Potential Risks and Benefits of Stormwater Reuse

Robert Pitt, Ph.D., P.E.
Department of Civil, Construction, and Environmental Engineering
The University of Alabama
Tuscaloosa, AL 35487

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Dangers of urban waters are well known

From the obvious to the lurking…

But ….. stormwater can be considered a valuable resource in many situations.

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Why Reuse Stormwater?

- It can be an important resources in all areas
- Water is in high demand and in short supply in many areas of the world
- Small fraction of our water use requirements must be of drinking water quality
- Treating all of our water to this highest standard is very costly and uses our best waters for many non-potable uses

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Estimated Costs of Water Management Options

	Estimated cost range (cents/m^3)
Reducing demand through conservation/efficiency	5 – 50
Treatment and reuse of wastewater for irrigation	30 – 60
Desalination of brackish water	45 – 70
Development of marginal water	55 – 85
Desalination of seawater	100 – 150

World Bank 1995

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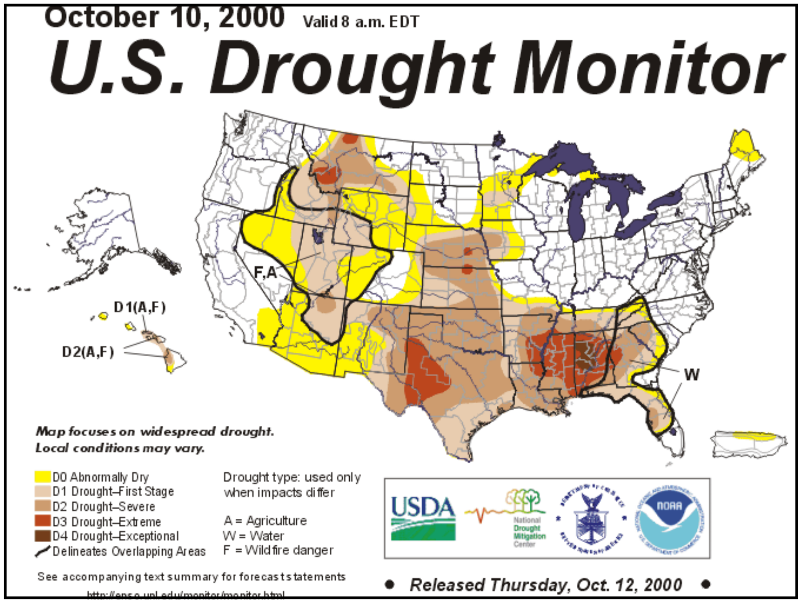

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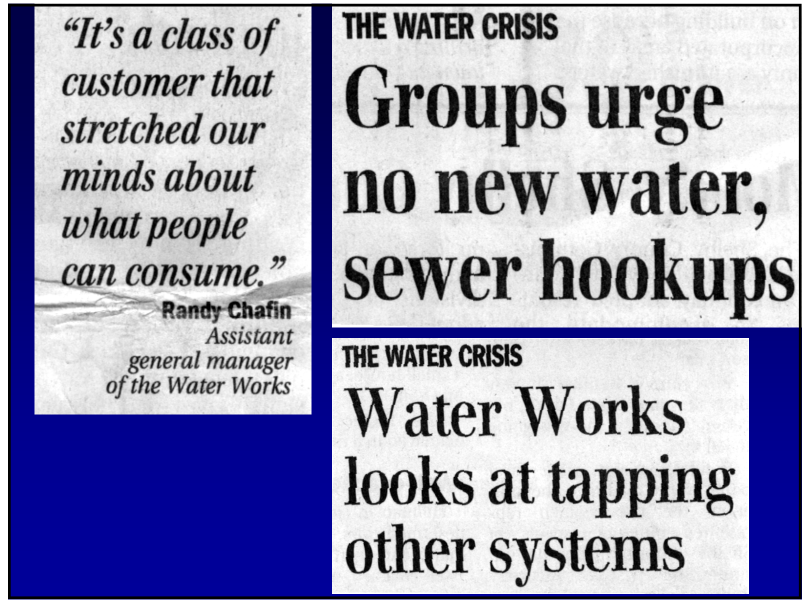

"It's a class of customer that stretched our minds about what people can consume."
Randy Chafin
Assistant general manager of the Water Works

THE WATER CRISIS

Groups urge no new water, sewer hookups

THE WATER CRISIS

Water Works looks at tapping other systems

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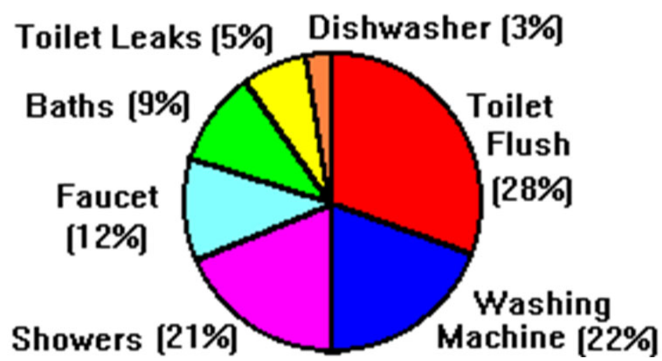
Percent Water Consumption



Much of the domestic water needs can be met with waters of impaired quality (30% of in-home use, plus most of outside irrigation uses).

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Guidelines for the Reuse of Impaired Waters and Risk Assessments

- Can stormwater be used to satisfy some of our water needs?

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Distribution of Maryland Residential Water Use and Required Quality (Mallory 1973)

Class	Use	Rate of Use (gal/person/day)	Percentage of Total Water Use
AA	Consumption by humans, food preparation, general kitchen use	6.5	7
A	Bathing, laundering, auto washing	31.0	36
B	Lawn irrigation	518 gal/day/acre	29
C	Toilet flushing	24.0	28

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Maximum Concentrations Allowed by Maryland for Different Reuse Categories, Compared to Typical Residential Stormwater Runoff (Mallory 1973)

Constituent (mg/L)	AA	A	B	C	Typical average residential stormwater quality and highest use without treatment
Total solids	150	500	500	1500	250 (A)
Suspended solids	-	-	10	30	50 (none)
Turbidity (NTU)	0-3	3-8	8-15	15-20	25 (none)
Color (color units)	15	20	30	30	25 (B)
pH (pH units)	7	6	6	6	6 to 9 (AA)
Oxygen, dissolved (minimum)	5	5	4	4	Near saturation (AA)
Total coliform bacteria (MPN/100 mL)	1	70	240	240	>10,000 (none)

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As shown on these tables, residential area stormwater can be used to meet at least class A water needs, except for suspended solids, turbidity, color, and coliform bacteria. The solids, turbidity and color levels are likely to be adequately reduced through storage and associated settling, plus possible post-settling filtration. The most serious impediment for the reuse of stormwater in residential areas is the bacteria levels.

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California Reuse Guidelines (Metcalf and Eddy 1991)

Use of reclaimed water (sanitary sewage)	Secondary treatment and disinfection	Secondary treatment, coagulation, filtration, and disinfection	Total coliform bacteria criteria (MPN/100 mL, median of daily observations)
Landscaped areas: golf courses, cemeteries, freeways	required		23
Landscaped areas: parks, playgrounds, schoolyards		required	2.2
Recreational impoundments: no public contact	required		23
Recreational impoundments: boating and fishing only	required		2.2
Recreational impoundments: body contact (bathing)		required	2.2

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Metcalf and Eddy (1991) state that primary treatment (similar to settling in a storage tank) reduces fecal coliform bacteria by less than 10%, whereas trickling filtration (without disinfection) can reduce fecal coliform levels by 85 to 99%. Chemical disinfection is usually required to reduce pathogen levels by 99.9+%, as likely needed to meet the above bacteria criteria for even the most basic water uses. Because of the risks associated with potential pathogens, reuse of stormwater in residential areas should only be considered where consumption and contact is minimized, restricting on-site reuse to classifications B and C, and only after adequate disinfection and site specific study to ensure acceptable risks. To further minimize risks, only the best quality stormwater (from a pathogen perspective) should be considered for reuse, such as roof runoff.

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- **Koch's Postulates** (Pelczar and Reid, 1972)
  - A pathogen must be consistently found in association with a given disease.
  - The pathogen must be isolated from the host and grown in pure culture.
  - When inoculated into test animals, the same disease symptoms must be expressed.
  - The pathogen must again be isolated from the test organism.

These fundamental risk assessment tests have not been conducted for stormwater organisms

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Characteristics of Stormwater

- Identify the likely problem constituents from a reuse perspective
- Determine the possible level of treatment needed

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Observed Bacteria Data in the National Stormwater Quality Database (NSQD)

Land Use (number of observations)	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)
Overall (3770)	5,080	17,000
Residential (1069)	7,750	24,000
Commercial (497)	4,550	10,800
Industrial (524)	2,500	13,000
Freeways (185)	1,700	17,000
Open Space (68)	3,100	24,000

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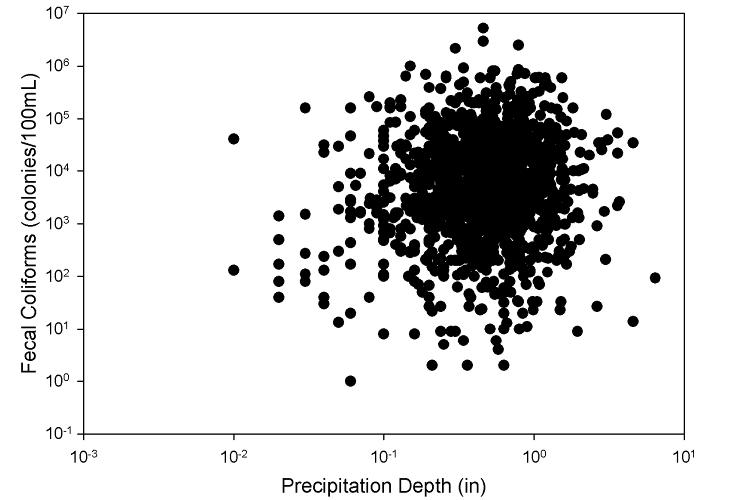
NSQD Fecal Coliform Scatterplot for Residential Areas



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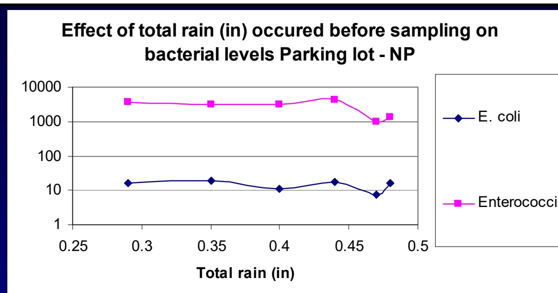
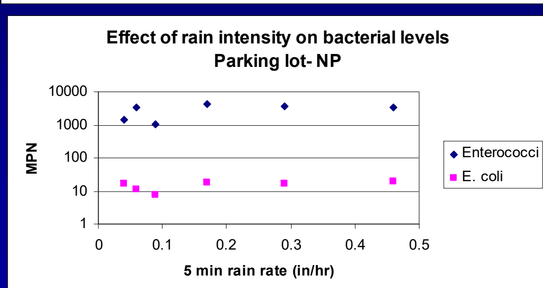
Tuscaloosa, AL, bacteria studies





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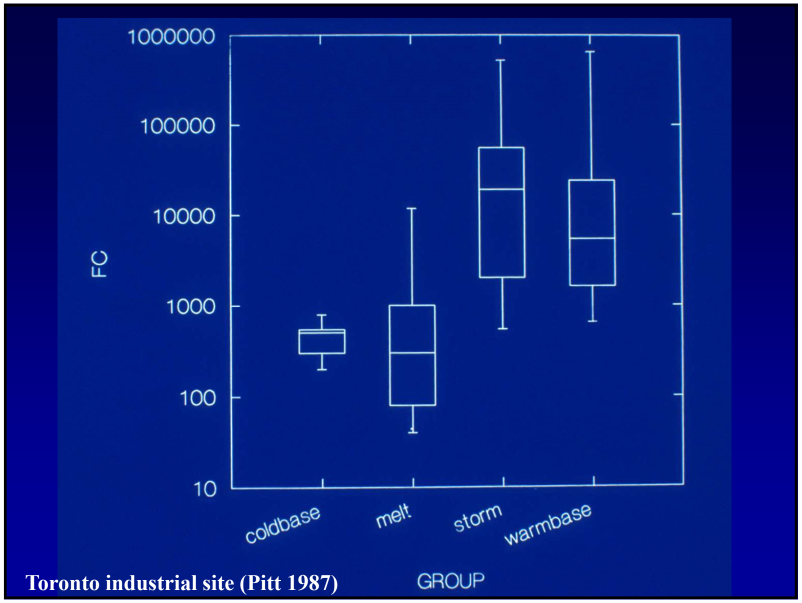

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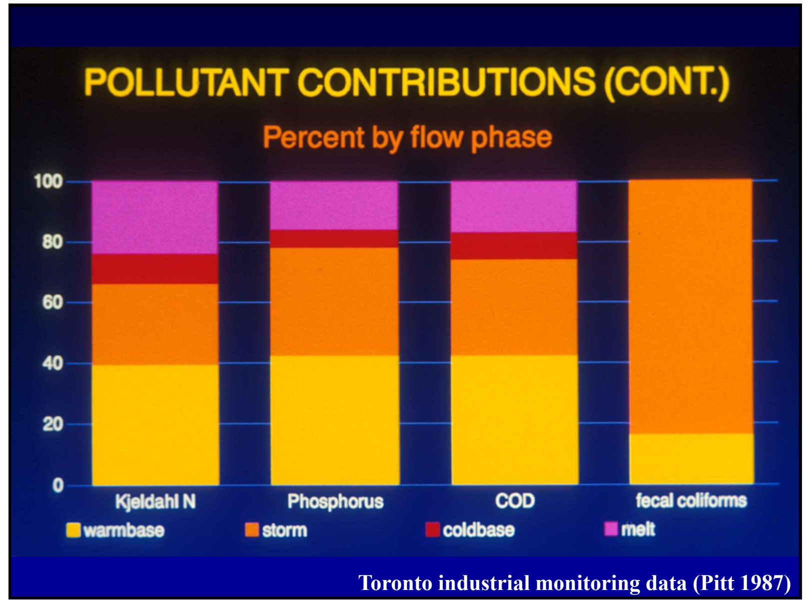

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Fecal Coliforms (MPN/100 mL)

Mean values for different projects

	Roofs	Paved Parking
Residential:	85 <2 1,400	250,000
Commercial:	9	2,900 350 210 480 23,000
Industrial:	1,600	8,660

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U.S EPA Water Quality Criteria For Swimming Waters (EPA 1986)

	Marine Waters	Fresh Waters
Main EPA research reference	Cabelli, *et al.* 1982	Dufour 1984
Acceptable swimming associated gastroenteritis rate (per 1000 swimmers)	Increase of 19 illnesses per 1000 swimmers	Increase of 8 illnesses per 1000 swimmers.
Comparable fecal coliform exposure	200 fecal coliforms / 100 mL	200 fecal coliforms / 100 mL
Steady state geometric mean indicator density	35 Enterococci / 100 mL	33 Enterococci / 100mL or 126 *E-coli* /100mL

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Bacteria Standards (cont.)

Single sample limits	Marine Waters	Fresh Waters
Designated bathing beach area	104 Enterococci / 100 mL	61 Enterococci / 100mL or 235 *E-coli* /100mL
Moderate full body contact recreation	124 Enterococci / 100 mL	89 Enterococci / 100mL or 298 *E-coli* /100mL
Lightly used full body contact recreation	276 Enterococci / 100 mL	108 Enterococci / 100mL or 406 *E-coli* /100mL
Infrequently used full body contact recreation	500 Enterococci / 100 mL	151 Enterococci / 100mL or 576 *E-coli* /100mL

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Sources of Bacteria in Urban Watersheds

- Potential for sewage contamination
- However, urban wildlife most likely responsible for most of the high observations (sewage contamination most likely associated with very high observations)

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One Early Method of Getting Rid of Wastewater

Wastewater treatment has only been around since the late 1800s. People dumped wastes into gutters, ditches, and out open windows.

"Tout-a-la-rue" (all in the streets), with the expectation that dogs, pigs, and rain would effectively remove wastes. This was the waste disposal policy in most western cities until the late 1800s.

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Sources of Bacteria in Urban Watersheds

- **Dry weather flows:**
  - **Poorly treated sewage discharges**
  - **Failing sewerage**
  - **Failing septic tanks**
  - **Livestock in streams (not common in urban areas!)**
- **Wet weather flows:**
  - **Warm weather stormwater discharges (urban wildlife)**
  - **Combined sewer overflows (CSOs)**
  - **Sanitary sewer overflows (SSOs)**

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Sanitary sewage from broken sewer entering storm drainage system and discharged to urban stream

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Separate sewer relief location during wet weather (SSO)

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Pet Wastes
DOG REGULATIONS
• KEEP PETS ON LEASH
• CLEAN UP DOG WASTE
CITY ORDINANCES 9044, 9561
VIOLATORS SUBJECT TO FINE

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Identification of Contamination Sources (Inappropriate Discharges)

- **Developed initial protocol in early 1990s**
- **EPA 104(b)3 funded project for 2001 – 2004 to Center for Watershed Protection and the University of Alabama to update.**
- **Reviewed Phase 1 cities experience in inappropriate discharge investigations**
- **Guidance manual for Phase 2 communities available**

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Field Screening Method Verification

- Completely developed 4,500 acre urban watershed (Village Creek) in Birmingham, AL.
- 83 stormwater outfalls, with samples collected during at least 8 visits over 30 months.

	Outfalls from large subwatersheds	Outfalls from creek-side businesses	Total
Always flowing	17%	11%	16%
Intermittently flowing	9%	33%	14%
Always dry	74%	56%	70%

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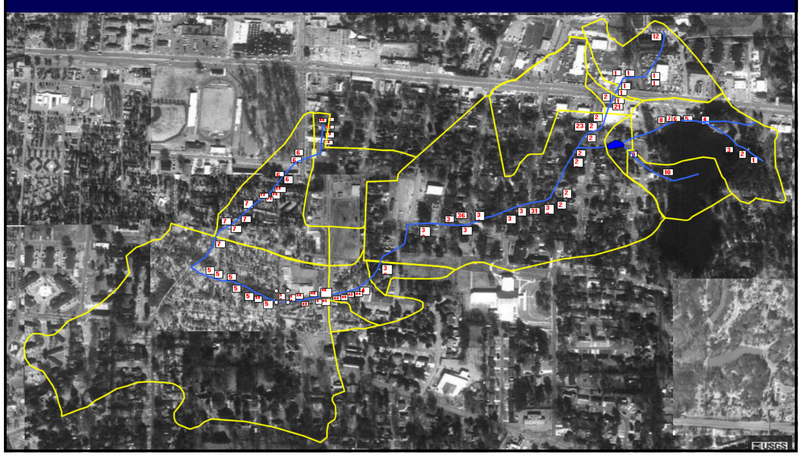
A typical storm drainage system in Tuscaloosa under study



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Tuscaloosa, Alabama, Study Area

- 65 outfalls in a residential and commercial area
- Conducted five creek walks
- 60% of the outfalls always dry
- 15 % of the outfalls always flowing
- 25% of the outfalls flowing intermittently
- Similar responses to earlier Birmingham observations.

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Optical Brighteners Test Kit (cotton pad can be left anchored in outfall pipe for several days, dried, then observed under UV light; inexpensive, but poor sensitivity)

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Detergents to Indicate Contamination

Water Source	Detergent, mean (mg/L)	Detergent, range (mg/L)
Shallow groundwater	0.00	All < 0.00
Springs	0.00	All < 0.00
Household tap	0.00	All < 0.00
Landscape runoff	0.00	All < 0.00
Sewage	1.50	0.48 – 4.40
Septic tank discharge	3.27	0.15 – 12.00
Laundry	26.9	17.0 – 37.0
Car washes	49.0	38.0 – 56.7
Radiator flushing	15.0	13.5 – 18.3
Plating wastes	6.81	1.45 – 15.0

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Fluorometric Measurements to Detect Fabric Brighteners in Discharges

- High efficiency interference filters
- Sillicon photodiode detector coming from a LED source
- Portable battery powered unit
- Weighs 6 pounds and 12 in x 9 in x 5 in
- Very sensitive, but expensive

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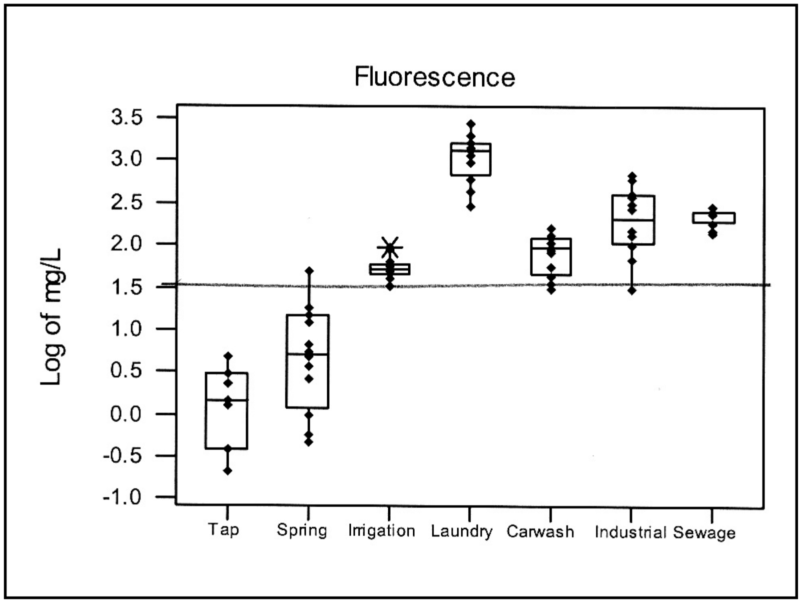

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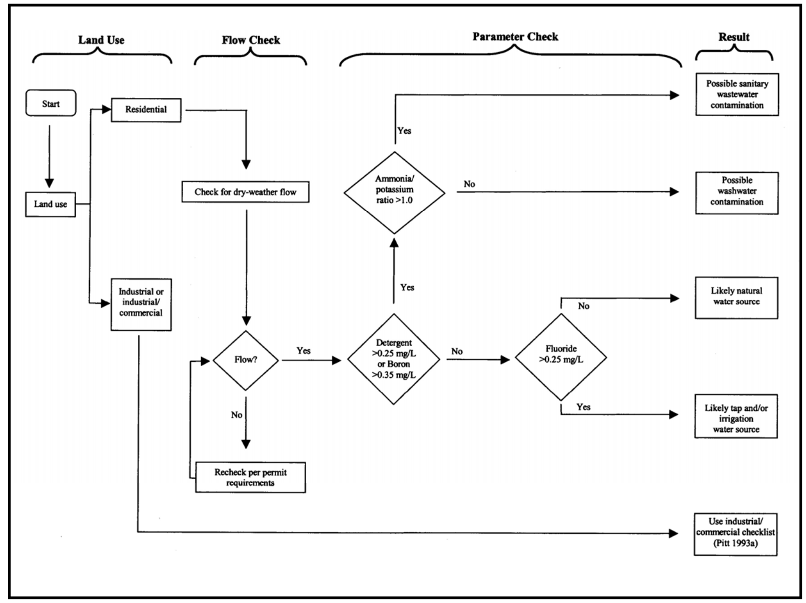

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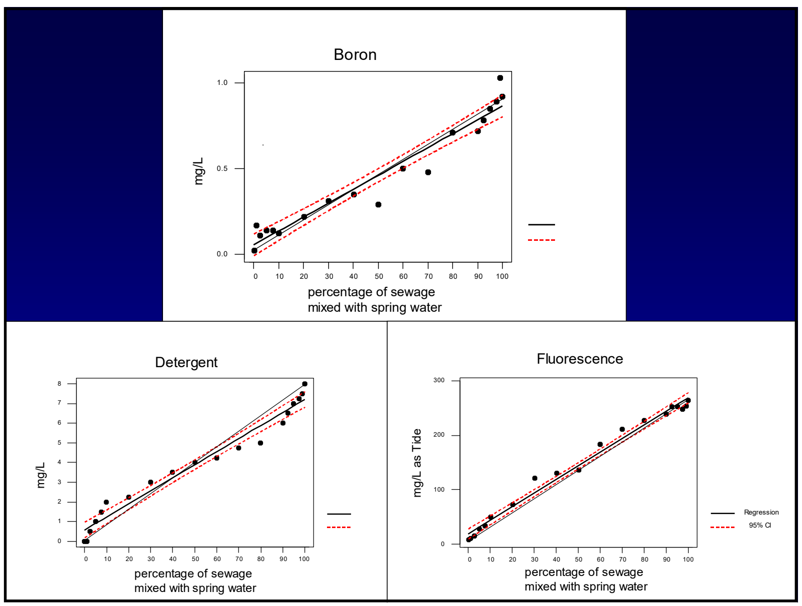

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Tuscaloosa Bacteria Source Study

- Eight sampling locations were selected
- Two from each of the land uses parking lots, open spaces , roof tops and streets
- Sites selected in pairs
  - One prone to animals and birds
  - Other not prone
- Other characteristics almost similar

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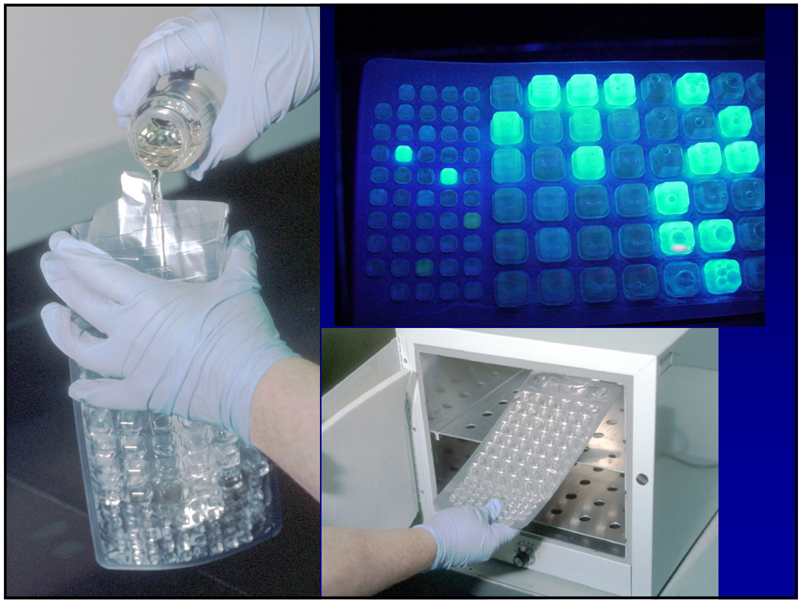


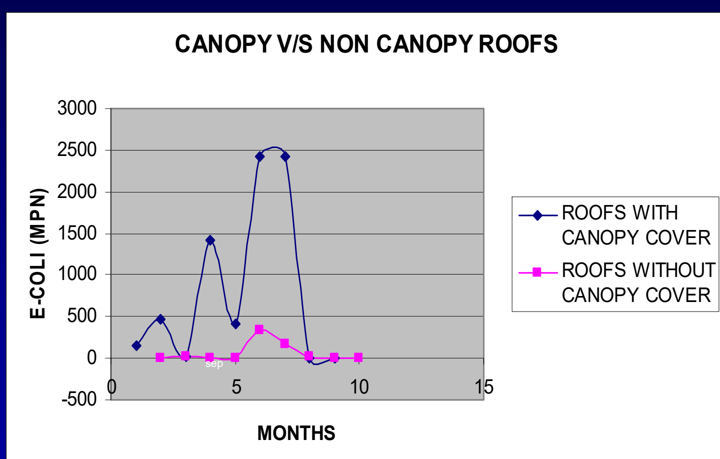
Roofs Runoff Sampling Sites

PRONE NOT PRONE

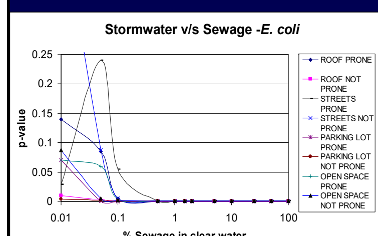
PRONE - Urban birds and animals more likely present

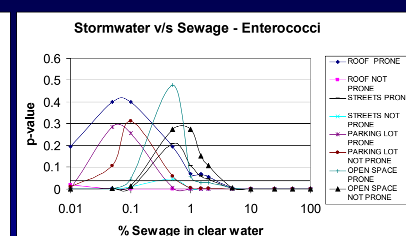
NOT PRONE - Urban birds and animals less likely present

Effect of Trees on Bacteria Observations (Sewage only *E. coli* urban source?)



Comparison of Sewage with Wet Weather Sheetflow Samples





p = 0.05, % Sewage = 0.13

E. Coli = 3470 MPN/100 mL

p = 0.05, % Sewage = 3.7

Enterococci= 18,530 MPN/100mL

Infrequently used full body contact recreation standards: 576 MPN/100 mL for *E. coli* and 151 MPN/100 mL for enterococci

Exposure to Contaminated Stormwater

- Contact recreation
- Fishing and canoeing in urban streams
- Reuse of stormwater for irrigation

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Water contact warning sign, Orange County, CA, beach.

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Reuse Opportunities for Stormwater

- Select areas that have limited contamination
- Pre-treat and store as needed
- Disinfection may be necessary to meet most reuse requirements
- Probably not economically feasible to store stormwater for long periods to alleviate extended drought conditions

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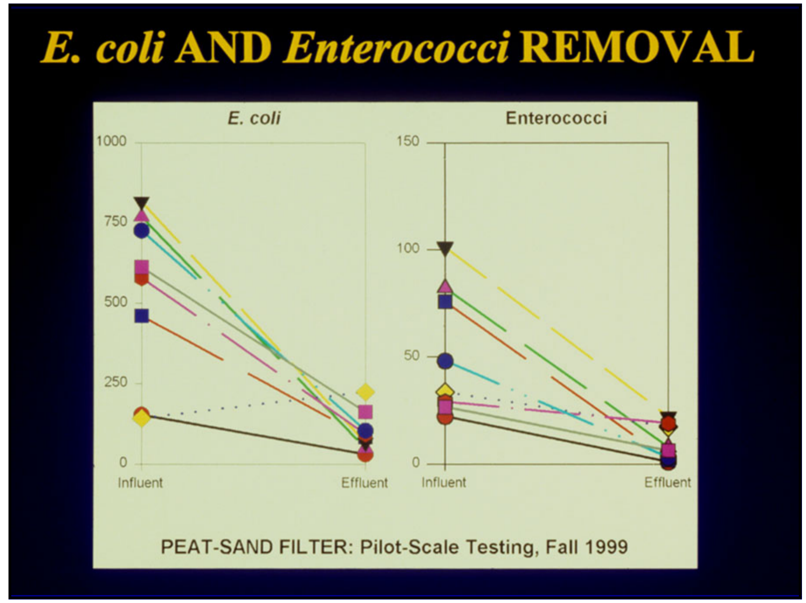

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Minocqua, WI, MCTT Installation

Combination grit, sedimentation, filtration, sorption and ion exchange

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Caltrans Full-Scale MCTT Test Results

	Mean % reductions and mean effluent quality
Suspended solids	80 (6 mg/L)
TKN	35 (0.82 mg/L)
Total Phosphorus	39 (0.11 mg/L)
Copper	38 (5 µg/L)
Lead	50 (3 µg/L)
Zinc	85 (13 µg/L)
Total petroleum hydrocarbons	85 (210 µg/L)
Fecal coliforms	82 (171 MPN/100 mL)

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Observed Wet Pond Performance (when constructed and operated according to best guidance)

- Suspended solids: 70 to 95%
- COD: 60 to 70%
- BOD_5: 35 to 70%
- Total Kjeldahl nitrogen: 25 to 60%
- Total phosphorus: 35 to 85%
- Bacteria: 50 to 95%
- Copper: 60 to 95%
- Lead: 60 to 95%
- Zinc: 60 to 95%

Relative effectiveness of stormwater controls on bacteria reductions

	Cost	Effectiveness
Inappropriate discharge elimination	Low	Can be high (~90%)
Public education (pet waste control)	Low to mod.	?????
Biofiltration (modified soils)	Low to mod.	Moderate (~80%)
Media filtration (to fast rate)	Low to mod.	Moderate (~50%)
Hydrodynamic device	High	Low (<25%)
Wet detention and wetlands	Moderate	Moderate (~80%)
Disinfection	Very high	Very high (~99%)

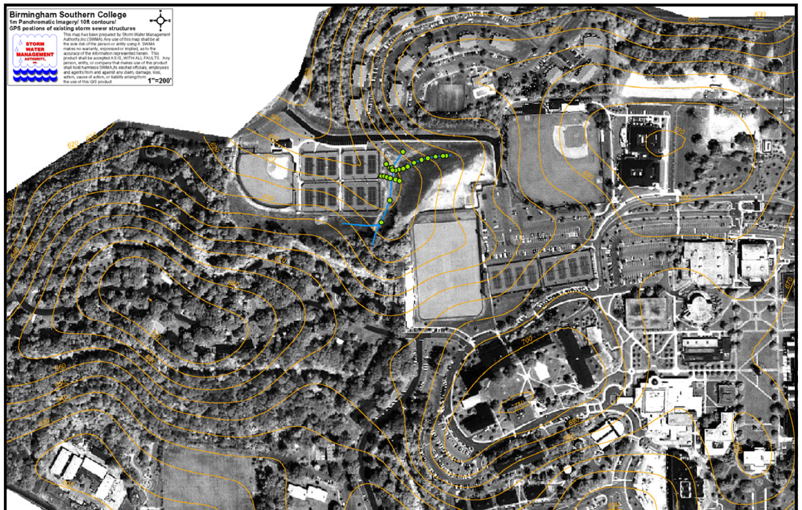
Stormwater can be a Resource

Ponds, rain barrels and cisterns for stormwater storage for irrigation and other beneficial uses. Many areas use roof runoff for all domestic needs.

Much of the domestic water needs can be met with waters of impaired quality (30% of in-home use, plus most of outside irrigation uses and fire-fighting use).

Cistern tank, Kamiros, Rhodes (ancient Greece, 7th century BC)

Steps alongside cistern



Birmingham Southern College Campus (map by Jefferson County Stormwater Management Authority)

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Birmingham Southern College Fraternity Row

	Acres	% of Total
Roadways	0.24	6.6%
Parking	0.89	24.5
Walks	0.25	6.9
Roofs	0.58	16.0
Landscaping	1.67	46.0
Total:	3.63	100.0

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Supplemental Irrigation

	Inches per month (example)	Average Use for 1/2 acre (gal/day)
Late Fall and Winter (Nov-March)	1 to 1-1/2	230 - 340
Spring (April-May)	2 to 3	460 - 680
Summer (June-August)	4	910
Fall (Sept-Oct)	2 to 3	460 - 680
Total:	28 (added to 54 inches of rain)	

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Capture and Reuse of Roof Runoff for Supplemental Irrigation

Tankage Volume (gal) per 4,000 ft^2 Building	Percentage of Annual Roof Runoff used for Irrigation
1,000	56%
2,000	56
4,000	74
8,000	90
16,000	98

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- Many technical reports on my research web site: http://unix.eng.ua.edu/~rpitt

I will be teaching a course on inappropriate discharge investigations in Fishkill, NY, on Oct 30 and 31, Contact Don Lake (thru Syracuse U) at (315-662-3744)