Specifying Pervious Concrete

Philip Kresge

National Resource Director

National Ready Mixed Concrete Association

NRMCA®

Think Outside the Box

- 8 Eight
- 5 Five
- 4 Four
- 9 Nine
- 1 One
- 7 Seven
- 6 Six
- 3 Three
- 2 Two
- 0 Zero

Infiltration Systems

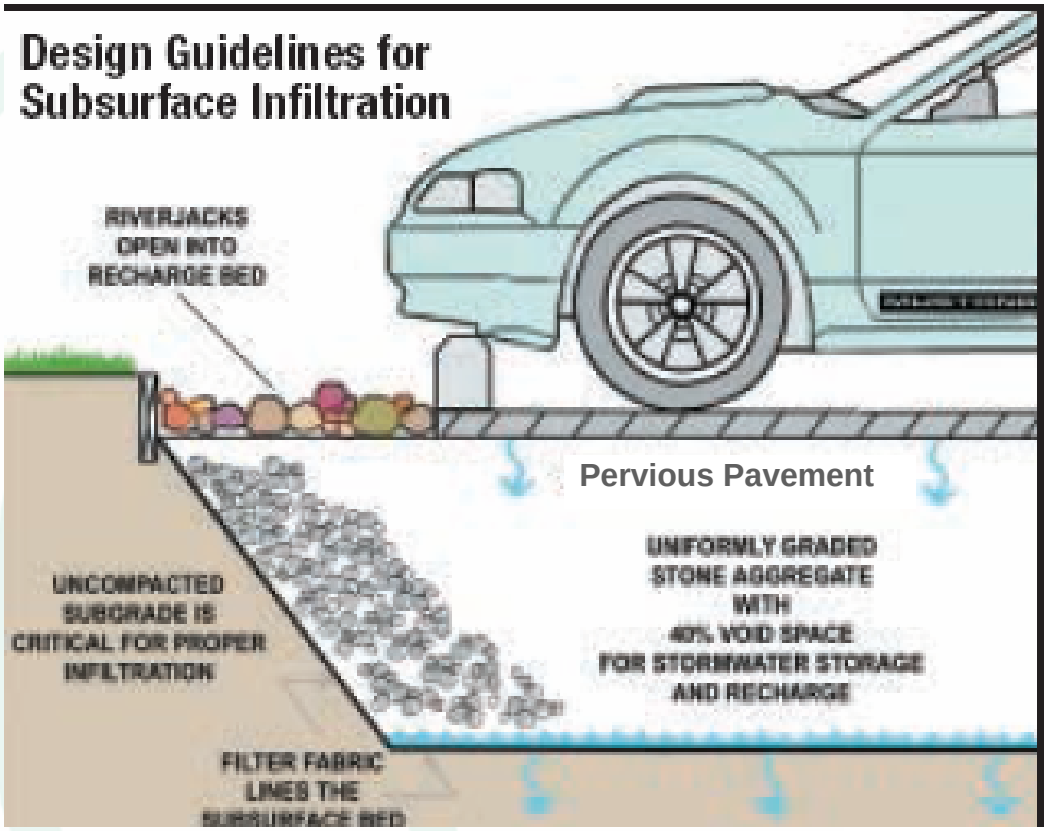
Developed in 1970's

Franklin Institute, Philadelphia, PA

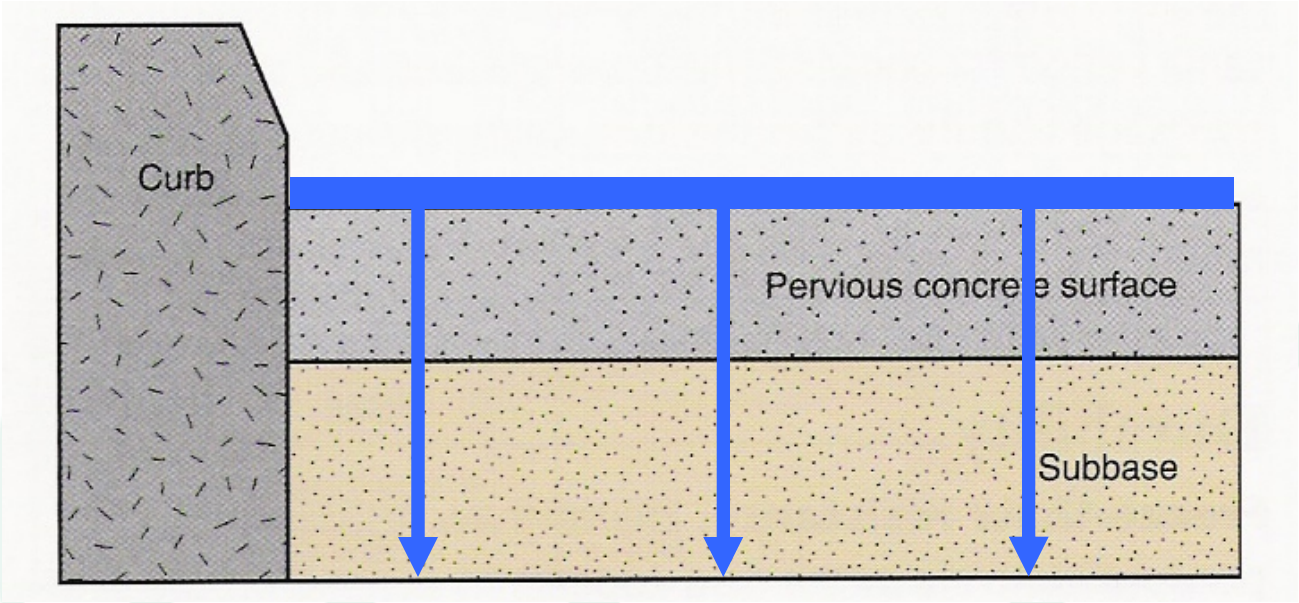
Infiltration System

- Subgrade compacted

  92 – 95%
- Filter fabric
- Underlying, open-graded stone bed
  - 6” to 24” clean aggregate base
- Porous pavement surface
  - 4” to 6”



* Illustration courtesy of T Cahill Associates



- Water drains through pavement into stone bed and infiltrates slowly into underlying soil mantle
  - 0.1 – 0.5 in/hr acceptable
  - Total drawdown time should not exceed 5 days

Why Specify Pervious Concrete?

Environmental Issues

- Water Quality
  - First-Flush Pollution Mitigation
  - Groundwater Recharge
  - Flood Prevention / Management

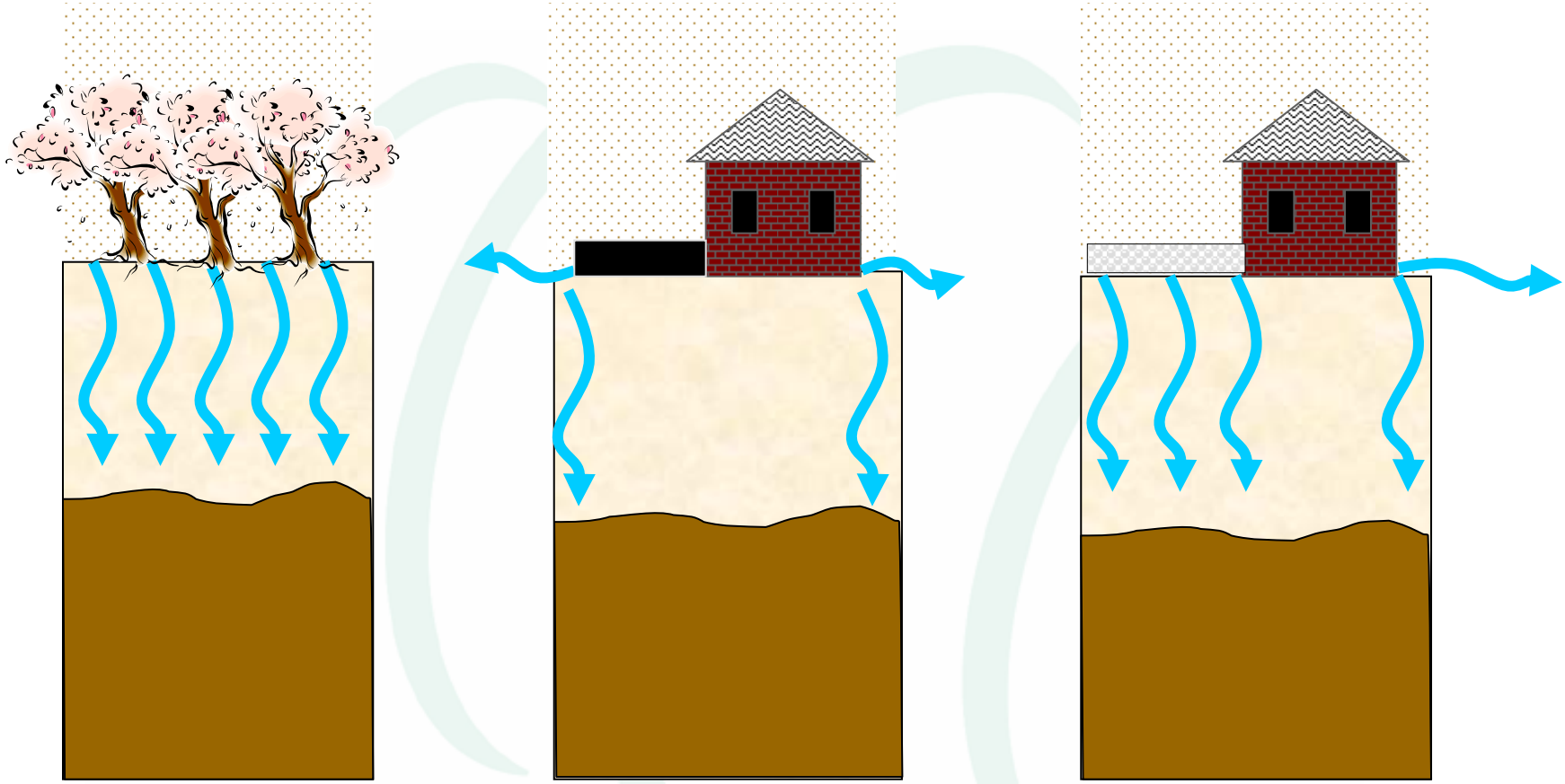
First Flush

- First 1” of rain
  - Contains contaminants
    - EPA requires collection and treatment prior to release
  - USGS study – Austin, TX
    - High concentration of polycyclic aromatic hydrocarbons (PAH)
    - Attributed to asphalt parking lot runoff
    - Runoff from asphalt-based sealants 10 times higher
    - Runoff from coal-tar based sealants 65 times higher
    - Source:
      - http://water.usgs.gov/nawqa/asphalt_sealers.html

First Flush

- Pervious concrete pavement reduces runoff
  - Eliminates first flush
  - Captured by void structure
  - Minimization of PAH
- Soil chemistry and biology will naturally treat water
  - Oil drips and other automotive pollutants are “attacked” by naturally occurring soil microbes

Your Drinking Water



Pre-Development

Post-Development

LID

US EPA - Clean Water Act

EPA Storm Water Phase II Final Rule (EPA 2000)

- Reduce or eliminate runoff
- “Treatment” of Pollutants (Percolation)
- Groundwater and aquifer recharge
- Minimize Flooding

Sustainable Development

Green Building Rating System

For New Construction & Major Renovations

(LEED-NC)

Version 2.2

NRMCA

Highlighted Credits

Sustainable Sites

Credit 6.1 & 6.2:
Stormwater Design

Credit 7.1:
Heat Island Effect,
Non-Roof

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

Sustainable Sites — **14 Possible Points**

Prereq 1	**Construction Activity Pollution Prevention**	Required
Credit 1	**Site Selection**	1
Credit 2	**Development Density & Community Connectivity**	1
Credit 3	**Brownfield Redevelopment**	1
Credit 4.1	**Alternative Transportation,** *Public Transportation Access*	1
Credit 4.2	**Alternative Transportation,** *Bicycle Storage & Changing Rooms*	1
Credit 4.3	**Alternative Transportation,** *Low Emitting & Fuel Efficient Vehicles*	1
Credit 4.4	**Alternative Transportation,** *Parking Capacity*	1
Credit 5.1	**Site Development,** *Protect or Restore Habitat*	1
Credit 5.2	**Site Development,** *Maximize Open Space*	1
Credit 6.1	**Stormwater Design,** *Quantity Control*	1
Credit 6.2	**Stormwater Design,** *Quality Control*	1
Credit 7.1	**Heat Island Effect,** *Non-Roof*	1
Credit 7.2	**Heat Island Effect,** *Roof*	1
Credit 8	**Light Pollution Reduction**	1

Stormwater Design Credit 6.1 & 6.2

EPA Storm Water Phase II Final Rule (EPA 2000)

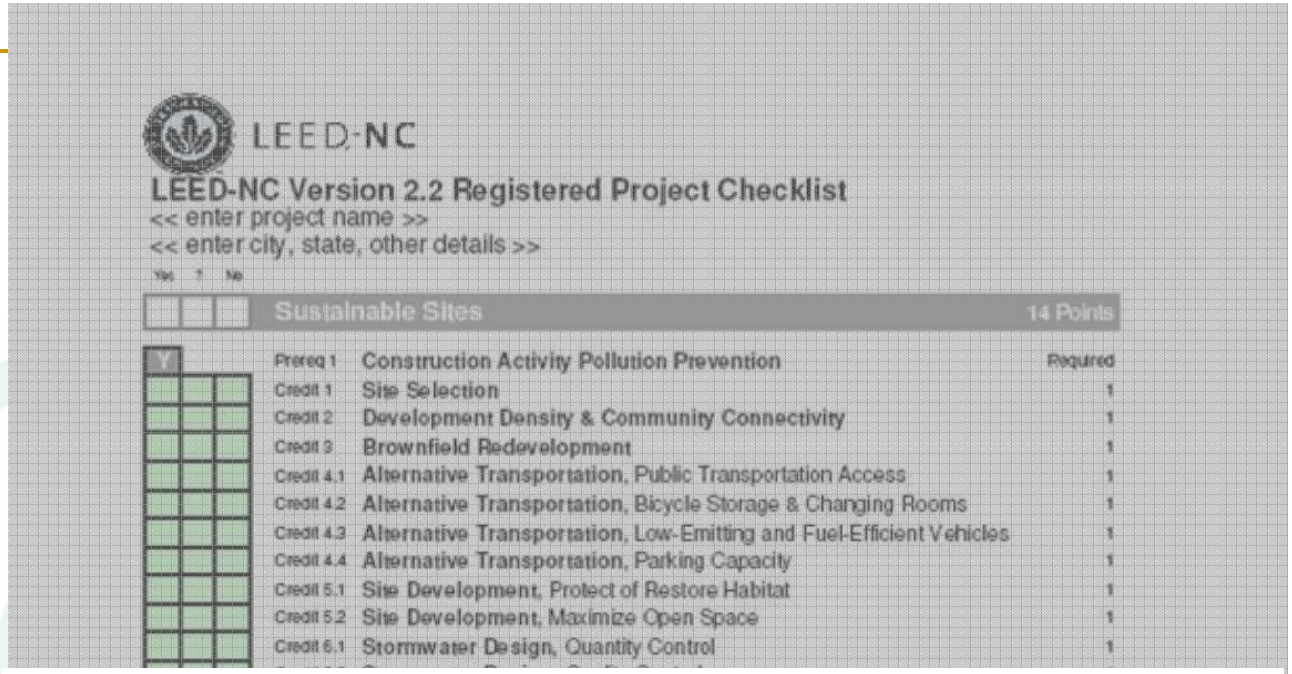
- Reduce or eliminate runoff
- "Treatment" of Pollutants (Percolation)
- Groundwater and aquifer recharge
- Minimize Flooding

Highlighted Credits

Water Efficiency

Credit 1.1 & 2.2:
Water Efficient Landscaping

Credit 3.1 & 3.2
Water Use Reduction



LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

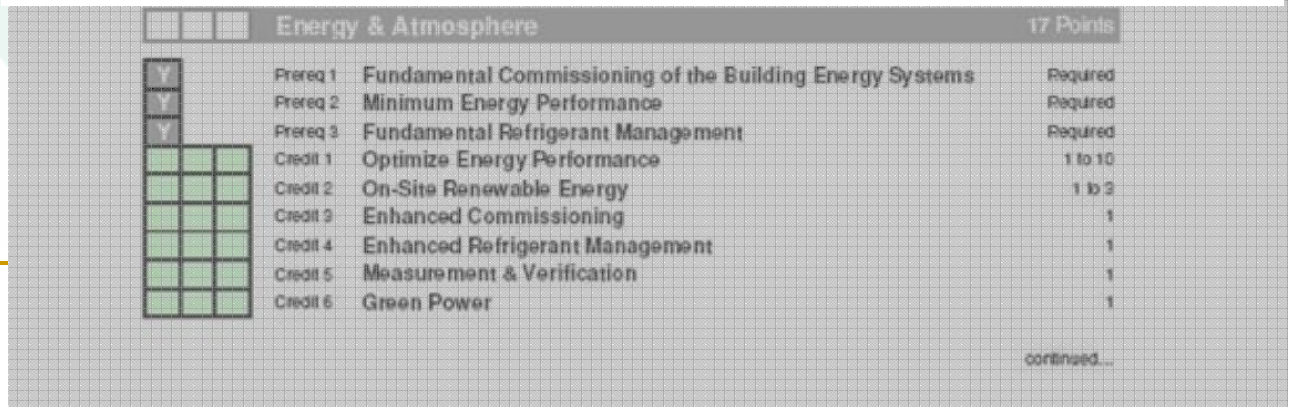
<< enter project name >>

<< enter city, state, other details >>

Yes	?	No	Sustainable Sites	14 Points
Y			Prereq 1 Construction Activity Pollution Prevention	Required
			Credit 1 Site Selection	1
			Credit 2 Development Density & Community Connectivity	1
			Credit 3 Brownfield Redevelopment	1
			Credit 4.1 Alternative Transportation, Public Transportation Access	1
			Credit 4.2 Alternative Transportation, Bicycle Storage & Changing Rooms	1
			Credit 4.3 Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles	1
			Credit 4.4 Alternative Transportation, Parking Capacity	1
			Credit 5.1 Site Development, Protect of Restore Habitat	1
			Credit 5.2 Site Development, Maximize Open Space	1
			Credit 6.1 Stormwater Design, Quantity Control	1

Water Efficiency **5 Possible Points**

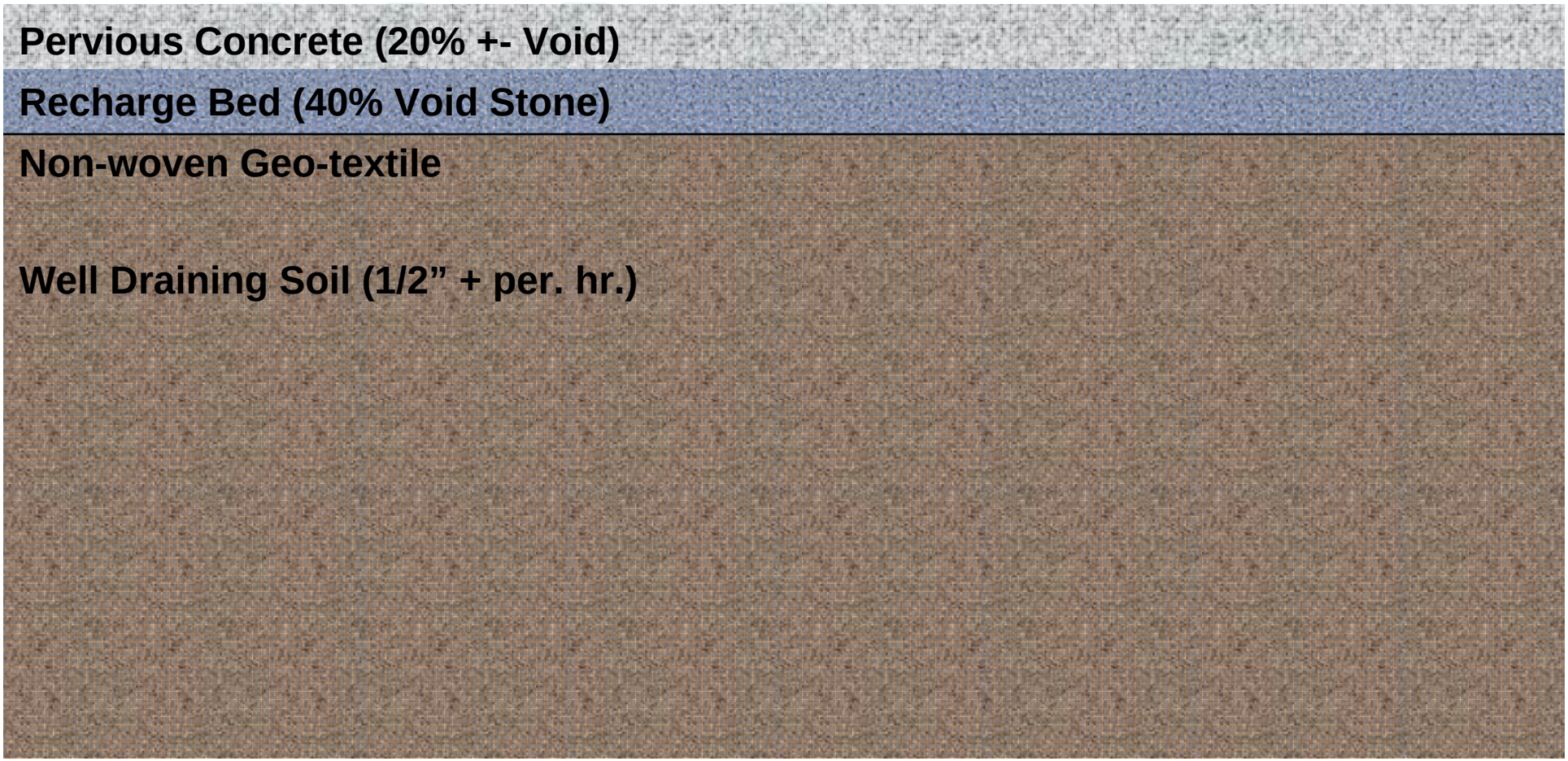
Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
Credit 1.2	**Water Efficient Landscaping**, No Potable or No Irrigation	1
Credit 2	**Innovative Wastewater Technology**	1
Credit 3.1	**Water Use reduction**, 20% Reduction	1
Credit 3.2	**Water Use reduction**, 30% Reduction	1

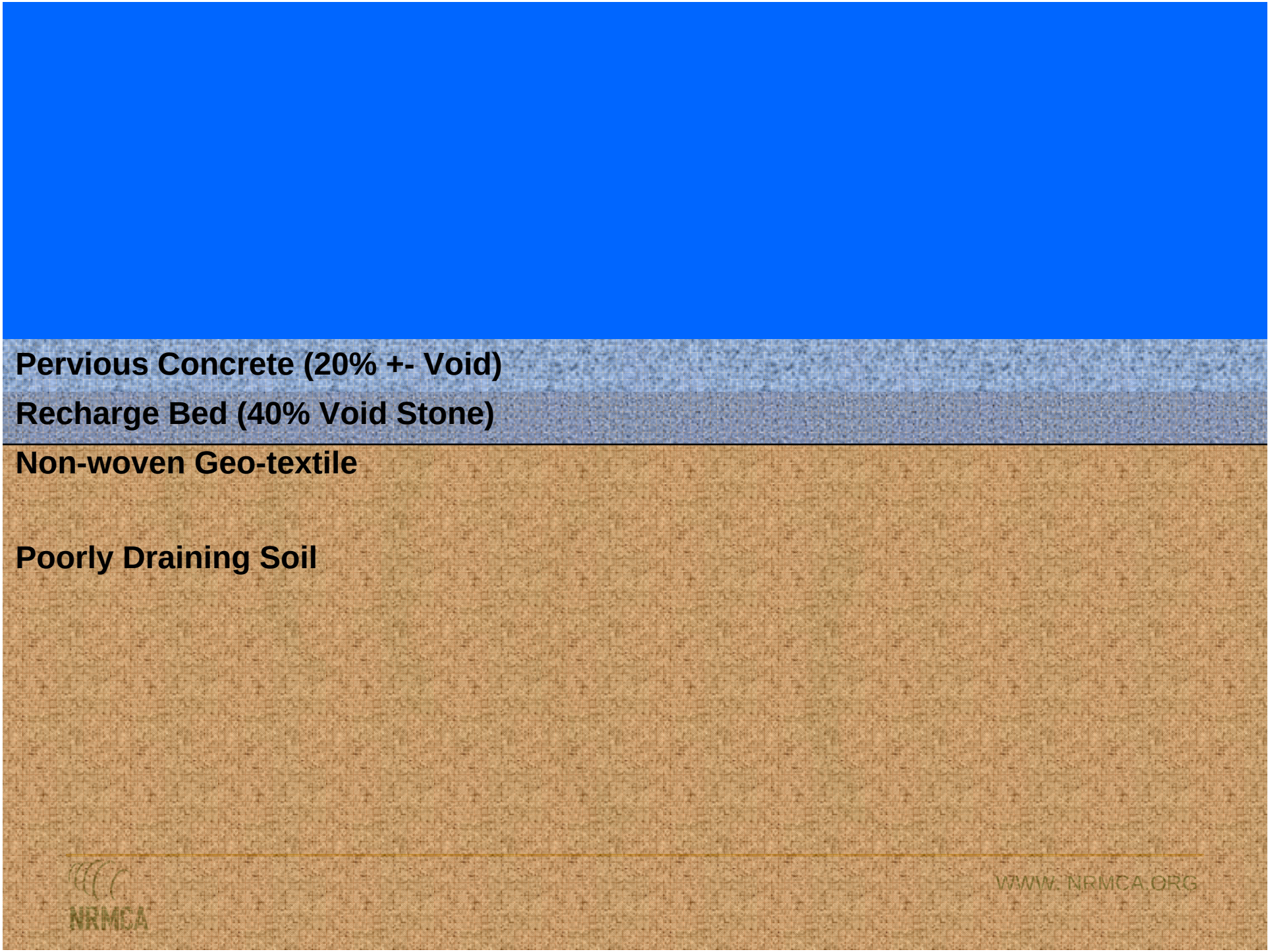


		Energy & Atmosphere	17 Points
Y		Prereq 1 Fundamental Commissioning of the Building Energy Systems	Required
Y		Prereq 2 Minimum Energy Performance	Required
Y		Prereq 3 Fundamental Refrigerant Management	Required
		Credit 1 Optimize Energy Performance	1 to 10
		Credit 2 On-Site Renewable Energy	1 to 3
		Credit 3 Enhanced Commissioning	1
		Credit 4 Enhanced Refrigerant Management	1
		Credit 5 Measurement & Verification	1
		Credit 6 Green Power	1

continued...

Design Considerations


Pervious Concrete (20% +- Void)
Recharge Bed (40% Void Stone)
Non-woven Geo-textile
Well Draining Soil (1/2” + per. hr.)


Pervious Concrete (20% +- Void)
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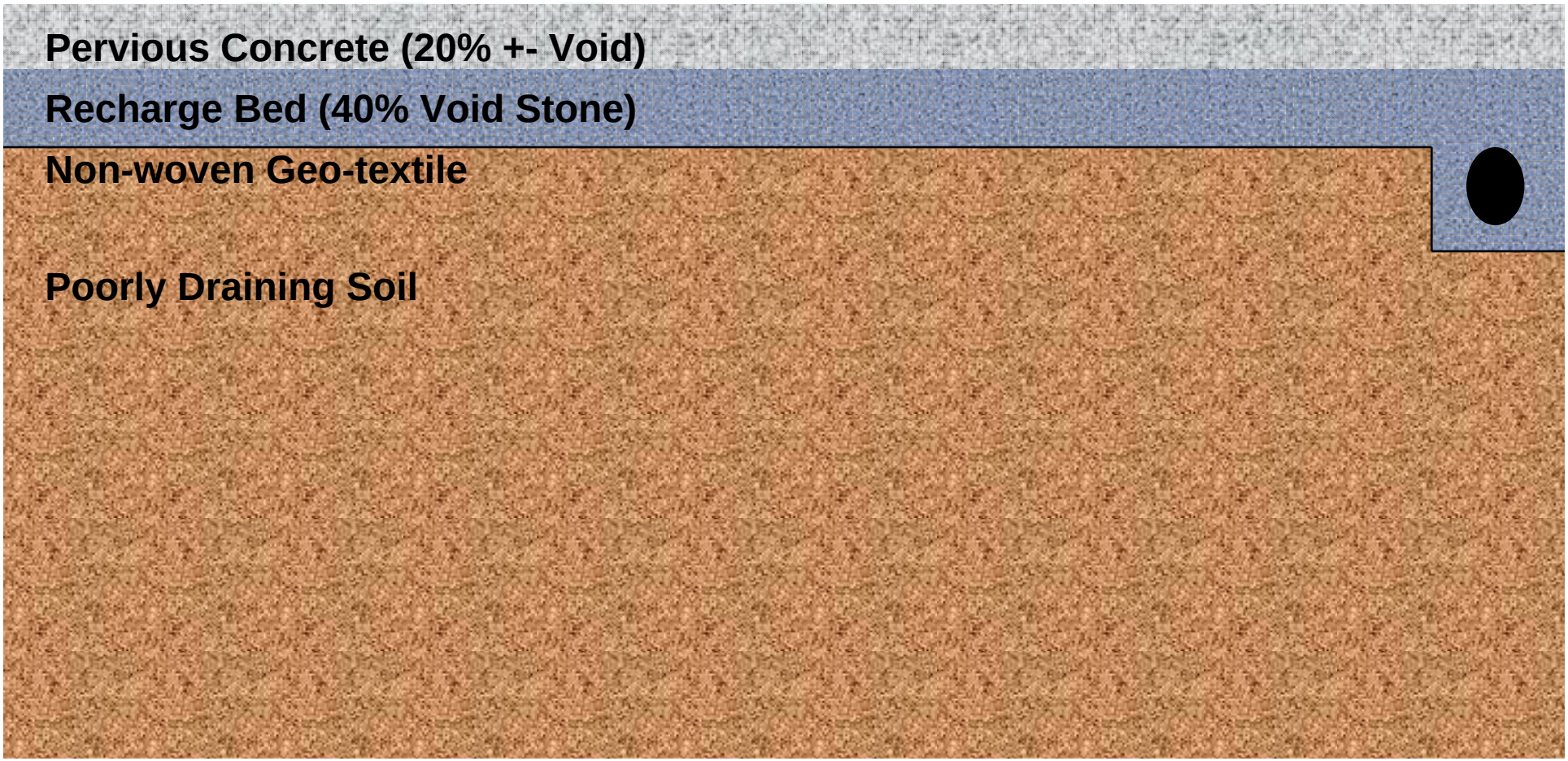
Non-woven Geo-textile
Poorly Draining Soil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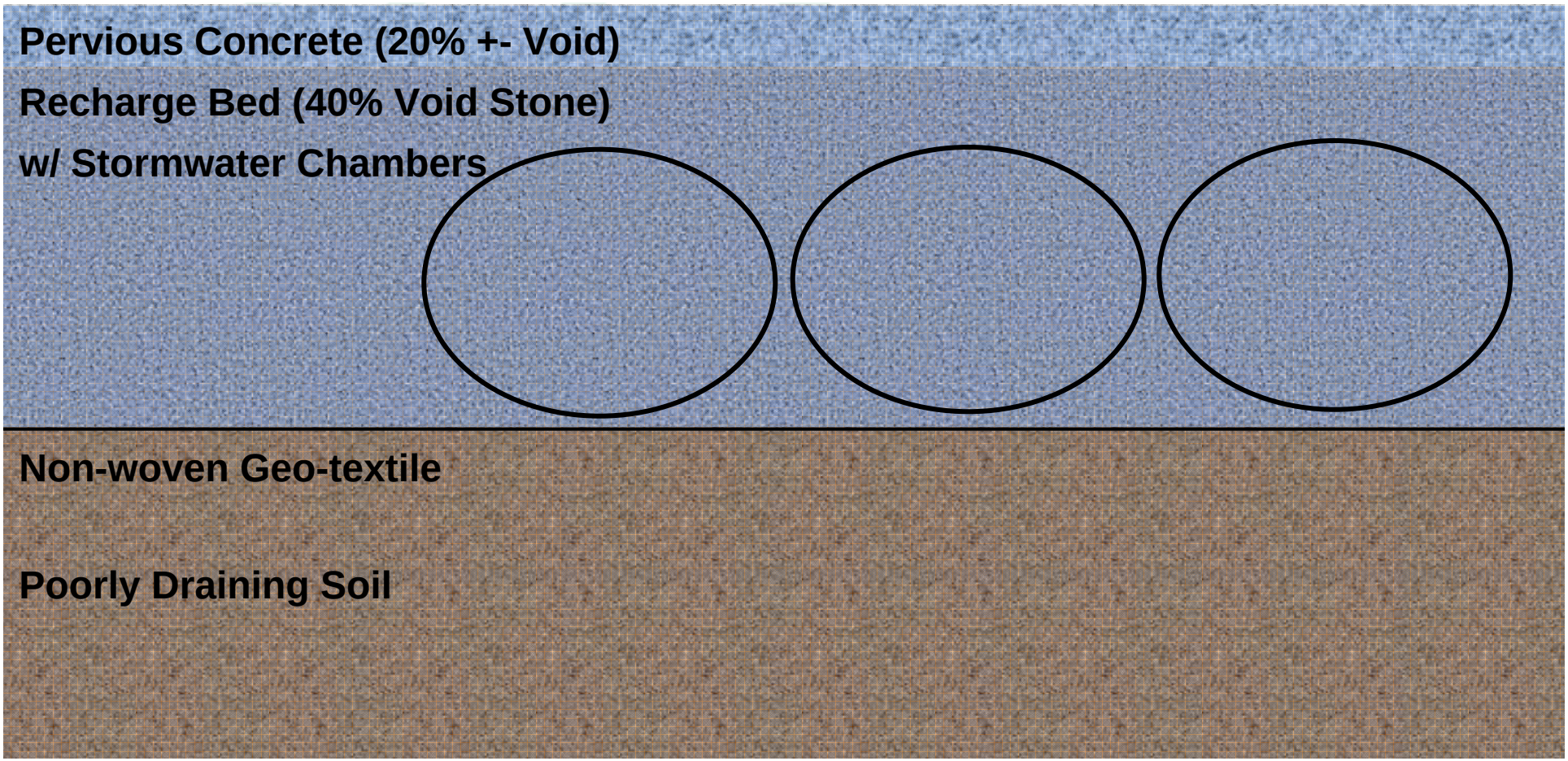
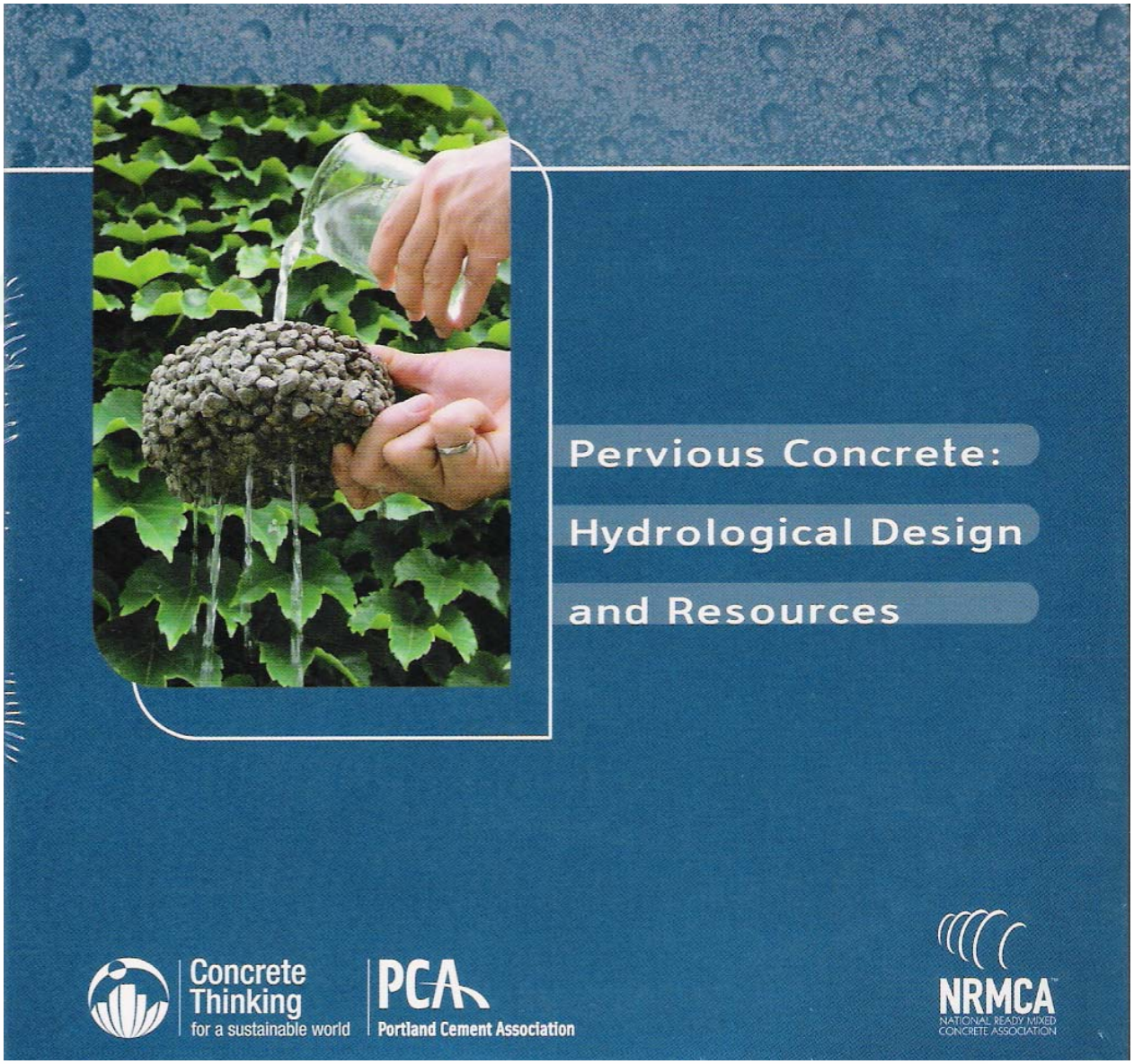

Pervious Concrete (20% +- Void)
Recharge Bed (40% Void Stone)
w/ Stormwater Chambers
Non-woven Geo-textile
Poorly Draining Soil

Hydrologic Analysis Software

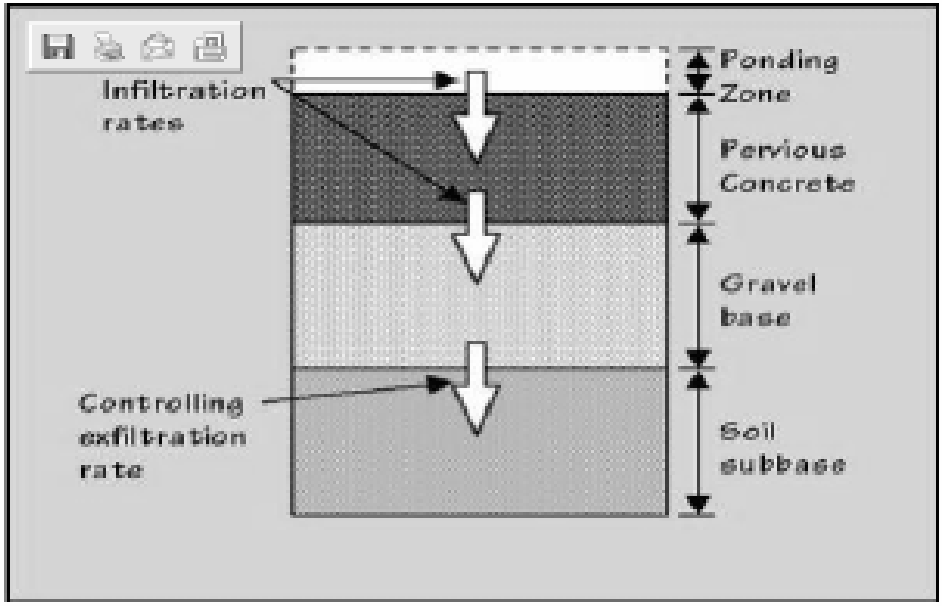


Hydrologic Software

- May be used as a design aid
- Provide preliminary designs for engineers
- Assist permit-granting agencies in verifying conformity to established stormwater runoff constraints

Passive Mitigation

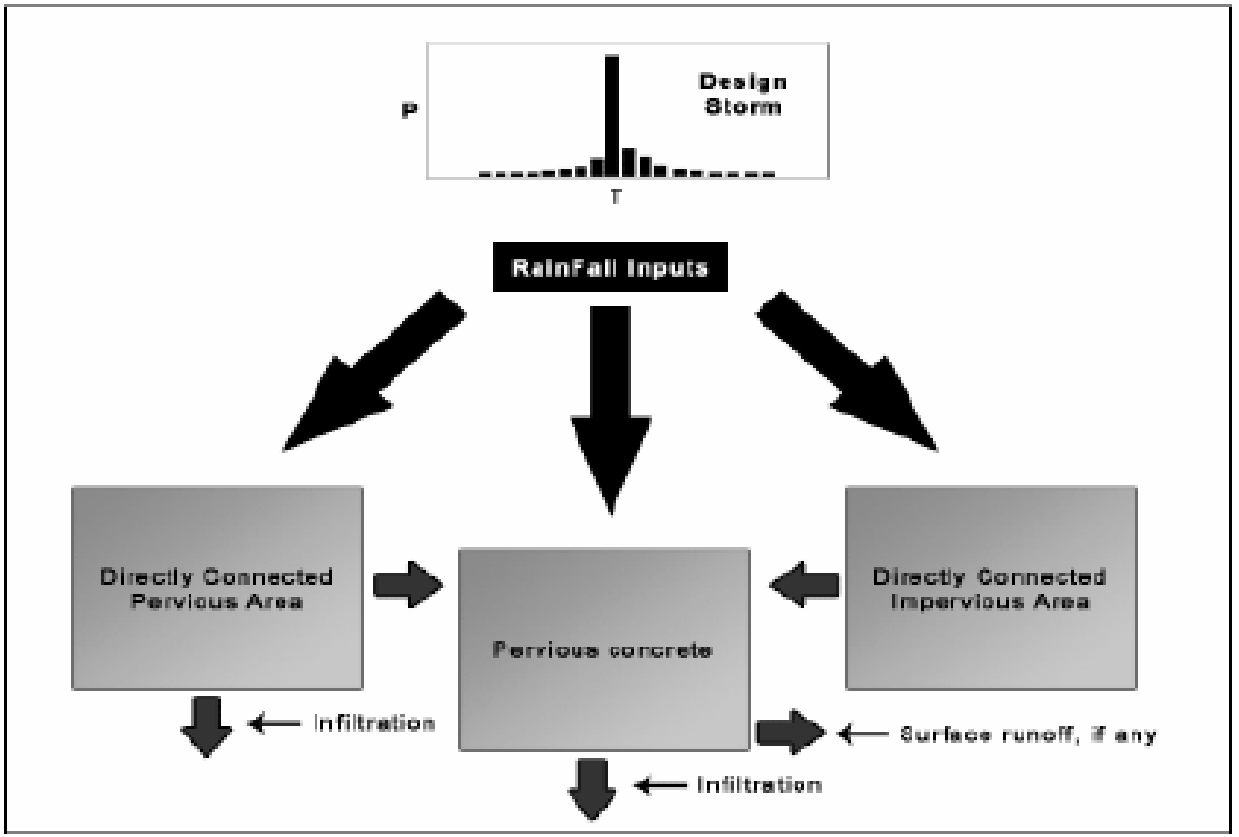
- Used to reduce quantity of impervious surface by replacing w/ pervious
- Can capture much, if not all, first flush
- Not intended to offset excess runoff from adjacent impervious surfaces



Active Mitigation

- Designed to maintain total runoff of a site at some specified level
- Must accommodate runoff from a much larger area
- Used when pervious concrete system is intended to capture a sizeable portion of the runoff from other areas
  - Buildings
  - Impervious pavements
  - Traffic islands
  - Buffer zones

Active Mitigation



System Performance Goals

- Have the pervious concrete system capture all of the stormwater resulting from rain falling on pavement surfaces (passive)
- Have the pervious concrete system capture not only the rain that falls directly on the pavement, but also from directly connected sections of impervious areas (active)
- Have the pervious concrete system reduce total runoff to a target value
  - Based on conditions of the site
  - Established by engineer and/or permitting agency

How the program works

- Estimates the volume of rainfall on the site in an appropriate design storm
- Estimates the volume of stormwater stored and infiltrated
- Estimates potential runoff
- Thereby determining if capacity of pervious concrete system is adequate

Navigating Through the Hydrologic Software

NRMCA®

Microsoft Excel - Crmca.xls

File Edit View Insert Format Tools Data Window Help Acrobat

Arial 9

Reply with Changes... End Review...

C10

Home

Data Input Sheet

Results

Instructions, Rainfall Info, SCS Curve Numbers

Pervious Concrete Spreadsheet For Hydrologic Analysis and Design

Overview

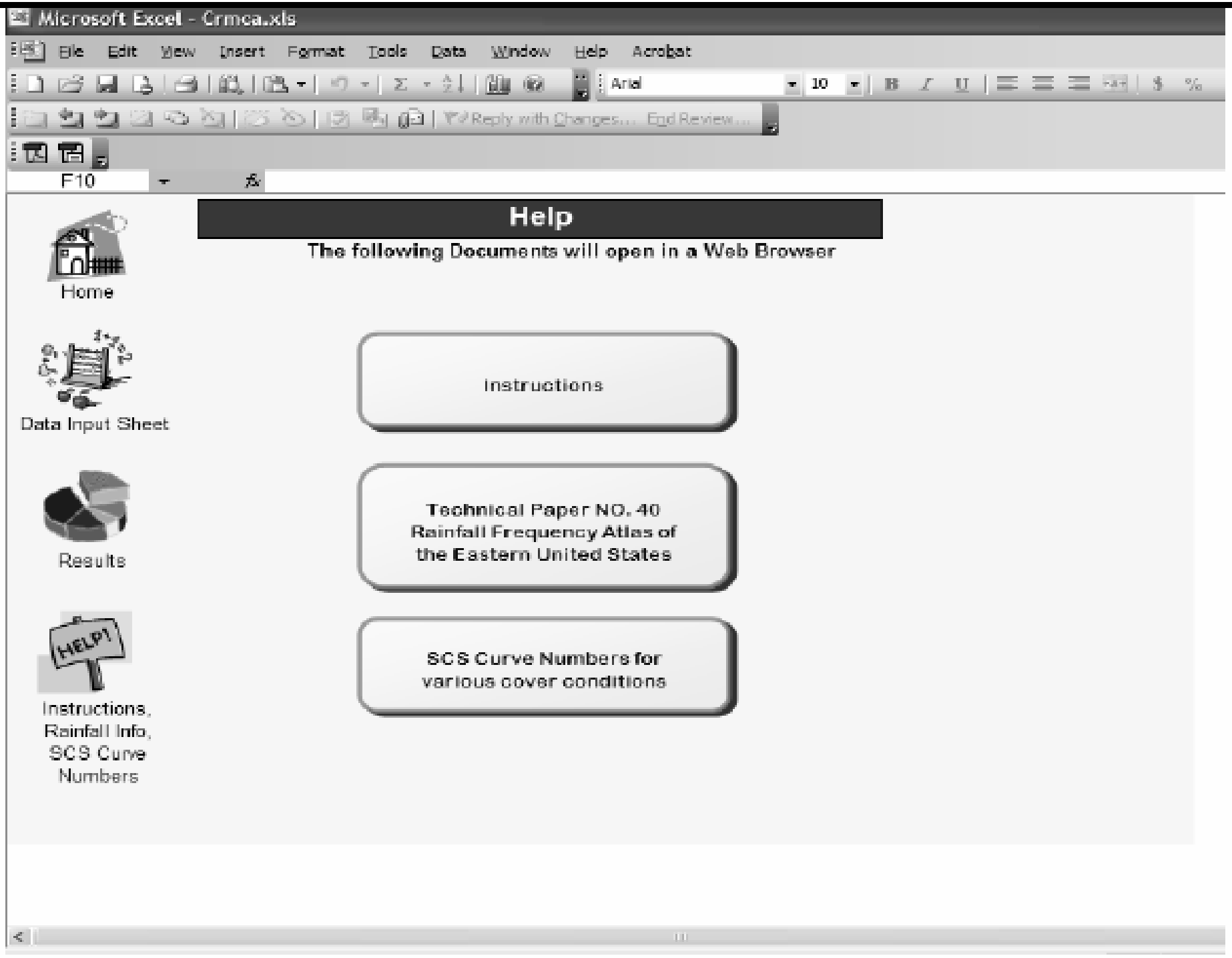
Click "**Data Input Sheet**" to begin entering in values.

Data Input Sheet

You can always click the top Left "Home Icon" to return to this page.

Contact:
Carolinas Ready Mixed Concrete Association
1805 J. N. Pease Place - Charlotte, NC 28262
V: (704) 717-9199 F: (704) 717-8688
email: info@crmca.com

Ready


Microsoft Excel - Crmca.xls
File Edit View Insert Format Tools Data Window Help Acrobat
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Reply with Changes... End Review...
F10
Help
The following Documents will open in a Web Browser
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Instructions, Rainfall Info, SCS Curve Numbers
Instructions
Technical Paper NO. 40 Rainfall Frequency Atlas of the Eastern United States
SCS Curve Numbers for various cover conditions

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Data Input Sheet

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Data Input Sheet

Project Details

Project:	Home Depot
Designer:	MZ
Date Run:	11/16/05

Pervious concrete		
Thickness	6	in
Surface area	43,560	sq ft
Porosity	15	%
Gravel base		
Thickness	6	in
Porosity	40	%
Ponding limit	0	in
Exfiltration rate	0.010	in/hr
Impervious surface		
Surface area	43,560	sq ft
Off-site drainage		
Area	0	sq ft
CN	0	

24-hr Precipitation	3.5	in
Location	Suwanee GA	
Return period	2	yr

Design Aim

Target CN	72

After you have completed entering the above data, click the Results Button:

Results

Thickness Design Guidelines

- 6”
- Light-duty / standard-duty parking lots
- Residential driveways

- 8”
- Residential streets
- Commercial driveways
- Heavier-duty parking lots

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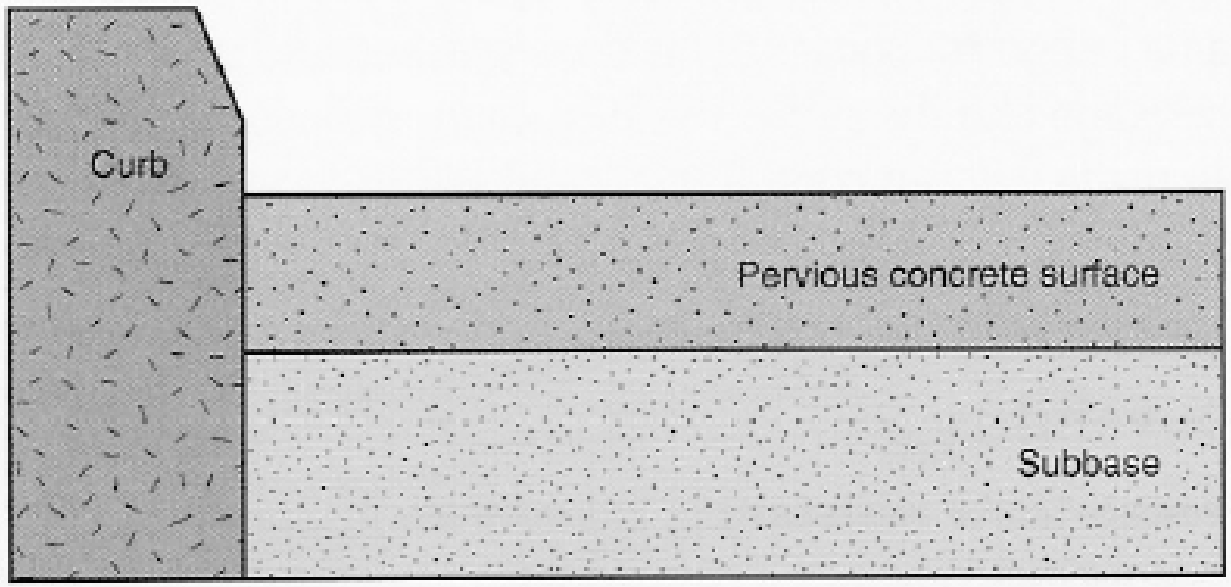

- Ponding limit allows for use of area above pavement surface, contained within confines off curb, to be included in calculations of temporary storage capacity

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Exfiltration Rates

- Malcolm says;
  - In sandy soils, use 0.5 to 1.0 in/hr
  - In silty soils, use 0.1 in/hr
  - In clayey soils, use 0.01 in/hr

Calculating for Underground Stormwater Chambers

- Assume volume of tanks is 100% void
- Stone base is 40% void
- Calculate weighted average void for tanks and stone base
- Enter this number as stone base void

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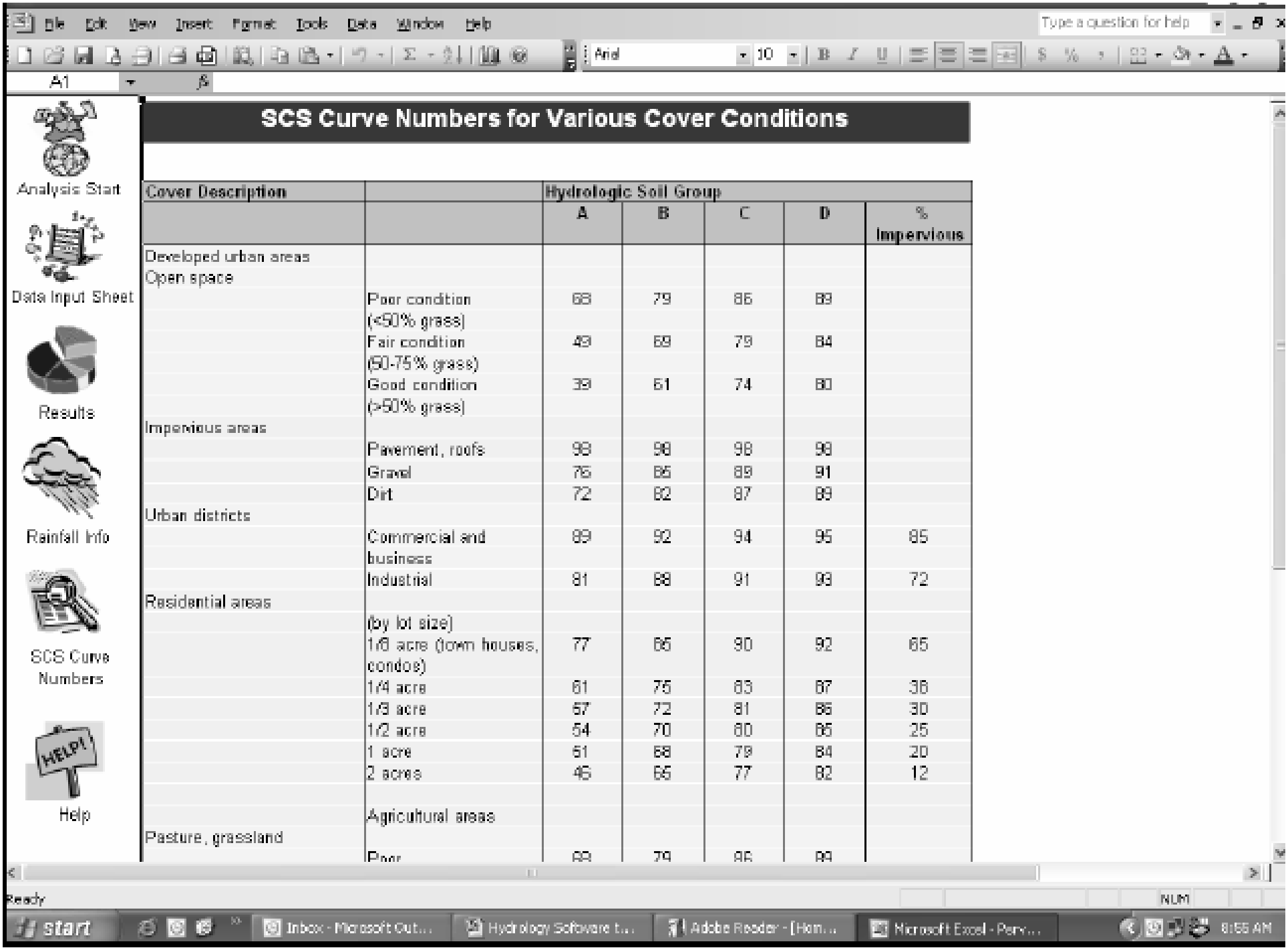
Active or Passive Mitigation?

- Calculate impervious surface on-site
- Calculate adjacent pervious area runoff
- Calculate adjacent impervious area runoff



SCS Curve Numbers for Various Cover Conditions

Cover Description		Hydrologic Soil Group				
		A	B	C	D	% Impervious
Developed urban areas						
Open space						
	Poor condition (<50% grass)	68	79	86	89	
	Fair condition (50-75% grass)	49	69	79	84	
	Good condition (>50% grass)	39	61	74	80	
Impervious areas						
	Pavement, roofs	98	98	98	98	
	Gravel	76	85	89	91	
	Dirt	72	82	87	89	
Urban districts						
	Commercial and business	89	92	94	95	85
	Industrial	81	88	91	93	72
Residential areas						
	(by lot size)					
	1/8 acre (town houses, condos)	77	85	90	92	65
	1/4 acre	61	75	83	87	38
	1/3 acre	57	72	81	86	30
	1/2 acre	54	70	80	85	25
	1 acre	51	68	79	84	20
	2 acres	46	65	77	82	12
	Agricultural areas					
Pasture, grassland						
	Poor	68	79	86	89	

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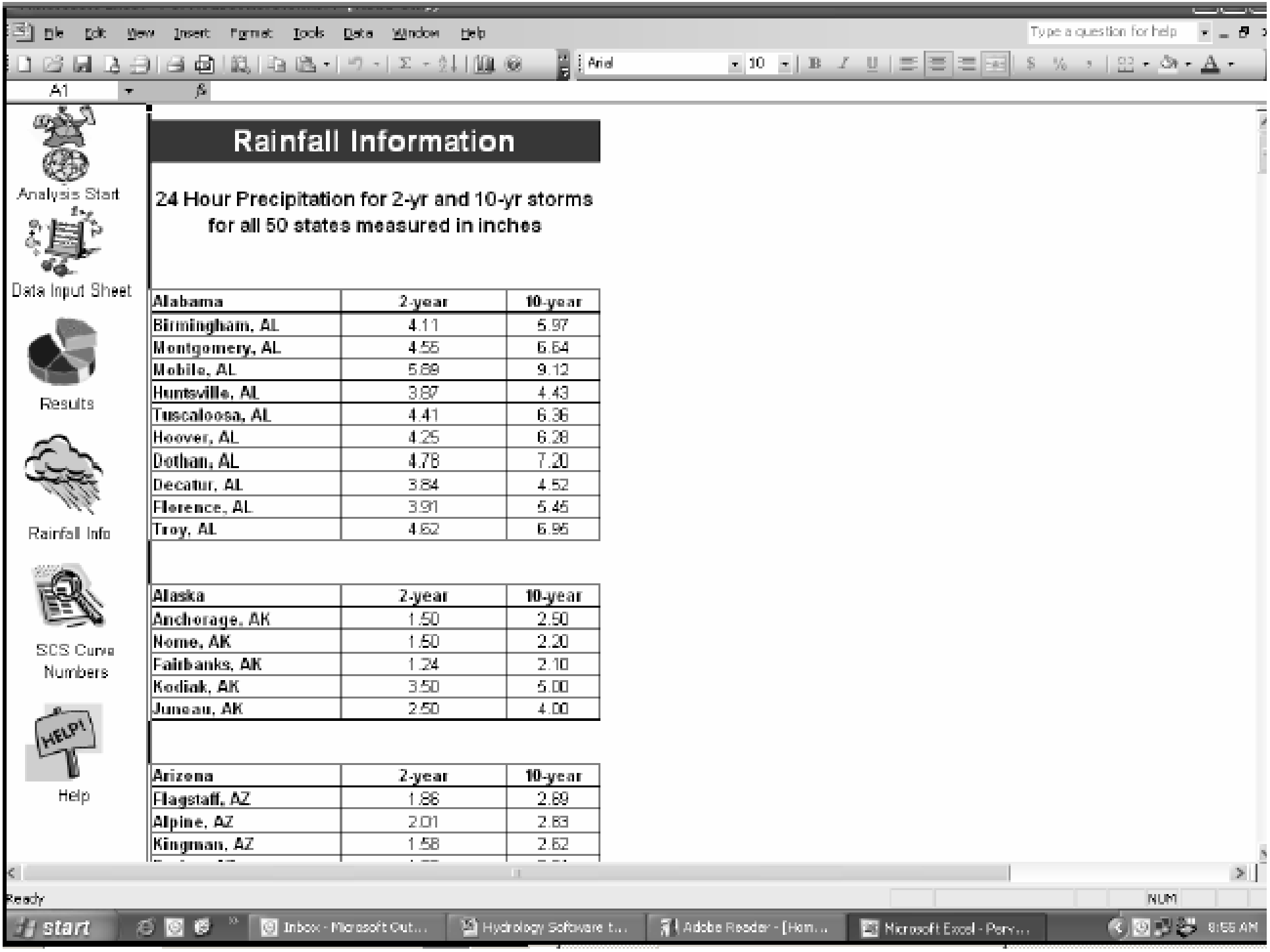
Storm Event

- Usually 2-yr event
- Suggest checking 5-yr event
- Program pre-loaded with data from US Weather Service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A1
Analysis Start
Data Input Sheet
Results
Rainfall Info
SCS Curve Numbers
HELP!
Help
Rainfall Information
24 Hour Precipitation for 2-yr and 10-yr storms for all 50 states measured in inches
Alabama | 2-year | 10-year
Birmingham, AL | 4.11 | 5.97
Montgomery, AL | 4.55 | 6.64
Mobile, AL | 5.69 | 9.12
Huntsville, AL | 3.87 | 4.43
Tuscaloosa, AL | 4.41 | 6.36
Hoover, AL | 4.25 | 6.28
Dothan, AL | 4.76 | 7.20
Decatur, AL | 3.84 | 4.52
Florence, AL | 3.91 | 5.45
Troy, AL | 4.62 | 6.95
Alaska | 2-year | 10-year
Anchorage, AK | 1.50 | 2.50
Nome, AK | 1.50 | 2.20
Fairbanks, AK | 1.24 | 2.10
Kodiak, AK | 3.50 | 5.00
Juneau, AK | 2.50 | 4.00
Arizona | 2-year | 10-year
Flagstaff, AZ | 1.86 | 2.69
Alpine, AZ | 2.01 | 2.83
Kingman, AZ | 1.58 | 2.62
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Design Aim

Target CN	72

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Results

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Design Aim

- Input target curve number
- Represents the permissible runoff
- Useful where post-construction CN must meet certain design criteria with regard to pre-construction CN

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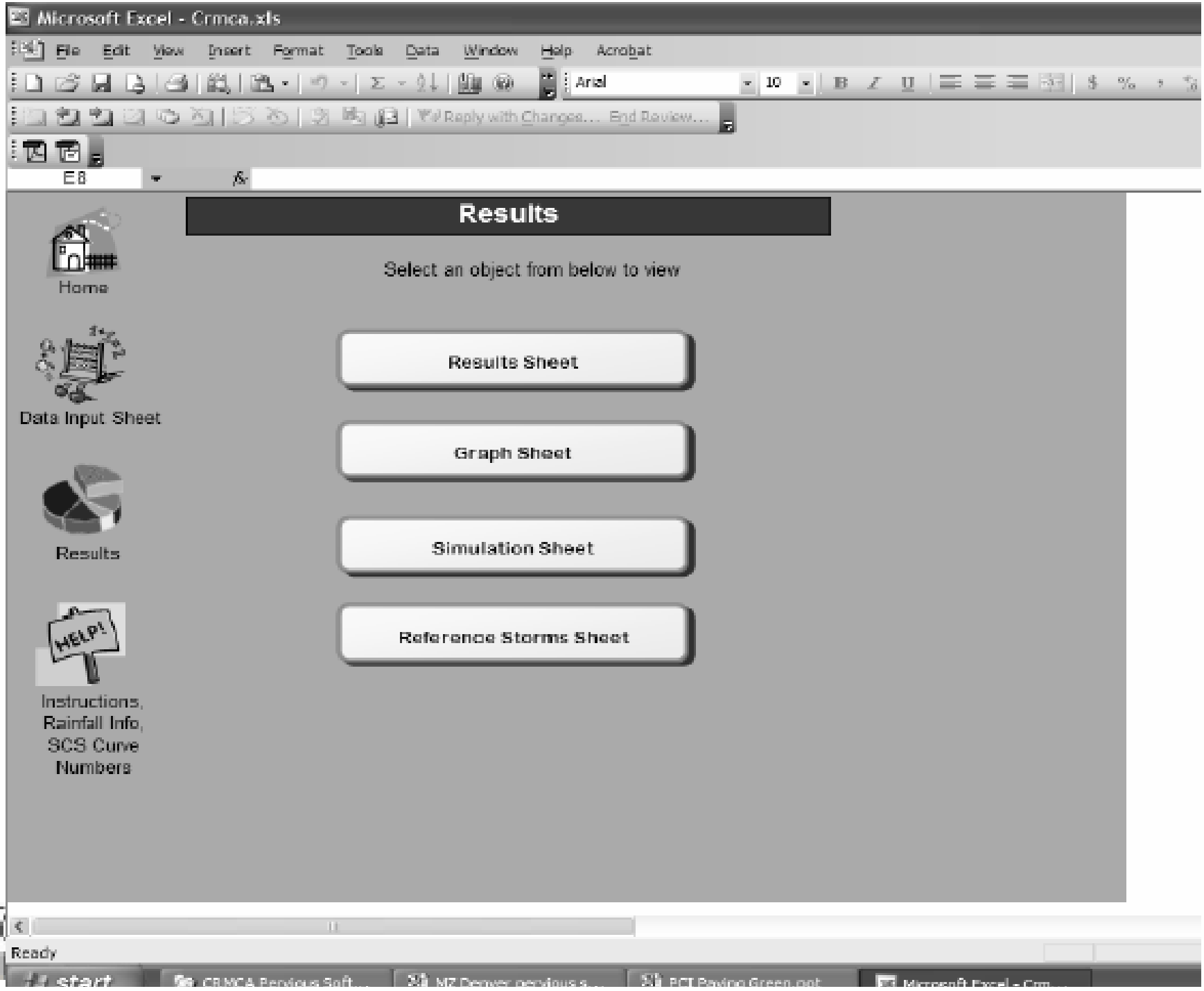
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Arial 10
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E8
Results
Select an object from below to view
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Data Input Sheet
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Results Sheet
Graph Sheet
Simulation Sheet
Reference Storms Sheet
Ready

Results Sheet

Project:	Home Depot
Designer:	MG

Values shown in blue are user inputs.
Values shown in red are computed results.
See section notes below.

Run date: 11/16/06

Configuration

Pervious concrete
- Thickness: 6 in
- Surface area: 43,560 sq ft
- Porosity: 15 %

Gravel base
- Thickness: 4 in
- Porosity: 40 %

Ponding limit: 0 in

Exfiltration rate: 0.100 in/hr

Impervious surface
- Surface area: 43,560 sq ft

Off-site drainage
- Area: 0 sq ft
- CN: 0

24-hr Precipitation: 3.1 in
Location: Your Location
Return period: 2 yr

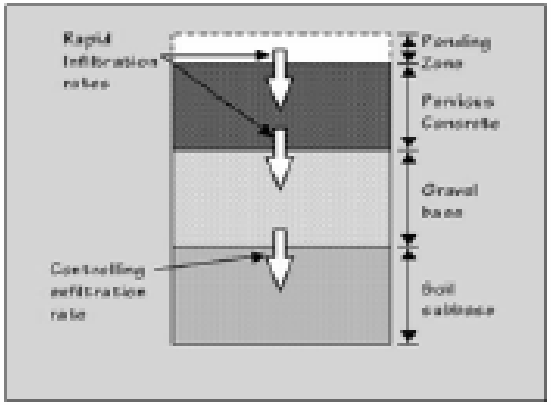
Design aim
- Target CN: 72
- Allowable runoff: 1.12 in

Summary of results

Effective CN	72
Estimated runoff (5 days)	1.12 in
Available storage used	100 %
Number of hours of ponding	0
Max ponding depth	0.0 in
Available storage after 24 hr	5 %
Available storage after 5 days	100 %
Stage after 5 days	0.0 in
Additional time to drain completely	0 hr

Intermediate results

Total drained surface area	87,120 sqft
Storage capacity, pervious concrete	3,267 cuft
Storage capacity, gravel base	1,808 cuft
Storage capacity, ponding	0 cuft
Total stormwater storage	5,075 cuft
Total precip volume	25,410 cuft
5-day exfiltration volume	17,297 cuft
Total runoff (overflow)	3,113 cuft
Water stored after 5 days	0 cuft
Water balance error	0.0 cuft



Caution: This spreadsheet is intended for study purposes to illustrate expected hydrologic behavior of pervious concrete. Designers must verify results for specific sites before independent use.

Designing for Special Considerations

Freeze-Thaw

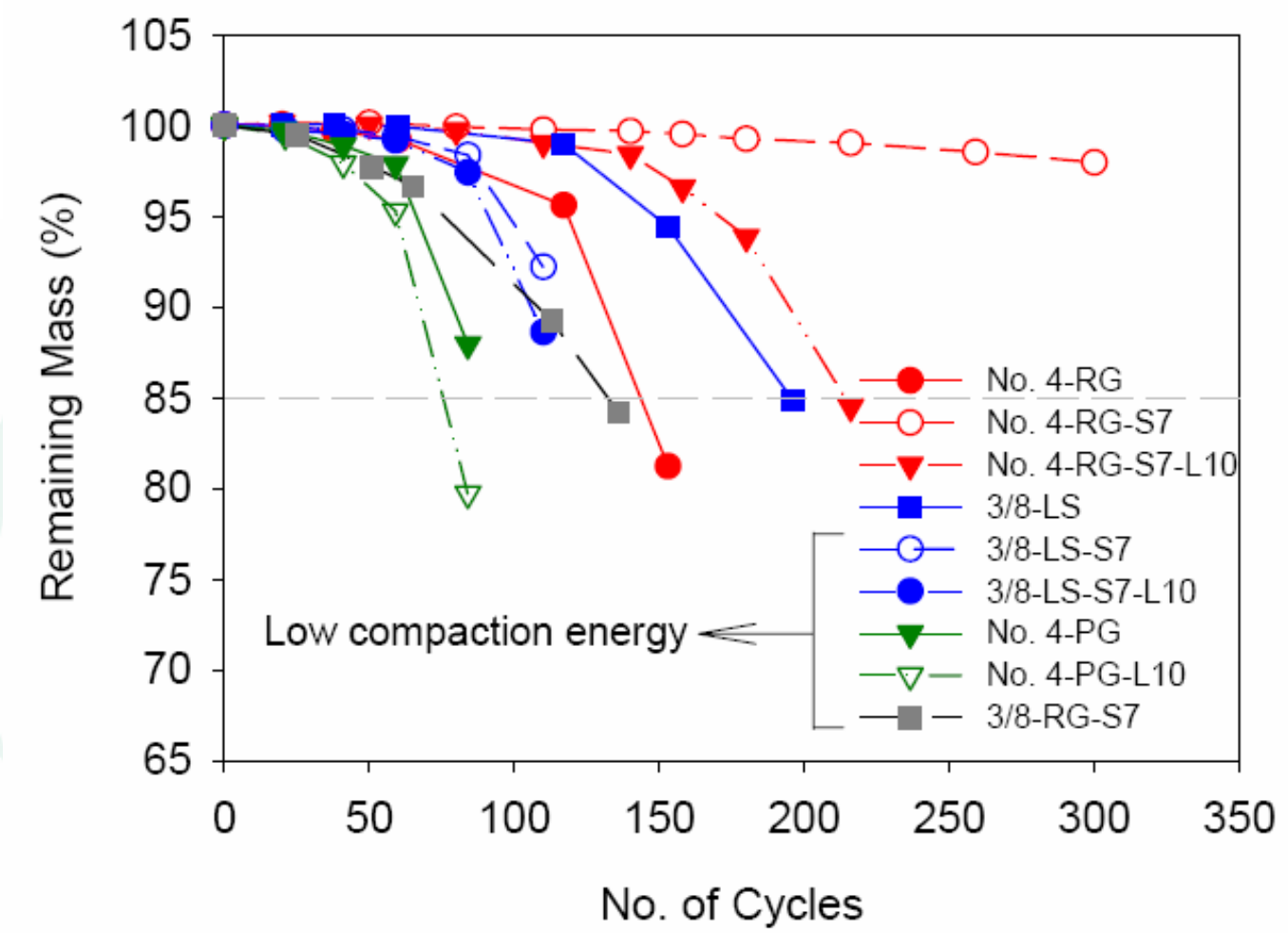
Iowa State University

- In conjunction with:
  - Center for Transportation Research and Education
  - National Center for Concrete Pavement Technology
- Prepared mixes with varying aggregates, admixtures, etc.

Table 4. Phase II Mixture Proportions

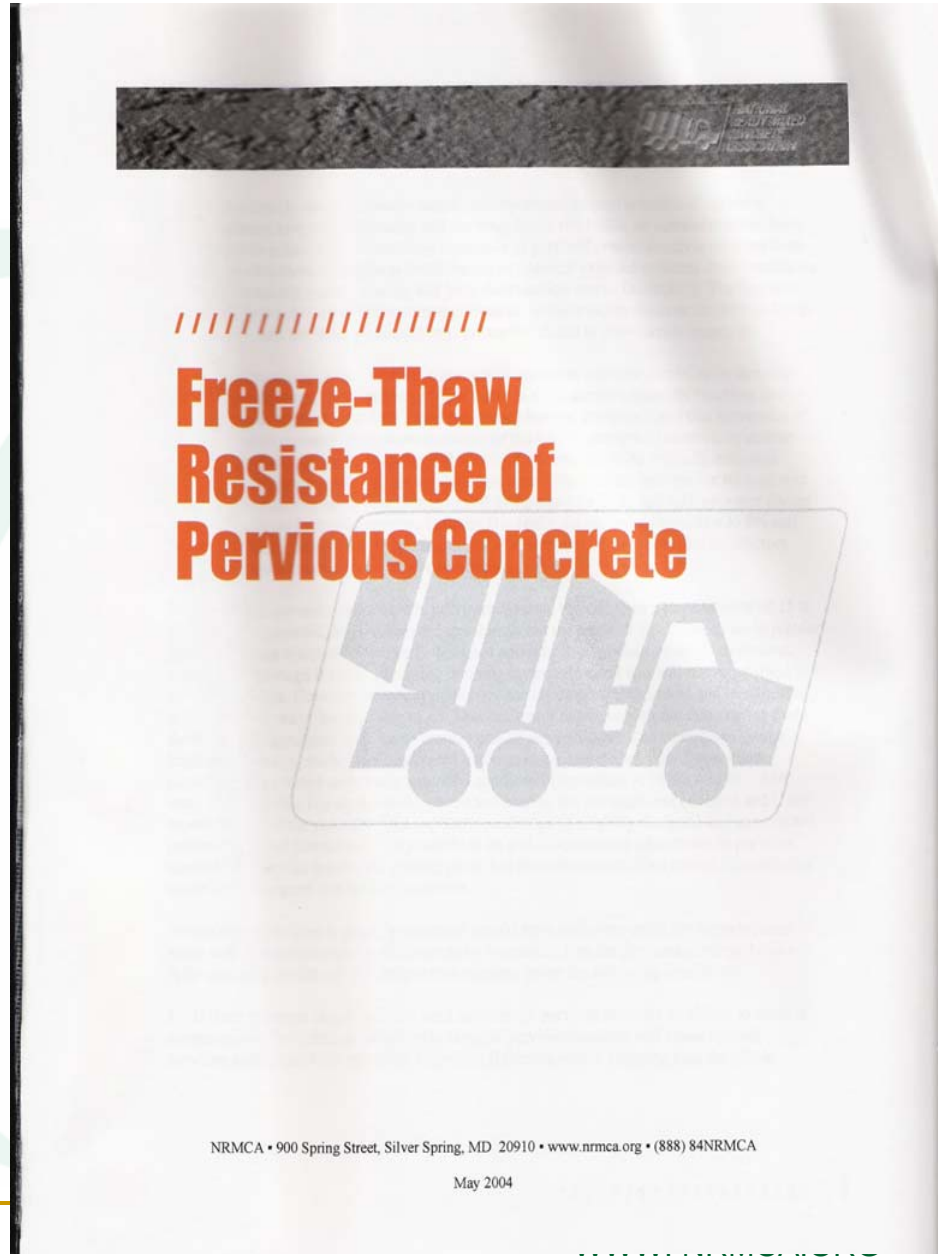
Mix	Aggregate Type	Size	Unit Weight (lb/CY) PC	Silica Fume	Latex	G	S	Water	Water/Binder
12	River Gravel	#4	571	-	-	2500	168	154	0.27
10	River Gravel	#4	525	-	52.5	2700	-	116	0.27
8	River Gravel	#4	520	-	52	2500	168	114	0.22
13	River Gravel	#4	542.5	-	28.5	2500	168	130	0.24
14	River Gravel	#4	485.4	-	85.6	2500	168	107	0.22
19	River Gravel	3/8"	571	-	-	2500	168	154	0.27
5	River Gravel	3/8"	522.5	27.5	-	2700	-	149	0.27
11	River Gravel	3/8"	520	52	-	2500	168	114	0.27
4	Limestone	3/8"	522.5	27.5	-	2700	-	149	0.27
16	Limestone	3/8"	571	-	57.1	2500	168	126	0.22
17	Limestone	3/8"	600	-	60	2500	200	132	0.22

3400 psi @ 7 days, 3800 psi @ 28 days for this mix
Permeability is over 300 gallons per hour



Samples have passed 300 cycles with approximately 2% loss of mass

- Study conducted by NRMCA Results available at www.nrmca.org



NRMCA

Freeze-Thaw Resistance

- Depends on saturation level
- Avoid critical saturation
  - Design
    - Infiltration System
    - Secret of success is to provide the water a place to go
  - Maintenance
    - Cleaning, as needed, in severe climates

Designing for Special Considerations

Heavy Traffic

Shelter Systems Ltd. Westminster, MD

- Pavement used as staging area for completed truss systems
- Required heavy duty pavement
  - 30 to 40 trucks per day

Shelter Systems Ltd. Westminster, MD

- R/M adjusted mix
- Added 500 lbs. fine agg. per CY
- Placed with ABG dual-compaction paver
- Rolled with small static roller
- Flexural strength 650 psi (7 days)

Shelter Systems Ltd. Westminster, MD

- Approximately 8 acres of pavement
- Mix design can accommodate 80” of rain per hour
- 10 times intensity of 100 year rainfall event!

ACI 522 Pervious Concrete Guide to Specification

ACI 522 – Pervious Concrete

- Specification Guide Document in Final Review
- Performance specification
- Provides Guidelines for
  - Quality Assurance
    - Materials
    - Testing
  - Placement

Section 1.6: Quality Assurance

1.6.1.1 ***Contractor qualification*** - Unless otherwise approved by Architect/Engineer, Contractor shall provide evidence of employment of one **(1) NRMCA certified Pervious Concrete Craftsman** who must be on site, overseeing each placement crew, during all concrete placement, or the contractor shall provide evidence of employment of five **(5) NRMCA certified Pervious Concrete Technicians**, who have received hands-on training in the construction of pervious concrete pavements, and who must be on site, working as members of each placement crew, during all concrete placement, or, with the approval of Architect/Engineer, contractor may provide written evidence of project experience and proficiency in successfully completing pervious concrete pavement construction, and submit evidence of completion of a pervious concrete craftsman certification program.

NRMCA Recommended Addendums to Specification

Section 1.6: Quality Assurance

1.6.1.2 ***Concrete Producer qualification*** – Unless otherwise approved by Architect/Engineer, ready mixed pervious concrete **shall be produced and provided by an NRMCA Certified plant**. If, rather than ready mixed pervious concrete, a volumetric mobile mixer is used to produce the pervious concrete, the mixer(s) must conform to the standards of the Volumetric Mixer Manufacturers Bureau (VMMB), to be verified by a current VMMB conformance plate affixed to the volumetric mixer equipment.

Section 1.6: Quality Assurance

1.6.1.2 ***Concrete Producer qualification*** – Unless otherwise approved by Architect/Engineer, ready mixed pervious concrete shall be produced and provided by an NRMCA Certified plant. If, rather than ready mixed pervious concrete, a **volumetric mobile mixer** is used to produce the pervious concrete, the mixer(s) **must conform to the standards of the Volumetric Mixer Manufacturers Bureau (VMMB),** to be verified by a current VMMB conformance plate affixed to the volumetric mixer equipment.

Section 1.5; Submittals

1.5.3.2 ***Pre-Placement Conference*** – A mandatory pre-placement conference will take place including at a minimum, the architect, engineer, general contractor, pervious concrete contractor, concrete supplier, and field testing agency. As a guide for the meeting, a copy of the document ***Checklist for the Concrete Pre-Construction Conference*** (co-published and available from the National Ready Mixed Concrete Association (NRMCA), 900 Spring Street, Silver Spring, MD, (301) 587-1400 ***or*** the American Society of Concrete Contractors (ASCC), 2025 South Brentwood Boulevard, St Louis, MO, (314) 962-0210), will be used to review all materials and personnel qualifications, concrete production, preparation, placing, curing, and testing procedures.

Resources

Specifying Pervious Concrete

- ACI 522 Guide Document
- PCA/NRMCA Pervious Concrete Pavements
- PCA/NRMCA Hydrologic Software
- www.PerviousPavement.org

NRMCA

Pervious Concrete Contractor Certification Program

NRMCA

Questions?

Thank You!

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