Inappropriate Discharges to Storm Drainage Systems – Identification and Verification

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Inappropriate discharges in residential areas

Inappropriate discharges in commercial areas

Inappropriate discharges in industrial areas

Sources of Inappropriate Discharges

- **Pathogenic & toxic pollutant sources**
  - **Sanitary wastewater**
  - **Commercial & Industrial discharges**
- **Nuisance & aquatic life threatening pollutant sources**
  - **Landscaped irrigation runoff**
  - **Construction site dewatering**
  - **Automobile washing**
  - **Laundry wastes**
- **Unpolluted water sources**
  - **Infiltrating groundwater**
  - **Natural springs**
  - **Domestic water line leaks**

Development and Testing of Methods for Interpreting Field Screening Data

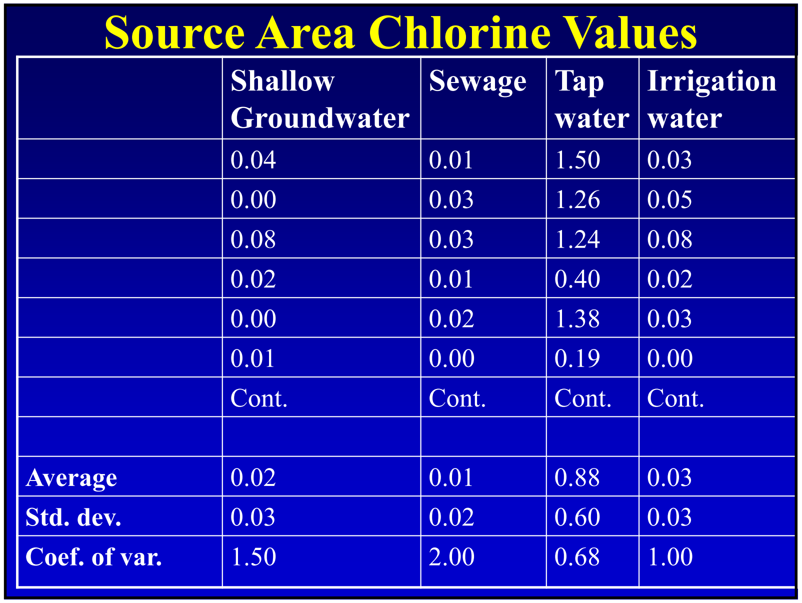
- **Physical indicators of contamination**
- **Detergents as indicators of contamination**
- **Flow chart for most significant flow component identification**
- **Chemical mass balance at outfall to quantify flow sources**

Physical Indicators of Gross Contamination (presence of any of these should indicate a problem)

- **Odor** (sewage, sulfide, oil, gasoline, rancid-sour)
- **Color** (yellow, brown, green, red, gray)
- **Turbidity** (cloudy, opaque)
- **Floatables** (petroleum sheen, sewage, food products, foam)
- **Deposits/stains** (sediment, oily)
- **Unusual vegetation conditions** (excessive growth, inhibited growth)
- **Damage to outfall structures** (concrete cracking, concrete spalling, metal corrosion)

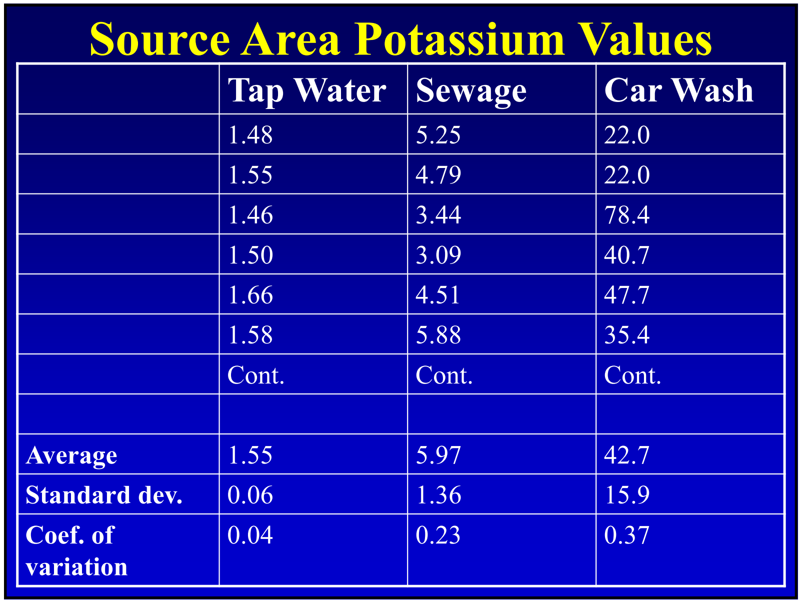
Historical Approach: Tracers to Identify Sources of Contamination

- **Purpose: Identify toxic/ pathogenic sources of water, typically raw sewage/industrial wastewaters, discharged to storm drain system.**
- **Ideal tracer to identify major flow sources has the following characteristics:**
  - **Significant difference in concentrations between possible pollutant sources;**
  - **Small variations in concentrations within each likely pollutant source category;**
  - **Conservative behavior (i.e., no significant concentration change due to physical, chemical or biological processes);**
  - **Ease of measurement with adequate detection limits, good sensitivity and repeatability.**



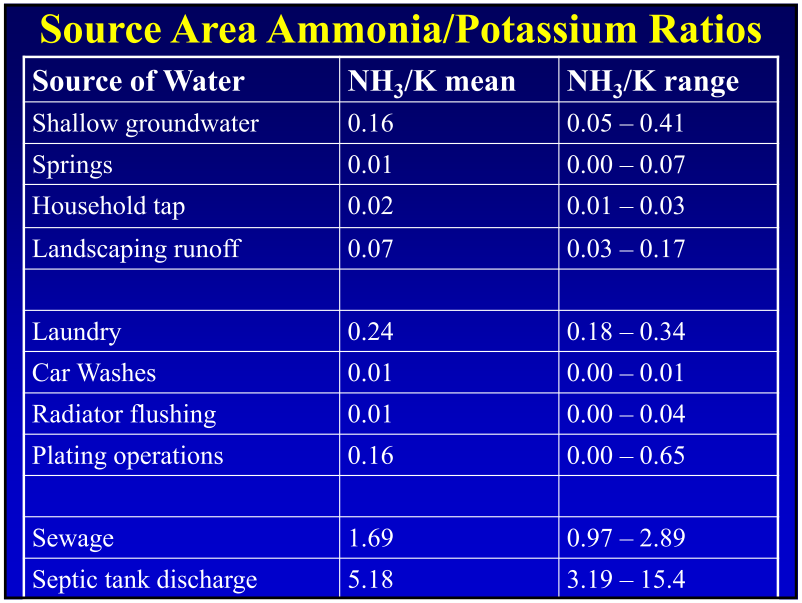
Source Area Chlorine Values

	Shallow Groundwater	Sewage	Tap water	Irrigation water
	0.04	0.01	1.50	0.03
	0.00	0.03	1.26	0.05
	0.08	0.03	1.24	0.08
	0.02	0.01	0.40	0.02
	0.00	0.02	1.38	0.03
	0.01	0.00	0.19	0.00
	Cont.	Cont.	Cont.	Cont.
Average	0.02	0.01	0.88	0.03
Std. dev.	0.03	0.02	0.60	0.03
Coef. of var.	1.50	2.00	0.68	1.00



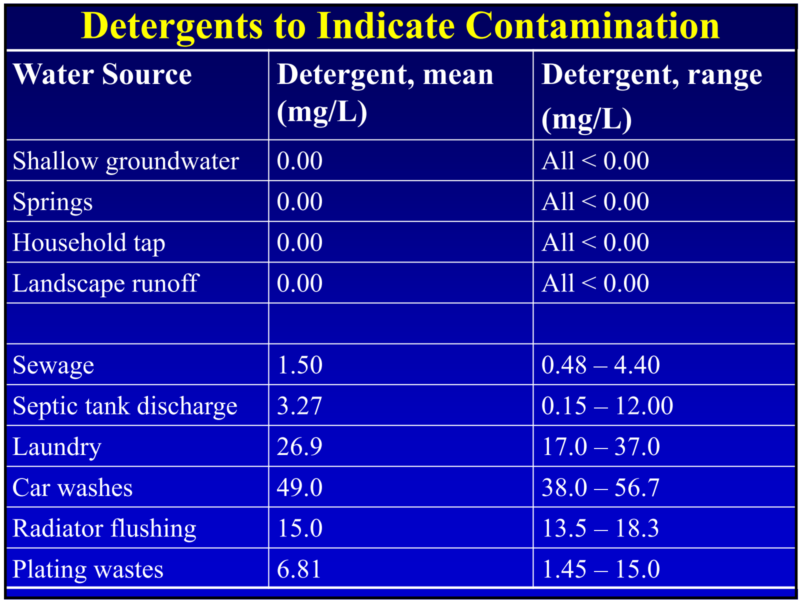
Source Area Potassium Values

	Tap Water	Sewage	Car Wash
	1.48	5.25	22.0
	1.55	4.79	22.0
	1.46	3.44	78.4
	1.50	3.09	40.7
	1.66	4.51	47.7
	1.58	5.88	35.4
	Cont.	Cont.	Cont.
Average	1.55	5.97	42.7
Standard dev.	0.06	1.36	15.9
Coef. of variation	0.04	0.23	0.37



Source Area Ammonia/Potassium Ratios

Source of Water	**NH_3/K mean**	**NH_3/K range**
Shallow groundwater	0.16	0.05 – 0.41
Springs	0.01	0.00 – 0.07
Household tap	0.02	0.01 – 0.03
Landscaping runoff	0.07	0.03 – 0.17
Laundry	0.24	0.18 – 0.34
Car Washes	0.01	0.00 – 0.01
Radiator flushing	0.01	0.00 – 0.04
Plating operations	0.16	0.00 – 0.65
Sewage	1.69	0.97 – 2.89
Septic tank discharge	5.18	3.19 – 15.4



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

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%

Results of Initial Field Verification Tests

Drainage areas for 10 outfalls were studied in detail in order to verify actual sources of contamination.

Data analysis method	**Information obtained**	**Percentage of false negatives**	**Percentage of false positives**
Physical indicators	Some contaminated outfalls missed and some uncontaminated outfalls falsely accused.	20%	10%
Detergents	All contaminated outfalls correctly identified!	0	0
Flow chart	All major contaminating sources identified correctly!	0	0
Chemical mass balance	All contaminated outfalls correctly identified, and most sources correctly identified and reasonably well quantified!	0	0

Summary of Evaluations

- **Previously developed methods used to identify sources of contaminants in storm drainage systems.**
- **Reviewed emerging techniques that may also be useful.**
- **The original methods, along with selected new procedures, were tested using almost 700 stormwater samples collected from telecommunication manholes from throughout the U.S.**

Emerging Technologies for Inappropriate Discharge Investigations

- Fecal Sterol Compounds (expensive and not discriminatory)
- Caffeine (expensive and not very sensitive)
- Detergent Compounds (expensive)
- Pharmaceuticals (expensive and only for selected conditions)
- DNA Analyses (**most promising**)
- Stable Isotope Analyses (suitable for selected sites and conditions)

Laboratory Analyses of Potential Sewage Indicators

- **Laboratory tests (funded by the University of New Orleans and EPA) examined sewage and laundry detergent samples.**
- **Initial boron tests found it to be a poor indicator of sewage, possibly due to changes in modern laundry detergents' formulations. Recent tests much better.**
- **Fluorescence (using specialized "detergent whitener" filter sets) excellent indicator of sewage, but not very repeatable.**
- **UV absorbence at 228 nm excellent sewage indicator (very little background absorbence in local spring waters, but strong response factor with increasing sewage strengths).**

Field Evaluations of Selected Indicator Parameters

- **Coprostanol found in about 25 percent of water samples (but in about 75% of the 350 sediment samples analyzed).**
- **Caffeine only found in <0.5% of the water samples.**
- **Elevated *E. coli* and enterococci concentrations observed in about 10% of the samples.**

Field Evaluations of Selected Indicator Parameters

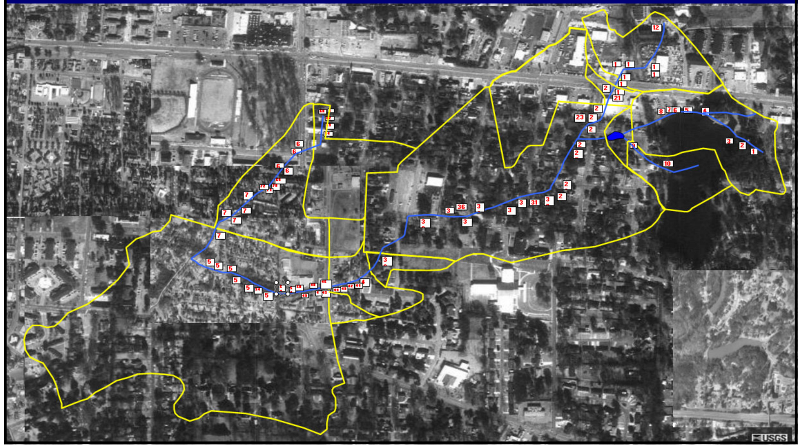
- **Strong sewage odors detected in about 10% of the water and sediment samples.**
- **About ten percent of the samples estimated to be contaminated with sanitary sewage using these methods, similar to what is expected for most stormwater systems.**

Current Research Project

- EPA 104(b)3 funded project for 2001 – 2004 to Center for Watershed Protection and the University of Alabama.
- Review Phase 1 cities experience in inappropriate discharge investigations
- Developed and tested updated protocol
- Preparing guidance manual for Phase 2

Storm Drainage System with Outfalls Under Study

A typical storm drainage system in Tuscaloosa under study

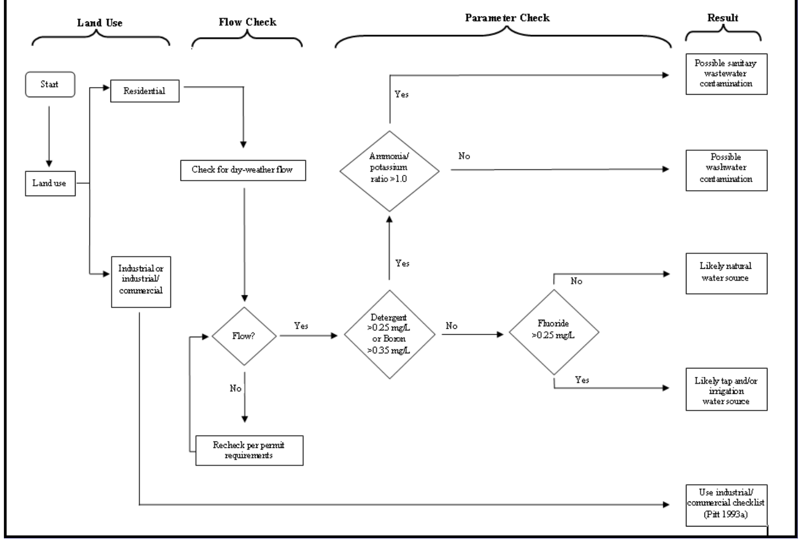


Tuscaloosa, Alabama, Study Area

- 65 outfalls in a residential and commercial area
- Conducted five complete 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.

Typical Inappropriate Discharge Site Being Studied

Basic Flow Chart

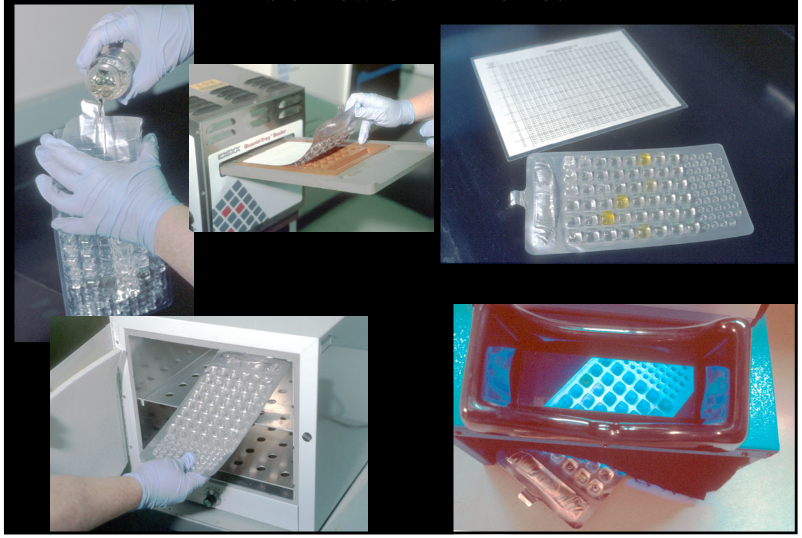


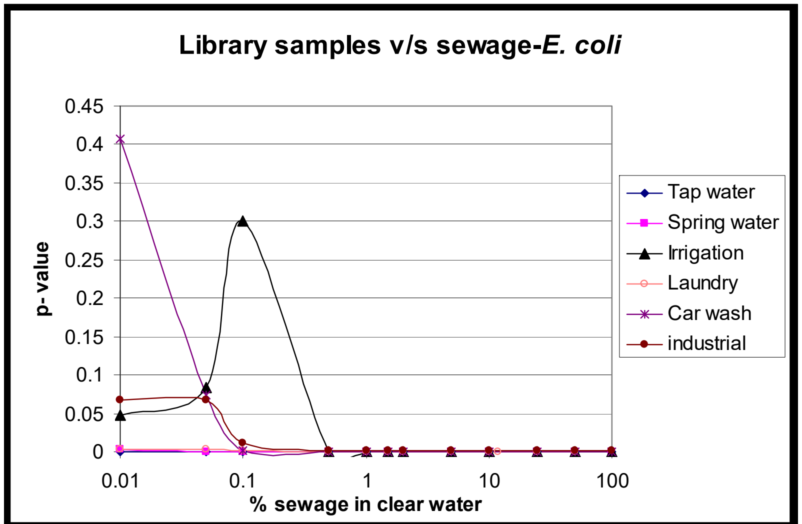
Example Flowsheet Evaluation

	Value	Likely source
Detergents	0.23 mg/L	Sanitary wastewater or washwater
Fluoride	0.35 mg/L	Domestic water source
Ammonia/ Potassium ratio	1.3	Sanitary wastewater source

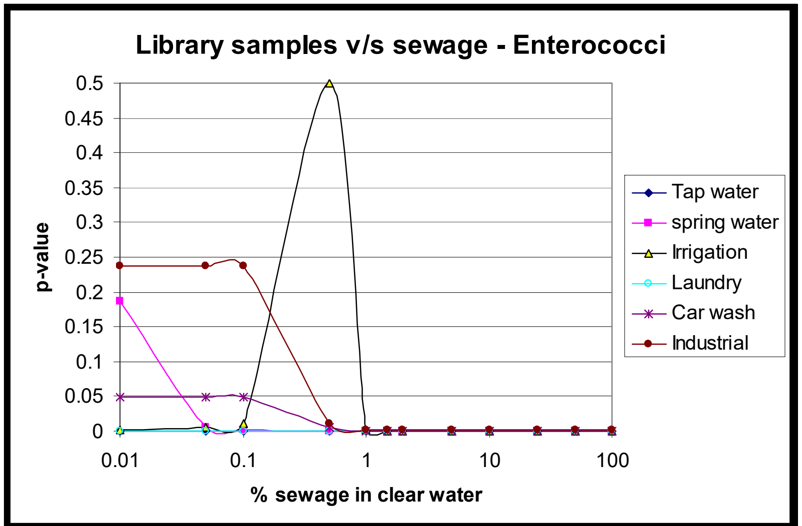
The major flow component is most likely sanitary wastewater

Bacteria Analyses to Supplement Basic Flow Chart Method





If *E. coli* > 12,000 MPN/100 mL, then 95% confident that at least 1% raw sewage in mixture.



If Enterococci > 5,000 MPN/100 mL, then 95% confident that at least 1% raw sewage in mixture).

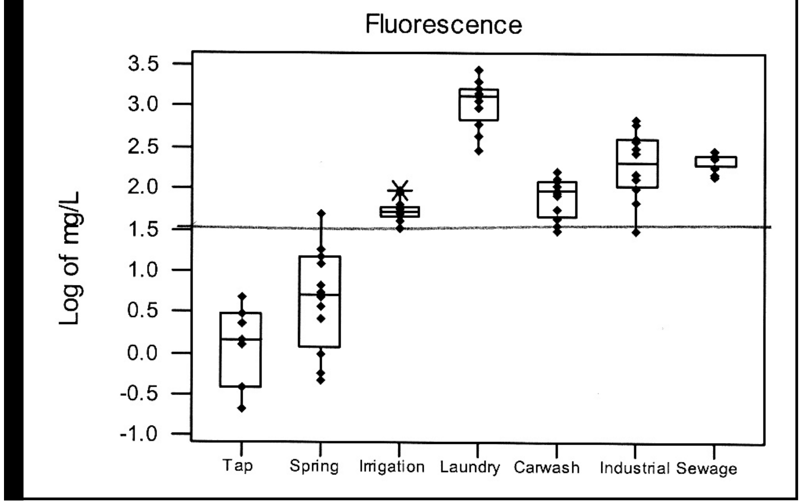
Optical Brighteners Test Kit

Cotton pad can be left anchored in outfall pipe for several days, dried, then observed under UV light; inexpensive, but poor sensitivity. Does accumulate useful debris though.

Fluorometric Measurements to Detect Optical Brighteners in Discharges

- High efficiency interference filters
- Sillicon photodiode detector and an LED UV light source
- Portable battery powered unit, is small and light.
- Very sensitive for washwaters and sewage detection, but expensive

Fluorescence does an Excellent Job in Discriminating between Clean and Dirty Water Sources



Chemical Mass Balance used to Quantify Source Contributions

$$(m_1)(x_{11}) + (m_2)(x_{12}) + (m_3)(x_{13}) = C_1$$

$$(m_1)(x_{21}) + (m_2)(x_{22}) + (m_3)(x_{23}) = C_2$$

$$(m_1)(x_{31}) + (m_2)(x_{32}) + (m_3)(x_{33}) = C_3$$

$$\Sigma_n(m_n)\,(x_{pn}) = C_p$$

m_n = the fraction of flow from source type n
x_{pn} = the concentration of tracer p in source type n
C_p = the concentration of tracer p in the outfall flow

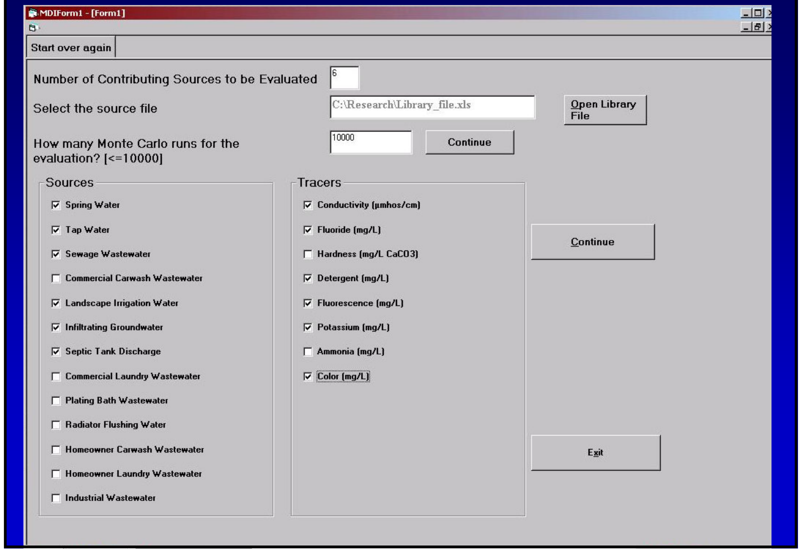
Example Background (Library) Data

Infiltrating Groundwater

Tracer	Median Concentration	COV	Distribution
Conductivity	51.4	0.84	N
Fluoride	0.06	0.5	L
Hardness	27.3	0.39	N
Detergent	0	0	
Fluorescence	29.9	1.55	L
Potassium	1.19	0.44	N
Ammonia	0.24	1.26	N
Color	8	1.42	L

The chemical mass balance model uses Monte Carlo routines to account for the uncertainty in the source water quality.

Monte Carlo Chemical Mass Balance Model



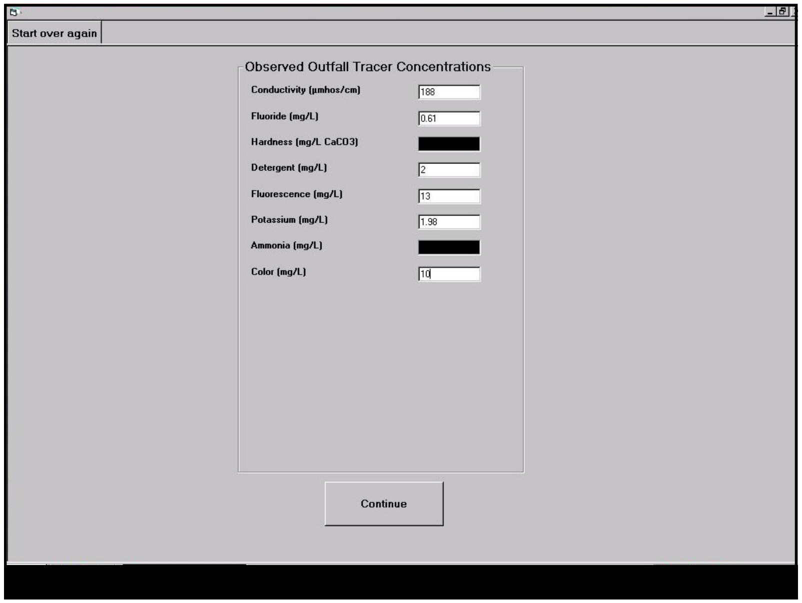
Number of Contributing Sources to be Evaluated: 6

Select the source file: C:\Research\Library_file.xls

How many Monte Carlo runs for the evaluation? [<=10000]: 10000

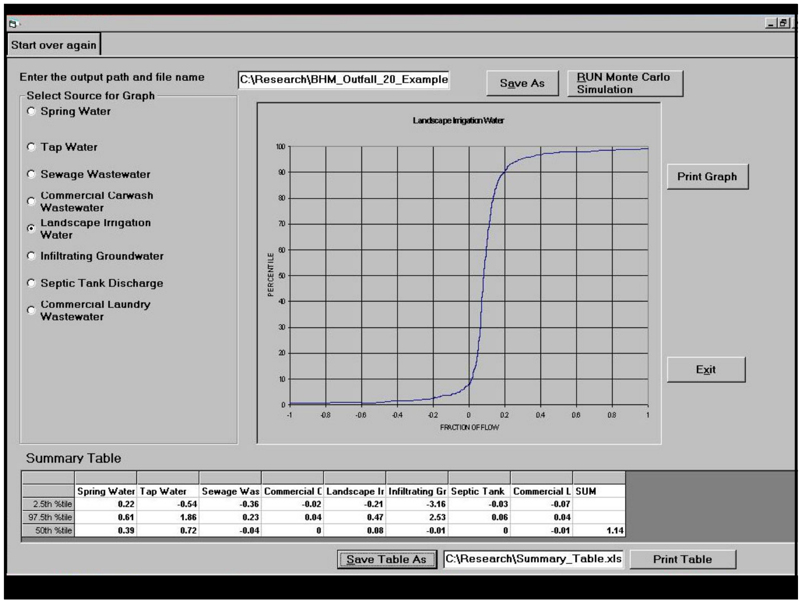
Sources
- ☑ Spring Water
- ☑ Tap Water
- ☑ Sewage Wastewater
- ☐ Commercial Carwash Wastewater
- ☑ Landscape Irrigation Water
- ☑ Infiltrating Groundwater
- ☑ Septic Tank Discharge
- ☐ Commercial Laundry Wastewater
- ☐ Plating Bath Wastewater
- ☐ Radiator Flushing Water
- ☐ Homeowner Carwash Wastewater
- ☐ Homeowner Laundry Wastewater
- ☐ Industrial Wastewater

Tracers
- ☑ Conductivity (µmhos/cm)
- ☑ Fluoride (mg/L)
- ☐ Hardness (mg/L CaCO3)
- ☑ Detergent (mg/L)
- ☑ Fluorescence (mg/L)
- ☑ Potassium (mg/L)
- ☐ Ammonia (mg/L)
- ☑ Color (mg/L)



Observed Outfall Tracer Concentrations

Conductivity (µmhos/cm)	188
Fluoride (mg/L)	0.61
Hardness (mg/L CaCO3)	
Detergent (mg/L)	2
Fluorescence (mg/L)	13
Potassium (mg/L)	1.98
Ammonia (mg/L)	
Color (mg/L)	10



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Summary Table

	Spring Water	Tap Water	Sewage Was	Commercial C	Landscape Ir	Infiltrating Gr	Septic Tank	Commercial L	SUM
2.5th %tile	0.22	-0.54	-0.36	-0.02	-0.21	-3.16	-0.03	-0.07	
97.5th %tile	0.61	1.86	0.23	0.04	0.47	2.53	0.06	0.04	
50th %tile	0.39	0.72	-0.04	0	0.08	-0.01	0	-0.01	1.14

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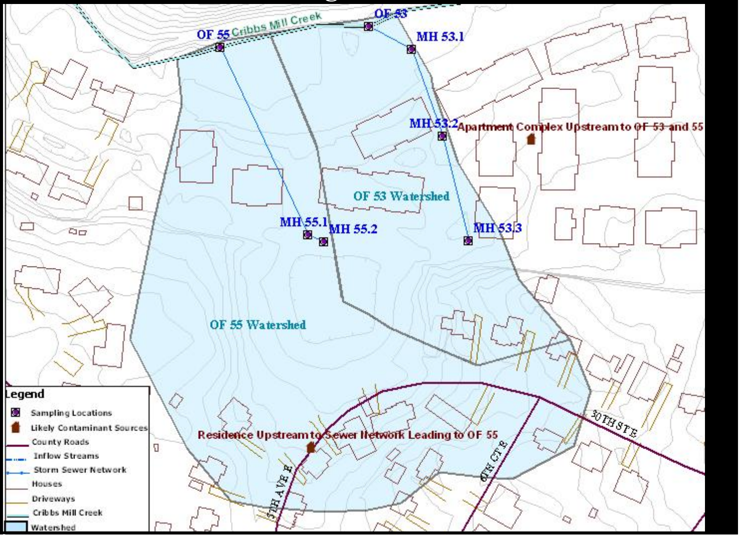
The use of GIS to identify potential contaminant sources in drainage areas.



Summary Table of Outfalls with Problem Sources

Corresponding outfall number	Flow chart result for all observations related to each outfall (No. of Contaminated sources)	Percentage of Samples with problems
3	4 of 13	31
4	0 of 19	0
27	0 of 9	0
36	2 of 13	15
39	1 of 8	13
45	0 of 13	0
53	2 of 16	13
55	4 of 9	44

Conclusions

- Methods using detergents (or boron), fluoride, ammonia, and potassium are still recommended as most useful for identifying contamination of storm drainage systems, with possible addition of specific tests for *E. coli* and enterococci, and fluorescence, for better confirmation of sanitary sewage contamination.
- Most newly emerging methods require exotic equipment and unusual expertise and therefore not very available, especially at low cost and with fast turn-around times. For now, these emerging methods are more useful for special research projects than for routine screening of storm drainage systems.

Conclusions (cont.)

- The physical indicators method only identifies the worst problems (but with false negatives and false positives).
- The detergents method identifies all problems, but with little other information.,
- The flow chart method works well, and identifies the major flow source.
- Mass balance calculations identifies and quantifies most flow components.
- Not difficult to collect data to conduct all of these complementary methods.

Acknowledgements

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