Impervious Cover

Measurement and application

Andrew Homsey
March 18th, 2009
NPS Meeting
St. Jones Reserve

Objectives

- Discuss what constitutes impervious cover (IC) and why it is important
- Look at some ways IC can be measured or estimated
- List some applications of IC in the real world

What is impervious cover?

- Any hard surface that prevents the infiltration of surface water into the ground.
  - Roads
  - Rooftops
  - Parking lots
  - Sidewalks, driveways, etc.

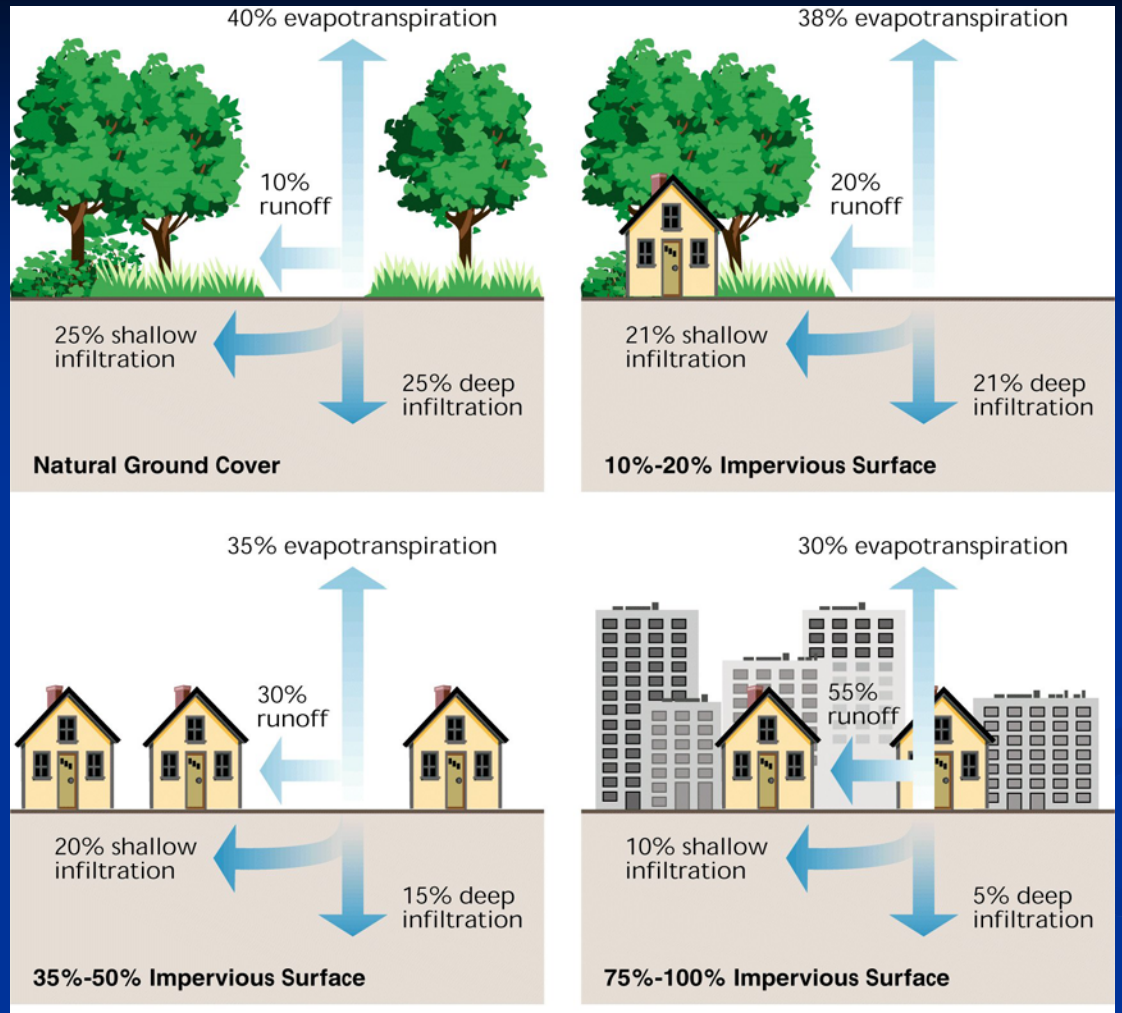
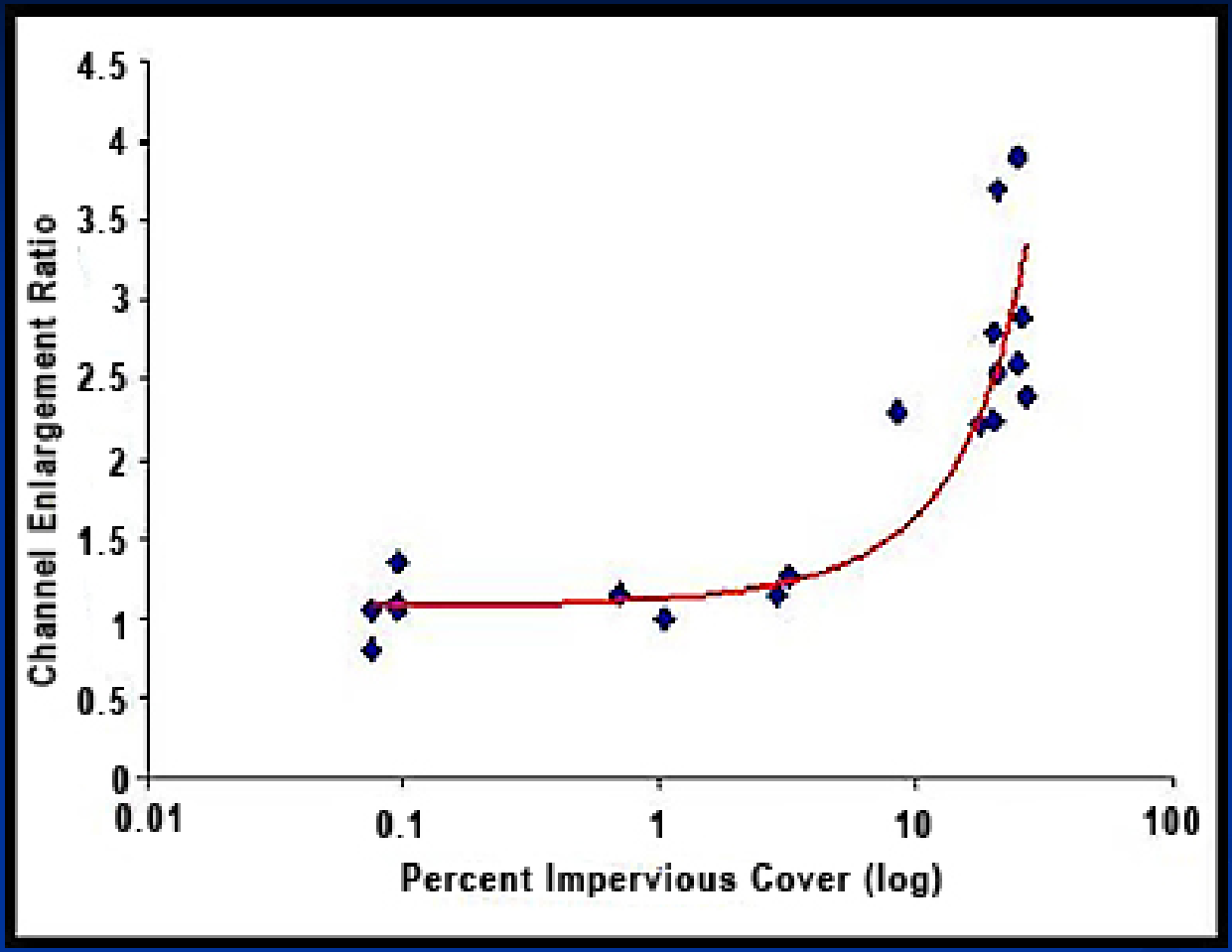


Fig. 3.21 -- Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

Federal Interagency Stream Corridor Restoration Handbook, 1998.jpg

Why is it important?

- It affects:
- Water quality
  - Increased levels of pollutants such as sediments, nutrients, organics, metals, temperature, etc.
- Hydrology, stream geometry
  - Increased “flashiness” of stream
  - Bank incision, erosion, channel widening, fewer pools & riffles, less sinuosity
  - Lowered base flow in times of low precipitation
- Stream health
  - Degraded habitat for macroinvertebrates
  - Less opportunity for fish with less woody debris and more impediments to movement
  - Higher temperatures



S. California Coastal Water Research Project, 2005

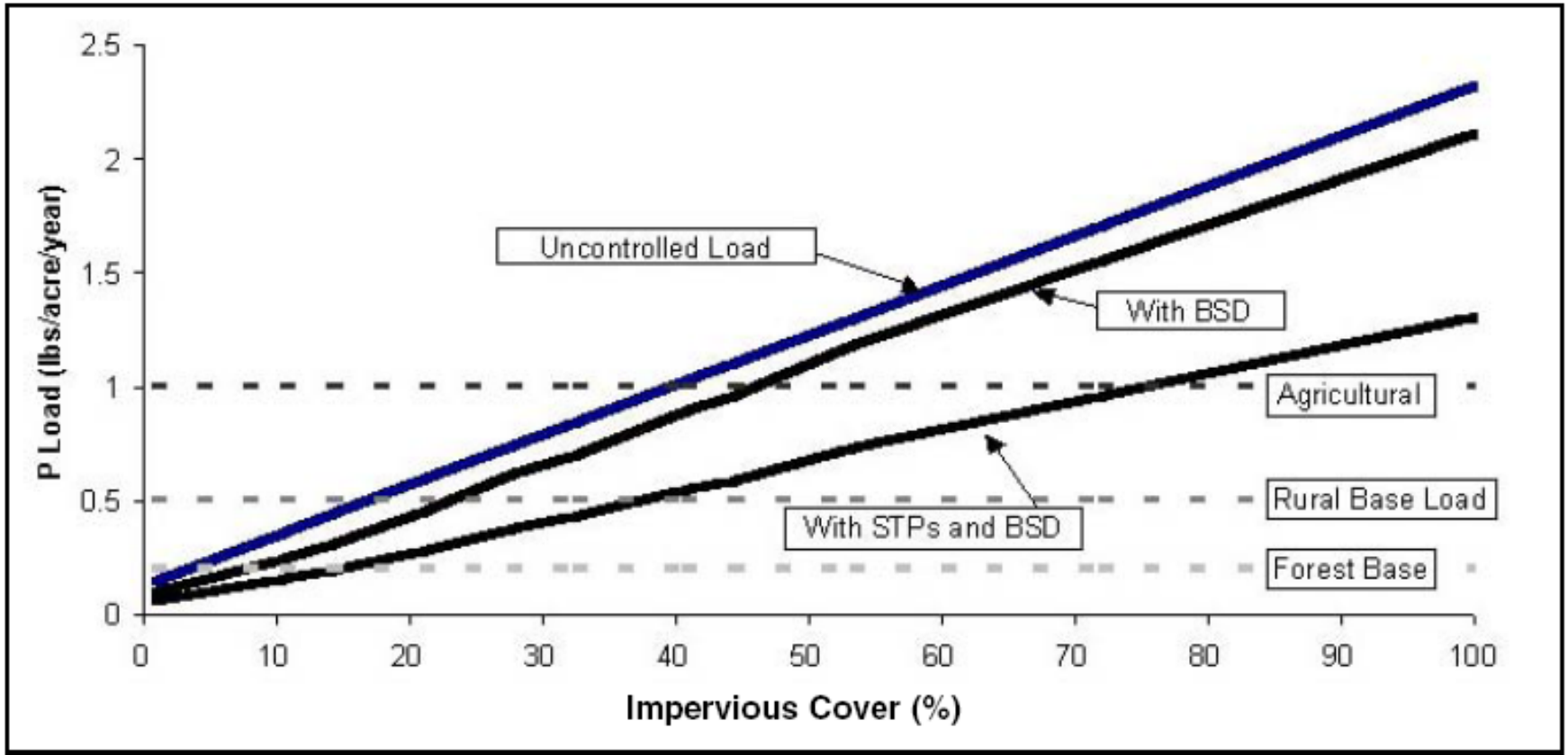


Figure 5: Estimated Phosphorus Load as a Function of Impervious Cover, Discounted Stormwater Treatment and Better Site Design (Schueler and Caraco, 2001)

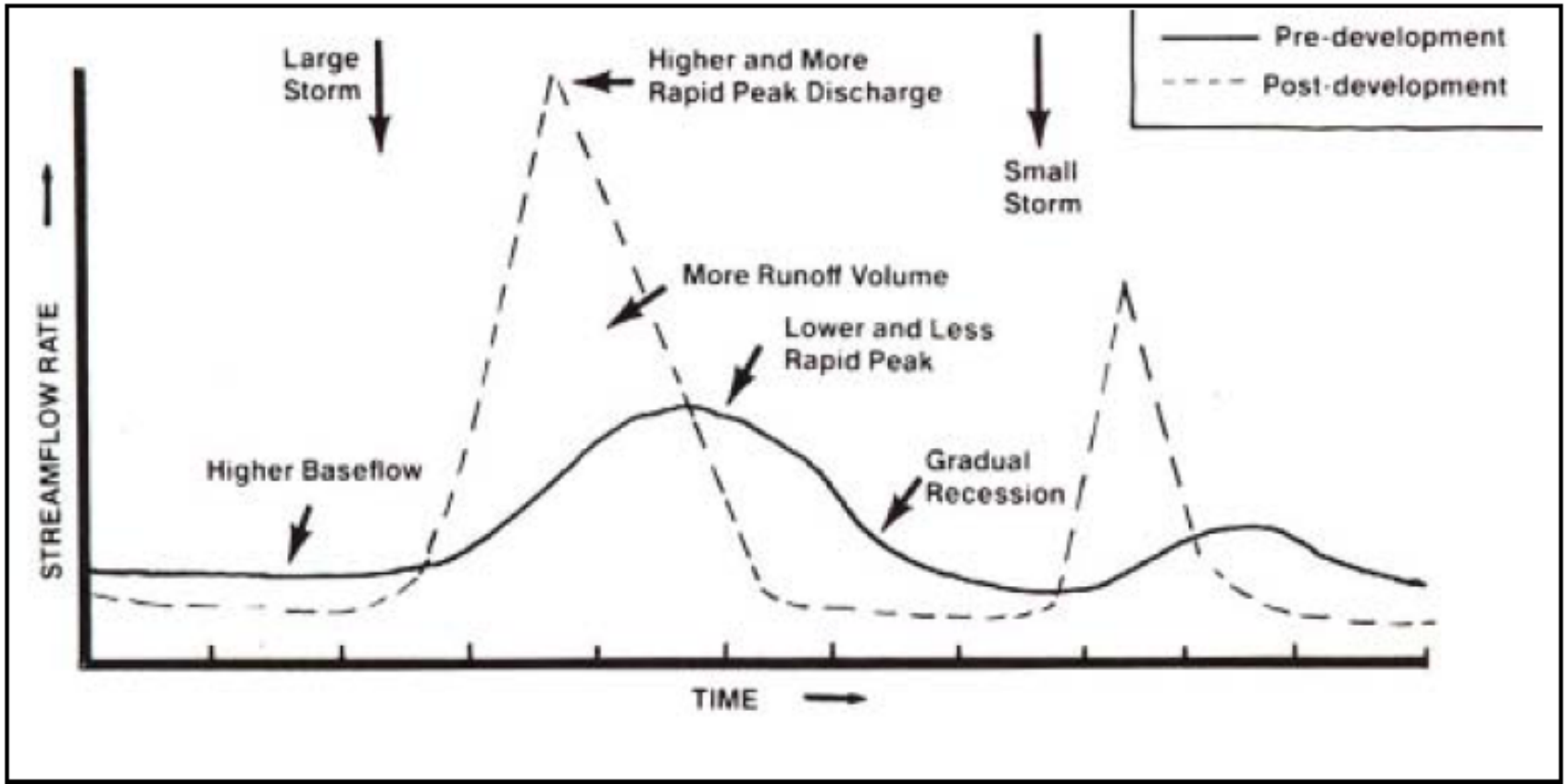


Figure 6: Altered Hydrograph in Response to Urbanization (Schueler, 1987)

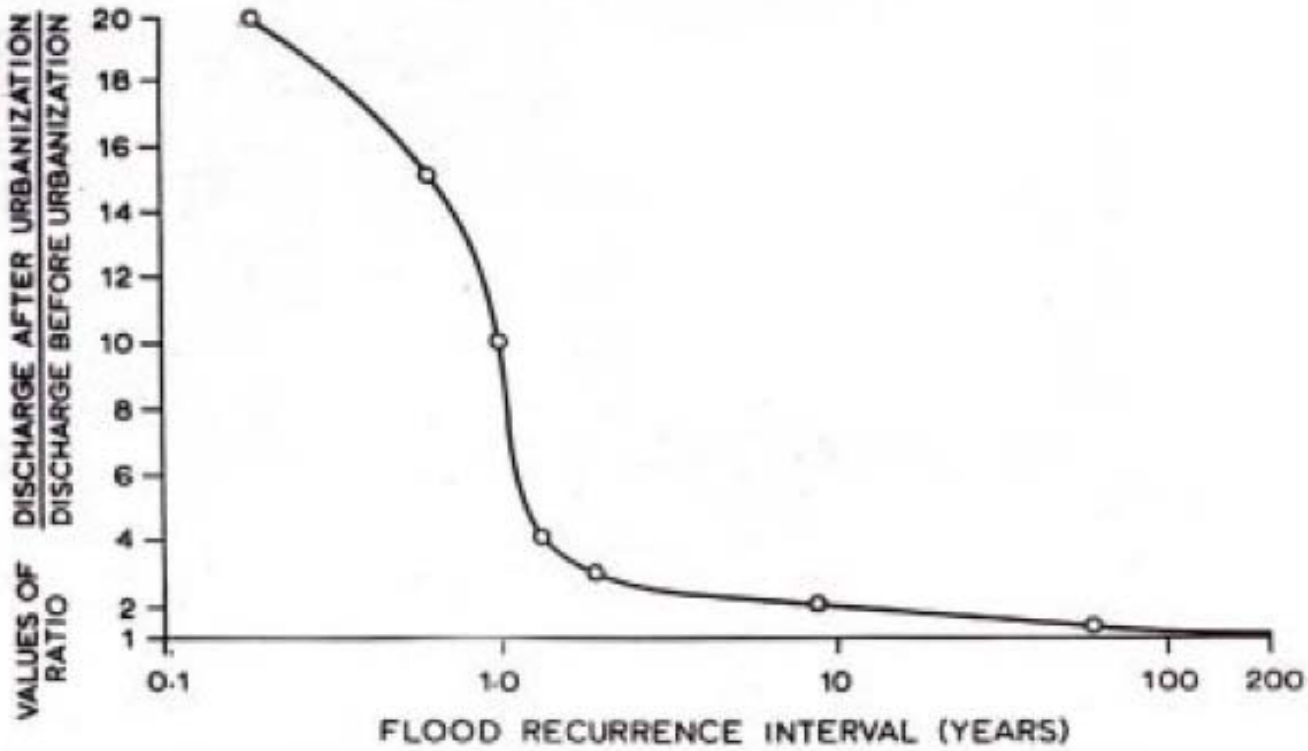


Fig. 3. Effect on flood magnitudes of paving 20% of a basin (based on Figure 2).

Figure 9: Effect on Flood Magnitudes of 30% Basin IC (Hollis, 1975)

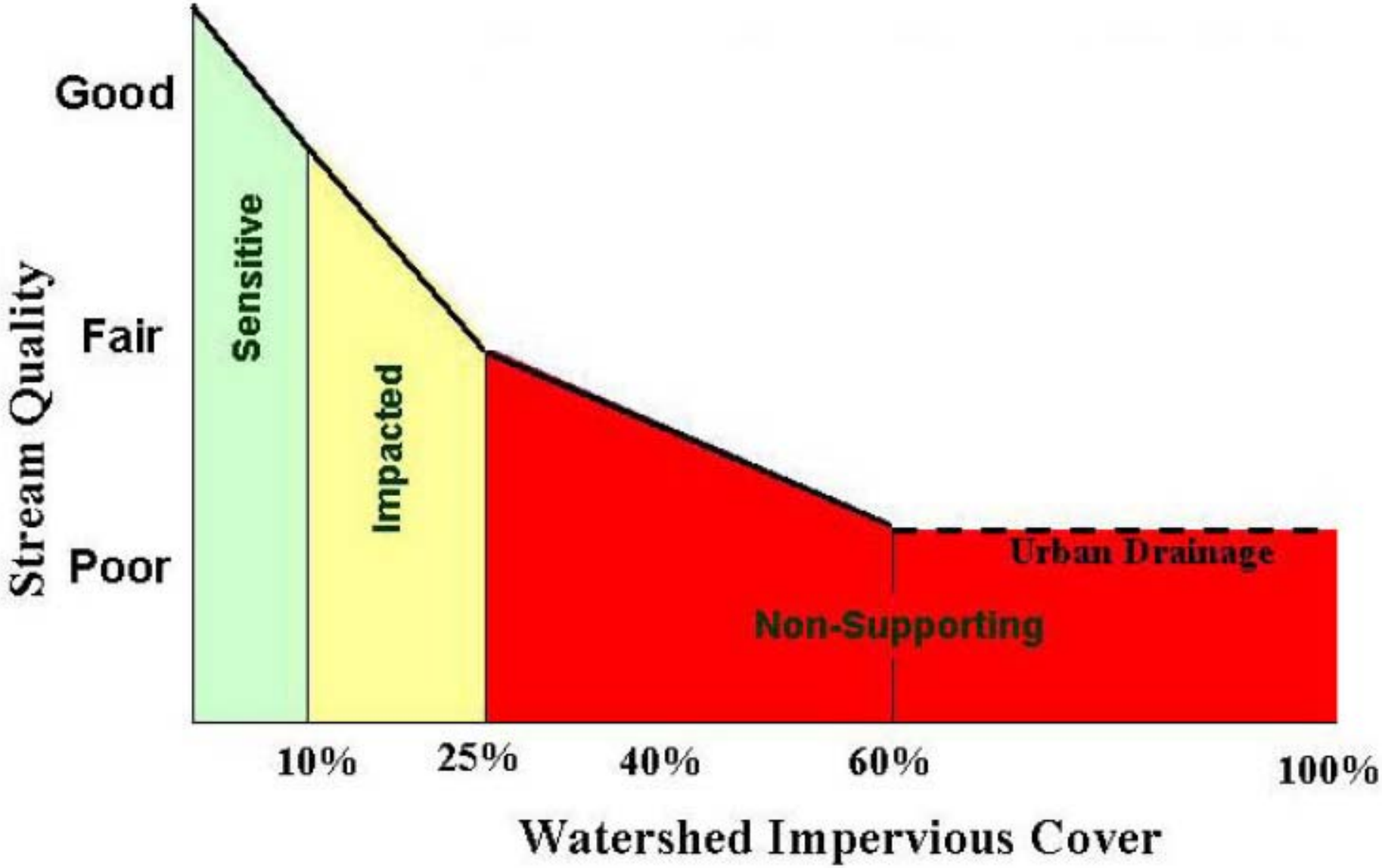
Table 12: Physical Impacts of Urbanization on Streams

Specific Impacts
Sediment transport modified
Channel enlargement
Channel incision
Stream embeddedness
Loss of large woody debris
Changes in pool/riffle structure
Loss of riparian cover
Reduced channel sinuosity
Warmer in-stream temperatures
Loss of cold water species and diversity
Channel hardening
Fish blockages
Loss of 1st and 2nd order streams through storm drain enclosure

CWP, 2003

The Impervious Cover Model

- Typically applied to smaller, lower-order streams
- Potential effects only
- Doesn’t take into account ameliorating effects such as BMPs
- Specific to mid-Atlantic



The Importance of Imperviousness, CWP, 1994

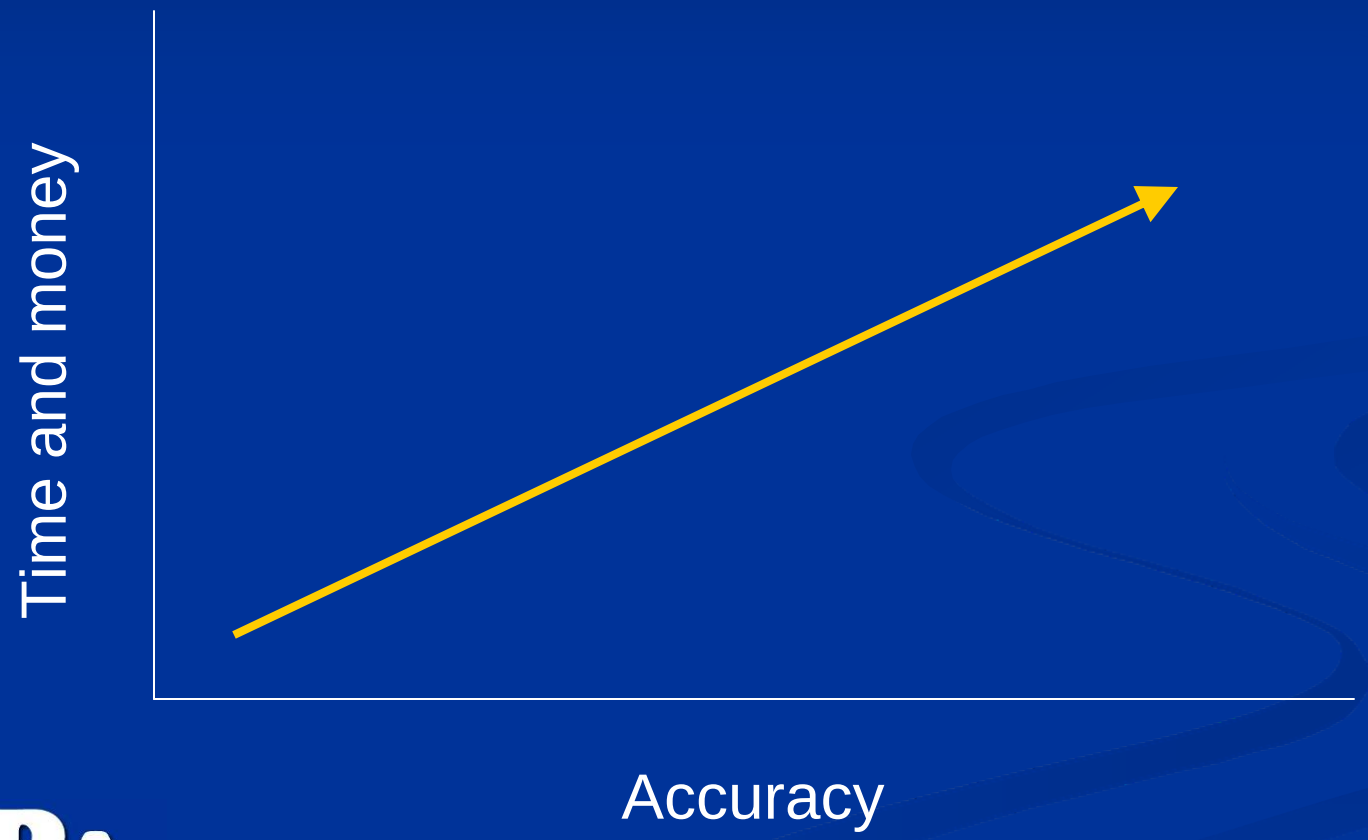
The picture is more complicated…

- Some material (e.g. hard-packed dirt) have different runoff potential
- Situation/pattern of imperviousness matters
- Slope
- Soil characteristics (texture, moisture, permeability)
- Some pervious areas are problematic also, e.g. Ag. fields, turf grass
- Effects such as buffers, BMPs are not well modeled on a watershed basis

Still important as an indicator

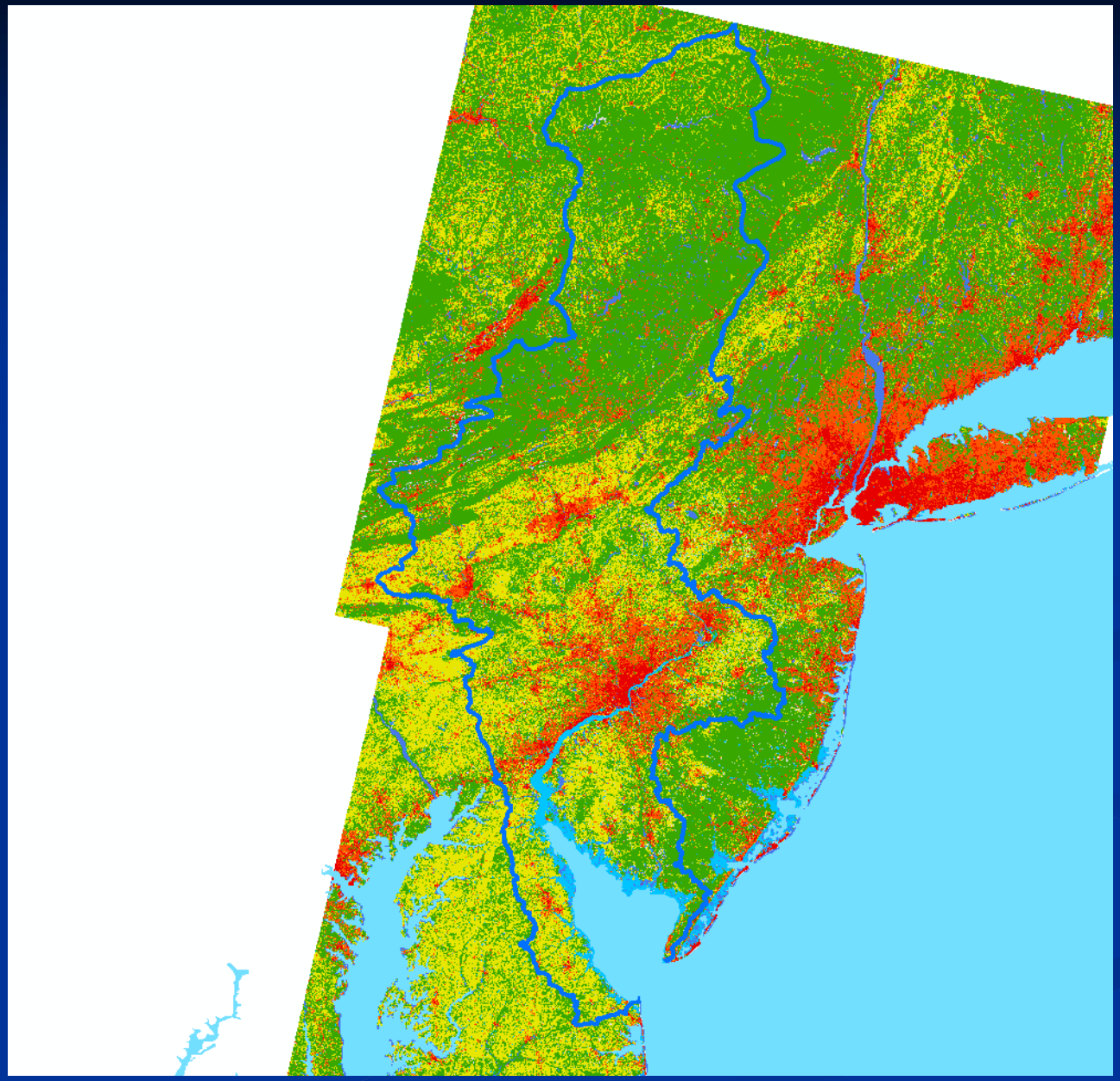
- Determined to correlate with a wide variety of (negative) effects
- Efficient: possible to measure quickly over a large area
- Multi-scale: can be applied across large basins or tiny catchments
- Many potential sources of data:
  - Proxy measurements
  - Remote sensing techniques
  - Feature extraction packages
  - Direct measurement from air photos or site plans

The end use will determine how IC data are measured



How to determine IC

- Land Use as a proxy
  - Regional scale – NLCD
  - Local scale – Delaware 1992, 1997, 2002, 2007 data
  - Problems:
    - Estimate only
    - Classification problem
    - Issue with LU change over time



Land Use	Impervious Cover %
Single Family Residential	20
Multi-Family Residential	45
Commercial	70
Transportation	75
Institutional	30
Industrial	85
Agriculture	3

S. NCC Watershed Project

value	Description	value	Description
11	Open Water	5	Water
21	Developed, Open Space	2	Developed - Low Intensity
22	Developed, Low Intensity	2	Developed - Low Intensity
23	Developed, Medium Intensity	1	Developed - High Intensity
24	Developed, High Intensity	1	Developed - High Intensity
31	Barren Land (Rock/Sand/Clay)	7	Barren/Open
41	Deciduous Forest	4	Forested
42	Evergreen Forest	4	Forested
43	Mixed Forest	4	Forested
52	Shrub/Scrub	3	Agriculture/Pasture/Shrubland
71	Grassland/Herbaceous	3	Agriculture/Pasture/Shrubland
81	Pasture/Hay	3	Agriculture/Pasture/Shrubland
82	Cultivated Crops	3	Agriculture/Pasture/Shrubland
90	Woody Wetlands	4	Wetland
91	Palustrine Forested Wetland	4	Wetland
92	Palustrine Scrub/Shrub Wetland	4	Wetland
93	Estuarine Forested Wetland	4	Wetland
94	Estuarine Scrub/Shrub Wetland	4	Wetland
95	Emergent Herbaceous Wetlands	6	Wetland
96	Palustrine Emergent Wetland (Persistent)	6	Wetland

Land use Code	Description	% Impervious
110	**Residential**	**30**
111	Single-Family Residential	30
112	Multi-Family Residential	65
114	Mobile-Home Parks	50
120	**Commercial**	**85**
121	Retail Sales/ Wholesale/ Professional Services	85
122	Vehicle-Related Activities	85
123	Junk/Salvage Yards	85
125	Warehouses	85
129	Other Commercial	85
130	**Industrial**	**72**
140	**Transportation/Communication**	**90**
141	Highways	90
142	Parking Lots	90
143	Railroads	90
144	Airports	90
145	Communication	90
146	Marinas/Docks	90
150	**Utilities**	**90**
160	**Mixed Urban/Built-Up**	**80**
170	**Other Urban**	**80**
180	**Institutional/Government**	**35**
190	**Recreation**	**0**
200	**Agriculture**	**0**
211	Cropland	0
212	Pastures	0
213	Idle Fields	0
215	Truck Crops	0
220	Orchard/Nursery/Horticulture	0
230	Confined Feeding Operations	0
240	Farmsteads/Farm Buildings	0
290	Other Agriculture	0
300	**Brushland/Rangeland**	**0**
310	Herbaceous Rangeland	0
320	Shrub/Brush Rangeland	0
330	Mixed Rangeland	0

Land use Code	Description	% Impervious
400	**Forest**	**0**
410	Deciduous Forest	0
420	Coniferous Forest	0
430	Mixed Forest	0
440	Clear-Cut Forest	0
500	**Water**	**100**
510	Streams/Canals	100
520	Lakes/Ponds	100
530	Reservoirs	100
540	Bays/Coves	100
600	**Wetland**	**100**
610	Forested Wetlands	100
620	Non-Forested Wetlands	100
700	**Barren**	**10**
720	Beaches	10
730	Inland Sandy Areas	10
740	Rock Outcrops	10
750	Extraction Areas	10
760	Transitional/Filled/Graded Areas	10
770	Mixed Barren And Vegetated	10

Kim Cloud, 2007

How to determine IC

- Other proxy methods, e.g. population
  - University of Connecticut study
  - More abstracted – may have extremely local applicability

The "Connecticut method"

$$\%IS = (a + b*PopDen + c_i*\%LU_i)$$

where,

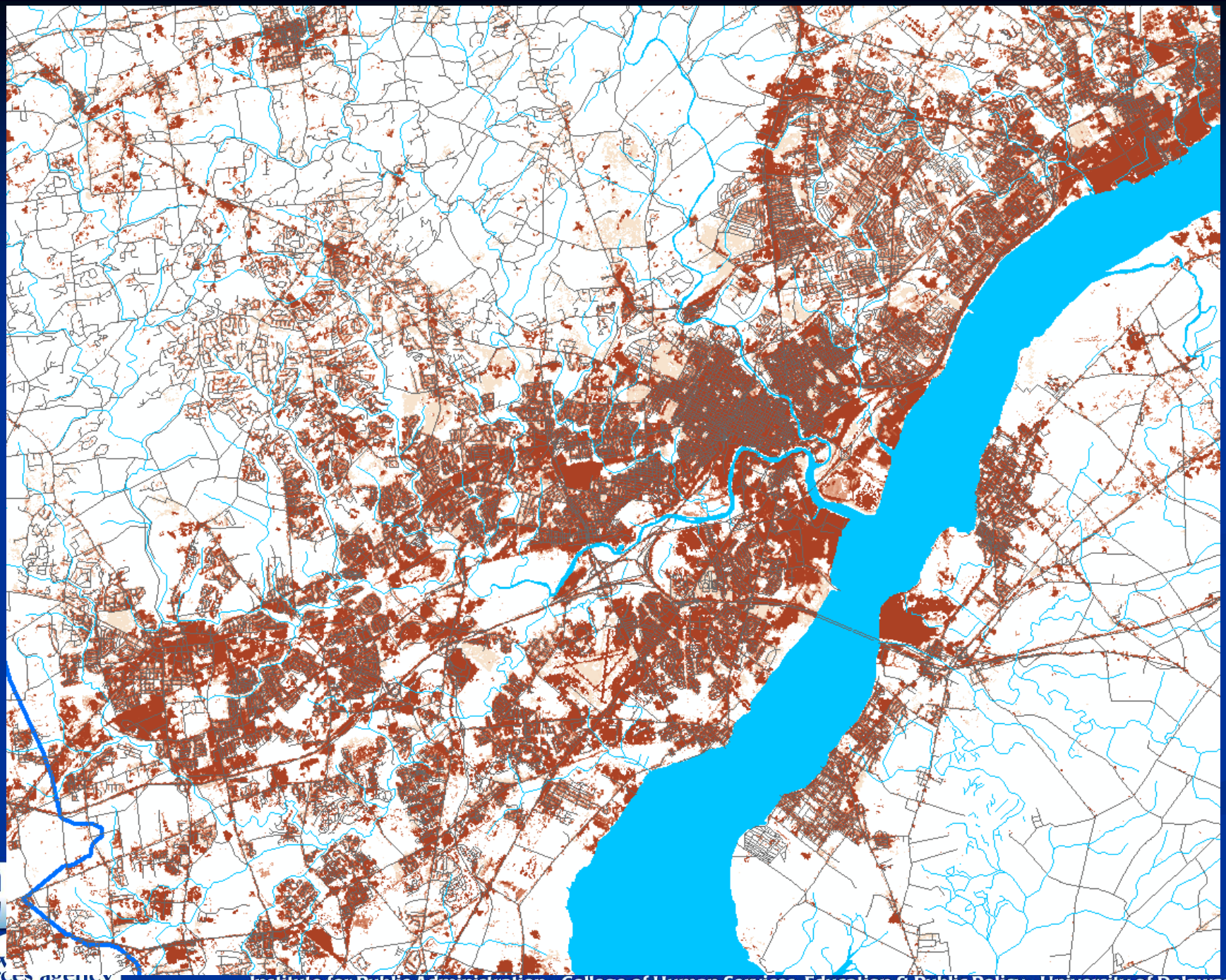
- %IS = the estimated percent imperviousness per tract
- PopDen = the population density (persons mi^{-2})
- Lu_i = the percentage of the tract occupied by land use "i"

- **Land use coefficients are determined from digitized calibration data**
- **Unclear how extensible this may be**

Sandy Prisloe and Daniel Civco, University of Connecticut

How to determine IC

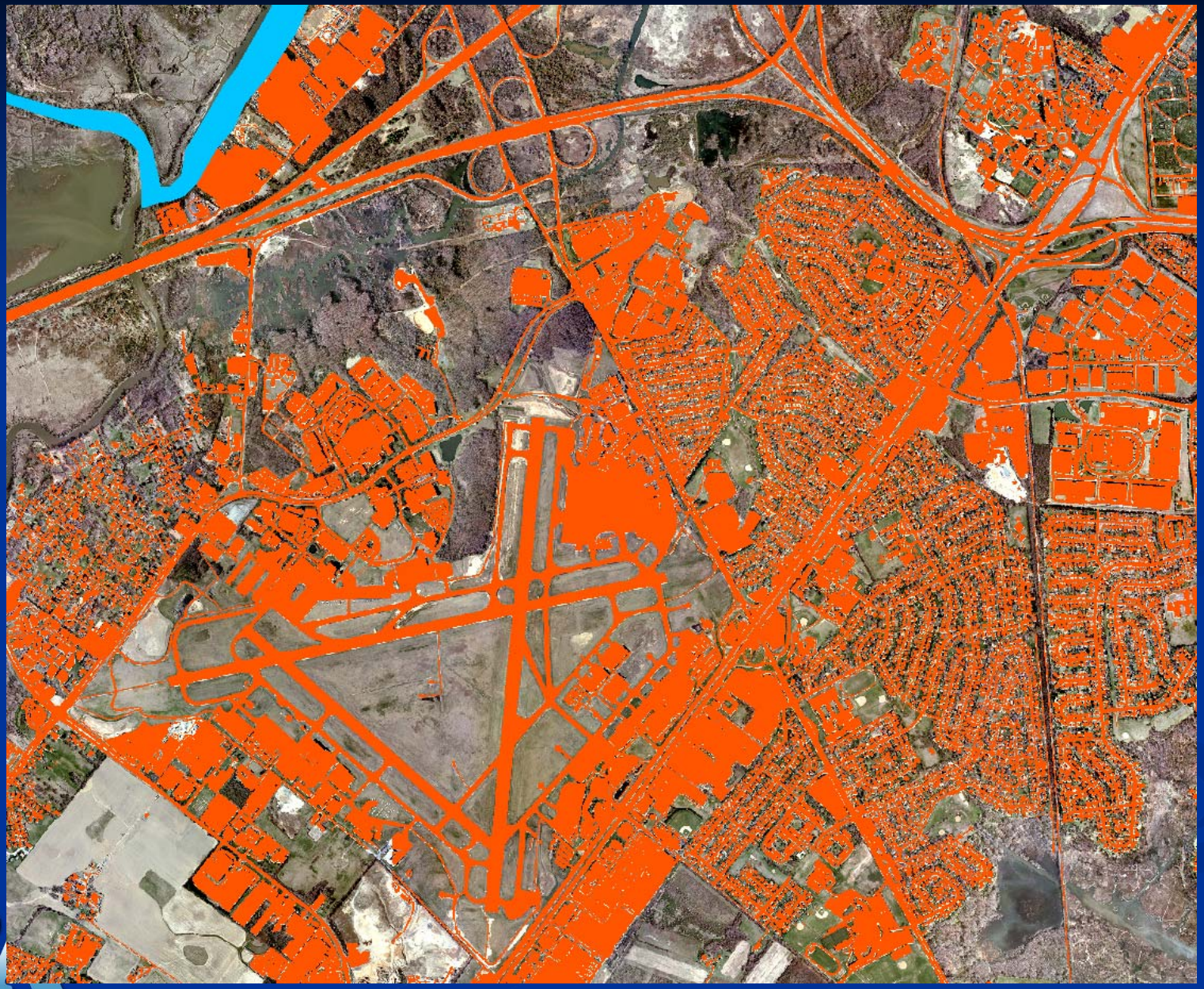
- Remote Sensing techniques
  - USGS national IC layer
  - Feature extraction
  - Combination of “expert systems” and human supervision
  - Very dependant on the type/availability of source data
  - Application and scale dependant



How to determine IC

- Direct measurement
  - Using aerial photography or satellite imagery, e.g. Delaware 2007
  - Engineering survey

Basins (HUC 8)
Watersheds (HUC 12)
Sub-watershed (WRA-WMU)
Municipal Boundaries
State Boundary
County Boundaries
Roads
Streams
0.5
0.25
0
0.5 Miles
DR1
SB1
DR3
DR2
SB2
AQ1
AQ2
AQ3

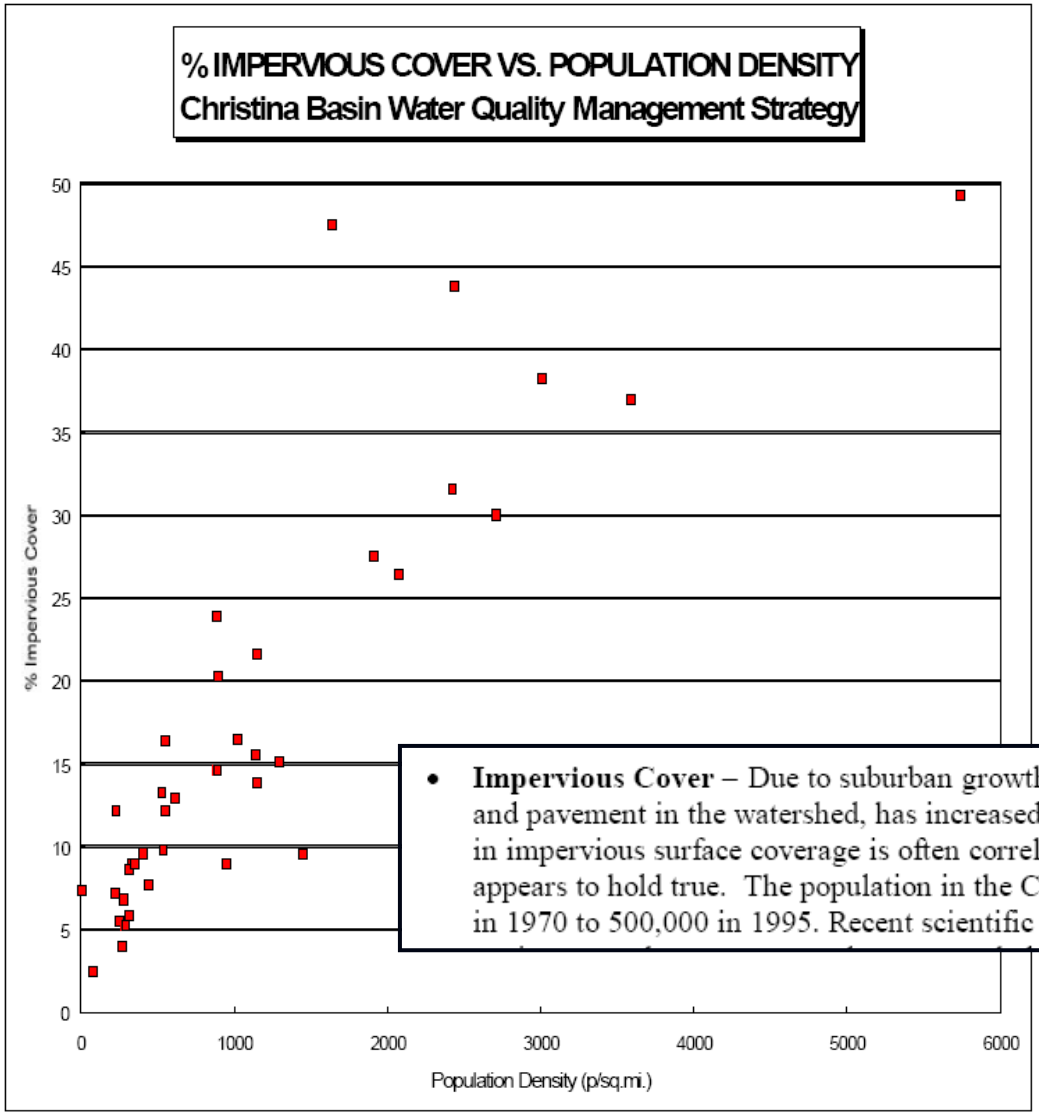


Comparison of methods

Subwatershed	% Impervious from hand digitization	% Impervious from Feature Analyst	% Impervious from "Delaware Method"
Back Creek	6	8	7
C and D West	6	8	6
Dove's Nest	10	14	13
Main Stem Drawyer's	6	9	7
C and D Canal West	6	8	6

Applications

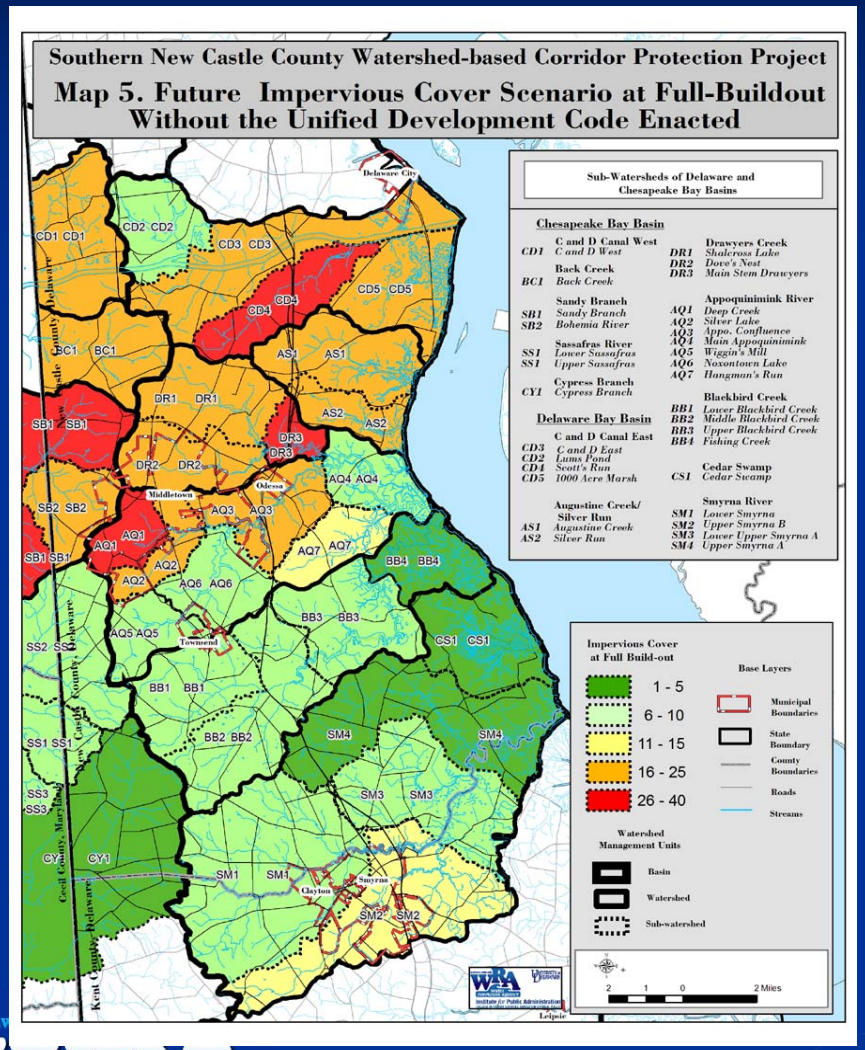
- Christina Basin Phase III Report: Water Quality Management Strategy
- Southern NCC priority watersheds
- Watershed “report cards”: White Clay Creek State of the Watershed
- WRPA ordinance
- Stormwater Utilities: e.g. Wilmington



- **Impervious Cover** – Due to suburban growth, the impervious cover, the amount of buildings and pavement in the watershed, has increased from 9% in 1975 to 16% in 1995. An increase in impervious surface coverage is often correlated with an increase in population. That appears to hold true. The population in the Christina Basin has increased 21% from 412,000 in 1970 to 500,000 in 1995. Recent scientific literature indicates that important

	Sub-watershed	Drainage Area in Acres	Drainage Area in Sq.Mi.	Current % Impervious Cover	% Impervious following current zoning	% Impervious with Current Zoning and UDC Restrictions
CD1	C and D Canal West	12749.22	19.92	6	16	13
BC1	Back Creek	4821.85	7.53	8	25	15
SB1	Sandy Branch	2785.66	4.35	5	21	13
SB2	Bohemia River	4098.54	6.40	4	26	10
SS1	Sassafras River	991.71	8.30	5	3	4
SS2	Upper Sassafras River	4265.33		3	9	4
CY1	Cypress Branch	8622.75	13.47	3	4	3
CD2	Lums Pond	3817.66	5.97	6	7	6
CD3	C and D Canal East	7020.78	10.97	6	18	12
CD4	Scott's Run	4168.14	6.51	7	40	22
CD5	Thousand Acre Marsh	337910.94	527.99	2	17	5
AS1	Augustine	4098.54	6.40	7	21	8
AS2	Silver Run	2370.00		8	16	14
DR1	Shallcross Lake	4122.49	6.44	6	22	12
DR2	Dove's Nest	3902.13	6.10	13	24	20
DR3	Main Stem Drawyers Creek	1320.17	2.06	7	26	15
AQ1	Deep Creek	2170.47	3.39	14	38	19
AQ2	Silver Lake	2009.30		8	19	12
AQ3	Appoquinimink Confluence	4277.63	6.68	10	21	13
AQ4	Main Stem Appoquinimink	3016.41	4.71	2	9	7
AQ5	Wiggin's Mill	2688.30	4.20	5	8	6
AQ6	Noxontown Pond	3511.45	5.49	6	9	6
AQ7	Hangman's Run	2695.22	4.21	4	13	9
BB1	Lower Blackbird Creek	4747.56	7.42	6	7	6
BB2	Middle Blackbird Creek	7098.01	11.09	4	8	5
BB3	Upper Blackbird Creek	13261.47	20.72	3	6	5
BB4	Fishing Creek	3445.87	5.38	0	1	1
CS1	Cedar Swamp	5248.14	8.20	1	1	1
CY1	Cypress Branch	8622.75	13.47	3	4	3
SM1	Lower Smyrna	11552.62	18.05	7	10	8
SM2	Upper Smyrna B	9523.90	14.88	8	13	9
SM3	Lower Upper Smyrna A	7568.01		4	7	5
SM4	Upper Smyrna A	10008.68		2	4	3

MAP 5. Future Impervious Cover Estimates *Without* the Unified Development Code Enforced at Full-Buildout



0 – 5 %

6 - 10 %

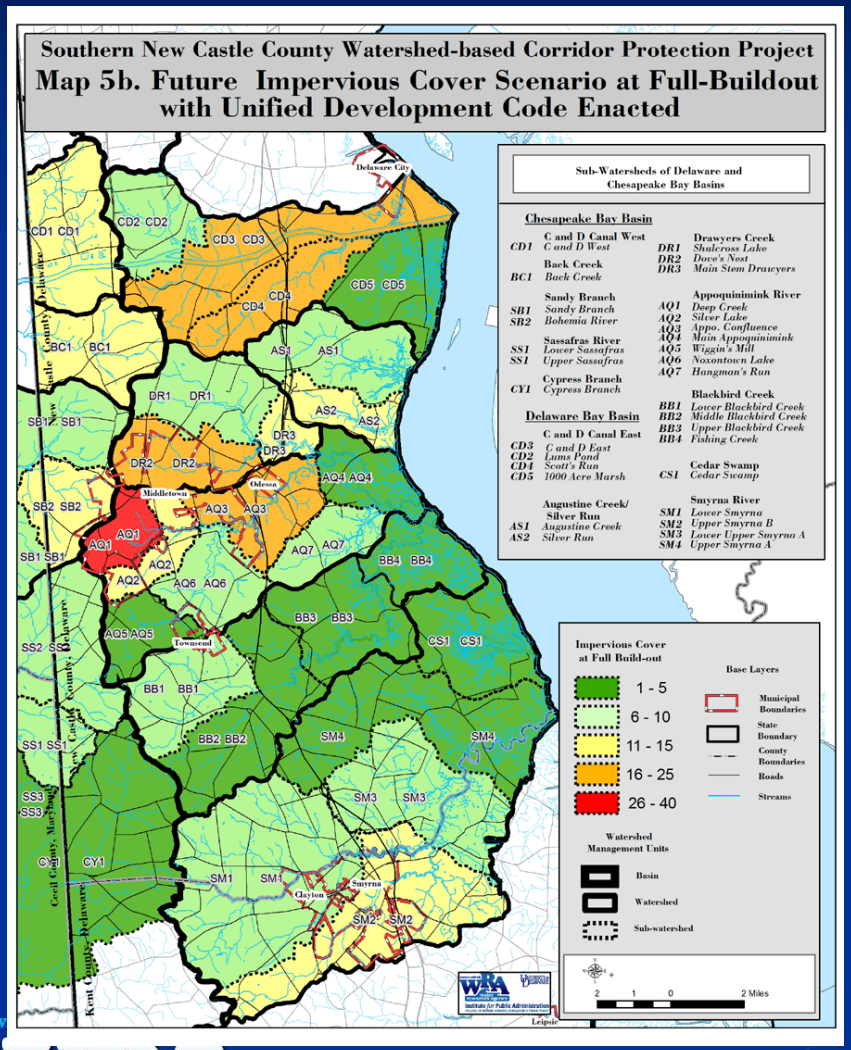
10 - 15 %

16 – 25%

25 – 40%

** Natural Resources that are protected under Federal or other local ordinances were considered in calculations

MAP 5b. Future Impervious Cover Estimates with the Unified Development Code Enforced at Full-buildout



0 – 5 %

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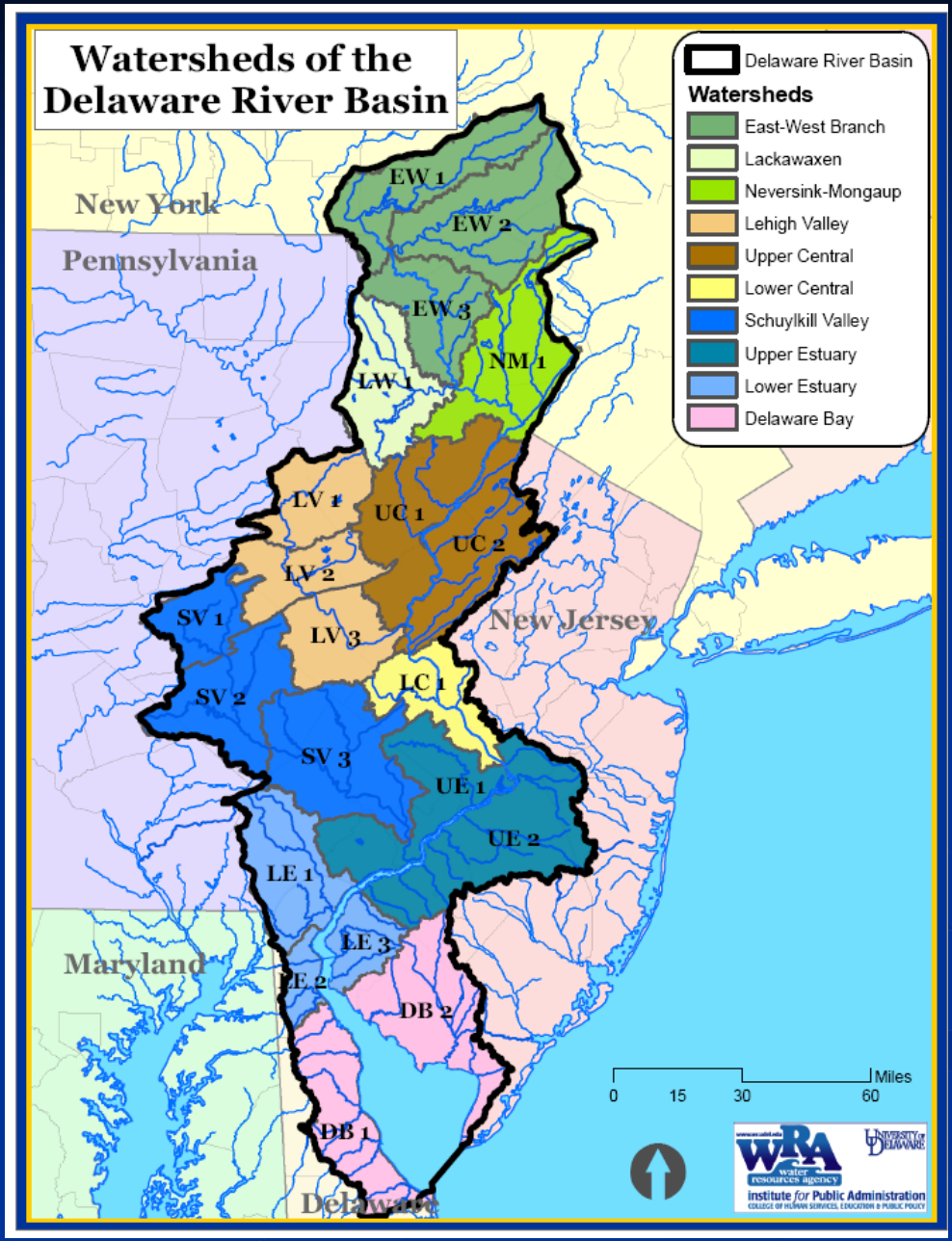
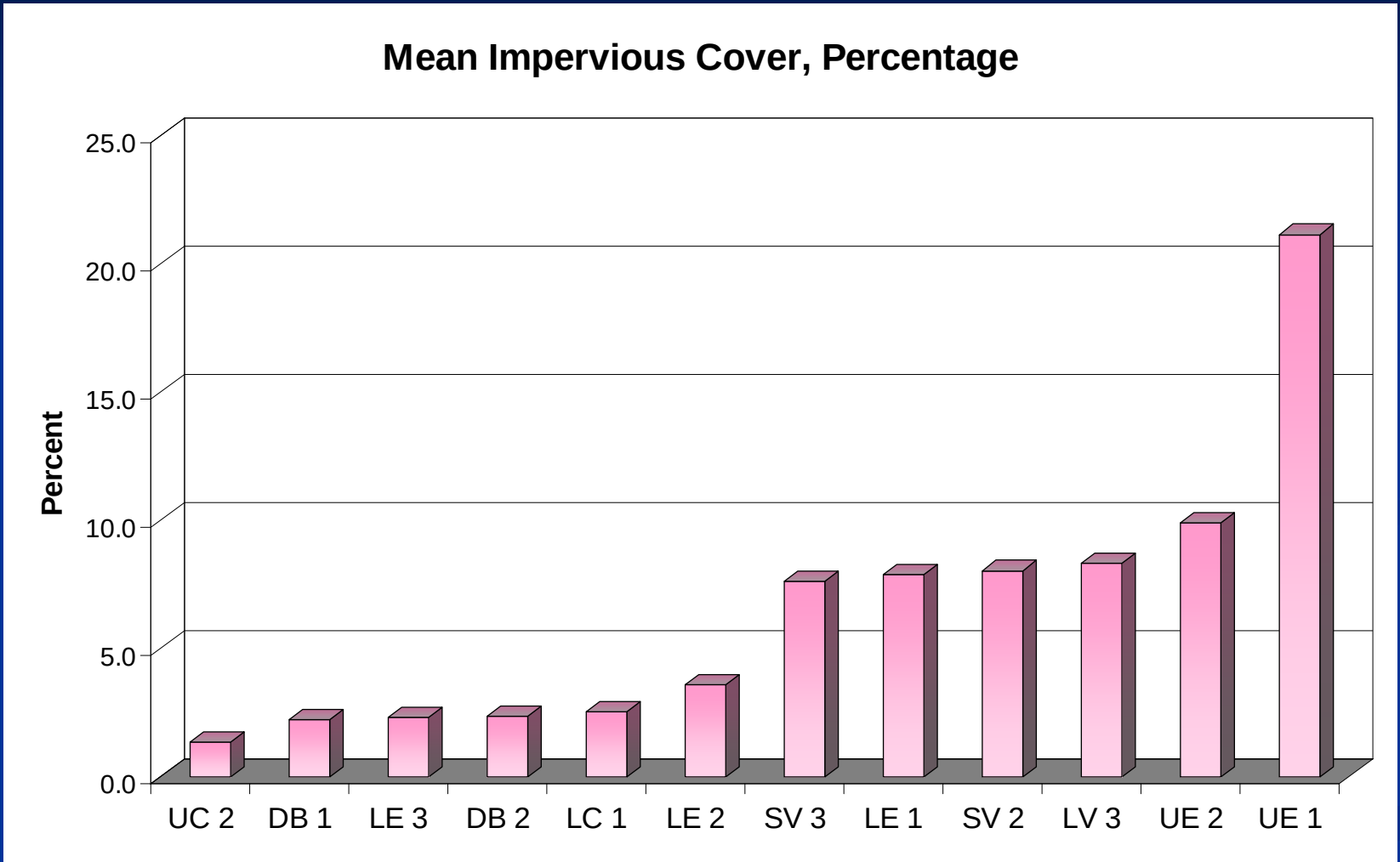
10 - 15 %

16 – 25%

25 – 40%


Watersheds of the Delaware River Basin
Delaware River Basin
Watersheds
East-West Branch
Lackawaxen
Neversink-Mongaup
Lehigh Valley
Upper Central
Lower Central
Schuylkill Valley
Upper Estuary
Lower Estuary
Delaware Bay
New York
Pennsylvania
New Jersey
Maryland
Delaware
EW 1
EW 2
EW 3
NM 1
LW 1
LV 1
LV 2
LV 3
UC 1
UC 2
LC 1
SV 1
SV 2
SV 3
UE 1
UE 2
LE 1
LE 2
LE 3
DB 1
DB 2
Miles
0
15
30
60
WRA water resources agency
University of Delaware
Institute for Public Administration

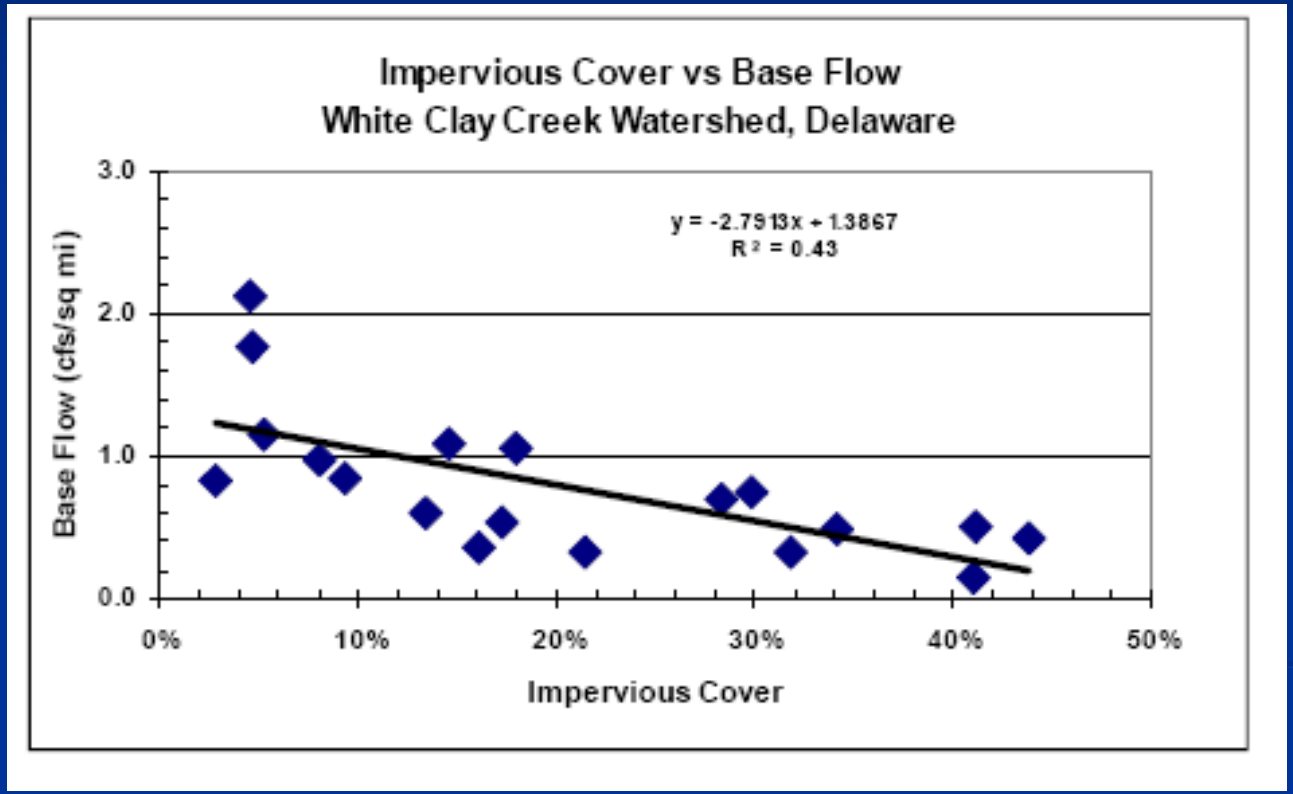

Mean Impervious Cover, Percentage
Percent
25.0
20.0
15.0
10.0
5.0
0.0
UC 2
DB 1
LE 3
DB 2
LC 1
LE 2
SV 3
LE 1
SV 2
LV 3
UE 2
UE 1

White Clay Creek State of the Watershed Report

Subwatershed	Percent Impervious Cover			
	1990	1995	2000	2005
East Branch White Clay Creek	7%	9%	11%	13%
Middle Branch White Clay Creek	7%	8%	9%	10%
West Branch White Clay Creek	8%	9%	9%	10%
White Clay Creek above Newark	8%	9%	10%	11%
White Clay Creek below Newark	42%	43%	47%	50%
Middle Run	6%	8%	9%	10%
Pike Creek	22%	24%	25%	26%
Mill Creek	27%	28%	30%	32%
Total	**15%**	**16%**	**18%**	**20%**

Source: Cloud, 2007

White Clay Creek State of the Watershed Report



GRADE

above Newark

B

Good

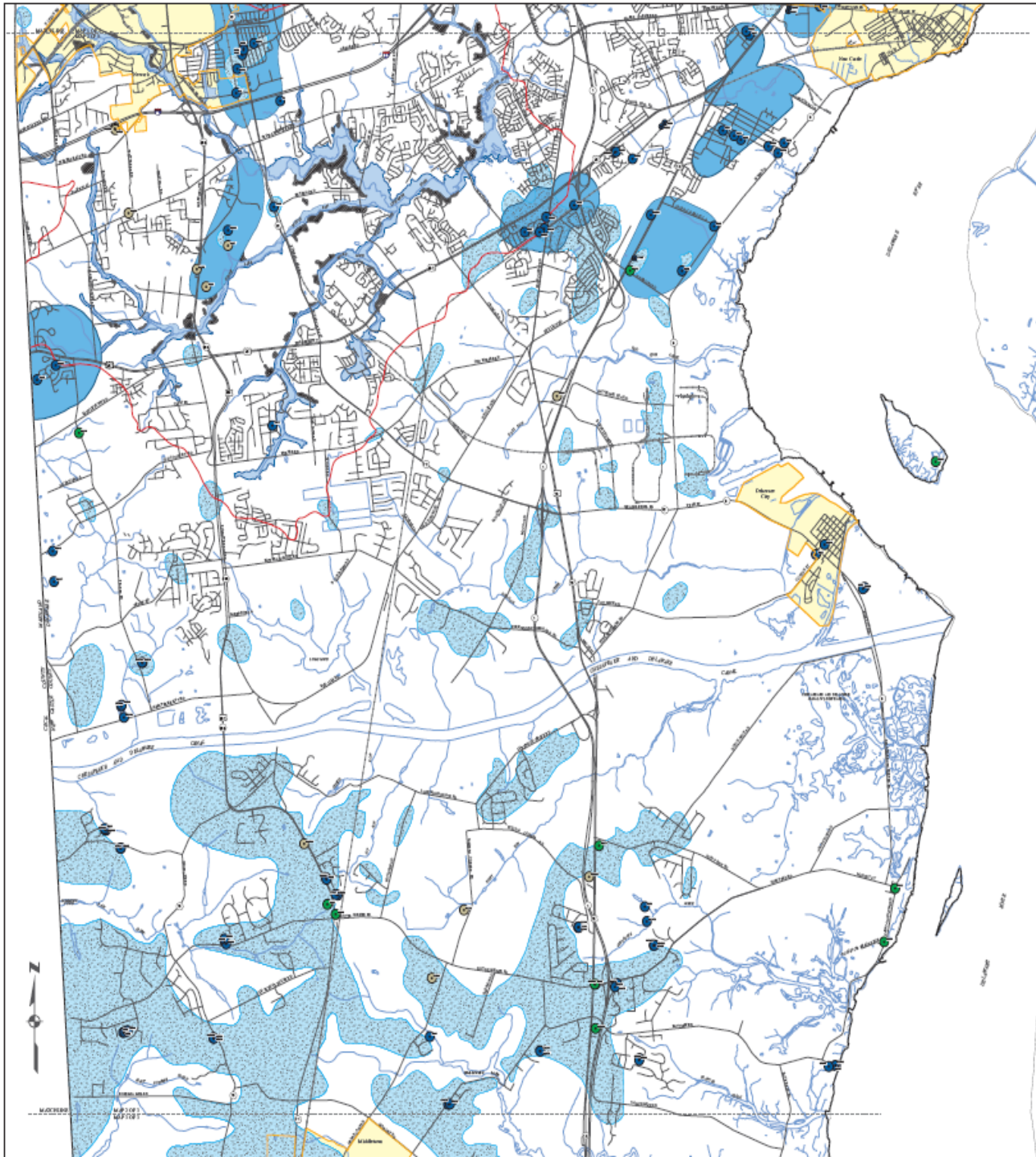
below Newark

D

Poor

TREND

▼



Source Watersheds

Watersheds upstream from Public Surface Water Intakes

Water Resource Protection Areas (WRPAs)

Wellhead WRPA

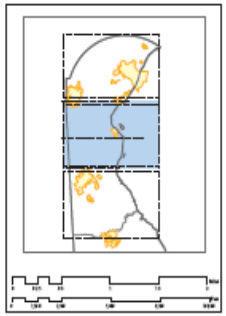
- Class A WRPA
- Class A WRPA - 150-foot Radius
- Transient, Non-Community Wells (Restaurants, Stores, Hotels, Parks, etc.)
- Non-Transient, Non-Community Wells (Schools, Daycare Centers, Office, Factory, etc.)
- Class B WRPA
- Class C WRPA

Surface Water WRPA

- Flood Plains
- Erosion Prone Slopes

Recharge WRPA

- Recharge Areas



Water Resource Protection Areas for City of Newark City of Wilmington New Castle County Delaware

Map 1 of 3

Storm Water Classes: Non-Residential

TABLE 1 = SINGLE FAMILY RESIDENTIAL PARCELS

Tier	Impervious Area Tiers	Impervious Area (Sq. Ft.)	Equivalent Storm Water Unit Ratio (ESU Ratio)
1	SWR1 / SWM1	0 to 799	1.00
2	SWR2 / SWM2	800 to 1,299	1.45
3	SWR3 / SWM3	1,300 to 2,399	2.48
4	SWR4 / SWM4	2,400 and over	4.40

TABLE 2 -ALL OTHER STORM WATER CLASSES

Stormwater Class	Stormwater Class Description	Runoff Co-efficients
COM	Commercial	95%
GOV	Government	95%
IND	Industrial	90%
INS	Institutional	90%
MFA	Multi Family Apartment	75%
	Direct Discharge Permit older	10%
	arks & Cemeteries	25%
	aved Surface	95%
	arking	90%
REC	ecreational Playgrounds / Arenas	35%
UTI	Utilities	90%
VAC	Vacant	30%

Total impervious area estimated for the parcel: 95% X 43,560 Sq. Ft. = 41,382 Sq.Ft.
Total original ESUs: 41,382 ÷ 789 = 52.45 ESUs

Total **original** quarterly storm water charge: 52.45 ESUs X $9.159 = **$480.39**

Conclusions

- Impervious cover matters for many measures of stream & watershed health
- No simple relationships, many confounding factors
- There seems to be some “threshold” effects
- Not good predictor of individual stream health--better for overall watershed “grade”
- Many ways to estimate or measure
- Can be used effectively in certain regulations