Linking Stormwater and Groundwater Management: the role of Low Impact Development

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Darla Inglis, Ph.D.
www.lowimpactdevelopment.org

The Mechanistic Model is how we address environmental issues

stormwater & LID

water supply

groundwater

wastewater

climate change

energy

Need to integrate into a Watershed Model

What take home or thought provoking messages do you want the audience to get?

An increasingly “sustainable watershed” perspective of water resource management is moving us from an issue specific approach toward a broader context of risks, benefits, and consequently, appropriate solutions.

This will necessitate an understanding (and coordination!) of related water resource management disciplines including regulatory, technical and policy considerations.

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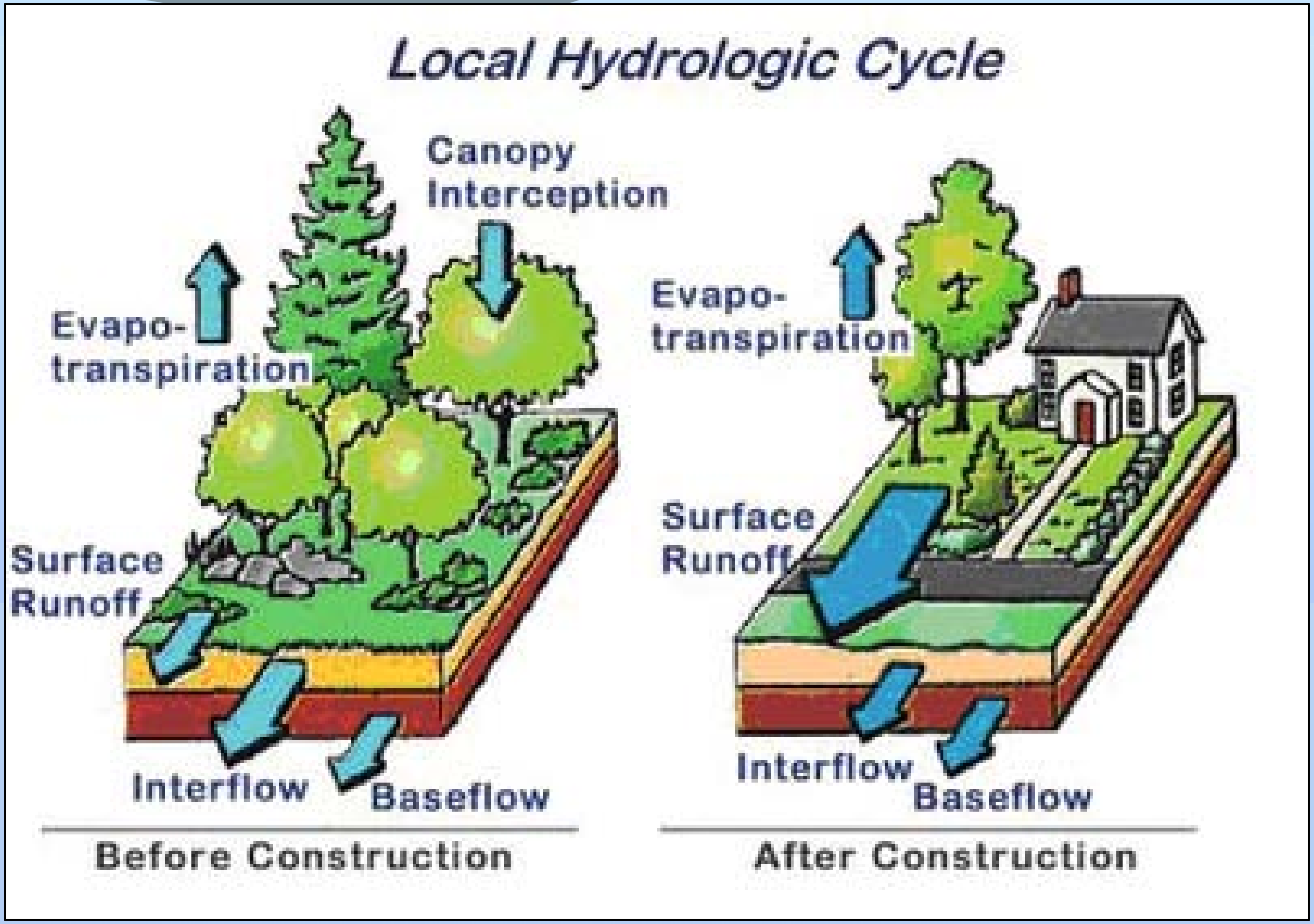
Presentation Outline:

1. Evolution of stormwater management and the role of LID
2. Pollutant fate in stormwater management systems and risk to groundwater resources
3. Solutions to improve LID use for water resource management

Evolution of Stormwater Management and the Role of LID

We’ve Changed the Hydrology of our Watersheds



(Courtesy of Maryland Dept. Env.)

This urban hydrology has negative impacts to public health, property, and the environment.

History of Stormwater Management

Courtesy of the City of Seattle

Courtesy of the City of New Brighton

Courtesy of the City of Seattle

Protection of Public Health & Property

↓

WQ and Peak Flow Management

↓

Decentralized Stormwater Management

Courtesy of the City of Seattle

Photo from Utility Vault for Stormwater Management, Inc.

LID is a Tool

←

What is LID?

LID is an approach that ….

…mimics the predevelopment site hydrology

by using:

site planning (nonstructural) and

management practices (structural)

that store, infiltrate, evaporate, and detain runoff. WQ treatment objectives can also be addressed.

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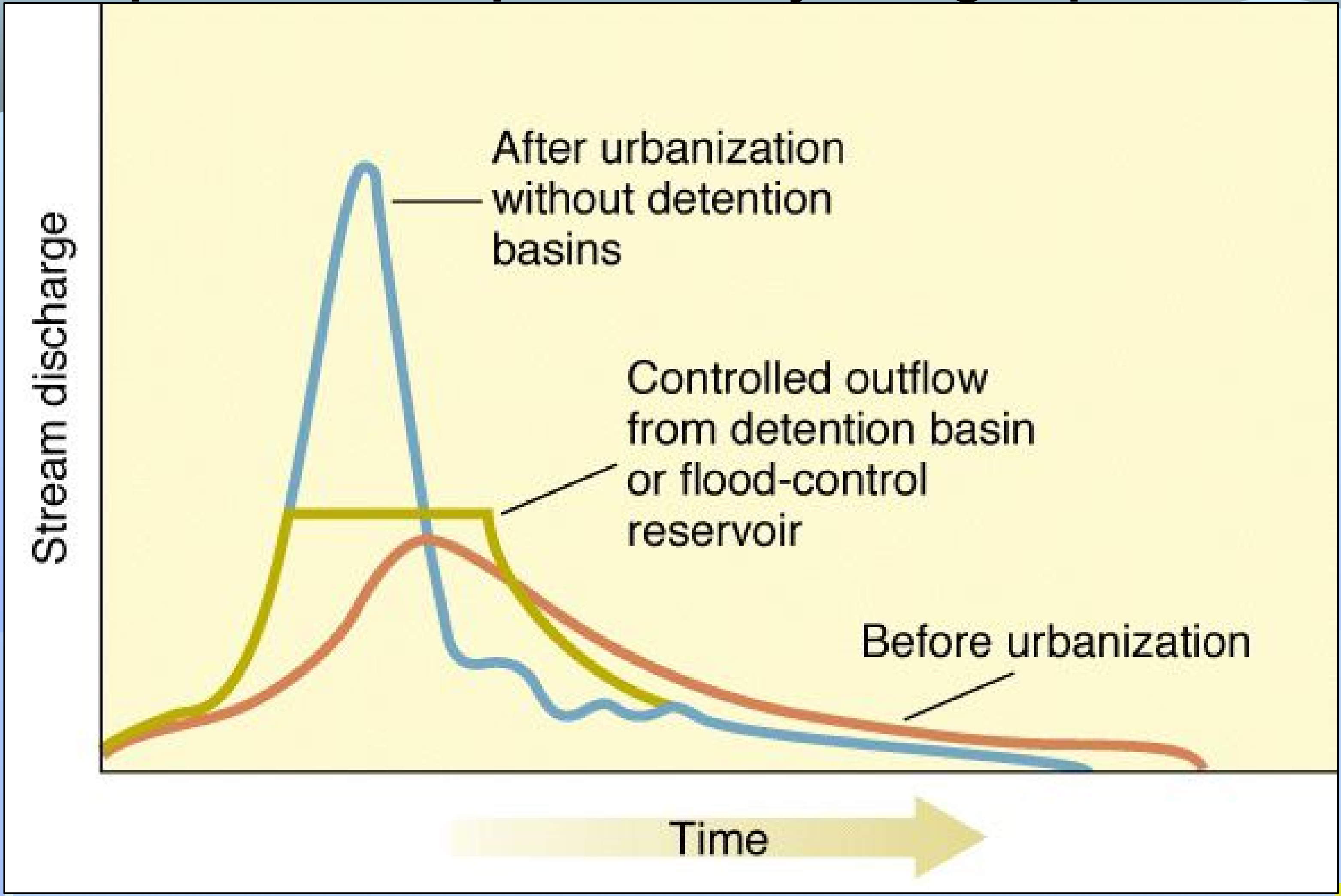
What does it mean to "mimic the predevelopment hydrograph?"



Courtesy Carlton College, MN

must address peak, duration, & volume

Examples of LID Strategies and BMPs

Non-structural

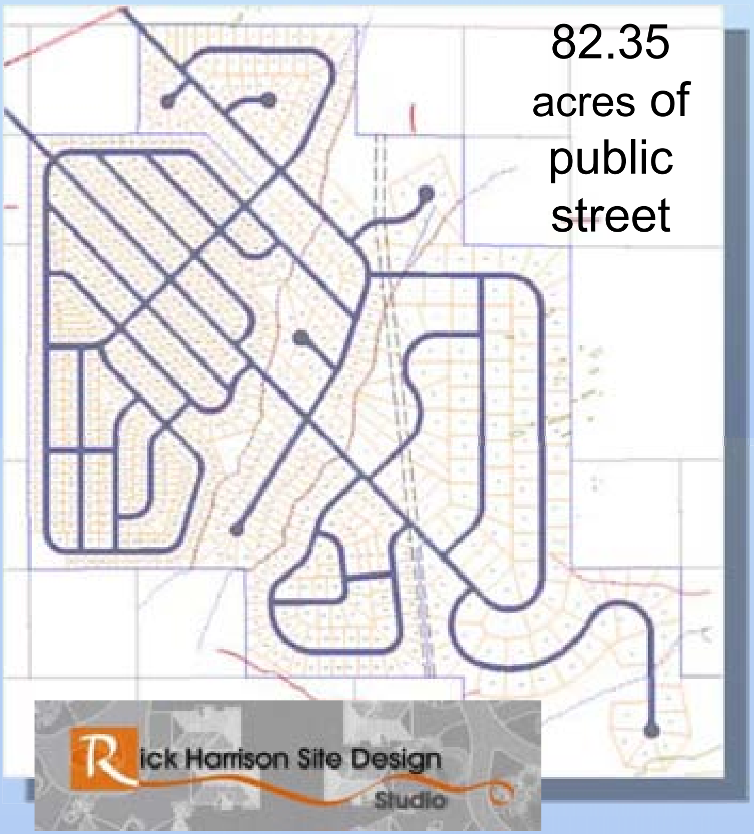
- -Minimize Impervious Surface

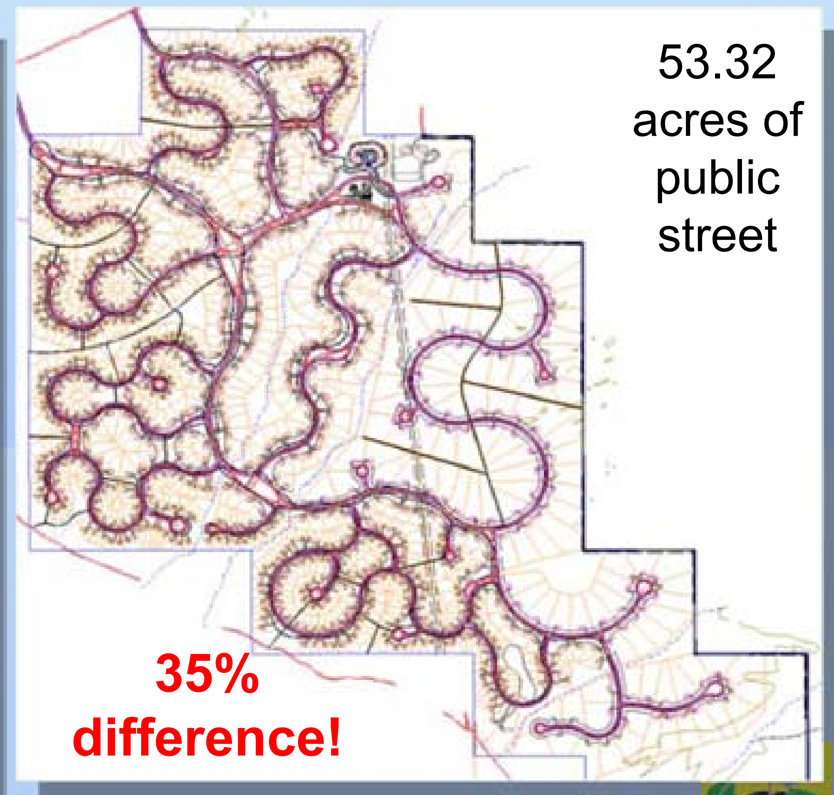
Structural

- -Porous pavements
- -Bioretention
- -Downspout disconnection
- -Cisterns
- -Green roofs

Non-structural LID Example: Minimize Impervious Areas

1) alternative roadway layout





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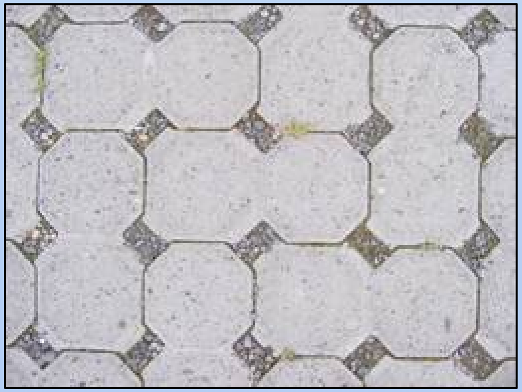
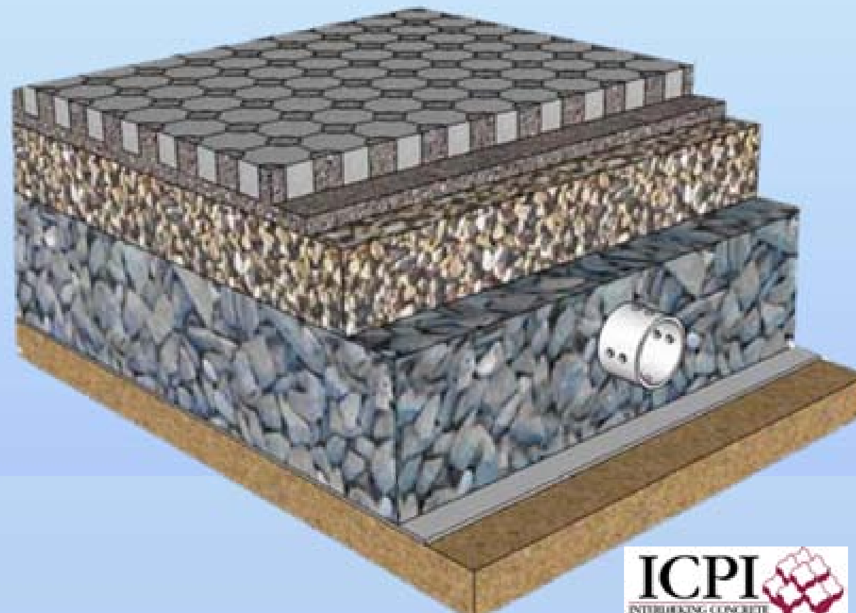
LID Structural Practices: Permeable Paving

What is it?

A porous surface that allows rainwater to percolate down into the ground instead of running off.



Permeable Paving in Parking Lots



ICPI
INTERLOCKING CONCRETE PAVEMENT INSTITUTE

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LID Structural Practices: Bioretention

LID stormwater volume and water quality design with a depressed shape, appropriate vegetation, and amended soils.

↑ rain gardens

↑ curb bulb extension

planting strip ←

LID Techniques: Bioswales

BEFORE → LID: BIOSWALE → AFTER

More LID bioretention designs

↑ Street right-of-way bioswale

Parking lot bioswale

←

Components of a Bioretention System

Overflow Weir to Storm Sewer

Native Plantings

Mulch Layer

Bioretention Soil Mix

Geotextile

Gravel Layer

Perforated Underdrain

Impermeable Liner*

Pollutant fate in stormwater management systems and risk to groundwater resources

Typical Stormwater Pollutants

Nutrients (P, N)

Heavy metals (Pb, Zn, Cu, Cd)

Suspended Solids

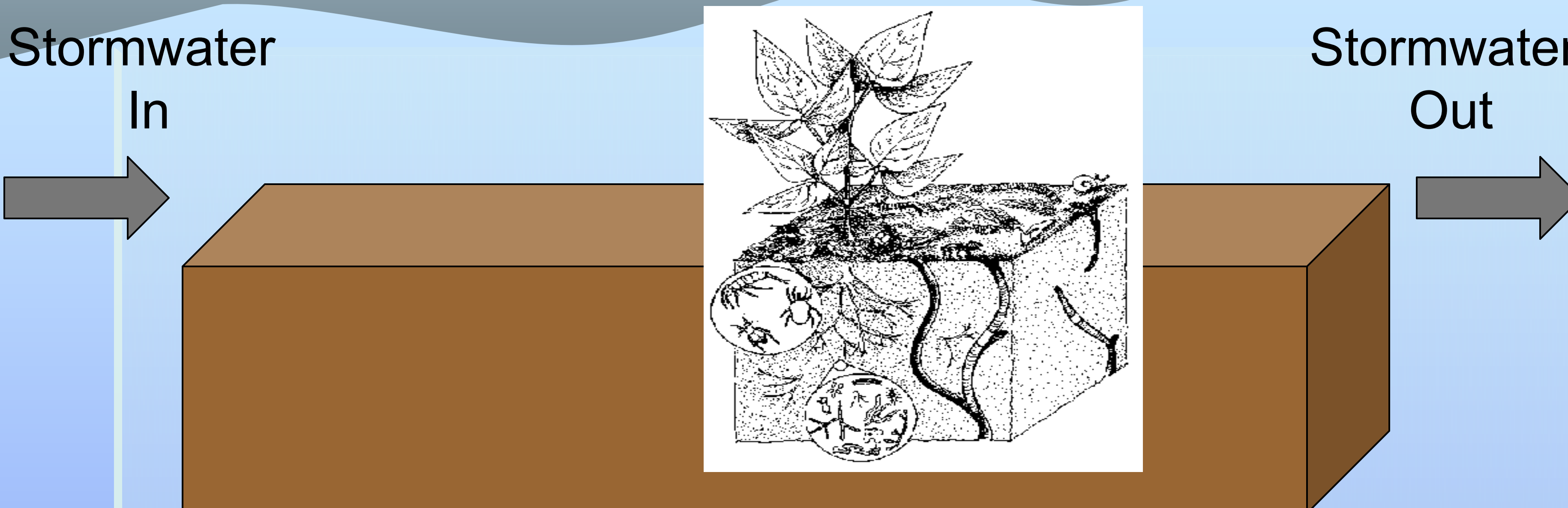
Petroleum Hydrocarbons

Pathogens

Salts

Flow?

Pollutant Fate in an LID System



-Sedimentation
-Filtration
-Adsorption
-Redox

-Degradation
-Plant Uptake
-Volatilization
-Pass through

-subsurface/groundwater contamination

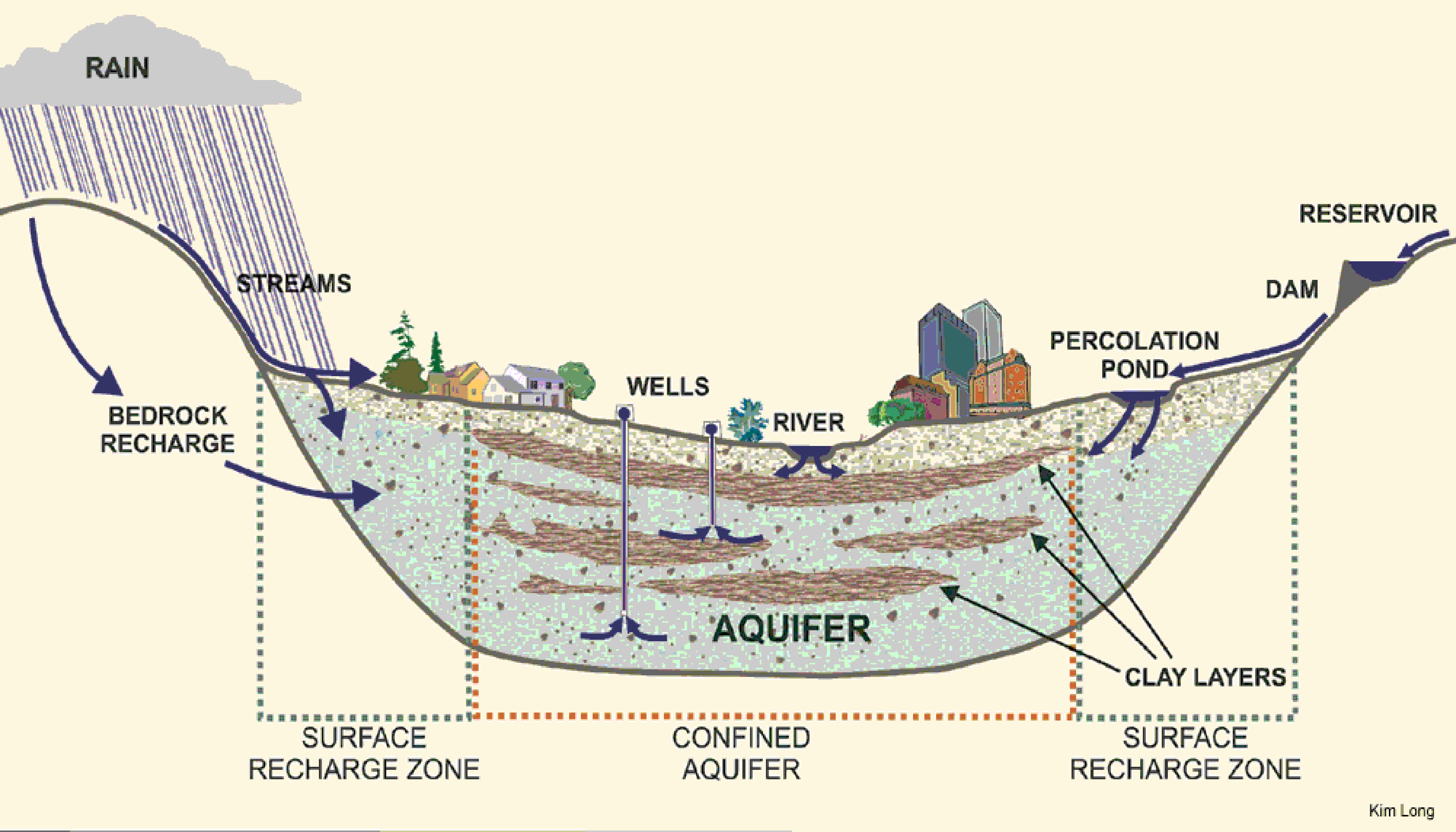
LID Infiltrative Systems: Design and Maintenance Considerations for Groundwater Protection

Factors:

-Location of LID facility in the watershed
-Pollutant type and concentration
-Underlying Soil type
-LID facility design
-LID facility operation and maintenance

Groundwater Considerations When Using LID

Location of the LID facility in the Watershed



Groundwater Considerations When Using LID

Groundwater Contamination Potential for Stormwater Pollutants

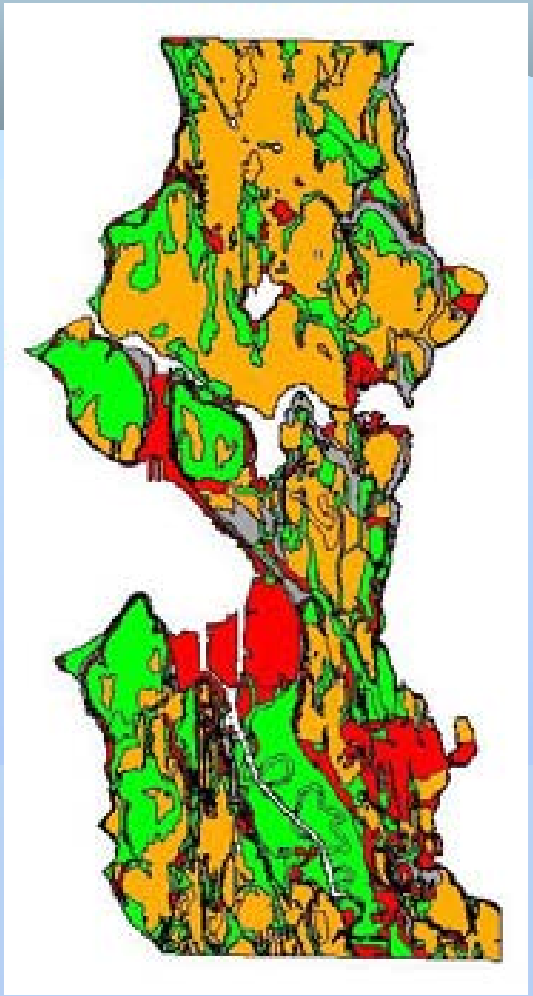
(Clark, S.E., Pitt, Pitt, R. 2007)

Compound class	Compounds	Mobility (worst case: sandy/low organic soils*)	Abundance in stormwater	Fraction filterable (dissolved)
Nutrients	Nitrate	I	Low/moderate	High
Pesticides	2,4-D	I	Low	Likely low
	γ-BHC (lindane)	II	Moderate	Likely low
	Atrazine	I	Low	Likely low
	Chlordane	II	Moderate	Very low
	Diazinon	I	Low	Likely low
Other organics	Volatile organic compounds (VOCs)	I	Low	Very high
	1,3-dichlorobenzene	III	High	High
	Benzo(a)anthracene	II	Moderate	Very low
	Bis (2-ethylhexyl) phthalate	II	Moderate	Likely low
	Fluoranthene	II	High	High
	Naphthalene	II/III	Low	Moderate
	Phenanthrene	II	Moderate	Likely low
	Pyrene	II	High	High
Pathogens	Enteroviruses	I	Likely present	Moderate
	Shigella	II/III	Likely present	Moderate
	P. aeruginosa	II/III	Very high	Moderate
	Protozoa	II/III	Likely present	Moderate
Heavy metals	Cadmium	III	Low	Moderate
	Chromium	III/IV	Moderate	Very low
	Lead	IV	Moderate	Very low
	Zinc	III/IV	High	High
Salts	Chloride	I	Seasonally high	High

Groundwater Considerations When Using LID

Underlying Soil Conditions

City of Seattle Infiltration Potential Map



Jeff Fowler, City of Seattle

Looked at:

Surface and underlying soil
Soil layering
Depth to groundwater
Steep slopes

Groundwater Considerations When Using LID

LID Facility Design

Include design elements to enhance treatment and minimize groundwater/soil contamination

Courtesy of Seattle Public Utilities

Groundwater Considerations When Using LID

Operations and Maintenance

Pre-treatment settling basins to improve TSS removal and improve efficiency of the LID system

Proper O&M for sediment clean out, soil health, vegetation

Summary and General Recommendations

1. LID can be an effective tool to meet water resource needs.

2. Planning, design and operation should consider broad range of water resource impacts.

   -Groundwater risk should be included in project planning.
   -LID design specifications should include GW mitigation.
   -LID maintenance protocols should be created for each site.

3. Hydrologic Cycle Management- how can better policy, technical, and regulatory decisions be implemented across related disciplines?

Presentation References:

Clark, S.E., Pitt, R. 2007. “Influencing factors and a proposed evaluation methodology for predicting groundwater contamination potential from stormwater infiltration practices.” Water Environment Research, 79, 29-36.

Weiss, P.T., LeFevre, G., Gulliver, J.S. 2008. “Contamination of soil and groundwater due to stormwater infiltration practices.” Project Report No.515. University of Minnesota Stormwater Assessment Project. http://www.safl.umn.edu

U.S. Water Supply

- Universal access to potable water.
- World's highest per capita use – approximately twice that of Europe.
- Cost of water is among the lowest in the world.
  - Average cost nationally approximately $2 per 1,000 gallons

U.S. Water Supply

- Population growth & development increasing demand.
- Sustained droughts in Southeast & Southwest.
- Climate change may decrease snowpack.
- Water managers in 36 states anticipate water shortages by 2020.

Prettyboy Reservoir, Maryland during 2002 drought.
Photo courtesy of National Weather Service.

Domestic Water Use

Typical Domestic Daily per Capita Water Use.

Use	Gallons per Capita	% of Daily Total
Potable indoor uses		
▪ Showers	11.6	7.0%
▪ Dishwashers	1.0	0.6%
▪ Baths	1.2	0.8%
▪ Faucets	10.9	6.6%
▪ Other uses, leaks	11.1	6.7%
Subtotal	**35.8**	**21.7%**
Non-potable indoor uses		
▪ Clothes washers	15.0	9.1%
▪ Toilets	18.5	11.2%
Subtotal	**33.5**	**20.3%**
Outdoor uses	**95.7**	**58.0%**

American Waterworks Association Research Foundation (AWWARF), *Residential End Uses of Water*, Denver, CO, AWWARF, 1999.

The Link Between Water Supply & Energy Use

Estimated Energy Consumption for Water Treatment and Distribution.

Activity	Energy Consumption kWh/MG	
	Northern California	Southern California
Supply and conveyance	150	8,900
Water Treatment	100	100
Distribution	1,200	1,200
Total	**1,450**	**10,200**

California Energy Commission, *California Water – Energy Issues*, Public Interest Energy Research Program, Presented at the Western Region Energy – Water Needs Assessment Workshop, Salt Lake City, Utah, January 10, 2006.

Facts Related to Water Supply

- Reducing water demand 10% could save 293 billion kWh of electricity each year.

- Energy costs account for 80% of typical water bill.

- 7 to 8% of national energy consumption tied to treating and distributing water.

Michael Nicklas, *Rainwater*, High Performance Buildings, Summer 2008.
G. Tracy Mehan, *Energy, Climate Change, and Sustainable Water Management*, Environment Reporter, 2007.

The Link Between Water Supply & CO_2 Emissions

Carbon Dioxide Emissions from Electric Power Generation.

Fuel Type	CO_2 Output Rate lbs CO_2/kWh	CO_2 Output per MG Water Delivered (x 1,450 kWh) Northern CA	CO_2 Output per MG Water Delivered (x 10,200 kWh) Southern CA
Coal	2.117	3,070 lbs	21,600 lbs
Petroleum	1.915	2,775 lbs	19,500 lbs
Natural gas	1.314	1,905 lbs	13,400 lbs

U.S. Department of Energy and U.S. EPA, *Carbon Dioxide Emissions from the Generation of Electric Power in the United States*, July 2000.

Are we looking at these issues correctly?

Rainwater Harvesting to Address Water Supply Issues:

Beyond Stormwater Management

Chicago Center for Green Technology. *Photo courtesy of Farr Associates.*

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Chesapeake Bay Foundation HQ

- Rainwater collected in 3 exposed cisterns.
- Captured water used for bathroom, sinks, gear washing, irrigation, fire suppression, and laundry.
- 90% decrease in potable water use.
- 73% of water used in building from cistern system.

Philip Merrill Building cisterns. *Photo: Chesapeake Bay Foundation.*

NRDC – Santa Monica, CA

- Cisterns installed beneath planting beds.
- Collected rainwater is added to graywater collection system and used for toilet flushing and irrigation.
- Building uses duel-flush toilets, waterless urinals, and drought-tolerant plants.
- 60% reduction in potable water demand.

Cisterns at NRDC Santa Monica, Office

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Stephen Epler Hall – Portland, OR

- 62,500 sf mixed-use student housing.
- Roof runoff is diverted to river rock “splash blocks” in public plaza and then to planter boxes.
- Effluent from planter boxes collected in underground cisterns.
- UV used to treat water prior to use.
- Saves over 100,000 gallons of potable water each year.

Epler Hall, PSU.