Chapter 12: Indicator Monitoring

Indicator monitoring is used to confirm illicit discharges, and provide clues about their source or origin. In addition, indicator monitoring can measure improvements in water quality during dry weather flow as a result of the local IDDE program. This chapter reviews the suite of chemical indicator parameters that can identify illicit discharges, and provides guidance on how to collect, analyze and interpret each parameter.

Program managers have a wide range of indicator parameters and analytical methods to choose from when determining the presence and source of illicit discharges. The exact combination of indicator parameters and methods selected for a community is often unique. This chapter recommends some general approaches for communities that are just starting an indicator monitoring program or are looking for simple, cost-effective, and safe alternatives to their current program.

Organization of the Chapter

This chapter provides technical support to implement the basic IDDE monitoring framework shown in Figure 44, and is organized into eight sections as follows:

1. Review of indicator parameters
2. Sample collection considerations
3. Methods to analyze samples
4. Methods to distinguish flow types
5. Chemical library
6. Special monitoring methods for intermittent and transitory discharges
7. In-stream dry weather monitoring
8. Costs for indicator monitoring

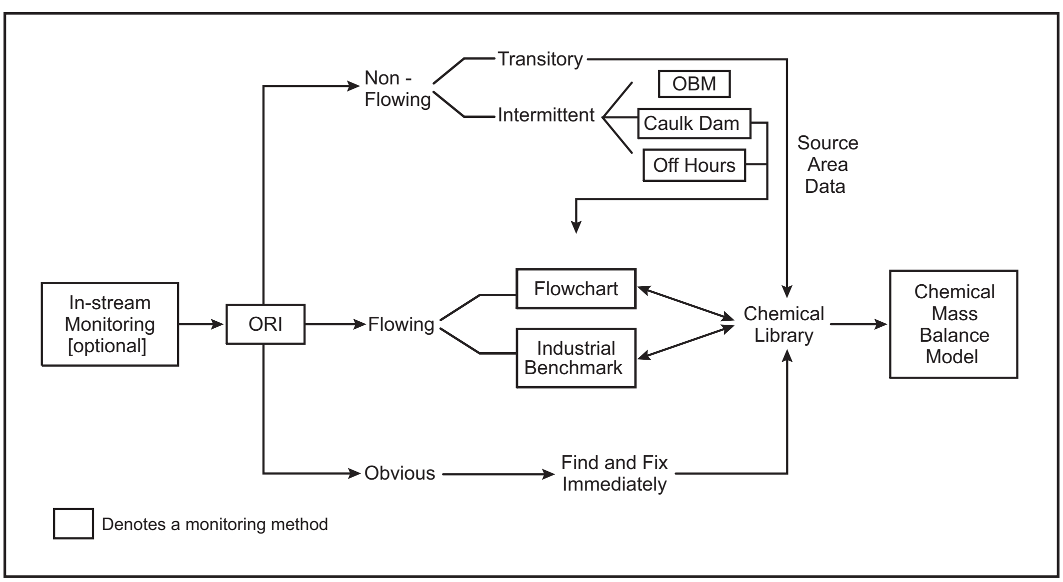

Figure 44: IDDE Monitoring Framework

Program managers developing an indicator monitoring program need a solid background in basic water chemistry, and field and laboratory methods. This chapter describes the major factors to consider when designing an indicator monitoring program for illicit discharges, and assumes some familiarity with water quality sampling and analysis protocols.

Indicator monitoring terminology can be confusing, so some of the basic terms are defined as they specifically relate to illicit discharge control. Some of the common terms introduced in this Chapter are defined below:

Chemical Library: A database and statistical summary of the chemical characteristics, or "fingerprint" of various discharge flow types in a community (e.g., sewage, wash water, shallow groundwater, tap water, irrigation water, and liquid wastes). The library is assembled by collecting and analyzing representative samples from the source of each major flow type in the community.

Chemical Mass Balance Model (CMBM): A computer model that uses flow characteristics from a chemical library file of flow types to estimate the most likely source components that contribute to dry weather flows.

Detergents: Commercial or retail products used to wash clothing. Presence of detergents in flow is usually measured as surfactants or fluorescence.

False Negative: An indicator sample that identifies a discharge as uncontaminated when it actually is contaminated.

False Positive: An indicator sample that identifies a discharge as contaminated when it is not.

Flow Chart Method: The use of four indicators (surfactants, ammonia, potassium, and fluoride) to identify illicit discharges.

Indicator Parameter: A water quality measurement that can be used to identify a specific discharge flow type, or discriminate between different flow types.

Monitoring: A strategy of sample collection and laboratory analysis to detect and characterize illicit discharges.

Optical Brightener Monitoring (OBM) Traps: Traps that use absorbent pads to capture dry weather flows, which can later be observed under a fluorescent light to determine if detergents using optical brighteners were present.

Reagent: A chemical added to a sample to create a reaction that enables the measurement of a target chemical parameter.

Sampling: Water sample collection from an outfall, pipe or stream, along with techniques to store and preserve them for subsequent laboratory analysis.

Surfactants: The main component of commercial detergents that detaches dirt from the clothing. The actual concentration of surfactants is much lower than the concentration of detergent, but analytical methods that measure surfactants are often referred to as "detergents." To avoid confusion, this chapter expresses the concentration of surfactants as "detergents as surfactants."

12.1 Indicator Parameters to Identify Illicit Discharges

At least fifteen different indicator parameters can confirm the presence or origin of an illicit discharge. These parameters are discussed in detail in Appendix F and include:

- Ammonia
- Boron
- Chlorine
- Color
- Conductivity
- Detergents
- *E. coli*, enterococi, and total coliform
- Fluorescence
- Fluoride
- Hardness
- pH
- Potassium
- Surface Tension
- Surfactants
- Turbidity

In most cases, however, only a small subset of indicator parameters (e.g., three to five) is required to adequately characterize an illicit discharge. This section summarizes the different indicator parameters that have been used.

An ideal indicator parameter should reliably distinguish illicit discharges from clean water and provide clues about its sources. In addition, they should have the following characteristics:

- Have a significantly different concentration for major flow or discharge types
- Exhibit relatively small variations in concentrations within the same flow or discharge type
- Be conservative (i.e., concentration will not change over time due to physical, chemical or biological processes)
- Be easily measured with acceptable detection limits, accuracy, safety and repeatability.

No single indicator parameter is perfect, and each community must choose the combination of indicators that works best for their local conditions and discharge types. Table 39 summarizes the parameters that meet most of the indicator criteria, compares their ability to detect different flow types, and reviews some of the challenges that may be encountered when measuring them. More details on indicator parameters are provided in Appendix F.

Data in Table 39 are based on research by Pitt (Appendix E) conducted in Alabama, and therefore, the percentages shown to distinguish "hits" for specific flow types should be viewed as representative and may shift for each community. Also, in some instances, indicator parameters were "downgraded" to account for regional variation or dilution effects. For example, both color and turbidity are excellent indicators of sewage based on discharge fingerprint data, but both can vary regionally depending on the composition of clean groundwater.

Table 39: Indicator Parameters Used to Detect Illicit Discharges					
Parameter	Discharge Types It Can Detect				Laboratory/Analytical Challenges
	Sewage	Washwater	Tap Water	Industrial or Commercial Liquid Wastes	
Ammonia	●	⦿	○	⦿	Can change into other nitrogen forms as the flow travels to the outfall
Boron	⦿	⦿	○	N/A	
Chlorine	○	○	○	⦿	High chlorine demand in natural waters limits utility to flows with very high chlorine concentrations
Color	⦿	⦿	○	⦿	
Conductivity	⦿	⦿	○	⦿	Ineffective in saline waters
Detergents – Surfactants	●	●	○	⦿	Reagent is a hazardous waste
E. coli Enterococci Total Coliform	⦿	○	○	○	24-hour wait for results Need to modify standard monitoring protocols to measure high bacteria concentrations
Fluoride*	○	○	●	⦿	Reagent is a hazardous waste Exception for communities that do not fluoridate their tap water
Hardness	⦿	⦿	⦿	⦿	
pH	○	⦿	○	⦿	
Potassium	⦿	○	○	●	May need to use two separate analytical techniques, depending on the concentration
Turbidity	⦿	⦿	○	⦿	

● Can almost always (>80% of samples) distinguish this discharge from clean flow types (e.g., tap water or natural water). For tap water, can distinguish from natural water.
⦿ Can sometimes (>50% of samples) distinguish this discharge from clean flow types depending on regional characteristics, or can be helpful in combination with another parameter
○ Poor indicator. Cannot reliably detect illicit discharges, or cannot detect tap water
N/A: Data are not available to assess the utility of this parameter for this purpose.
Data sources: Pitt (this study)
*Fluoride is a poor indicator when used as a single parameter, but when combined with additional parameters (such as detergents, ammonia and potassium), it can almost always distinguish between sewage and washwater.

12.2 Sample Collection Considerations

Sample collection is an important aspect of an IDDE program. Program managers need to be well informed about the key facets of sampling such as sample handling, QA/QC, and safety. The guidance in this section is limited to an overview of sample collection considerations including: equipment needed for collecting samples, elements of sampling protocols, and general tips. Several useful documents are available that detail accepted water quality sampling protocols such as the following:

- Burton and Pitt (2002) - Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers

- USGS National Field Manual for the Collection of Water-Quality Data http://water.usgs.gov/owq/FieldManual/
- *Standard Methods for the Examination of Water and Wastewater* http://www.standardmethods.org/
- *EPA NPDES Stormwater Sampling Guidance Document* http://cfpub.epa.gov/npdes (Note: while this document is oriented towards wet weather sampling, there are still many sampling procedures that apply to dry weather sampling)

State environmental agencies are also a good resource to contact for recommended or required sampling protocols.

Equipment Needed for Field Sampling

The basic equipment needed to collect samples is presented in Table 40. Most sampling equipment is easily available for purchase from scientific supply companies and various retail stores.

Developing a Consistent Sample Collection Protocol

Samples should never be collected haphazardly. To get reliable, accurate, and defensible data, it is important to develop a consistent field sampling protocol to collect each indicator sample. A good field sampling protocol incorporates eight basic elements:

1. Where to collect samples
2. When to collect samples
3. Sample bottle preparation
4. Sample collection technique
5. Storage and preservation of samples
6. Sample labeling and chain of custody plan
7. Quality assurance/control samples
8. Safety considerations

Appendix G provides more detail on each monitoring element. Some communities already have established sampling protocols that are used for in-stream or wet weather sampling. In most cases these existing sampling protocols are sufficient to conduct illicit discharge sampling.

Tips for Collecting Illicit Discharge Samples

The following tips can improve the quality of your indicator monitoring program.

1. Remember to fill out an ORI field form at every outfall where samples are collected. The ORI form documents sample conditions, outfall characteristics and greatly aids in interpreting indicator monitoring data.

2. Most state water quality agencies have detailed guidance on sampling protocols. These resources should be consulted and the appropriate guidelines followed. Another useful guidance on developing a quality assurance plan is the "Volunteer Monitor's Guide to Quality Assurance Project Plans" (EPA, 1996).

Table 40: Equipment Needed for Sample Collection
• A cooler (to be kept in the vehicle) • Ice or "blue ice" (to be kept in the vehicle) • Permanent marker (for labeling the samples) • Labeling tape or pre-printed labels • Several dozen one-liter polyethylene plastic sample bottles • A "dipper," a measuring cup at the end of a long pole, to collect samples from outfalls that are hard to reach • Bacteria analysis sample bottles (if applicable), typically pre-cleaned 120mL sample bottles, to ensure against contamination

3. Sample in batches where feasible to cut down on field and mobilization time.
4. Avoid sampling lagged storm water flows by sampling at least 48 to 72 hours after runoff producing events.
5. It may be necessary to collect multiple samples at a single outfall if preservatives are going to be used. Preservatives are typically necessary when long hold times are required for samples before analysis occurs. Appendix G contains guidance on the required preservation and maximum allowable hold times for various parameters.

12.3 Methods to Analyze Indicator Samples

This section reviews methods to analyze indicator samples, and begins with a discussion of whether they should be analyzed in-house or sent to an independent contract lab. Next, recommended methods for analyzing indicator parameters are outlined, along with data on their comparative cost, safety, and accuracy. Lastly, tips are offered to improve an indicator monitoring program.

Analyzing Samples In-house vs. Contract Lab

Program managers need to decide whether to analyze samples in-house, or through an independent monitoring laboratory. The decision on which route to take is often based on the answers to the following questions:

- *What level of precision or accuracy is needed for the indicator parameter(s)?* Precise and accurate data are needed when indicator monitoring is used to legally document a violation or enforcement action. The lab setting is important, since the quality of the data may be challenged. Precise data are also needed for outfalls that have very large drainage areas. These discharges are often diluted by groundwater, so lab methods must be sensitive and have low detection limits to isolate illicit discharges that are masked or blended with other flow types. Accurate data are also needed for large outfalls since the cost and effort triggered by a false positive reading to track and isolate discharges in a large and complex drainage area is much greater.
- *How quickly are sampling results needed?* Fast results are essential if the community wants to respond instantly to problem outfalls. In this case, the capability to collect and analyze indicator samples in-house is desirable to provide quick response.
- *How much staff time and training is needed to support in-house analysis?* Local staff that perform lab analysis must be certified in laboratory safety, quality control and proper analytical procedures. Communities that do not expect to collect many indicator samples may want to utilize a contract lab to reduce staff training costs.
- *Does a safe environment exist to analyze samples and dispose of wastes?* A safe environment is needed for lab analysis including storage in a fireproof environment, eyewash stations, safety showers, fume hoods and ventilation. Lab workers should have standard safety equipment such as gloves, safety glasses and lab coats. Lastly, many of the recommended analytical methods create small quantities of hazardous wastes that need to be properly disposed. Program

managers should carefully evaluate in-house work space to determine if a safe lab environment can be created.

- *What is the comparative cost for sample analysis in each option?* The initial up-front costs to use an independent laboratory are normally lower than those required to establish an in-house analysis capability. An in-house analysis capability normally becomes cost-effective when a community expects to analyze more than 100 indicator samples per year. Section 12.8 outlines some of the key budget factors to consider when making this decision, but program managers should always get bids from reputable and certified contract labs to determine analysis costs.

- *Are existing monitoring laboratories available in the community?* Cost savings are often realized if an existing wastewater treatment or drinking water lab can handle the sample analysis. These labs normally possess the equipment, instruments and trained staff to perform the water quality analyses for indicator parameters.

Considerations for In-house Analysis Capability

Three basic settings can be used to analyze indicator parameters in-house: direct field measurements, small office lab, and a more formal municipal lab. The choice of which in-house setting to use depends on the indicator parameters selected, the need for fast and accurate results and safety/disposal considerations.

In-Field Analysis – A few indicator parameters can be analyzed in the field with probes and other test equipment (Figure 45). While most field parameters can identify problem outfalls, they generally cannot distinguish the specific type of discharge. Some of the situations where in-field analysis[10] is best applied are:

- When a community elects to use one or two indicator parameters, such as ammonia and potassium, that can be measured fairly easily in the field

- When field crews measure indicator parameters to trace or isolate a discharge in a large storm drain pipe network, and need quick results to decide where to go next

Office Analysis – Many of the recommended indicator parameters can be analyzed in an informal "office" lab with the possible exception of surfactants and fluoride (Figure 46). The office analysis option makes sense in communities that have available and trained staff, and choose analytical methods that are safe and have few hazardous waste disposal issues. Another option is to use the office lab to conduct most indicator analyses, but send out fluoride and surfactant indicator samples to a contract lab.

> **TIP**
>
> The methodology for any bacteria analysis also has a waste disposal issue (e.g., biohazard). Check state guidance for appropriate disposal procedures.

[10] Some communities have had success with in-field analysis; however, it can be a challenging environment to conduct rapid and controlled chemical analysis. Therefore, it is generally recommended that the majority of analyses be conducted in a more controlled "lab" setting.

Formal Laboratory Setting – The ideal option in many communities is to use an existing municipal or university laboratory. Existing labs normally have systems in place to dispose of hazardous material, have room and facilities for storing samples, and are equipped with worker safety features. Be careful to craft a schedule that does not interfere with other lab activities.

When in-house analysis is used, program managers need to understand the basic analytical options, safety considerations, equipment needs and analysis costs for each analytical method used to measure indicator parameters. This understanding helps program managers choose what indicator parameters to collect and where they should be analyzed. Much of this information is detailed in Appendix F and summarized below.

Supplies and Equipment

The basic supplies needed to perform lab analysis are described in Table 41, and are available from several scientific equipment suppliers. In addition, reagents, disposable supplies and some specialized instruments may be needed, depending on the specific indicator parameters analyzed. For a partial list of suppliers, consult the Volunteer Stream Monitoring Manual (US EPA, 1997), which can be accessed at www.epa.gov/owow/monitoring/volunteer/stream/appendb.html. Table 42 summarizes the equipment needed for each analytical method.

Figure 45: Analyzing samples in the back of a truck

Figure 46: Office/lab set up in Fort Worth, TX

Table 41: Basic Lab Supplies	
Disposable Supplies • Deionized water (start with about 10 gallons, unless a reverse osmosis machine is available) • Nitric acid for acid wash (one or two gallons to start) **Safety** • Lab or surgical gloves • Lab coats • Safety glasses	**Glassware/Tools** • About two dozen each of 100 and 200 mL beakers • Two or three 100 mL graduated cylinders • Two or three tweezers • Pipettes to transfer samples in small quantities

Table 42: Analytical Methods Supplies Needed				
Indicator Parameter	**Specific Glassware**	**Equipment**	**Reagents or Kits**	**Unique Suppliers**
Ammonia	Sample Cells	Spectrophotometer or Colorimeter	Hach reagents for method 8155	www.hach.com
Boron	None	Spectrophotometer or Colorimeter	Hach reagents for method 10061	www.hach.com
Chlorine	None	Spectrophotometer or Colorimeter	Hach reagents for method 8021	www.hach.com
Color	None	None	Color Kit	www.hach.com
Conductivity	None	Horiba probe	Standards	www.horiba.com
Detergents - Surfactants (MBAS)	None	None	Chemets Detergents Test	www.chemetrics.com
E. Coli	None	Sealer Black Light Comparator	Colilert Reagent Quanti-Tray Sheets	IDEXX Corporation www.idexx.com
Fluorescence	Cuvettes	Fluorometer	None	Several
Fluoride	None	Spectrophotometer or Colorimeter	Hach reagents for method 8029	www.hach.com
Hardness	Erlenmeyer Flask	Burette and Stand or Digital Titrator	EDTA Cartridges or Reagent and Buffer Solution	www.hach.com
pH	None	Horiba Probe	Standards	www.horiba.com
Potassium	None	Horiba Probe	Standards	www.horiba.com
Potassium (Colorimetric)	None	Spectrophotometer or Colorimeter	Hach Reagents for method 8012	www.hach.com

Cost

Table 43 compares the per sample cost to analyze indicator parameters. In general, the per sample cost is fairly similar for most parameters, with the exception of bacteria analyses for *E. coli*, total coliform, or Enterococci. Reagents typically cost less than $2.00 per sample, and equipment purchases seldom exceed $1,000. The typical analysis time averages less than 10 minutes per sample. More information on budgeting indicator monitoring programs can be found in Section 12.8.

Table 43: Chemical Analysis Costs					
Parameter	**Analysis Cost**				
	Per Sample Costs				**Approximate Initial Equipment Cost (Item)**
	Disposable Supplies	**Analysis Time (min/ sample)**	**Staff Cost (@$25/hr)**	**Total Cost Per Sample**	
Ammonia	$1.81	25[3]	$10.42	$12.23	$950[4] (Colorimeter)
Boron	$0.50	20[3]	$8.33	$8.83	$950[4] (Colorimeter)
Chlorine	$0.60	5	$2.08	$2.68	$950[4] (Colorimeter)
Color	$0.52	1	$0.42	$0.94	$0
Conductivity	$0.65[2]	4[3]	$1.67	$2.32	$275 (Probe)
Detergents – Surfactants[1]	$3.15	7	$2.92	$6.07	$0
Enterococci, *E. Coli* or Total Coliform[1]	$6.75	7 (24 hour waiting time)	$2.92	$9.67	$4,000 (Sealer and Incubator)
Fluoride[1]	$0.68	3	$1.25	$1.93	$950[4] (Colorimeter)
Hardness	$1.72	5	$2.08	$3.80	$125 (Digital Titrator)
pH	$0.65[2]	3.5[3]	$1.46	$2.11	$250 (Probe)
Potassium (High Range)	$0.50[2]	5.5[3]	$2.29	$2.79	$250 (Probe)
Potassium (Low Range)	$1.00	5	$2.08	$3.08	$950[4] (Colorimeter)
Turbidity	$0.50[2]	6[3]	$2.50	$3.00	$850 (Turbiditimeter)

[1] Potentially high waste disposal cost for these parameters.
[2] The disposable supplies estimates are based on the use of standards to calibrate a probe or meter.
[3] Analysts can achieve significant economies of scale by analyzing these parameters in batches.
[4] Represents the cost of a colorimeter. The price of a spectrophotometer, which measures a wider range of parameters, is more than $2,500. This one-time cost can be shared among chlorine, fluoride, boron, potassium and ammonia.

Additional Tips for In-house Laboratory Analysis

The following tips can help program managers with in-house laboratory analysis decisions:

- Program managers may want to use both in-house analysis and contract labs to measure the full range of indicator parameters needed in a safe and cost-effective manner. In this case, a split sample analysis strategy is used, where some samples are sent to the contract lab, while others are analyzed in house.

- Remember to order enough basic lab supplies, because they are relatively cheap and having to constantly re-order supplies and wash glassware can be time-consuming. In addition, some scientific supply companies have minimum order amounts, below which additional shipping and handling is charged.
- Be careful to craft a sample analysis schedule that doesn't interfere with other lab operations, particularly if it is a municipal lab. With appropriate preservation, many samples can be stored for several weeks.

Considerations for Choosing a Contract Lab

When a community elects to send samples to an independent contract lab for analysis, it should investigate seven key factors:

1. Make sure that the lab is EPA-certified for the indicator parameters you choose. A state-by-state list of EPA certified labs for drinking water can be found at: http://www.epa.gov/safewater/privatewells/labs.html. State environmental agencies are also good resources to contact for pre-approved laboratories.
2. Choose a lab with a short turn-around time. Some Phase I communities had problems administering their programs because of long turn-around times from local labs (CWP, 2002). As a rule, a lab should be able to produce results within 48 hours.
3. Clearly specify the indicator parameter and analysis method you want, using the guidance in this manual or advice from a water quality expert.
4. Ensure that the maximum hold time for each indicator parameter exceeds the time it takes to ship samples to the lab for analysis.
5. Carefully review and understand the shipping and preservation instructions provided by the contract lab.
6. Look for labs that offer electronic reporting of sample results, which can greatly increase turn-around time, make data analysis easier, and improve response times.
7. Periodically check the lab's QA/QC procedures, which should include lab spikes, lab blanks, and split samples. The procedures for cleaning equipment and calibrating instruments should also be evaluated. These QA/QC procedures are described below.
    - *Lab spikes* – Samples of known concentration are prepared in the laboratory to determine the accuracy of instrument readings.
    - *Lab blanks* – Deionized water samples that have a known zero concentration are used to test methods, or in some methods to "zero" the instruments.
    - *Split samples* – Samples are divided into two separate samples at the laboratory for a comparative analysis. Any difference between the two sample results suggests the analysis method may not be repeatable.
    - *Equipment cleaning and instrument maintenance protocols* – Each lab should have specific and routine procedures to maintain equipment and clean glassware and tubing. These procedures should be clearly labeled on each piece of equipment.

- *Instrument calibration* – Depending on the method, instruments may come with a standard calibration curve, or may require calibration at each use. Lab analysts should periodically test the default calibration curve.

Table 44 summarizes estimated costs associated with sample analyses at a contract lab.

12.4 Techniques to Interpret Indicator Data

Program managers need to decide on the best combination of indicator parameters that will be used to confirm discharges and identify flow types. This section presents guidance on four techniques to interpret indicator parameter data:

- Flow Chart Method (recommended)
- Single Parameter Screening
- Industrial Flow Benchmarks
- Chemical Mass Balance Model (CMBM)

Table 44: Typical Per Sample Contract Lab Costs	
Parameter	**Costs**
Ammonia	$12 - $25
Boron	$16 - $20
Chlorine	$6 - $10
Color	$7 - $11
Conductivity	$2 - $6
Detergents – Surfactants	$17- $35
Enterococci, *E. Coli* or Total Coliform	$17 - $35
Fluoride	$14 - $25
Hardness	$8 - $16
pH	$2 - $7
Potassium	$12 - $14
Turbidity	$9 - $12

All four techniques rely on benchmark concentrations for indicator parameters in order to distinguish among different flow types. Program managers are encouraged to adapt each technique based on local discharge concentration data, and some simple statistical methods for doing so are provided throughout the section.

The Flow Chart Method

The Flow Chart Method is recommended for most Phase II communities, and was originally developed by Pitt *et al.* (1993) and Lalor (1994) and subsequently updated based on new research by Pitt during this project. The Flow Chart Method can distinguish four major discharge types found in residential watersheds, including sewage and wash water flows that are normally the most common illicit discharges. Much of the data supporting the method were collected in Alabama and other regions, and some local adjustment may be needed in some communities. The Flow Chart Method is recommended because it is a relatively simple technique that analyzes four or five indicator parameters that are safe, reliable and inexpensive to measure. The basic decision points involved in the Flow Chart Method are shown in Figure 47 and described below:

Step 1: Separate clean flows from contaminated flows using detergents

The first step evaluates whether the discharge is derived from sewage or washwater sources, based on the presence of detergents. Boron and/or surfactants are used as the primary detergent indicator, and values of boron or surfactants that exceed 0.35 mg/L and 0.25 mg/L, respectively, signal that the discharge is contaminated by sewage or washwater.

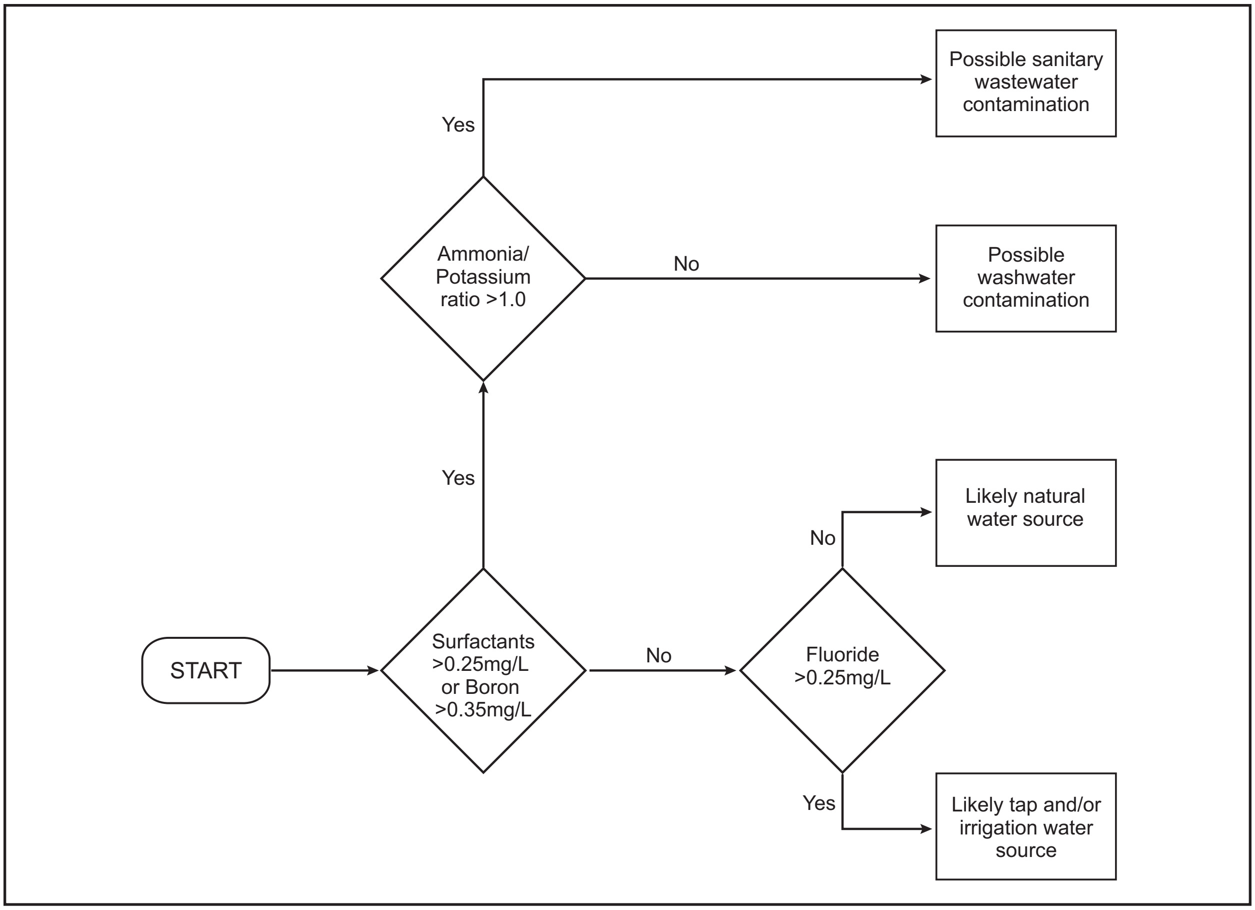

Figure 47: Flow Chart to Identify Illicit Discharges in Residential Watersheds

Step 2: Separate washwater from wastewater using the Ammonia/ Potassium ratio

If the discharge contains detergents, the next step is to determine whether they are derived from sewage or washwater, using the ammonia to potassium ratios. A ratio greater than one suggests sewage contamination, whereas ratios less than one indicate washwater contamination. The benchmark ratio was developed by Pitt *et al.* (1993) and Lalor (1994) based on testing in urban Alabama watersheds.

Step 3: Separate tap water from natural water

If the sample is free of detergents, the next step is to determine if the flow is derived from spring/groundwater or comes from tap water. The benchmark indicator used in this step is fluoride, with concentrations exceeding 0.60 mg/L indicating that potable water is the source. Fluoride levels between 0.13 and 0.6 may indicate non-target irrigation water. The purpose of determining the source of a relatively "clean discharge" is that it can point to water line breaks, outdoor washing, non-target irrigation and other uses of municipal water that generate flows with pollutants.

Adapting the Flow Chart Method

The Flow Chart Method is a robust tool for identifying illicit discharge types, but may need to be locally adapted, since much of the supporting data was collected in one region of the country. Program managers should look at four potential modifications to the flow chart in their community.

1) Is boron or surfactants a superior local indicator of detergents?

Surfactants are almost always a more reliable indicator of detergents, except for rare cases where groundwater has been contaminated by sewage. The disadvantage of surfactants is that the recommended analytical method uses a hazardous chemical as the reagent. Boron uses a safer analytical method. However, if boron is used as a detergent indicator, program managers should sample boron levels in groundwater and tap water, since they can vary regionally. Also, not all detergent formulations incorporate boron at high levels, so it may not always be a strong indicator.

2) Is the ammonia/potassium ratio of one the best benchmark to distinguish sewage from washwater?

The ammonia/potassium ratio is a good way to distinguish sewage from washwater, although the exact ratio appears to vary in different regions of the country. The benchmark value for the ratio was derived from extensive testing in one Alabama city. In fact, data collected in another Alabama city indicated an ammonia/potassium ratio of 0.6 distinguished sewage from wash water. Clearly, program managers should evaluate the ratio in their own community, although the proposed ratio of 1.0 should still capture the majority of sewage discharges. The ratio can be refined over time using indicator monitoring at local outfalls, or through water quality sampling of sewage and washwater flow types for the chemical library.

3) Is fluoride a good indicator of tap water?

Usually. The two exceptions are communities that do not fluoridate their drinking water or have elevated fluoride concentrations in groundwater. In both cases, alternative indicator parameters such as hardness or chlorine may be preferable.

4) Can the flow chart be expanded?

The flow chart presented in Figure 47 is actually a simplified version of a more complex flow chart developed by Pitt for this project, which is presented in Appendix H. An expanded flow chart can provide more consistent and detailed identification of flow types, but obviously requires more analytical work and data analysis. Section 12.5 provides guidance on statistical techniques to customize the flow chart method based on your local discharge data.

Single Parameter Screening

Research by Lalor (1994) suggests that detergents is the best single parameter to detect the presence or absence of the most common illicit discharges (sewage and washwater). The recommended analytical method for detergents uses a hazardous reagent, so the analysis needs to be conducted in a controlled laboratory setting with proper safety equipment. This may limit the flexibility of a community if it is conducting analyses in the field or in a simple office lab.

Ammonia is another single parameter indicator that has been used by some communities with widespread or severe sewage contamination. An ammonia concentration greater than 1 mg/L is generally considered to be a positive indicator of sewage contamination. Ammonia can be analyzed in the field using a portable spectrophotometer, which allows for fairly rapid results and the ability to immediately track down sources and improper connections (see Chapter 13 for details on tracking down illicit discharges)[11]. Since ammonia can be measured in the field, crews can get fast results and immediately proceed to track down the source of the discharge using pipe testing methods (see Chapter 13 for details).

As a single parameter, ammonia has some limitations. First, ammonia by itself may not always be capable of identifying sewage discharges, particularly if they are diluted by “clean” flows. Second, while some washwaters and industrial discharges have relatively high ammonia concentrations, not all do, which increases the prospects of false negatives. Lastly, other dry weather discharges, such as non-target irrigation, can also have high ammonia concentrations that can occasionally exceed 1 mg/L. Supplementing ammonia with potassium and looking at the ammonia/potassium ratio is a simple adjustment to the single parameter approach that helps to further and more accurately characterize the discharge. Ratios greater than one indicate a sewage source, while ratios less than or equal to one indicate a washwater source. Potassium is easily analyzed using a probe (Horiba Cardy™ is the recommended probe).

[11] In-field analysis may be appropriate when tracking down illicit flows, but it is typically associated with challenging and uncontrollable conditions. Therefore, it is generally recommended that analyses be conducted in a controlled lab setting.

Industrial Flow Benchmark

If a subwatershed has a high density of industrial generating sites, additional indicator parameters may be needed to detect and trace these unique discharges. They are often needed because industrial and commercial generating sites produce discharges that are often not composed of either sewage or washwater. Examples include industrial process water, or wash down water conveyed from a floor drain to the storm drain system.

This guidance identifies seven indicator parameters that serve as industrial flow benchmarks to help identify illicit discharges originating from industrial and other generating sites. The seven indicators (ammonia, color, conductivity, hardness, pH, potassium and turbidity) are used to identify liquid wastes and other industrial discharges that are not always picked up by the Flow Chart Method. Table 45 summarizes typical benchmark concentrations that can distinguish between unique industrial or commercial liquid wastes. Note that two of the seven indicator parameters, ammonia and potassium, are already incorporated into the flow chart method.

Table 46 illustrates how industrial benchmark parameters can be used independently or as a supplement to the flow chart method, based on data from Alabama (Appendix E). The best industrial benchmark parameters are identified in pink shading and can distinguish industrial sources from residential washwater in 80% of samples. Supplemental indicator parameters denoted by yellow shading, can distinguish industrial source from residential washwater in 50% of samples, or roughly one in two samples.

Most industrial discharges can consistently be identified by extremely high potassium levels. However, these discharges would be misclassified as washwater when just the Flow Chart Method is used. Other benchmark parameters have value in identifying specific industrial types or operations. For example, metal plating bath waste discharges are often indicated by extremely high conductivity, hardness and potassium concentrations.

Adapting Industrial Flow Benchmark

By their very nature, industrial and other generating sites can produce a bewildering diversity of discharges that are hard to classify. Therefore, program managers will experience some difficulty in differentiating industrial sources. Over time, the composition of industrial discharges can be refined as chemical libraries for specific industrial flow types and sources are developed. This can entail a great deal of sampling, but can reduce the number of false positive or negative readings.

Table 45: Benchmark Concentrations to Identify Industrial Discharges

Indicator Parameter	Benchmark Concentration	Notes
Ammonia	≥50 mg/L	• Existing "Flow Chart" Parameter • Concentrations higher than the benchmark can identify a few industrial discharges.
Color	≥500 Units	• Supplemental parameter that identifies a few specific industrial discharges. Should be refined with local data.
Conductivity	≥2,000 μS/cm	• Identifies a few industrial discharges • May be useful to distinguish between industrial sources.
Hardness	≤10 mg/L as CaCO3 ≥2,000 mg/L as CaCO3	• Identifies a few industrial discharges • May be useful to distinguish between industrial sources.
pH	≤5	• Only captures a few industrial discharges • High pH values may also indicate an industrial discharge but residential wash waters can have a high pH as well.
Potassium	≥20 mg/L	• Existing "Flow Chart" Parameter • Excellent indicator of a broad range of industrial discharges.
Turbidity	≥1,000 NTU	• Supplemental parameter that identifies a few specific industrial discharges. Should be refined with local data.

Table 46: Usefulness of Various Parameters to Identify Industrial Discharges

Industrial Benchmark Concentration	Detergents as Surfactants (mg/L)	Ammonia (mg/L)	Potassium (mg/L)	Initial "Flow Chart" Class	Color (Units)	Conductivity (:S/cm)1	Hardness (mg/L as $CaCO_3$)	pH	Turbidity (NTU)	Best Indicator Parameters to Identify This Flow Type	Additional Indicator Parameters to Identify This Flow Type
	--	≥50	≥20		≥500	≥2000	≤10 ≥2,000	≤5	≥1,000		
Concentrations in Industrial and Commercial Flow Types											
Automotive Manufacturer[1]	5	0.6	66	**Wash water**	15	220	30	6.7	118	Potassium	
Poultry Supplier[1]	5	4.2	41	**Wash water**	23	618	31	6.3	111	Potassium	
Roofing Product Manufacturing[1]	8	10.2	27	**Wash water**	>100[2]	242	32	7.1	229	None	Potassium Color
Uniform Manufacturing[1]	6	6.1	64	**Wash water**	>100[2]	798	35	10.4	2,631	Potassium	Color Turbidity
Radiator Flushing	15	(26.3)	(2,801)	**Wash water**	(3,000)	(3,278)	(5.6)	(7.0)	-	Potassium Conductivity Color	Hardness
Metal Plating Bath	7	(65.7)	(1,009)	**Wash water**	(104)	(10,352)	(1,429)	(4.9)	-	Ammonia Potassium Conductivity Hardness	pH
Commercial Car Wash	140	0.9; (0.2)	4; (43)	**Wash water**	>61; (222)	274; (485)	71; (157)	7.7; (6.7)	156		Potassium Turbidity
Commercial Laundry	(27)	(0.8)	3	**Wash water**	47	(563)	(36)	(9.1)	-		

Best Indicators, shaded in pink, distinguish this source from residential wash water in 80% of samples in both Tuscaloosa and Birmingham, AL.
Supplemental indicators, shaded in yellow, distinguish this source from residential wash water in 50% of samples, or in only one community.
(Data in parentheses are mean values from Birmingham); Data not in parentheses are from Tuscaloosa
[1] Fewer than 3 samples for these discharges.
[2] The color analytical technique used had a maximum value of 100, which was exceeded in all samples. Color may be a good indicator of these industrial discharges and the benchmark concentration may need adjustment downward for this specific community.

Chemical Mass Balance Model (CMBM) for Blended Flows

The Chemical Mass Balance Model (CMBM) is a sophisticated technique to identify flow types at outfalls with blended flows (i.e., dry weather discharges originating from multiple sources). The CMBM, developed by Karri (2004) as part of this project is best applied in complex sewersheds with large drainage areas, and relies heavily on the local chemical library discussed in **the next section.**

The CMBM can quantify the fraction of each flow type present in dry weather flow at an outfall (e.g., 20% spring water; 40% sewage; 20% wash water). The CMBM relies on a computer program that generates and solves algebraic mass balance equations, based on the statistical distribution of specific flow types derived from the chemical library. The CMBM is an excellent analysis tool, but requires significant advance preparation and sampling support. More detailed guidance on how to use and interpret CMBM data can be found in Appendix I.

The chemical library requires additional statistical analysis to support the CMBM. Specifically, indicator parameter data for each flow type need to be statistically analyzed to determine the **mean**, the **coefficient of variation**, and the **distribution type**. In its current version, the CMBM accepts two distribution types: normal or lognormal distributions. Various statistical methodologies can determine the distribution type of a set of data. Much of this analysis can be conducted using standard, readily-available statistical software, such as the Engineering Statistics Handbook which is available from the National Institute of Standards and Technology, and can be accessed at http://www.itl.nist.gov/div898/handbook/.

12.5 The Chemical Library

The chemical library is a summary of the chemical composition of the range of discharge types found in a community. The primary purpose of the library is to characterize distinct flow types that may be observed at outfalls, including both clean and contaminated discharges. A good library includes data on the composition of tap water, groundwater, sewage, septage, non-target irrigation water, industrial process waters, and washwaters (e.g., laundry, car wash, etc.). The chemical library helps program managers customize the flow chart method and industrial benchmarks, and creates the input data needed to drive the CMBM.

To develop the library, samples are collected directly from the discharge source (e.g., tap water, wastewater treatment influent, shallow wells, septic tanks, etc.). Table 47 provides guidance on how and where to sample each flow type in your community. As a general rule, about 10 samples are typically needed to characterize each flow type, although more samples may be needed if the flow type has a high coefficient of variation. The measure of error can be statistically defined by evaluating the coefficient of variation of the sample data (variability relative to the mean value), and the statistical distribution for the data (the probable spread in the data beyond the mean). For more guidance on statistical techniques for assessing sampling data, consult Burton and Pitt (2002) and US EPA (2002), which can be accessed at http://galton.uchicago.edu/~cises/resources/EPA-QA-Sampling-2003.pdf.

Chemical libraries should also be compared to databases that summarize indicator monitoring of dry weather flows at suspect outfalls. Outfall samples may not always be representative of individual flow types because of mixing of flows and dilution, but they can serve as a valuable check if the discharge source is actually confirmed. Program managers can also use both the chemical library and indicator database to refine flow chart or industrial benchmarks (see Appendix J for an example).

Over time, communities may want to add other flow types to the chemical library, such as transitory discharges that generate small volume flows such as "dumpster juice," power washing and residential car washing. Transitory discharges are hard to detect with outfall monitoring, but may cumulatively contribute significant dry weather loads. Understanding the chemical makeup of the transitory discharges can help program managers prioritize education and pollution prevention efforts.

Table 47: Where and How to Sample for Chemical "Fingerprint" Library

Flow Type	Places to Collect the Data	Any Other Potential Sources?
Shallow Groundwater	• From road cuts or stream banks • Samples from shallow wells • USGS regional groundwater quality data • Dry weather in-stream flows at headwaters with no illicit discharges	None. Locally distinct.
Spring Water	• Directly from springs	None. Locally distinct.
Tap water	• Individual taps throughout the community • or analyze local drinking water monitoring reports or annual consumer confidence reports	None. Locally distinct.
Irrigation	• Collect irrigation water from several different sites. May require a hand operated vacuum pump to collect these shallow flows (see Burton and Pitt, 2002)	None. Locally distinct.
Sewage	• Reported sewage treatment plant influent data provides a characterization of raw sewage and is usually available from discharge monitoring reports. Because the characteristics of sewage will vary within the collection system depending upon whether the area is serving residential or commercial uses, climate, residence time in the collection system, etc, it is often more accurate and valuable to collect "fingerprint" samples from within the system, rather than at the treatment plant.	Data in Appendix E can provide a starting point, but local data are preferred.
Septage	• Outflow of several individual septic tanks or leach fields	
Most Industrial Discharges	• Direct effluent from the industrial process (Obtain samples as part of industrial pre-treatment program in local community)	Data in Appendix E characterize some specific industrial flows. Industrial NPDES permit monitoring can also be used.
Commercial Car Wash; Commercial Laundry	• Sumps at these establishments	Data in Appendix E can provide a starting point, but local data are preferred.

Evaluating Interpretive Techniques Using Outfall Indicator Monitoring Data

Outfall sampling data for confirmed sources or flow types can be used to test the accuracy and reliability of all four interpretive techniques. The sampling record is used to determine the number of false positives or false negatives associated with a specific interpretive technique. A simple tabulation of false test readings can identify the types and levels of indicator parameters that are most useful.

Table 48 provides an example of how the Flow Chart Method was tested with outfall monitoring data from Birmingham, AL (Pitt *et al*., 1993). In this case, the Flow Chart Method was applied without adaptation to local conditions, and the number of correctly (and incorrectly) identified discharges was tracked. Tests on 10 Birmingham outfalls were mostly favorable, with the flow chart method correctly identifying contaminated discharges in all cases (i.e., washwater or sewage waste water). At one outfall, the flow chart incorrectly identified sewage as washwater, based on an ammonia (NH_3)/ potassium (K) ratio of 0.9 that was very close to the breakpoint in the Flow Chart Method (ratio of one). Based on such tests, program managers may want to slightly adjust the breakpoints in the Flow Chart Method to minimize the occurrence of errors.

12.6 Special Monitoring Techniques for Intermittent or Transitory Discharges

The hardest discharges to detect and test are intermittent or transitory discharges to the storm drain system that often have an indirect mode of entry. With some ingenuity, luck, and specialized sampling techniques, however, it may be possible to catch these discharges. This section describes some specific monitoring techniques to track down intermittent discharges. Transitory discharges cannot be reliably detected using conventional outfall monitoring techniques, and are normally found as a result of hotline complaints or spill events. Nevertheless, when transitory discharges are encountered, they should be sampled if possible.

Techniques for Monitoring Intermittent Discharges

An outfall may be suspected of having intermittent discharges based on physical indicators (e.g., staining), poor in-stream dry weather water quality, or the density of generating sites in the contributing subwatershed. The only sure way to detect an intermittent discharge is to camp out at the outfall for a long period of time, which is obviously not very cost-effective or feasible. As an alternative, five special monitoring techniques can be used to help track these elusive problems:

- Odd hours monitoring
- Optical brightener monitoring traps
- Caulk dams
- Pool sampling
- Toxicity monitoring

Table 48: Evaluation of the Flow Chart Method Using Data from Birmingham, Alabama (Adapted from Pitt et al., 1993)								
Outfall ID	Outfall Concentrations (mg/L)					Predicted Flow Type	Confirmed Flow Type	Result
	Detergents-Surfactants (>0.25 is sanitary or wash water)	NH3	K	NH3/K (>1.0 is sanitary)	Fluoride (>0.25 is tap, if no detergents)			
14	0	0	0.69	0.0	0.04	Natural Water	Spring Water	Correct
20	0	0.03	1.98	0.0	0.61	Tap Water	Rinse Water (Tap) and Spring Water	Correct
21	20	0.11	5.08	0.0	2.80	Washwater	Washwater (Automotive)	Correct
26	0	0.01	0.72	0.0	0.07	Natural Water	Spring Water	Correct
28	0.25[1]	2.89	5.96	0.5	0.74	Washwater	Washwater (Restaurant)	Correct
31	0.95	0.21	3.01	0.1	1.00	Washwater	Laundry (Motel)	Correct
40z	0.25[1]	0.87	0.94	0.9	0.12	Washwater	Shallow Groundwater and Septage	Identifies Contaminated but Incorrect Flow Type
42	0	0	0.81	0.0	0.07	Natural Water	Spring Water	Correct
48	3.0	5.62	4.40	1.3	0.53	Sanitary Wastewater	Spring Water and Sewage	Correct
60a	0	0.31	2.99	0.1	0.61	Tap Water	Landscaping Irrigation Water	Correct

[1] These values were increased from reported values of 0.23 mg/L (outfall 28) and 0.2 mg/L (outfall 40z). The analytical technique used in Birmingham was more precise (but more hazardous) than the method used to develop the flow chart in Figure 47. It is assumed that these values would have been interpreted as 0.25 mg/L using the less precise method.

Odd Hours Monitoring

Many intermittent discharges actually occur on a regular schedule, but unfortunately not the same one used by field crews during the week. For example, some generating sites discharge over the weekend or during the evening hours. If an outfall is deemed suspicious, program managers may want to consider scheduling "odd hours" sampling at different times of the day or week. Some key times to visit suspicious outfalls include:

- Both morning and afternoon
- Weekday evenings
- Weekend mornings and evenings

Optical Brightener Monitoring Traps

Optical brightener monitoring (OBM) traps are another tool that crews can use to gain insight into the "history" of an outfall without being physically present. OBM traps can be fabricated and installed using a variety of techniques and materials. All configurations involve an absorbent, unbleached cotton pad or fabric swatch and a holding or anchoring device such as a wire mesh trap (Figure 48) or a section of small diameter (e.g., 2-inch) PVC pipe. Traps are anchored to the inside of outfalls at the invert using wire or monofilament that is secured to the pipe itself or rocks used as temporary weights.

Field crews retrieve the OBM traps after they have been deployed for several days of dry weather, and place them under a fluorescent light that will indicate if they have been exposed to detergents. OBM traps have been used with some success in Massachusetts (Sargent *et al.*, 1998) and northern Virginia (Waye, 2000). Although each community used slightly different methods, the basic sampling concept is the same. For more detailed guidance on how to use OBM traps and interpret the results, consult the guidance manual found at: http://www.naturecompass.org/8tb/sampling/index.html and http://www.novaregion.org/obm.htm.

Although OBM traps appear useful in detecting some intermittent discharges, research during this project has found that OBM traps only pick up the most contaminated discharges, and the detergent level needed to produce a "hit" was roughly similar to pure washwater from a washing machine (see Appendix F for results).

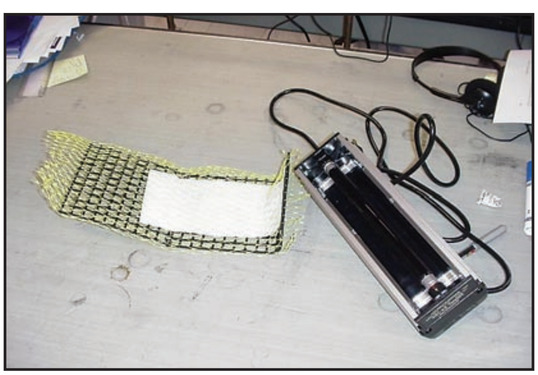

Figure 48: OBM Equipment includes a black light and an OBM Trap that can be placed at an outfall
Source: R. Pitt

Consequently, OBM traps may be best suited as a simple indicator of presence or absence of intermittent flow or to detect the most concentrated flows. OBM traps need to be retrieved before runoff occurs from the outfalls, which will contaminate the trap or wash it away.

Caulk Dams

This technique uses caulk, plumber's putty, or similar substance to make a dam about two inches high within the bottom of the storm drain pipe to capture any dry weather flow that occurs between field observations. Any water that has pooled behind the dam is then sampled using a hand-pump sampler, and analyzed in the lab for appropriate indicator parameters.

Pool Sampling

In this technique, field crews collect indicator samples directly from the "plunge pool" below an outfall, if one is present. An upstream sample is also collected to characterize background stream or ditch water quality that is not influenced by the outfall. The pool water and stream sample are then analyzed for indicator parameters, and compared against each other. Pool sampling results can be constrained by stream dilution, deposition, storm water flows, and chemical reactions that occur within the pool.

Toxicity Monitoring

Another way to detect intermittent discharges is to monitor for toxicity in the pool below the outfall on a daily basis. Burton and Pitt (2002) outline several options to measure toxicity, some of which can be fairly expensive and complex. The Fort Worth Department of Environmental Management has developed a simple low-cost outfall toxicity testing technique known as the Stream Sentinel program. Stream sentinels place a bottle filled with minnows in the pool below suspected outfalls and measure the survival rate of the minnows as an indicator of the toxicity of the outfall [12] (see Figure 49).

One advantage of the sentinel program is that volunteer monitors can easily participate, by raising and caring for the minnows, placing bottles at outfalls, and visiting them everyday to record mortality. The long-term nature of sentinel monitoring can help pick up toxicity trends at a given outfall. For example, Fort Worth observed a trend of mass mortality on the second Tuesday of each month at some outfalls, which helped to pinpoint the industry responsible for the discharges, and improved sample scheduling (City of Fort Worth, 2003). More information about the Stream Sentinel program can be found at: www.fortworthgov.org/DEM/stream_sentinel.pdf.

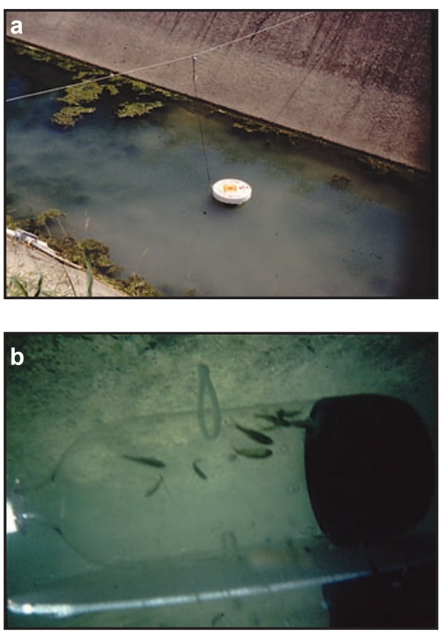

Figure 49: Float and wire system to suspend a bottle in a stream sentinel station deployed in Fort Worth, TX (a); Minnows in the perforated bottle below the water surface (b).

Due to the cost and difficulty of interpreting findings, toxicity testing is generally not recommended for communities unless they have prior experience and expertise with the method.

Techniques for Monitoring Transitory Discharges

Transitory discharges, such as spills and illegal dumping, are primarily sampled to assign legal responsibility for enforcement actions or to reinforce ongoing pollution prevention education efforts. In most cases, crews attempt to trace transitory discharges back up the pipe or drainage area using visual techniques (see Chapter 13). However, field crews should always collect a sample to document the event. Table 49 summarizes some follow-up monitoring strategies to document transitory discharges.

12.7 Monitoring of Stream Quality During Dry Weather

In-stream water quality monitoring can help detect sewage and other discharges in a community or larger watershed. Stream monitoring can identify the subwatersheds with the greatest illicit or sewage discharge potential that is then used to target outfall indicator monitoring. At the smaller reach scale, stream monitoring may sometimes detect major individual discharges to the stream.

[12] It may be necessary to obtain approval from the appropriate state of federal regulatory agency before conducting toxicity monitoring using vertebrates.

Table 49: Follow Up Monitoring for Transitory Discharges	
Condition	**Response**
Oils or solvents	Special hydrocarbon analysis to characterize the source of the oil
Unknown but toxic material	Full suite of metals, pesticides, other toxic materials
Probable sewage	Monitor for parameters associated with the Flow Chart Technique (detergents, ammonia, potassium, fluoride) for residential drainage areas

Stream Monitoring to Identify Problem Reaches or Subwatersheds

Stream monitoring data can be used to locate areas in subwatersheds where illicit discharges may be present, and where human or aquatic health risks are higher. To provide this information, stream monitoring should be conducted regularly during dry weather conditions to track water quality (at least monthly) and to document changes in water quality over a period of time. Stream monitoring data are particularly effective when combined with ORI data. For example, a subwatershed with many ORI physical indicators of illicit discharges (e.g., a high number of flowing outfalls) that also has poor stream water quality would be an obvious target for intensive outfall monitoring.

Stream monitoring parameters should reflect local water quality goals and objectives, and frequently include bacteria and ammonia. Bacteria are useful since sewage discharges can contribute to violations of water contact standards set for recreation during dry weather conditions. Table 50 summarizes water quality standards for *E. coli* that EPA recommends for water contact recreation. It is important to note that individual states may use different action levels or bacteria indicators (e.g., Enterococci or fecal coliform) to regulate water contact recreation. For a review of the impacts bacteria exert on surface waters, consult CWP (2000).

An important caveat when interpreting stream monitoring data is that a violation of bacteria standards during dry weather flow does not always mean that an illicit discharge or sewage overflow is present. While raw sewage has bacteria concentrations that greatly exceed bacteria standards (approximately 12,000 MPN/100 mL) other bacteria sources, such as urban wildlife, can also cause a stream to violate standards. Consequently, stream monitoring data need to be interpreted in the context of other information, such as upstream land use, past complaints, age of infrastructure, and ORI surveys.

Ideally, stream monitoring stations should be strategically located with a minimum of one station per subwatershed, and additional stations at stream confluences and downstream of reaches with a high outfall density. Stations should also be located at beaches, shellfish harvesting and other areas where discharges represent a specific threat to public health. See Burton and Pitt (2002) for guidance on stream monitoring.

Stream Monitoring to Identify Specific Discharges

Stream monitoring data can help field crews locate individual discharges within a specific stream reach. Immediate results are needed for this kind of monitoring, so indicator parameters should be analyzed using simple field test kits or portable analytical instruments (e.g., spectrophotometer). Bacteria is not a good indicator parameter to use for this purpose because lab results cannot be received for at least one day (analytical method requires a "hold time" of 24 hours). Table 51 summarizes nutrient indicator parameters along with their "potential problem level" benchmarks. It is important to note that other factors, such as animal operations, can elevate stream nutrient concentrations, so data should always be interpreted in the context of surrounding land use. Stream monitoring benchmarks should be continuously refined as communities develop a better understanding of what dry weather baseline concentrations to expect.

If stream monitoring indicates that a potential problem level benchmark has been exceeded, field crews continue stream sampling to locate the discharge through a process of elimination. Crews walk upstream taking regular samples above and below stream confluences until the benchmark concentration declines. The crews then take samples at strategic points to narrow down the location of the discharge, using the in-pipe monitoring strategy described in Chapter 13.

Table 50: Typical "Full Body Contact Recreation" Standards for *E. coli*
(Source: EPA, 1986)[1]

Use	Criterion
Designated beach area	235 MPN /100 mL
Moderately-used full body contact recreation area	298 MPN /100 mL
Lightly-used full body contact recreation	406 MPN /100 mL
Infrequently-used full body contact recreation	576 MPN /100 mL

[1] These concentrations represent standards for a single sampling event. In all waters, a geometric mean concentration of 126 MPN/100 mL cannot be exceeded for five samples taken within one month.

Table 51: Example In Stream Nutrient Indicators of Discharges
(Zielinski, 2003)

Parameter	Potential Problem Level*	Possible Cause of Water Quality Problem
Total Nitrogen (TN)	3.5 mg/l	High nutrients in ground water from agriculture, lawn practices, or sewage contamination from illicit connection, sanitary line break or failing septic system.
Total Phosphorus (TP)	0.4 mg/l	Contamination from lawn practices, agriculture, sewage or washwater.
Ammonia (NH_3)	0.3 mg/l	Sewage or washwater contamination from illicit connection, sanitary line break or failing septic system.

**Nutrient parameters are based on USGS NAWQA data with 85% of flow weighted samples being less than these values in urban watersheds (Note: data from Nevada were not used, due to climatic differences and for some parameters they were an order of magnitude higher). Communities can modify these benchmarks to reflect local data and experience.*

12.8 The Costs of Indicator Monitoring

This section provides general guidance on scoping and budgeting an indicator monitoring program. The required budget will ultimately be dictated by the monitoring decisions and local conditions within a community. The budgeting data presented in this section are based on the level of indicator sampling effort in two hypothetical communities, using different numbers of samples, indicator parameters, and analysis methods.

Budgets for Indicator Monitoring in a Hypothetical Community

Communities can develop annual budgets for indicator monitoring if the degree of sampling effort can be scoped. This is normally computed based on the expected number of samples to analyze and is a function of stream miles surveyed and outfall density. For example, if a community collects samples from 10 stream miles with eight outfalls per mile, it will have 80 samples to analyze. This number can be used to generate start-up and annual monitoring cost estimates that represent the expected level of sampling effort. Table 52 summarizes how indicator monitoring budgets were developed for two hypothetical communities, each with 80 outfalls to sample. Budgets are shown using both in-house and contract lab set-ups, and are split between initial start-up costs and annual costs.

Community A: Primarily Residential Land Use, Flow Chart Method

In this scenario, six indicator parameters were analyzed, several of which were used to support the Flow Chart Method. The community took no additional samples to create a chemical library, and instead relied on default values to identify illicit discharges. The community analyzed the samples in-house at a rate of one sample (includes analysis of all six parameters) per staff hour.

Community B: Mixed Land Use - Multiple Potential Sources, Complex Analysis

In the second scenario, the community analyzed 11 indicator parameters, including a bacteria indicator, and took samples of eight distinct flow types to create a chemical library, for a total of 88 samples. The community analyzed the samples in-house at a rate of one sample per 1.5 staff hours.

Some general rules of thumb that were used for this budget planning example include the following:

- $500 in initial sampling equipment (e.g., sample bottles, latex gloves, dipper, cooler, etc).
- Outfall samples are collected in batches of 10. Each batch of samples can be collected and transported to the lab in two staff days (two-person crew required to collect samples for safety purposes).
- Staff rate is $25/hr.
- Overall effort to collect samples for the chemical library and statistically analyze the data is approximately one staff day per source type.
- The staff time needed to prepare for field work and interpret lab results is roughly two times that required for conducting the field work (i.e., eight days of collecting samples requires 16 days of pre- and post-preparation).

Costs for Intermittent Discharge Analyses

Equipment costs for most specialized intermittent discharge techniques tend to be low (<$500), and are dwarfed by staff effort. As a rule of thumb, assume about four hours of staff time to deploy, retrieve and analyze samples collected from a single outfall using these techniques.

Table 52: Indicator Monitoring Costs: Two Scenarios

	Community A: In-House	Community A: Contract Lab	Community B: In-House	Community B: Contract Lab
Initial Costs				
Initial Sampling Supplies and Lab Equipment [1]	$1,700	$500	$7,500	$500
Staff Cost: Library Development [2]	$0	$0	$4,600[3]	$2,000
Analysis Costs: Library Development (Reagents or Contract Lab Cost)	$0	$0	$1,400	$13,000[4]
Total Initial Costs	**$1,700**	**$500**	**$13,500**	**$15,500**
Annual Costs in Subsequent Years				
Staff Field Cost (Sample Collection) [2, 5, 6]	$3,200	$3,200	$3,200	$3,200
Staff Costs: Chemical Analysis [2]	$2,000	$200[7]	$3,000	$200
Staff Time to Enter/ Interpret Data [2, 6]	$3,200	$3,200	$4,800	$4,800
Analysis Costs: Annual Outfall Sampling (Reagents or Contract Lab Cost)	$600	$8,400[4]	$1,400	$13,000[4]
Total Annual Cost	**$9,000**	**$15,000**	**$12,400**	**$21,200**

Notes:
[1] $500 in initial sampling equipment.
[2] Samples can be shipped to a contract lab using one staff hour.
[3] Overall effort to collect samples for the library and statistically analyze the data is approximately one staff day per source type.
[4] For contract lab analysis, assume a cost that is an average between the two extremes of the range in Table 43.
[5] Outfall samples are collected in batches of 10. Each batch of samples can be collected and transported to the lab in two staff days (two-person crew required to collect samples for safety purposes).
[6] Assume that the staff time needed to interpret lab results and prepare for field work is roughly 16 staff days. An additional eight days are required for the flow type pre- and post-preparation for Community 2.
[7] Staff rate is $25/hr.