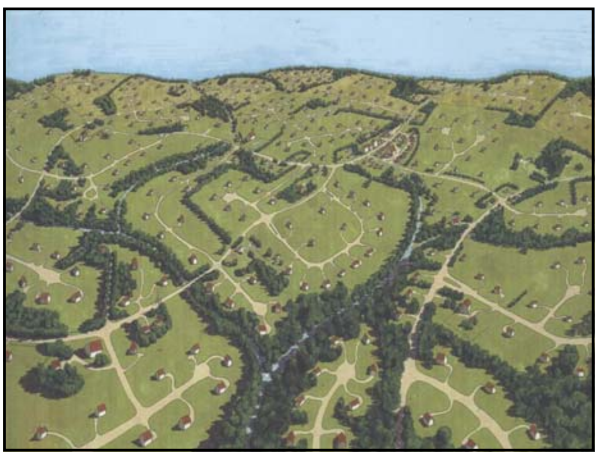
- Smart Growth Principles
- LEED (Leadership in Energy and Environmental Design) - LEED for Neighborhood Developments (LEED-ND)
- The Ahwahnee Principles: Toward More Livable Communities

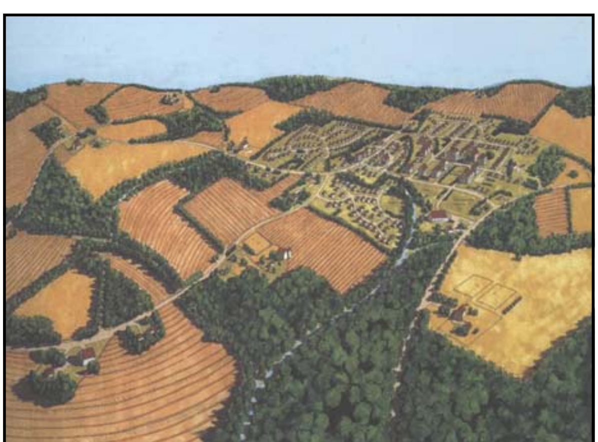


Smart Growth Principles:

Using Smart Growth Techniques as Stormwater Best Management Practices, EPA December 2005.

- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Encourage community and stakeholder collaboration
- Foster distinctive, attractive places with strong sense of place
- Make development decisions predictable, fair, cost effective
- Mix land use
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Provide a variety of transportation choices of smart growth
- Strengthen/direct development toward existing communities
- Take advantage of compact building design



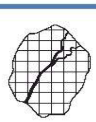
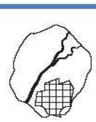


LEED-ND is USGBC's Solution

-Smart Location & Linkage	30 Points
-Neighborhood Pattern & Design	39 Points
-Green Construction & Technology	31 Points
-Innovation & Design Process	5 Points

The Ahwahnee Water Principles
for Resource Efficient Land Use

- Community design should be compact, mixed use, walkable and transit-oriented so that automobile-generated urban runoff pollutants are minimized and the open lands that absorb water are preserved to the maximum extent possible.
- Natural resources such as wetlands, flood plains, recharge zones, riparian areas, open space, and native habitats should be identified, preserved and restored as valued assets for flood protection, water quality improvement, groundwater recharge, habitat, and overall long-term water resource sustainability.
- Water holding areas such as creek beds, recessed athletic fields, ponds, cisterns, and other features that serve to recharge groundwater, reduce runoff, improve water quality and decrease flooding should be incorporated into the urban landscape.
- All aspects of landscaping from the selection of plants to soil preparation and the installation of irrigation systems should be designed to reduce water demand, retain runoff, decrease flooding, and recharge groundwater.
- Permeable surfaces should be used for hardscape. Impervious surfaces such as driveways, streets, and parking lots should be minimized so that land is available to absorb storm water, reduce polluted urban runoff, recharge groundwater and reduce flooding.
- Dual plumbing that allows graywater from showers, sinks and washers to be reused for landscape irrigation should be included in the infrastructure of new development.
- Community design should maximize the use of recycled water for appropriate applications including outdoor irrigation, toilet flushing, and commercial and industrial processes. Purple pipe should be installed in all new construction and remodeled buildings in anticipation of the future availability of recycled water.
- Urban water conservation technologies such as low-flow toilets, efficient clothes washers, and more efficient water-using industrial equipment should be incorporated in all new construction and retrofitted in remodeled buildings.

Scenario A	Scenario B	Scenario C
		
10,000 houses built on 10,000 acres produce:	10,000 houses built on 2,500 acres produce:	10,000 houses built on 1,250 acres produce:
10,000 acres x 1 house x 18,700 ft^3/yr of runoff =	2,500 acres x 4 houses x 6,200 ft^3/yr of runoff =	1,250 acres x 8 houses x 4,950 ft^3/yr of runoff =
187 million ft^3/yr of stormwater runoff	**62 million ft^3/yr of stormwater runoff**	**49.5 million ft^3/yr of stormwater runoff**
Site: 20% impervious cover	**Site: 38% impervious cover**	**Site: 65% impervious cover**
Watershed: 20% impervious cover	**Watershed: 9.5% impervious cover**	**Watershed: 8.1% impervious cover**

Land and Water - A Critical Relationship:

•The higher-density scenarios generate less stormwater runoff per house at all scales…

•For the same amount of development, higher-density development produces less runoff and less impervious cover than low-density development…

•For a given amount of growth, lower-density development impacts more of the watershed.

Protecting Water Resources with Higher-Density Development (EPA January 2006)

Land and Water - A Critical Relationship:

	Imperv	Acres Req	Tot Runoff cu ft/yr*	Runoff/DU cu ft/yr*
Scenario A 1 DU/ac	20%	8	149,600	18,700
Scenario B 4 DU/ac	38%	2	49,600	6,200
Scenario C 8 DU/ac	65%	1	39,600	4,950

Protecting Water Resources with Higher-Density Development (EPA January 2006)

***Calculations only account for impervious cover and would be increased substantially for low-density if increase in runoff from lawn area compaction were included.**

Land and Water - A Critical Relationship:

"…the 'Sprawl Scenario' consumed eight times more open space, generated 43 percent more runoff, four times more sediment, almost four times more nitrogen, and three times more phosphorus than the 'Town Scenario' development (Belle Hall Study, South Carolina Coastal Conservation League, 1995)
"The study found that compact development would generate significantly less water pollution than current development patterns, which are mostly characterized by low-density development, for all categories of pollutants. The reduction ranged from over 40 percent for phosphorus and nitrogen to 30 percent for runoff. (Rutgers University, 2000. *The Costs and Benefits of Alternative Growth Patterns: The Impact Assessment of the New Jersey State Plan.* **New Brunswick: Center for Urban Policy Research)**

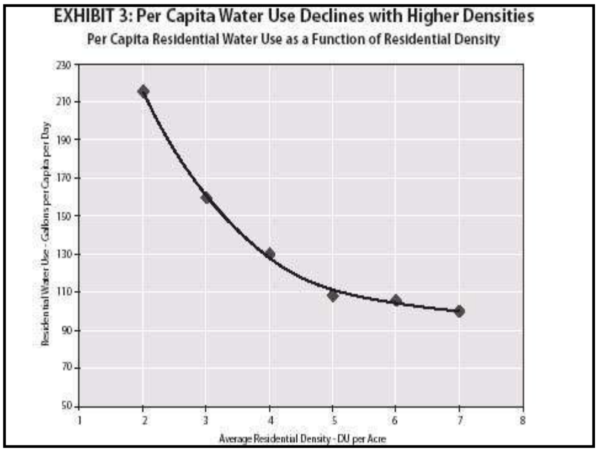
Protecting Water Resources with Higher-Density Development (EPA January 2006)

Smart Growth Water Conservation Issues:

Less water use per dwelling unit/
per land use
Less water use loss in distribution
Use of conservation plumbing fixtures
Less costly distribution system construction
Less costly distribution system maintenance
Easier to pay for/easier to plan for

"Large lots are a major contributor to both residential and commercial water use. Lawn care, car washing, swimming pools, and other outdoor uses can account for 50 to 70 percent of household water use. (American Water Works Association Fact Sheet, 2004.www.awwa.org/pressroom)

Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies, **EPA January 2006**



Smart Growth
Wastewater Treatment Issues:

Treatment: land-based application of effluent
- Private or public
  - Spray, drip, other proven technologies
- Off-site or on-site
  - Community on-lot disposal systems
  - Drainage areas in open space

Collection:
- Less costly distribution system construction
- Less costly distribution system maintenance
- Easier to pay for/easier to plan for

Cost of Providing Public Water/Sewer	
½ ac lot in Compact Development	$283
½ ac lot in Sprawl Development	$472

Speir, Cameron and Kurt Stephenson, 2002. Does Sprawl Cost Us All? Isolating the Effects of Housing Patterns on Public Water and Sewer Costs. J. of the American Planning Assoc 68(1): 56-70.

Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies, **EPA January 2006**

Sustainability Requires Smarter Growth…

Smarter Water Resources Management…

…Smarter Stormwater
…Smarter Water Use
…Smarter Wastewater

…Smarter Ordinances.

Sustainable Stormwater Management:

Non-Structural Approaches
Preventive

Structural Practices
Mitigative

Applicant/Developer role is critical.

Municipal role is critical – smarter ordinances.

Preventive Non-Structural BMP Categories with Specific BMP's

Protect Sensitive and Special Value Resources from Watershed to Site
- BMP Protect sensitive/special value features
- BMP Protect/conserve/enhance riparian areas
- BMP Protect/conserve natural flow pathways in overall stormwater planning and design

Cluster and Concentrate
- BMP Cluster uses at each site; build on smallest area possible
- BMP Concentrate uses areawide through Smart Growth

Minimize Disturbance and Minimize Maintenance
- BMP Minimize total disturbed area – grading
- BMP Minimize soil compaction in disturbed areas
- BMP Re-vegetate and re-forest disturbed areas, using native species

Reduce Impervious Cover
- BMP Reduce street imperviousness
- BMP Reduce parking imperviousness

Disconnect/Distribute/Decentralize
- BMP Rooftop disconnection
- BMP Disconnection from storm sewers

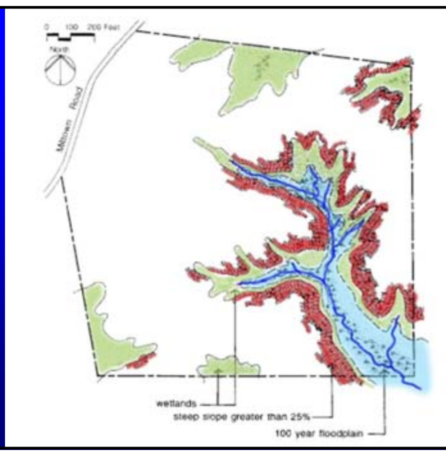
and ***Source Control***

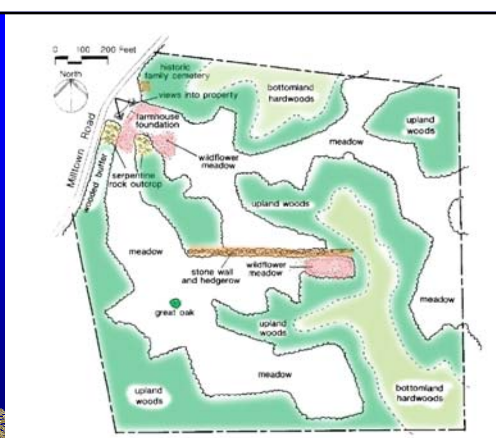
Prevention as a ton of cure… everywhere but especially in the developing urban fringe – greenfields.

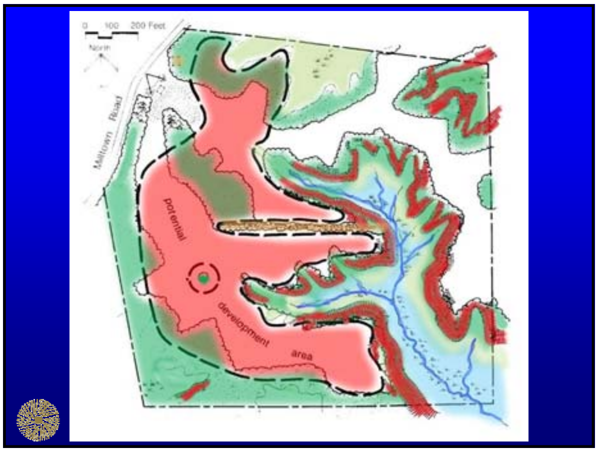
Preventive Non-Structural BMP Categories with Specific BMPs:

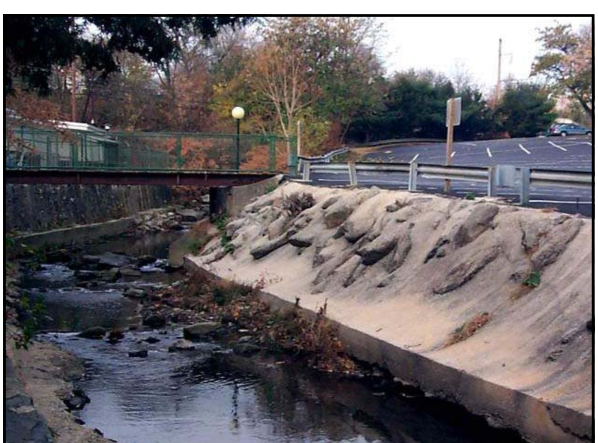
Protect Sensitive and Special Value Resources
Watershed to Site

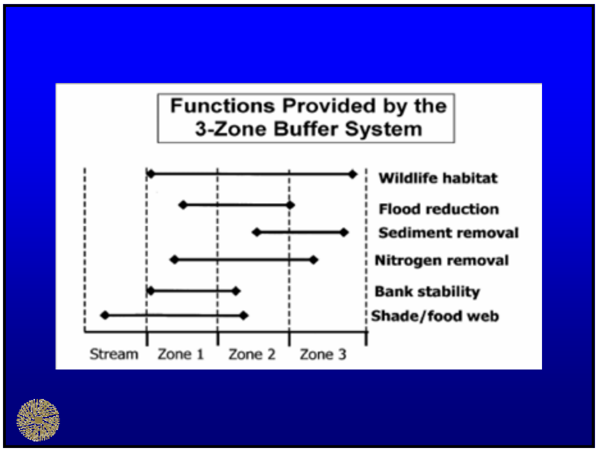
- **BMP Protect sensitive/special value features**
- **BMP Protect/conserve/enhance utilize riparian areas**
- **BMP Protect/utilize natural flow pathways in overall stormwater planning and design**

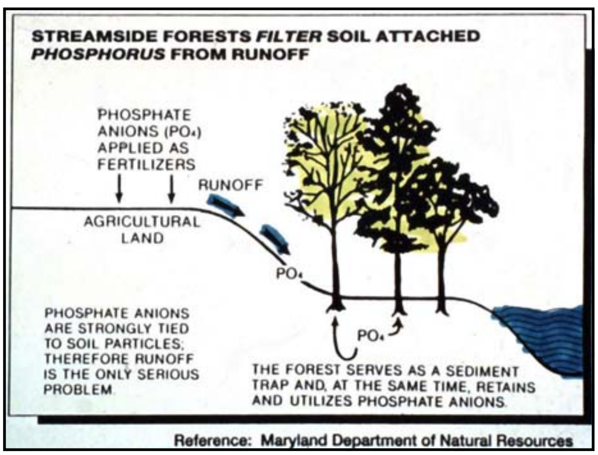





0 100 200 Feet
North
Milltown Road
potential
development
area




Functions Provided by the
3-Zone Buffer System
Wildlife habitat
Flood reduction
Sediment removal
Nitrogen removal
Bank stability
Shade/food web
Stream
Zone 1
Zone 2
Zone 3


STREAMSIDE FORESTS FILTER SOIL ATTACHED PHOSPHORUS FROM RUNOFF
PHOSPHATE ANIONS (PO4) APPLIED AS FERTILIZERS
RUNOFF
AGRICULTURAL LAND
PO4
PO4
PHOSPHATE ANIONS ARE STRONGLY TIED TO SOIL PARTICLES; THEREFORE RUNOFF IS THE ONLY SERIOUS PROBLEM.
THE FOREST SERVES AS A SEDIMENT TRAP AND, AT THE SAME TIME, RETAINS AND UTILIZES PHOSPHATE ANIONS.
Reference: Maryland Department of Natural Resources

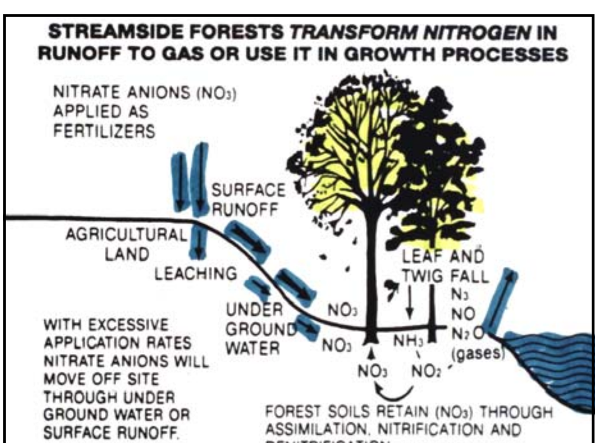

STREAMSIDE FORESTS TRANSFORM NITROGEN IN RUNOFF TO GAS OR USE IT IN GROWTH PROCESSES
NITRATE ANIONS (NO3) APPLIED AS FERTILIZERS
SURFACE RUNOFF
AGRICULTURAL LAND
LEACHING
UNDER GROUND WATER
NO3
NO3
LEAF AND TWIG FALL
N2
NO
N2O
(gases)
NH3
NO3
NO2
WITH EXCESSIVE APPLICATION RATES NITRATE ANIONS WILL MOVE OFF SITE THROUGH UNDER GROUND WATER OR SURFACE RUNOFF.
FOREST SOILS RETAIN (NO3) THROUGH ASSIMILATION, NITRIFICATION AND DENITRIFICATION.

Figure 4.5

Use sensitive areas such as natural drainage areas to form boundaries or buffer zones between clusters of housing.

Case Study #6
Pleasant Hill Farm
Conventional Development

Total size of site: 84 acres
Total number of lots: 90
Average size of lots: 19,000 sq. ft.
Percent undisturbed: 41.8%
Percent impervious: 26.2%

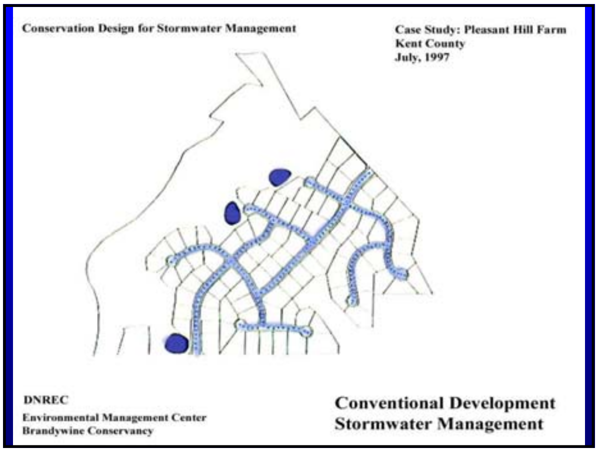
Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy

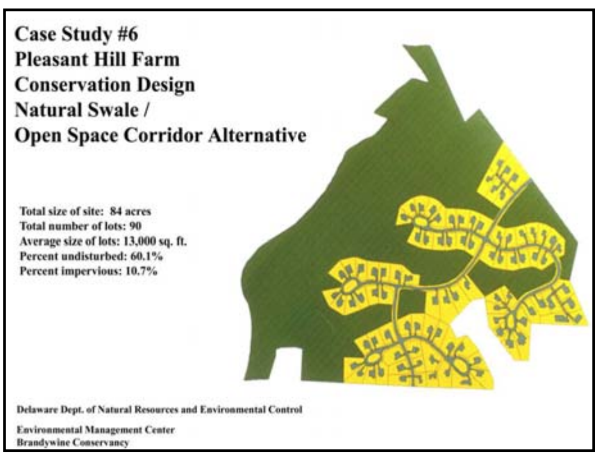
Conservation Design for Stormwater Management

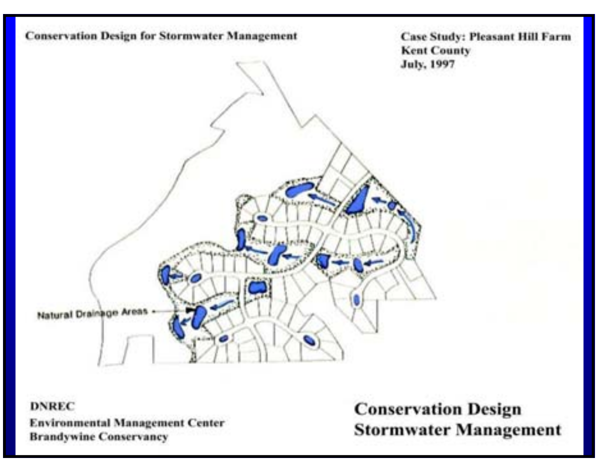
Case Study: Pleasant Hill Farm
Kent County
July, 1997

DNREC
Environmental Management Center
Brandywine Conservancy

Special Features
Wetlands/Floodplains


Conservation Design for Stormwater Management
Case Study: Pleasant Hill Farm
Kent County
July, 1997
DNREC
Environmental Management Center
Brandywine Conservancy
Conventional Development
Stormwater Management


Case Study #6
Pleasant Hill Farm
Conservation Design
Natural Swale /
Open Space Corridor Alternative
Total size of site: 84 acres
Total number of lots: 90
Average size of lots: 13,000 sq. ft.
Percent undisturbed: 60.1%
Percent impervious: 10.7%
Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy


Conservation Design for Stormwater Management
Case Study: Pleasant Hill Farm
Kent County
July, 1997
Natural Drainage Areas
DNREC
Environmental Management Center
Brandywine Conservancy
Conservation Design
Stormwater Management

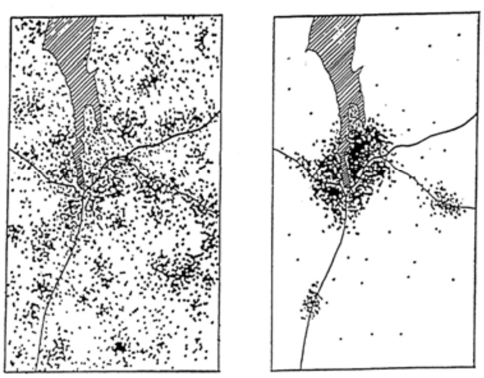
Preventive Non-Structural BMP Categories with Specific BMPs:

Cluster and Concentrate

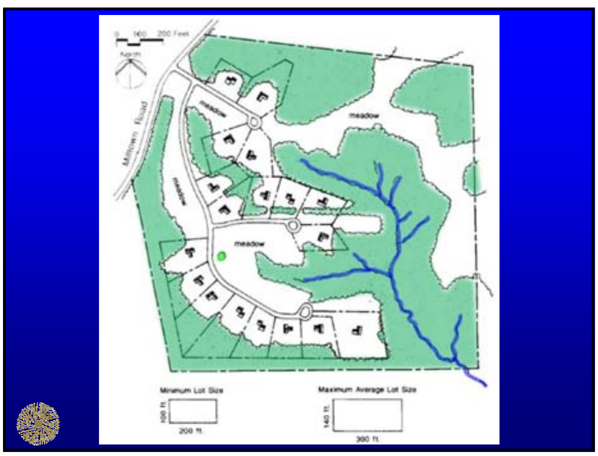
BMP Cluster uses at each site; build on the smallest area possible

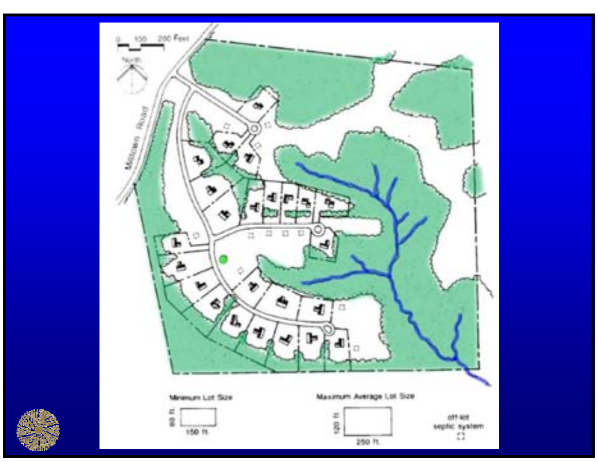
BMP Concentrate uses areawide through Smart Growth practices (Chester County's *Landscapes*, DVRPCs *Connections*)

FIGURE 13: DISPERSED VERSUS CONCENTRATED DEVELOPMENT AT THE REGIONAL SCALE



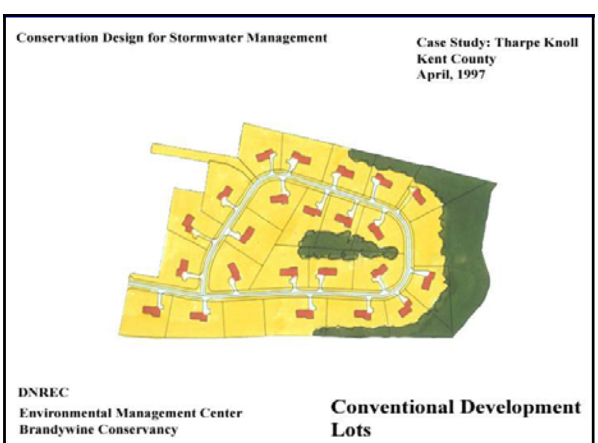

0 100 200 Feet
North
Milltown Road


0 100 200 Feet
North
Milltown Road
meadow
meadow
meadow
meadow
Minimum Lot Size
100 ft.
200 ft.
Maximum Average Lot Size
140 ft.
300 ft.


0 100 200 Feet
North
Milltown Road
Minimum Lot Size
150 ft.
Maximum Average Lot Size
120 ft.
250 ft.
off-lot
septic system


meadow
meadow
wooded spray irrigation area
The Green
Minimum Lot Size
120 ft.
Maximum Average Lot Size
150 ft.


Conservation Design for Stormwater Management
Case Study: Tharpe Knoll
Kent County
April, 1997
DNREC
Environmental Management Center
Brandywine Conservancy
Pre-Development Landcover


Conservation Design for Stormwater Management
Case Study: Tharpe Knoll
Kent County
April, 1997
DNREC
Environmental Management Center
Brandywine Conservancy
Conventional Development Lots

Conservation Design for Stormwater Management

Case Study: Tharpe Knoll
Kent County
April, 1997

DNREC
Environmental Management Center
Brandywine Conservancy

Conservation Design
Lots: Alternative 2

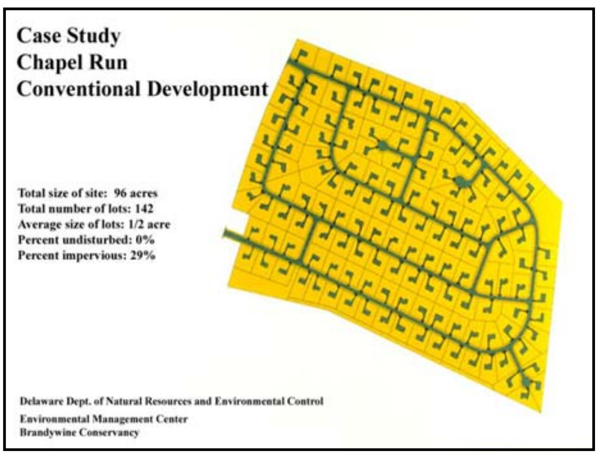
Runoff Calculations*
Tharpe Knoll

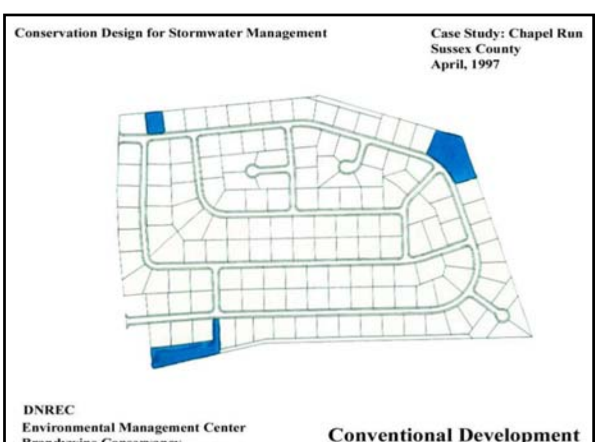
	1-yr	100-yr
Pre-Development	0.5	4.8
Conventional Development	0.9	5.9
Conservation Design	0.5	4.7

*Calculated as inches/storm event,
as per TR-55 Soil Cover Complex

Cost Comparison :
Tharpe Knoll

Conventional Development	$561,650
Conservation Design	$244,800


Case Study
Chapel Run
Conventional Development
Total size of site: 96 acres
Total number of lots: 142
Average size of lots: 1/2 acre
Percent undisturbed: 0%
Percent impervious: 29%
Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy


Conservation Design for Stormwater Management
Case Study: Chapel Run
Sussex County
April, 1997
DNREC
Environmental Management Center
Brandywine Conservancy
Conventional Development

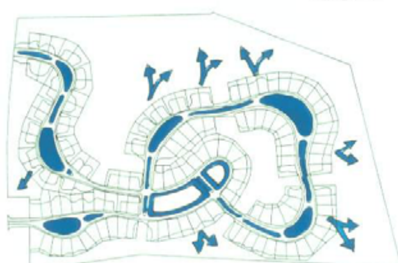
Case Study
Chapel Run
Conservation Design
Parkway Alternative

Total size of site: 96 acres
Total number of lots: 142
Average size of lots: 1/4 acre
Percent undisturbed: 59.6%
Percent impervious: 14.9%

Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy

Conservation Design for Stormwater Management

Case Study: Chapel Run
Sussex County
April, 1997



DNREC
Environmental Management Center
Brandywine Conservancy

Conservation Design
Stormwater Management

Runoff Calculations*
Chapel Run

	1-yr	100-yr
Pre-Development	0.4	4.3
Conventional Development	0.9	5.9
Conservation Design	0.4	4.3

*Calculated as inches/storm event,
as per TR-55 Soil Cover Complex

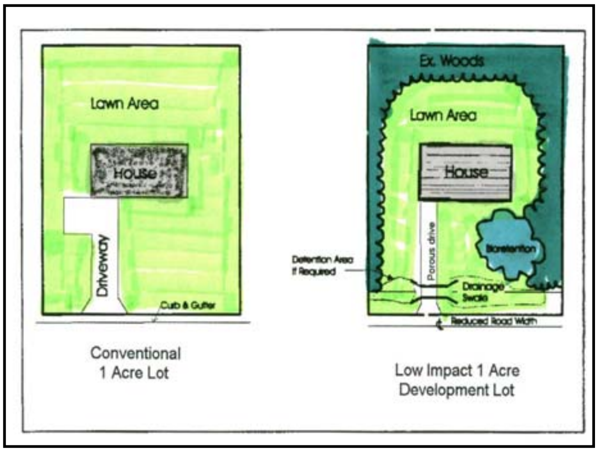
Cost Comparison: Chapel Run

Conventional Development	$2,460,200
Conservation Design-Parkway	$ 888,735

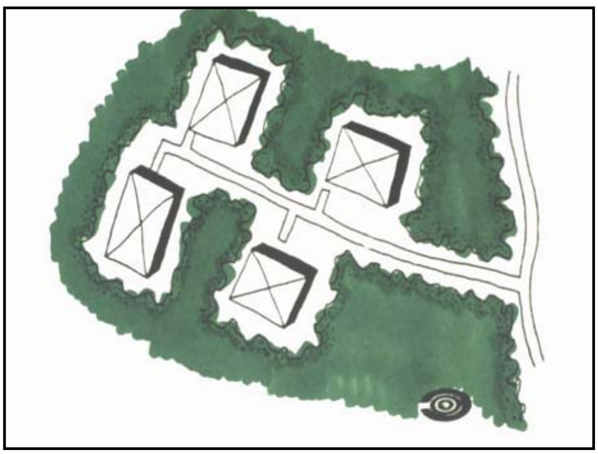
Preventive Non-Structural BMP Categories with Specific BMPs:

Minimize Disturbance/Minimize Maintenance

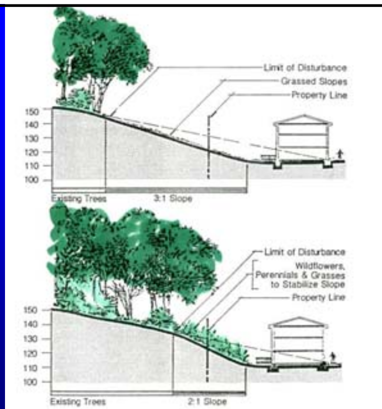
- **BMP** Minimize total disturbed area – grading
- **BMP** Minimize soil compaction in disturbed areas
- **BMP** Re-vegetate and re-forest disturbed areas, using native species



Lawn Area
House
Driveway
Curb & Gutter
Conventional
1 Acre Lot
Ex. Woods
Lawn Area
House
Porous drive
Bioretention
Detention Area
If Required
Drainage
Swale
Reduced Road Width
Low Impact 1 Acre
Development Lot

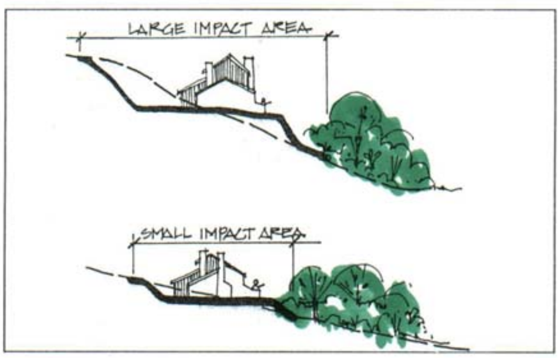



Minimize soil compaction…



Drawing of Northridge grading proposal. (Illustration courtesy of Michael T. Rose Companies.)

Figure 3.2.1: Making Flat Areas for Homesites On Steep Slopes Disturbs More Land Area Than On Flat Slopes



Source: Minnesota Pollution Control Agency, 1989

Revegetation….

Preventive Non-Structural BMP Categories with Specific BMPs:

Reduce Impervious Cover

BMP Reduce street imperviousness

BMP Reduce parking imperviousness

FIGURE 35: COMPARISON OF HEADWATER STREET WIDTHS

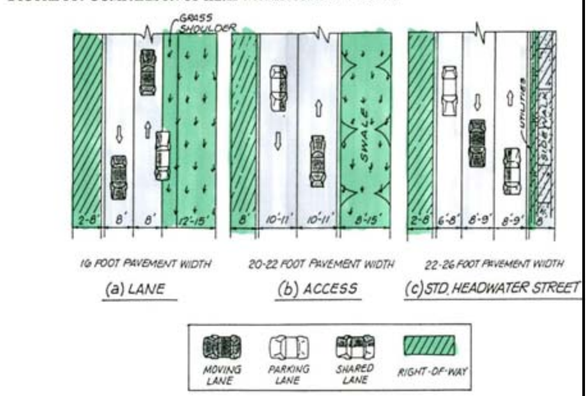


Table 1: Narrow Residential Street Widths

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	---
	21 ft. (parking on one side)	---
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	---
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	---
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

(Cohen, 1997; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998)

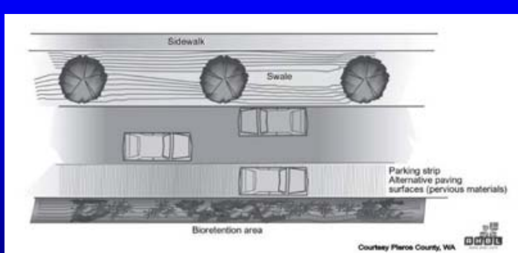


FIGURE 41: FIVE TURNAROUND OPTIONS AT THE END OF A RESIDENTIAL STREET

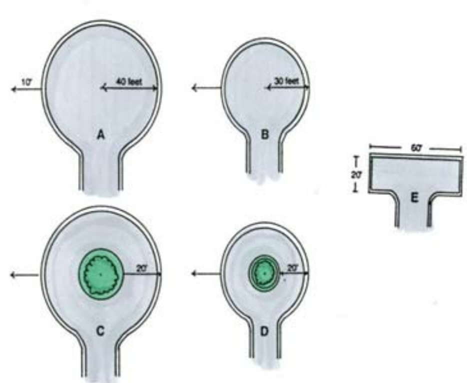
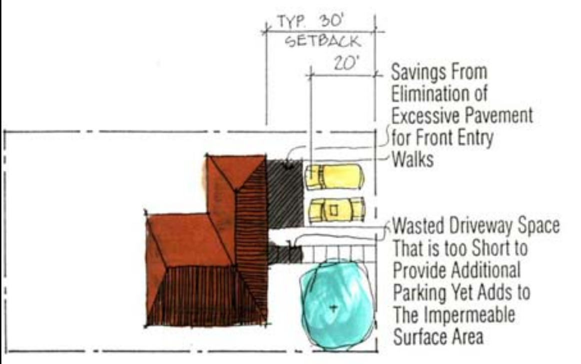



PHOTO: BRUCE K. FERGUSON

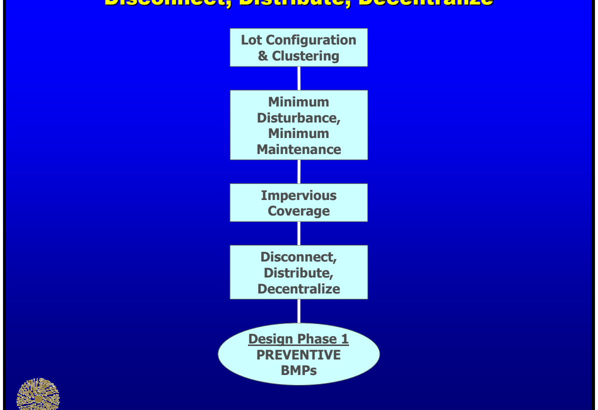

Orange Bowl - Miami, FL
• 6.7 acres of GP²
• Water Table @12"
• Aisles crowned toward GP²
• Native Grasses
-no irrigation
-reduced mowing

Figure 4.2

Reduce Front-yard Setbacks to Lessen Paved Surface Area



Disconnect, Distribute, Decentralize



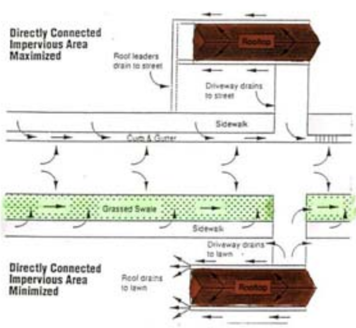
Preventive Non-Structural BMP Categories with Specific BMPs:

Disconnect/Distribute/Decentralize

- **BMP Rooftop disconnection**
- **BMP Disconnection from storm sewers**

Figure 4.4

Examples of Directly Connected Impervious Areas



Preventive Non-Structural BMP Categories with Specific BMPs:

Maximize preventive source controls

- **BMP Trash/debris collection**
- **BMP Street sweeping, spills**
- **BMP Fertilization regulations**
- **Others**

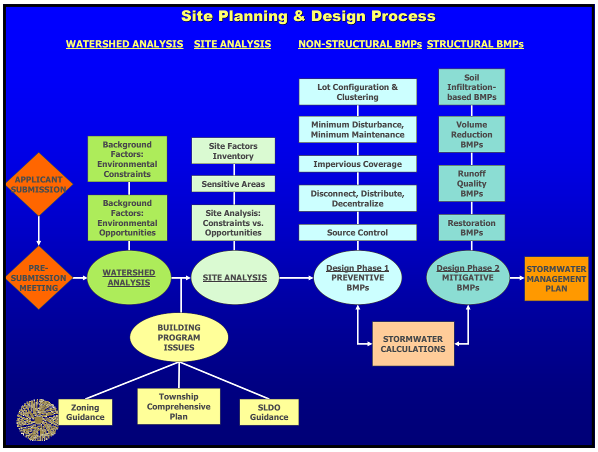
10 Stormwater Management Principles:

- -Prevent first,
- -Mitigate second.
- -Manage as a resource – not a waste!
- -Maintain water cycle balance, pre- to post.
- -Integrate early into site design process.
- -Protect/utilize natural systems (soil, vegetation).
- -Manage as close to the source as possible.
- -Disconnect. Decentralize. Distribute.
- -Slow it down – don't speed it up.
- -Achieve multiple objectives; do as much with as little as possible.

System Balance….

"…everything is connected to everything else…."

Site Planning & Design Process



Mitigative Structural Best Management Practices

Runoff Volume/Infiltration-Oriented

Vegetative and Soil-Based

1. **Rain/recharge gardens/Bioretention**
2. **Vegetated filter strips**
3. **Vegetated Swales (Bio-infiltration, Dry, Wet)**
4. **Porous pavement with infiltration beds**
5. **Infiltration basins**
6. **Subsurface infiltration beds**
7. **Infiltration trenches**
8. **French drains/dry wells**
9. **Outlet control (level spreaders, etc.)**
10. **Retentive grading techniques, berms**

Runoff Volume/Non-Infiltration-Oriented

11. **Vegetated roofs**
12. **Cisterns/Rain Barrels/Capture Reuse**

Runoff Quality/Non-Infiltration

13. **Constructed wetlands**
14. **Wet ponds/retention basins**
15. **Filters**
16. **Water quality inserts**
17. **Detention/Extended Detention**
18. **Special Storage: Parking Lot, Rooftop, etc.**

Restoration BMPs

19. **Riparian Corridor Restoration**
20. **Revegetation/Reforestation**
21. **Soils Amendment**

Sustainability in Stormwater Management: Green Infrastructure from the City to the Urban Fringe

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Brandywine Conservancy
Environmental Management Center

An Integrated Tier of Standards: Recharge, Water Quality, Channel Protection, Major Flooding

Stormwater Management Objectives*	Recommended Standard
Extreme Flood Protection (4"+/-)	Peak Rate Control if necessary
Channel Protection (2"+/-)	No Runoff Volume Increase for 2-year, 24-hour Storm
Water Quality (1"+/-)	
Recharge (0.4"+/-)	


LID Site Design Process Checklist
Step 1. Applicant's Concept Development
Step 3. Pre-Submission Meeting/Site Visit
Step 4. Inventory for Opportunities/Constraints
Watershed Factors Inventory
Site Factors Inventory
Constraints/Opportunities
Step 5. Revisions to Development Concept