A Guidance Manual for Identifying and Eliminating Illicit Connections to Municipal Separate Storm Sewer Systems (MS4)

Prepared by:
Galveston County Health District
Pollution Control Division

In Cooperation with:
Houston-Galveston Area Council,
Galveston Bay Estuary Program,
and
Texas Commission on Environmental Quality
(formerly: Texas Natural Resource Conservation Commission)

August 2002

Table of Contents

Introduction 1

I. Mapping 3

II. Initial Dry Weather Flow Survey 4

III. Tracers 4

- A. Physical Tracers 5
  1. Color 5
  2. Odor 6
  3. Turbidity 7
  4. Water Temperature 8
  5. Flow 8
  6. Other Relevant Observations 9
- B. Biological Tracers 11
  1. Bacteria 11
- C. Chemical Tracers 13
  1. Dissolved Oxygen 13
  2. pH 14
  3. Chlorine 16
  4. Ammonia 18
  5. Phosphates 19
- D. Confirmation Techniques 20
  1. Dye Testing 20
  2. Optical Brighteners 23
  3. Televising 26
- E. Future Tracers 26
  1. DNA 26
  2. Caffeine 27
  3. Pharmaceuticals/Drugs 27
  4. Viruses 28
  5. Infared heat detection systems (IHDS) 28

IV. Sampling 28

A. Preparing to Sample 29

B. Collecting Samples 29

C. Using the Sample Results 30

V. Documentation and Reporting 31

Appendices

A. References & Literature Cited
B. Glossary
C. Field Investigation Sheet
D. Charcoal Packet Processing and Elution
E. Optical Brightener Equipment List
F. Optical Brightener Data Sheet
G. Optical Brightener Quality Assurance/Quality Control Sheet
H Magnolia Creek Station
I. Sampling Equipment List
J. Field Sampling Sheet
K. Summary of Illicit Connection Investigation (Supervisor Report)
L. Table 1. Field Survey Parameters and Associated Non-Storm Water Flow Source Categories
M. Investigation Check List
N. Tracer Summary Datasheet

Introduction

This guidance manual for identifying and eliminating illicit connections to municipal separate storm sewer systems (MS4) was developed for two reasons. First, as a tool to assist all MS4 operators with Phase I and Phase II storm water program compliance, and second, to address the goals and needs of *The Galveston Bay Plan: The Comprehensive Conservation and Management Plan for Galveston Bay (The Plan)*. This manual outlines MS4 mapping options, dry weather survey procedures, sampling methods and illicit connection investigative techniques. This guidance manual also provides alternative ideas for municipalities to choose what is best suited for them based upon budget, personnel, and time constraints.

Background: In 1972, the Federal Water Pollution Control Act was passed with the intent to eliminate the discharge of pollutants into navigable waters, to protect and propagate shellfish and wildlife, to provide for recreation in or on the waters of the nation, and to prohibit the discharge of toxic pollutants in concentrations which would impair the multiple uses of all waters. Over the next thirty years, various legislation was enacted that addressed aspects of both point source and non-point source (NPS) pollution. By 1994, the "National Water Quality Inventory" indicated that storm water discharges from sources such as separate storm sewers, construction sites, waste disposal sites, and resource extraction activities were major causes of water quality impairment. One estuarine survey highlighted in the inventory found nearly fifty percent (50%) of the identified cases of water quality impairment were attributed to storm water runoff or NPS pollution.

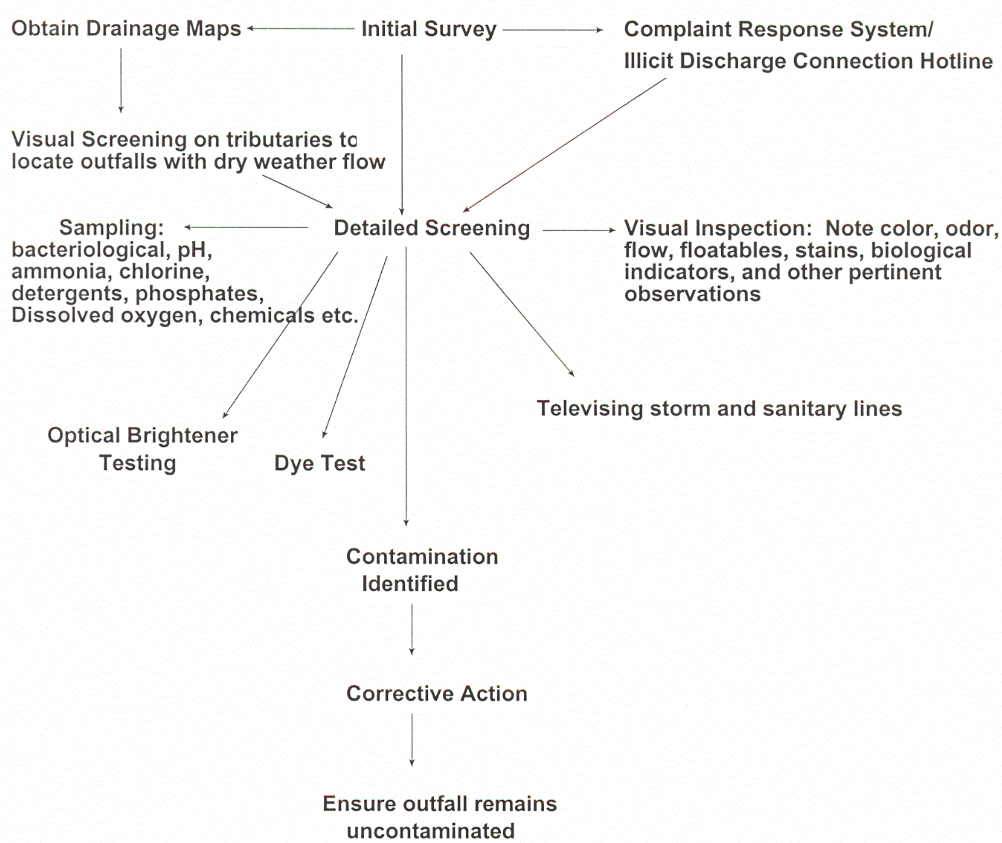
The National Pollutant Discharge Elimination System (NPDES) Phase I Storm Water regulations were developed in response to the 1987 Amendments to the Clean Water Act (CWA). Under Phase I, the Environmental Protection Agency (EPA) mandated medium and large municipal separate storm sewer systems (MS4) located in incorporated communities or counties with populations of 100,000 or more to permit their storm water discharges. Plus, NPDES Phase I permits became required for eleven categories of industrial activities, including any construction activity disturbing five or more acres of land. The regulations included the incentive to adopt "no exposure" practices in commercial and industrial operations and were intended to produce significant reductions in pollutant discharges and improvement in surface water quality. Ultimately, federally mandated Phase II Storm Water Regulations were passed to address the small MS4s (serving less than 100,000 persons).

Effective February 2000, small MS4 operators in urbanized areas and construction sites that disturb one to five acres became regulated. EPA believes that the implementation of the six minimum control measures identified for small MS4s should significantly reduce pollutants in urban storm water compared to existing levels. One of the six measures is the detection and elimination of illicit discharges to the MS4s. Illicit discharges include wastes and wastewater from non-storm water sources. Illicit discharges enter the MS4 through either direct connections such as piping mistakenly or deliberately connected to the storm drains or indirect connections such as infiltration into the MS4 from cracked sanitary sewer pipes.

In 1994, the Galveston Bay National Estuary Program also completed the development of *The Galveston Bay Plan: The Comprehensive Conservation and Management Plan for Galveston Bay (The Plan)*. Galveston Bay provides huge economic benefits to the region and the state. *The Plan* identified the threats to the bay resulting from pollution, development and overuse, then outlined a management strategy to maintain or improve the natural resources of the bay. The bay's second most serious problem was identified as being NPS pollution resulting from storm water runoff. There are sixteen initiatives in *The Plan* to reduce or eliminate NPS pollution. The first initiative is to help local municipalities implement storm water pollution prevention programs.

The Plan also has six initiatives related to point source pollution. In the past, discharges of pollutants from municipal and industrial wastewater treatment plants have upset the healthy balance of marine life in portions of the Galveston Bay estuary system. However, since the 1970's, the closely regulated permitting process has successfully reduced the pollutant loadings from large municipal and industrial discharges. The primary concerns today relate to wet weather by-passes and overflows, compliance issues with small wastewater treatment plants and illicit storm sewer connections. Initiative PS-5 of *The Plan* requires the implementation of a dry-weather illegal connections program. The objective is to actively search for illicit connections to the MS4s and eliminate them.

Figure 1: Identifying and Eliminating Illicit Connections Flow Chart



I. Mapping

Mapping is the first critical step in the detection and elimination of illicit connections between the sanitary and storm sewer systems. Accurate maps will enhance record keeping, facilitate investigations, and improve efficiency of field personnel. Detailed maps plus thorough field investigation notes will be invaluable for identifying the sources of the dry weather flows detected throughout any MS4. If maps are not created, the investigator will spend valuable time trying to locate the points of entry which facilitate tracking during the initial and detailed surveys.

Use a walking stick for balance and to warn off snakes.
Wear steel-toed/ steel shank work boots for foot protection.
Wear snake guards if walking through tall grass & brush.
Carry a cell phone if alone.
Use two-way radios if partnered.

Two options for Mapping: Owners or operators of the MS4 basically have two options when creating their maps. Either Geographic Informational System (GIS) or AutoCAD (computer assisted drawing) maps can be designed/updated **or** paper maps using U.S. Quadrangles, aerial photos, and/or street maps must be fabricated/created by hand. Combining GIS with AutoCAD provides the greatest flexibility and advantage to the MS4 operator/owner. Electronic mapping is the most desirable because it will meet today's information needs plus prepare the cities/utility districts for federal assets inventory responsibilities in the future.

- <u>Electronic base maps</u> may be acquired from several sources. Cities in Galveston County may acquire base maps with street names, property lines, ownership information, property values, etc. from the Galveston Central Appraisal District. Other cities may choose to get TIGER files from the Census Bureau or digitized base maps may be available from their own county appraisal districts or Houston-Galveston Area Council.

  Electronic maps which have sanitary sewer lines (including pipe size and flow direction), manholes and lift stations overlaid with storm sewer lines, manholes, inlets and outfalls are the investigator's most useful tool. Electronic maps can be constructed using different methods. Collecting global positioning satellite (GPS) coordinates on all manholes, outfalls, etc. provide the Geographic Information System (GIS) specialist with the data to "layer" information onto the base map. Conversely, geo-referenced satellite imagery allows all the information to be digitized directly without field GPS coordinates.

- <u>Hand drawn paper maps</u>. U.S. Quadrangles (Quads) have very good scale, topographic lines, and details regarding land uses. However, Quads are not updated on a regular basis. Aerial photos or satellite images, which are taken every few years in some locations, will help update specific Quads for your area but enlarged area street/highway maps may be the best maps to build upon. Since many are given away free of charge, they can be copied and enlarged to draw lines detailing drainage ditches. Arrows can also be used to indicate where and on which side of the ditch a storm water outfall is located.

Color coding maps. Color is the easiest way to designate problems and review accumulated data at-a-glance. Color is good for designating which outfalls have dry weather flow and which do not. Color can be used to separate "flows" into categories based upon volume (gallons per minute). Color can also be used to record information about problem areas upstream of an outfall with a dry weather flow. Use what works best for you.

II. Initial Dry Weather Flow Survey

After maps are completed, dry weather flows must be located. Investigators should walk, drive or float each waterway to identify outfalls having flow. Surveys should not be conducted within 12 hours of a rainfall event or until run-off has ceased. GCHD found 72 hours to be necessary after a significant rainfall. Conduct the survey as follows:

- Label map outfalls with appropriate color to indicate flow/non-flow.
- Document physical characteristics of all dry weather flows using the Illicit Discharge/ Connection Field Investigation Sheet found in Appendix C.
- Conduct field analyses on each flow and document. See Section III-A.
- Collect lab samples at this time as needed. See Sections III-B, III-C and IV-B.

On rare occasions an illicit connection may be identified during the initial survey but usually multiple detailed investigations are necessary. Physical characteristics, field analyses and laboratory tests are collectively known as "Tracers" and are described in detail in the following section.

III. Tracers

A tracer is a distinct characteristic, parameter or combination of such used to test for the presence of a pollutant(s). An ideal tracer should have the following traits:

- promotes time efficiency for field investigator(s),
- inexpensive,
- easy to perform in the field (requires minimum training to receive good results),
- provides results in the field (exception: laboratory samples),
- measures appropriate detection limits,
- produces a measurable concentration for comparison against a non-polluted standard,
- stable characteristics with no significant concentration change over time due to physical, chemical or biological processes,
- non-toxic to the environment (having no waste to return to lab for proper disposal), and/or
- appropriate to the situation (residential vs. industrial).

A. Physical Tracers

The presence of color, odor, turbidity, water temperature, estimated flow rates, biological activity, floatables, oil sheens and other observations can be very useful in identifying an illicit connection. Occasionally, these indicators can be used alone but are best used in conjunction with other field and/or lab tests to correctly identify a pollution source.

1. Color

The color of water is influenced by the presence or absence of substances such as metallic salts, organic matter, dissolved or suspended materials. Water appearance or color may also be an important indicator of water quality problems. The following are common colors and their possible causes (Kolbe):

Color	Possible Sources
Tan to brown	Runoff from rainfall event, construction, or soil erosion
Blue green/ brown green	Plankton bloom, sewage, fertilizer runoff, vehicular wash water or "tracing dye"
Milky white	Paint, lime, milk, or grease
Milky or dirty dishwater gray	Gray water or wastewater, musty odor present
Black	Septic wastewater, sulfuric acid spill or a turnover of oxygen depleted water. Hydrogen sulfide odor usually present.
Dark red, purple, blue, black	Industry - fabric dye, paper ink
Orange-red	Leachate from iron deposits; Tracing dye; Deposits on stream beds often associated with oil well operations such as brine water discharges; oily sheen or petroleum odor may be present.
Bright yellow green	Anti-freeze, tracing dye or algal bloom

Figure 2. Source of brown flow was sediment.

Figure 3. Source of blue-green flow was sewage.

Figure 4. Source of white flow was grease from a fast food restaurant.

Figure 5. Source of blue water was a car wash facility.

Technique #1 - the investigator makes a subjective visual description.

Technique #2 - The New Zealand National Institute of Water and Atmospheric Research developed a technique using a viewing box in conjunction with the Munsell Color Coding System. Comparison cards are used to match the color of the water. A viewing box and set of cards cost approximately $800.

Pros: Easy to track colored water upstream through underground drainage system.
Cons: Not every illicit discharge will have a color to trace.

2. Odor
Odor has very subjective characteristics and differs from one individual to another. Plus an investigator's ability to detect odors may change during the time of exposure. Because of this phenomenon, odors should be noted when first approaching an outfall or storm drain opening.

The following are some common odors and their probable causes:

Odor	Possible Sources
Musty	Raw or partially treated sewage, livestock waste, algae
Rotten egg/ Hydrogen Sulfide	Raw sewage, sulfuric acid, anaerobic water
Sewage/fecal	Raw sewage
Chlorine	Broken drinking water line, sprinkler runoff, swimming pool backwash water, wastewater treatment plant discharge, industrial discharges
Sharp, pungent odor	Chemicals or pesticides
Gasoline, spent petroleum	Industrial discharge, illegal dumping of wastes or waste water.

Pros: An odor can be very helpful in identifying the source of the flow or narrowing the area of focus.
Cons: Not every illicit flow will have an odor.
Investigators can become de-sensitized to a particular odor within minutes of exposure.

3. Turbidity

Turbidity in water is caused by suspended clay particles, silt, finely divided organic and inorganic matter, plankton and microscopic organisms. Movement of the water keeps these materials in suspension and prevents sunlight from filtering through the water. The heavier the turbidity, the more opaque the water appears. Highly turbid water can clog fish gills, reduce photosynthesis, and obscure in-stream habitat. Where a highly turbid flow exists there may be an illicit discharge occurring.

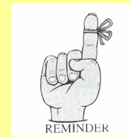
Technique #1 - collect a quantity of water in a white bucket and estimate the turbidity based upon how cloudy the water appears. Assign a ranking such as high, medium, or low turbidity.

Technique #2 - use a turbidity meter. Commercial meters measure the amount of light allowed to pass through a glass tube filled with a solution. However, turbidity meters are not 100% accurate and not every meter is accurate for all conditions. Some meters work best in low turbidity while others are more accurate in medium or heavy turbidity. Others require several correction factors to improve their accuracy.

Pros: The “type” of turbidity may help identify the source of the flow.
Cons: Turbidity alone will not identify whether multiple sources are present.
No single meter is good for all conditions.

4. Water Temperature

The temperature of the dry weather flow can sometimes be useful in identifying flows contaminated by sanitary wastewater. Household and commercial sewage tends to have a consistently warm temperature year round. Therefore, during colder months, any sewage escaping from the sanitary sewer into the storm sewer system may leave a temperature trail.

> Allow 1 minute for thermometer or probe to stabilize.
>
> 
>
>
> Thermometer, water sample, and sampling container should NOT be in direct sunlight or exposed to a strong breeze.

Technique #1 - collect a quantity of sample in a bucket then submerge the tip of a thermometer in the water. Take the reading while bulb is submerged.

Technique #2 - use a multi-probe meter with a temperature probe, submerge the probe directly in the stream or submerge the probe into a bucket of sample water. Take reading while probe is submerged.

Pros: Inexpensive and time efficient.
Cons: Only helpful in cold weather otherwise, temperature difference is not significant enough to track.

5. Flow

Determining flow will help set investigation priorities. High flow but minimal contamination may take precedent over a lower flow with higher pollutant level. Two simple and inexpensive techniques that can be used to monitor flow.

Case Study #1: Setting investigation priorities based upon flow.

> Two outfalls have *E.coli* results of >24,000 mpn/100ml, but one outfall has a flow of 1 gpm and the second outfall has a 3 gpm flow, the outfall with the higher flow rate and higher impact would take priority for investigation. The actual bacteria loading, from a source point to the receiving stream, can be calculated using the bacteria and flow data. The number of bacteria in a 100 ml sample along with the flow in gallons per minute is entered into the following formula:
>
> Bacteria (x) gpm (x) 54800* = bacteria/day.

Technique #1 - use a bucket and a stopwatch. This method must have a drop space large enough to accommodate a measuring container (bucket) under the lower edge of the outfall. Either the container is held under the outfall for one minute and the volume of the flow is measured **or** the time for "how fast the container fills" is recorded. Either way, the gallons per minute can easily be calculated. This procedure should be conducted at least 3 times and an average taken. The latter option is best suited for very small flows.

Technique #2 - use a tracing dye or floatable item such as a cheese ball, match, or cork, a tape measure, a stop watch, and two people. First, measure the distance from the outfall to the first upstream storm water manhole. Second, one person drops the floatable object into the upstream manhole and starts the stop watch. Third, as the object flows out the pipe, the time is documented. Repeat this procedure two more times and take an average of the results. Next, calculate the volume of the channel segment to finish determining flow.

$$\text{Distance} \div \text{Time} = \text{Velocity}$$

$$\text{Velocity} \times \text{Volume} = \text{Flow}$$

Pros: Inexpensive method and time efficient
Outfall investigations can be prioritized

Cons: The flow, using the above methods, is an estimate and not exact
The end of the pipe can be submerged making the bucket method non-functional.
The floatable may be hindered or trapped due to uneven substrate or excessive debris within the underground pipe.

Case Study #2: Using flow as an indicator of contamination.

> During an intensive survey, a storm water outfall that is usually dry was found to have a heavy flow of 5 gpm. The water was clear with few or no solids. There was no strong odor associated with the flow. But suds were present in the receiving stream. Since there had been no significant rainfall for more than seven (7) days, further investigation was warranted. A sanitary sewer overflow (SSO) was located upstream. The manhole lid was straining the solids and the wastewater was flowing directly into a nearby storm drain inlet.

6. Other Relevant Observations

"Other" observations about the outfall, the area surrounding the outfall, or activities occurring in the vicinity will sometimes give clues to the source of a flow or the cause of the pollution. Noting these observations and using them to complete the investigation "puzzle" will provide a complete picture.

Figure 6. Trash and debris washed out of the storm drain.

Figure 7. Heavy algal flow.

Figure 8. Oil dumped at a storm drain outfall.

- Debris includes trash, leaves, and grass clippings
- Floatables are from a sanitary waste, commercial or an industrial source
- Vegetation such as algae or "sewer lilies" is present only around and in close proximity of the storm water outfall.
- Lack of any vegetation or stunted plant life may indicate a problem.
- Stains or deposits - dark stains, crystalline, oil, or amorphous powder
- Sewage fungus, *Sphaerotilus natans*, is a soft, gray, filamentous bacteria. When present in large quantities, the bacteria will form a sheet or layer which can be seen with the naked eye. It is found primarily in areas polluted by wastewater or activated sludge and is associated with low dissolved oxygen conditions. The growth of *S. natans* is stimulated by nitrogen and phosphorus
- Surface scum, film, or foam and an associated color may indicate possible sources of contamination.

Figure 9. Paint stained concrete.

Figure 10. Rainbow sheen on water caused by oil.

Figure 11. White foam from soap.

Figure 12. Surface scum from sewage.

Surface Scum	Possible Sources
Tan foam	Harmless, cause is high flow or wave action
White foam	Found around wastewater outfalls, thin, mostly due to soaps
Yellow, brown, black film	Tree pollens
Rainbow film	Oil or other fuel type

Activities in the watershed may also indicate causes or sources of contamination:

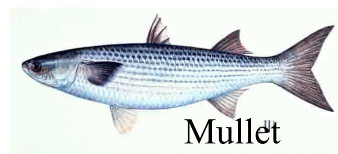
Lawn mowing - illegal dumping of organic waste, ie. grass clippings.

Construction activities - source of sediment, heavy turbidity, petroleum products associated with large equipment.

Livestock such as horses, cows, etc. - contribute contamination in the form of bacteria, nutrients and organic matter.

B. Biological Tracers

Biological tracers include all things living or that grow. Certain organisms are known to indicate polluted or lesser quality waters. Examples are listed below:

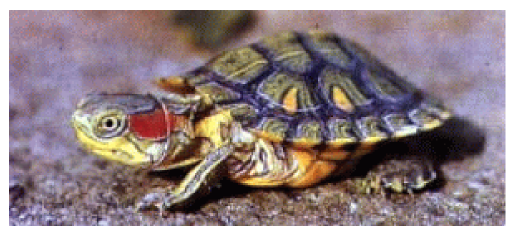

Mullet

Mullet are an example of an opportunistic fish species that tend to congregate around "easy" nutrients such as sewage solids flowing from a storm water outfall.

Red-eared sliders are turtles which like "easy" nutrients and their presence may indicate a possible storm water outfall problem.

Sewage fungus, *Sphaerotilus natans*

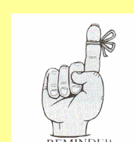
Lush green vegetation around an outfall especially when other vegetation is less green or less dense may indicate a nutrient source.


Red-eared slider

1. Bacteria

Pathogenic organisms are prevalent in fecal contaminated water and pose a great risk to human health. Due to their variety and the complexity involved in identifying individual types of bacteria, indicator organisms are used to assess the potential for presence of pathogens due to fecal contamination (Samadpour). A group of bacteria called fecal coliforms can be detected using a relatively simple laboratory method but they are not specific to warm-

E.coli for fresh water
enterococci for tidal or salt water
fecal coliform for all water



blooded animals and the test may produce false positives. The species, *Esherichia coli (E. coli)*, is part of the fecal coliform group and is specific to humans and other warm-blooded animals. EPA recommends it as the best freshwater indicator organism when evaluating health risk for recreational waters. If the water body in question is salt water or tidally influenced waters, enterococci bacteria should be used as the indicator organism due to its ability to survive in high salinity conditions.

Bacterial sampling depends on available funding. Even though relatively inexpensive, collecting ten to twelve samples in one day could cost $ 100 or more. The bacteriological sampling technique is as follows:

1. Whenever possible, bacteria samples should be collected directly into a sterile, 100 ml bottle. If a sampling device such as a bucket must be used, the bucket must be rinsed several times with the water to be sampled. The bacteria sample shall be collected before any meters are placed in the sampled water.
2. The sample bottle shall be properly labeled with the site ID, date, and analysis desired and placed in ice immediately.
3. Deliver to laboratory for testing. Costs are fairly inexpensive (range $ 8 - $ 12 each) and results are usually available within 24 hours.

If bacterial testing was done, the results can be used in conjunction with flow data to determine the bacterial loading to the receiving waters (See case study #3).

Pros: Good indicator of pollution sources
Inexpensive
Easy sampling technique
Get results quickly

Cons: Use sterile conditions to avoid contamination
Samples must be returned to laboratory within six (6) hours of collection for results to be valid

Case Study #3: Calculating the Human Equivalence (HE) of a contaminated flow.

If the fecal sample result equals 24,000 mpn/100 ml and the flow from an outfall is measured to be 3 gpm, then the Bacterial Loading will equal 3,945,600,000 fecal coliform. If one adult human is equivalent to 2 billion fecal coliform per day, then 3,945,600,000 ÷ 2,000,000,000 will equal 1.97 adults. This result may indicate that the source is from a very small flow such as a single house or the leak into the storm system if very small.

Bacteria results X flow (gpm) X 54800 = Bacterial Loading (bacteria/day)

Bacterial Loading ÷ 2,000,000,000 = Human Equivalent (HE)

C. Chemical Tracers

Measuring the chemical characteristics or make-up of a dry weather flow will help the investigator track the source of the flow and identify the cause of the contamination or vice versa. Chemical tests are needed to supplement the physical parameters noted and confirm contamination. Chemical tracers can either be tested for in the field, if the right equipment is available, or samples may be taken to a laboratory for analyses. The chemical tests - DO, pH, chlorine, ammonia, phosphate, dye testing, and optical brighteners - are described below. Each section includes approximate costs, equipment needs, sampling tips, and the pros and cons of each test. A case study is also included to illustrate how each chemical test was helpful in locating an illicit connection for GCHD.

Salinity, specific conductance, total suspended solids, biological oxygen demand, and fluoride also may be useful indicators on occasion but they have not been discussed in this manual. Plus, other tests available to the investigator (organics, metals, etc.) are not discussed in this manual. Cost per test or requirements such as ultra clean sampling techniques make some tests prohibitive for small entities.

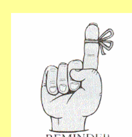
1. Dissolved Oxygen

Dissolved oxygen (DO) is essential for the continued survival of most aquatic organisms. The *Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2002* designates aquatic life uses for all water bodies as exceptional, high, intermediate, limited, or no significant aquatic life use. In freshwater, the *absolute minimum criteria* are 4.0, 3.0, 3.0, 2.0, 1.5 milligram per liter (mg/L) respectively. Several factors affect the ability of water to absorb and hold dissolved oxygen. As water temperatures increase, DO generally decreases. Also, an algal bloom will increase the DO during the day while the same bloom will consume or “use” the oxygen at night sometimes causing total depletion. Lastly, bacteria metabolize available DO during the decomposition of organic matter.

Methods for measuring Dissolved Oxygen: There are three methods for measuring DO. The choice of procedure depends on the interferences present, the accuracy desired, and, in some cases, convenience or expedience.

- The Winkler Method is a titration procedure based on the oxidizing property of DO. It involves performing a 5-10 minute analytical test on a quantity of sample water in the field. A field kit can be assembled using equipment from an existing lab or a Digital Titrator/ Modified Winkler kit may be purchased for approximately $200.
- Two (2) colorimetric tests are available from Hach Corporation for screening

To collect water samples for DO measurements:



Do NOT agitate/aerate water to be measured.

Submerse probe completely in bucket of sample water and stir slowly (about 1 revolution/second for at least 90 seconds (SWQM)) or until the display stabilizes.

purposes. First, a colored disc comparitor is used to match the color of the solution generated by adding chemical reagents. Second, a hand-held colorimeter is used to measure the color intensity after being mixed with the appropriate reagents. Both are read directly from the devices. The methodology for each kit is explained in the instruction manual.

- DO meters use membrane covered electrodes to measure the rate of diffusion of molecular oxygen across a membrane. A DO meter can be purchased as a stand alone meter or as a multi-probe instrument having multiple functions such as temperature, pH, conductivity, and/or salinity. Meter prices range from \$800 to ~\$5,000 depending on the capabilities of the meter.

Pros Simple, easy to learn procedures.
Colorimetric kits: relatively inexpensive.
Meters: produce fastest results.

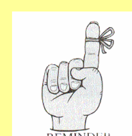
Cons Low DO is not positive indication of pollution. Low DO may be due to warm water temperatures.
Bucket or telescoping pole required to collect sufficient sample volume. Sampling technique will potentially add DO to water.
DO meters: require significant initial investment but have low long term costs.
Meter: requires regular calibration and maintenance.

2. pH

Potential hydrogen (pH) measures the hydrogen ion activity in solution. Waters with a pH less than 7 are considered to be acidic while water with a pH greater than 7 are alkaline or basic. A pH between 6.5 and 8.2 is considered ideal for a healthy environment. Conversely, levels below 5.0 and above 10.5 can cause unhealthy stream conditions for aquatic life. Normal storm water, and even sanitary wastewater, has a pH around 7 or neutral. Since pH is logarithmic, a pH of 4.0 is ten times more acidic than a pH of 5.0. Measuring pH can identify whether the flow is industrial, commercial or domestic in nature.

Not only does pH affect aquatic life, but pH may also influence the toxicity of other chemicals. Ammonia becomes more poisonous in high pH (basic) solutions and heavy metals can leach out of stream sediment in acidic solutions (NVRC). Industries that release low pH (acidic) dry weather discharges include (but are not limited to) textile mills, phamaceutical manufacturers, metal finishers/ fabricators, as well as companies producing resins, fertilizers and pesticides. In contrast, industries releasing high

To collect water samples for pH measurements:



Avoid collecting sediment with water to be measured.

Stir probe slowly (about 1 revolution/second for at least 90 seconds (SWQM)) or until the display stabilizes.

Rinse probe with de-ionized water between readings and before storage.

Even if a meter and probe are used,

pH (alkaline) wastes are commonly soap manufacturers, textile mills, metal plating industries, steel mills, and producers of rubber or plastic.

Methods for measuring pH: There are three (3) methods for measuring pH.

- pH paper is available in several different ranges. Besides the full range (0-14), they can be purchased for the high, mid, or low ranges.
- Test strips provide semi-quantitative results. One supplier advertised 50 test strips for less than $10.
- Colorimetric methods such as a color cube kits, color disc kits or a pocket colorimeter use a reagent to produce a color which is then matched to the comparitor or measured for light transmission. Colorimeters are more accurate than the color discs which are more accurate then the color cube kits. The methodology for each kit is explained in the instruction manual. Kits range from $15 - $55.
- A pH meter with electrode produces the fastest and most accurate results. However, probes are susceptible to fouling by oil and greases. Meter prices range from $450 to $1000.

Pros	Method is excellent detector of chemical releases
	pH paper: very inexpensive, quick and easy to use
	pH colorimetric tests: relatively inexpensive, accurate results
	pH meter: moderate in price, best results in fastest time
Cons	Method is insufficient indicator of sanitary sewer discharges
	pH paper: must be kept dry and stored in cool, dark place
	pH paper: is not very accurate for small changes
	pH meters: require routine calibrations and maintenance of probe

Case Study #4: Using pH as an indicator of contamination

While performing routine mapping and sampling, a milky white discharge was found flowing from a storm water outfall. A crystalized film had formed on the water surface and a white deposit was settling out on the bottom of the "pool." A pH of 12 was measured at the outfall but decreased to 9.5 about 10 yards downstream. Upstream of the outfall, a large amount of lime had been spread over a construction site to condition the soil. Because there were no silt fences at the site, rainfall and/or other water runoff was causing the lime slurry to flow into a drainage ditch and thence to the storm drain outfall. Lime is very alkaline in nature and therefore accounts for the high pH measurements.

Case Study #5: Investigation of contamination using pH levels.

An unusually high flow with a pH of 11.07 was found discharging from a storm water outfall. Investigative tracking of the pH revealed the source to be a car dealership. Paint and vehicular wash water was being discharged to a floor drain which had been plumbed to the ditch instead of the sanitary sewer. A Harris County Pollution Control Department investigator was called in to assist with getting the facility to correct the illegal plumbing.

Before

After

3. Chlorine

While beneficial for public health reasons (killing pathogenic organisms), chlorine is also harmful to the environment. Its lethal affect depends on concentration and time of exposure. Final wastewater treatment plant effluent and potable water are usually the only waters disinfected with chlorine. However, chlorine is also used in the production of plastics, cleaning products and insecticides. Therefore, detecting a chlorine residual in a dry weather flow and then tracking it upstream through an underground drainage system will usually result in locating the source of a contaminated discharge or cross-connection. In times of water shortages, it also helps to identify sprinkler systems with excess run-off or breaks in a drinking water line.

Chlorine also interferes with lab tests such as BOD, cyanide and pesticide/herbicide testing. Therefore, samples known to have a Cl_2 residual must be dechlorinated (treated with sodium thiosulfate to remove the Cl_2 ions) when the samples are collected or before analysis begins (SWQM, TNRCC).

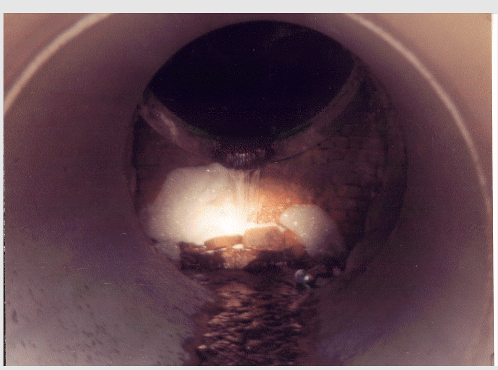
Methods for testing chlorine residual: Water samples are tested for free and/or total Cl_2 residual depending on the method used. Overall, the process of preparing the sample and reading the results takes a maximum of 5 minutes. Free Cl_2 residual are read immediately whereas, total Cl_2 residual tests usually require the sample to stand for a period of time before reading the results. For exact specifications refer to your kit's instruction manual.

- Chlorine test strips can be used to detect higher concentrations of chlorine (0.5, 1.0, 2.0, etc.) as would be found in a discharge from a swimming pool filtration system. Test strips provide semi-quantitative results. The individually wrapped strips cost around 50¢ each.
- colorimetric test kits such as a color cube kit, color disc kit or a pocket colorimeter use a reagent to produce a color which is then matched to a comparitor or measured for light transmission. Colorimeters are more accurate than the color discs which are more accurate then the color cube kits. The methodology for each kit is explained in the instruction manual. Kits range from $55 - $325.

Pros	All methods are quick and easy to perform
	Able to identify water line breaks
	Can detect illegal pool, spa discharges, and vehicular wash water
Cons	Test strips do not detect low concentrations
	Cost per test strip is moderately high
	Very few outfalls have a significant enough amount of chlorine to be able to track upstream
	Meters require regular calibration and maintenance

Case Study #6: Using chlorine as an indicator to locate an illicit discharge.

Using a high-beam cordless spotlight, billowing suds were discovered accumulating within a large concrete storm drain which discharged directly into a creek. The chlorine residual was >3 mg/l. Tracking upstream, the flow became cloudy with a whitish hue and had a pungent odor. The flow originated at a nearby fast-food restaurant that had a large grease spill in the dumpster area. The grease had been sprinkled with hTh chlorine and was being power washed. All wastewater was flowing into an open pipe in the driveway. The open pipe drained directly into the storm drain. Management was notified of the violation and actions were taken to correct the matter immediately.



4. Ammonia

Ammonia (NH_3) is produced by the decomposition of plant and animal protein. Ammonia is also a main ingredient in fertilizers. Its presence in surface waters usually indicates domestic or agricultural pollution. At certain levels, ammonia is toxic to fish and creates an oxygen demand in the receiving water. It is also an excellent indication of contamination by sanitary wastewater.

Methods for measuring ammonia: There are several methods available to test for the presence of ammonia. Some of the methods are less accurate but can still be used as a screening tool. The methods are listed below.

- Ammonia nitrogen test strips are available to measure ammonia in increments of 0, 0.25, 0.5, 1.0, 3.0, & 6.0 parts per million (ppm) or mg/L. Test strips provide semi-quantitative results. Each test strip costs ~ 60¢ and they are available in packages of twenty-five (25).
- Colorimetric test kits such as a color cube kit, color disc kit or a pocket colorimeter use a reagent to produce a color which is then matched to a comparitor or measured for light transmission. Colorimeters are more accurate than the color discs which are more accurate then the color cube kits. Most kits are available in ranges - high, medium, and low concentrations. The smallest increment available in any kit is 0.1 mg/L. While not acceptable for determining surface water quality, it can be used to screen for pollution sources. The methodology for each kit is explained in the instruction manual. Kits range from $30 - $325.
- Portable ISE meters with ammonia sensing electrodes are available for field use. The cost of a meter with the required electrode will range from $1,000 - to $1,500. The methodology for the meter is explained in the owner's instruction manual. There are accuracy issues with the electrodes, see **Cons** below.
- Analytical tests can be conducted in a laboratory. Water samples are collected and returned to the lab for analysis. Costs per test range from $20 - $30. This test is the most accurate available but turn-around time for results is a major hindrance.

Pros Test strips and kits easy to use in the field.
Test strips and kits provide results in the field which can facilitate immediate tracking.
Good indicator of sanitary sewage.

Cons Time consuming: depending on which kit is used - can take up to 15-20 minutes per sample analysis.
Most of the time values are too small to track.
Additional steps must be taken to negate the interferences: saltwater may interfere with test methods reducing accuracy up to 30%; chlorine must be removed from sample prior to testing; iron, sulfides, and extreme hardness in the water will also cause interferences.
Regular calibration and maintenance required on all meters.

Case Study #7: Elevated ammonia levels from sanitary sewage

For more than twenty years, residents had complained about persistent sanitary sewer problems. During an intensive sampling event, investigators noted a foul odor associated with the drainage ditch and storm water outfall. Biological indicators, such as red-eared slider turtles, plus ammonia levels measuring up to 7.32mg/L and high levels of *E. coli* bacteria confirmed the presence of an illicit connection. After several investigation attempts, it was discovered that two residential service lines had been hooked up to the storm sewer instead of the sanitary sewer. Wastewater was draining straight into the drainage ditch behind the owners' property. The proper authorities were contacted and the problem was corrected.

5. Phosphates

Phosphorus occurs in natural water and wastewaters almost solely as phosphate. A certain amount of phosphate is essential fro most plants and animals, but too much phosphate in water can contribute to eutrophication. Phosphates may enter water from agricultural run-off an biological and industrial wastes. They may be added to water in municipal and industrial water treatment processes to control corrosion. Phosphates (PO_4) were most commonly found in soap and detergent discharges from household and industrial laundering activities and are common ingredients in fertilizers.

Methods for measuring phosphates: There are several methods available to test for the presence of phosphates. Some of the methods are less accurate but can still be used as a screening tool. The methods are listed below.

- Orthophosphate test strips are available to measure phosphorus in increments of 0, 5.0, 100, 200, & 500 parts per million (ppm) or mg/L. Test strips provide semi-quantitative results. Each test strip costs ~ 30¢ and they are available in packages of fifty (50).
- Colorimetric test kits such as a color cube kit, color disc kit or a pocket colorimeter use a reagent to produce a color which is then matched to a comparitor or measured for light transmission. Colorimeters are more accurate than the color discs which are more accurate then the color cube kits. Most kits are available in ranges - high, medium, and low concentrations. The smallest increment available in any kit is 0.02 mg/L. While these kits are not acceptable for determining surface water quality, they can be used to screen for pollution sources. The methodology for each kit is explained in the instruction manual. Kits range from $20 - $325.
- Analytical tests can be conducted in a laboratory. Water samples are collected and returned to the lab for analysis. Costs per test range from $18 - $30. This test is the most accurate available but turn-around time for results is a major hindrance.

Pros	Test strips and kits: easy to use in the field. Test strips and kits: provide results in the field which can facilitate immediate tracking.
Cons	Test strips: accurate for gross contamination only. Test kits: depending on which kit is used - can take up to 15-20 minutes per sample analysis. Most of the time values are too small to track. Some amount of PO_4 can be found at almost every outfall because it is naturally occurring, fertilizer run-off from lawns is common and residential car washing generally produces a run-off.

Case Study #8: Using phosphates to identify an illicit discharge

A outfall was investigated due to elevated bacteria levels detected in a continuous dry weather flow estimated at >5 gpm. The flow was followed to the first manhole upstream where an incoming lateral line that was discharging sudsy water. A PO_4 level of 3.10 mg/L was measured. The lateral line was coming from a car dealership where two problems were identified. First, the shop floor was cleaned by hosing the wastewater outside to a storm drain located in the driveway and, second, vehicles were being washed next to the garage instead of on the car wash pad. All wastewater was flowing directly into the storm grate.

D. Confirmation Techniques

1. Dye Testing

Dye testing uses a brightly colored, fluorescent substance to detect leaks in the sewage system, locate illegal sewer connections, trace cross connections, monitor flow studies, analyze septic systems and track groundwater movement. Tracing dye is available in many forms - liquid, tablet, powder, wax, and strips.

Liquid dye is very concentrated and disperses quickly. It is easy to use and works well in all volumes of flow. Dye strips are similar to the liquid but are less messy. Powder can be very messy and must dissolve in liquid to reach its full potential. Tablets are compressed powder and are particularly useful for releasing dye over time. Tablets are less messy than the powder form. All forms of the dye stain hands and clothes so caution should be taken when handling the containers. Latex gloves provide a good barrier and adequate hand protection.

Tracing dye is available in different colors such as blue, red, violet, and yellow-green. Several colors should be kept on hand so multiple lines can be tested at the same time. When dye testing, use the color which creates the greatest contrast with the receiving water. Yellow-green dye is the preferred dye because of its great contrast in color but it disappears quickly in sunlight. Red, however, is most helpful when there is a lot of algae present. Red also withstands sunlight and lingers in the environment longer.

Equipment needed for dye testing:

- fluorescent dyes,
- rubber or latex gloves,
- manhole hook or pick ax,
- camera (for documentation),
- high power flashlight,
- two-way radios (if two investigators).

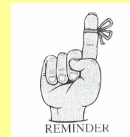
Methods for conducting dye testing: Depending on the scenario, there are different techniques for dye testing. It is always helpful to have two people testing but one person can complete the job. Ideally, one person drops the dye and the second person looks for evidence of dye downstream.

- If a residential property is suspect, dye can be placed in the house clean-out and washed downline using a nearby hose (seek permission from the property owner first). If dye surfaces in the storm drain system, then the problem most likely exists in the service line for this private property. The property owner should be informed of the situation and served a notice to make necessary repairs.

- When a commercial property needs to be tested, dye should be flushed down a restroom toilet or washed down the janitor's sink (speak to manager or owners first). Flush quickly and repeatedly to prevent staining. If dye surfaces in the storm system, it is most likely the commercial business responsibility to fix the problem. Inform the manager or owner and serve a notice to make repairs.

- To dye test a sanitary sewer line, choose a sanitary manhole upstream of the storm water outfall **or** upstream of where the sanitary line crosses the storm line **or** upstream of the area of concern. Choose the upstream sanitary manhole that has no odor, color, or any other relevant observations that may signify a pollution source. If dye surfaces in the storm drain system, the problem and responsibility most likely lies with the city or utility district.

- If dye **does not** surface in the storm drain after a period of time **or** if the investigator cannot wait for the dye to surface, secure charcoal packets any place where dye is expected to surface. Leave the packets in place for a week or two then retrieve and analyze. Complete instructions for processing the charcoal packets are provided in Appendix D. The charcoal packets are necessary because dye can take anywhere from a few minutes to days to surface in the storm drainage system. Even though another site visit must be made, the packets save time. Personnel do not have to wait at the site and multiple check-backs and/or risk of missing the dye is avoided.



Heavy flows from rain, a garden hose, or flushing a toilet several times, can speed up the dye testing process.

A partially blocked sanitary sewer line can slow down the dye process or give false results.

A fully charged or blocked sanitary sewer line may be the only time a cross-connection occurs and is detectable.

Case Study #9: Dye testing to confirm sewer leak at private home

Elevated bacteria levels at a storm water outfall led to an upstream investigation and additional sampling. Results narrowed the area of concern and the city storm sewer lines were televised. No problems were located so residential homes were dye tested via clean outs. Dye from one home surfaced in the storm sewer. The residential service line was televised and two breaks were identified. The line was repaired at the owners expense.

Case Study #10: Dye testing a sump pump to confirm an illicit connection

During routine ambient monitoring, a white, 2 inch PVC pipe was found gushing water directly into a creek for about 30 seconds and then the discharge stopped. The pipe was located next to a car repair shop. An investigation revealed a sump pump located in the underground area of the shop. Knowing these units function intermittently, the sump was dye tested. After filling with enough water, the pump turned on and dye discharged out of the PVC pipe at the creek. City representatives were informed of the illicit connection and asked to oversee needed repairs.

Pros	Dye is water soluble, biodegradable, fairly stable, has a low toxicity and has been used for over 100 years Highly detectable and only a small amount is needed Relatively inexpensive Can narrow down the pollution source area to a street block or even a specific house or building
Cons	Can be very time consuming. May require several check backs if charcoal packets are not used.

2. Optical Brightener

Optical brighteners (OB), or fabric whitening agents, are good tracers because they indicate a presence of laundry effluent which is specific to humans. OB's can be used to identify storm drain cross connections, sewage system exfiltration, and faulty septic systems, plus differentiate between human and animal waste.

Equipment needed for OB detection: Below is a brief list of the primary needs. A complete equipment list can be found in Appendix E. Start up costs for all materials can range anywhere from $100 to $500, the most expensive item being the UV light.

- Individually wrapped, untreated cotton pads,
- Vinyl-coated "cages" to hold the pads,
- A 4-6 watt fluorescent ultraviolet light box.

Method for deploying optical brightener traps: Optical brightener placement is best suited for pipes, storm drains and small streams (out of direct sunlight).

Figure 13: Optical Brightener Device

- Insert untreated cotton pad into the vinyl-coated cage and secure the cage shut using a zip tie or rubber band. (See picture at right.)
- Secure the cage in the pipe, storm sewer, or stream using high test monofilament line tied to a rock, a manhole lid (with holes), aluminum (tent) spikes, or a nearby branch.
- Complete *Field Investigation Sheet* (Appendix C) and collect bacterial samples (if needed) on the day of deployment.
- On the *OB Data Sheet* (See Appendix F), list the site ID, date of deployment, and various locations of cage(s). Expose the cage device for approximately 7 days. Leave out longer if heavy rainfall has occurred. (This time frame allows for at least one laundry event to take place.) If dry weather flow contains heavy sediment or debris, shorten the deployment time period.
- Temporarily install a rain gauge at the site if possible.

- During retrieval, rinse the gauze pads in the receiving water to remove excess sediment.
- Squeeze excess water from the pad and place pad in clean zip lock baggie.

Figure 14: OB device deployed in storm drain.

- Label a piece of dark manila folder with the site ID or location, date of placement, amount of rainfall and the date of retrieval and staple to the gauze pad. Place pad with label in a clean baggie and transport in a dark container to minimize exposure to the sun.
- Complete data sheets with the date of retrieval, number of days the pad was exposed to a flow and total rainfall (See Appendix F).
- Return to office or lab and dry pads by hanging them on a clean monofilament line in a dark area.
- After the pads have dried, place the gauze pad (with attached label) under a UV light to check for fluorescence. A UV light box is the simplest method for examining the pads, otherwise use a UV light strip in a darkened room.
- Compare a "control" pad (clean) to the dried pads and rate each as Positive, Negative, or Inconclusive. A pad having a definite glow or fluorescence is positive for exposure to grey water. A pad that looks similar to the control is negative for laundry wastewater. Any pads with an inconclusive or questionable result should have the location retested. Consider lengthening the new pad's exposure time.
- At least 10% of the dried pads should be re-read by a second trained personnel for Quality Control (See Appendix G). GCHD recommends 100% QC check for confirmation.

Do NOT touch gauze pad to clothing or hands that may have laundry detergent residual.

Check cages after heavy rainfall to ensure devices are still secure.

Do NOT use white paper labels. They may contain optical brighteners and will contaminate the sample.

A negative pad may occur at a flow with high bacterial contamination. The source may be from a non-detergent using facility or be agricultural in nature. If only the outfall was tested and the pad was positive, the site should be re-tested along with several upstream sites to narrow down the area of the source. Bacteria sampling at each upstream site is also beneficial. OB success rate may be improved if:

- they are deployed in a constant, dry weather flow rate
- the sampling device (cage) is completely submerged so the entire gauze pad is exposed

- the device is hidden from public view (as much as possible) to avoid tampering
- use an ultra-clean methodology to minimize false positives

Factors decreasing OB success rates include:

- heavy rainfall
- sediment and debris clogging or burying the gauze

Pros	Inexpensive supplies
	Animal / human waste differentiation
	Does not require a laboratory to attain results,
	One field personnel can complete all steps
Cons	Can be time consuming
	Results are not obtained for at least one week
	Heavy rains require longer deployment periods.

Case Study # 11: Storm drain tracking using OB devices.

Due to elevated bacteria levels (*E. coli* >24,000 mpn/100 ml) and a thick, white colored flow from a storm water outfall, an investigation of a residential area was under taken. The color was tracked and found in five (5) upstream storm water manholes. Between the 5th and 6th manhole, painters were seen actively painting a home but the painters insisted that their paint brushes and equipment were washed inside the home and not outside. Initially, a break in the service line of this house was suspected but dye testing was negative. Dye surface in the sanitary line only. Next, optical brightener devices were placed at the outfall and in four (4) upstream storm water manholes. The devices were left for eight (8) days, retrieved, dried, and analyzed. At the time of retrieval, the manholes were no longer white and the painting had ceased. The outfall and 1st upstream manhole were positive for optical brighteners while the other manholes were negative. Additional *E. coli* and ammonia sampling mirrored the OB results. *E. coli* was >24,000 mpn/100 ml at the outfall and the 1st manhole and dropped to 200 mpn/100 ml or below for the remaining upstream manholes. Ammonia was high at the outfall and first manhole, dropping considerably at the second. Using the *E. coli*, ammonia and OB results, the area of concern was localized to about 14 homes. The city televised the storm lines and found no problems so each home was scheduled for dye testing. Ironically, the first house tested revealed a problem and has been referred to the city for repairs. See Appendix H for map of sample sites and data.

3. Televising

Cities with budgets capable of supporting a crew for televising have an advantage over those that do not. After the area of a possible pollution source is narrowed down, the surrounding sanitary and/or storm sewer lines can be televised to locate the exact position of the break, infiltration, or cross connection. This method is also much safer then having field personnel do confined space entries to look for pollution sources.

Pros	Best way to pinpoint exact location of breaks, infiltration, and cross connections.
	Video tapes can be viewed after crew has left the field
Cons	Very expensive to maintain equipment
	Crews (multiple employees) must be trained to operate equipment
	Require line cleaning before televising
	Cameras are limited on the size of pipes they can view
	Cameras cannot take pictures if pipes are full of liquid

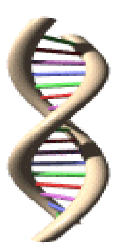
E. Future Tracers

As this project was being implemented and the manual drafted, ongoing research identified several new and innovative technologies that were being developed to help determine pollution types and their sources. These tracers were not utilized for various reasons but brief discussions have been included for future reference. These new technologies include testing for DNA, caffeine, pharmaceuticals, viruses, and using infrared heat detection. This research should be reviewed periodically to determine whether a technique is applicable to a given situation, if it becomes cost effective, and whether necessary laboratory support is available.

1. DNA

Microbial Source Tracking (MST) uses DNA testing, or "fingerprinting" of *E. coli*, to differentiate between human and non human waste. *E. coli* bacteria is found in all warm-blooded animals but each DNA sequence within every *E. coli* strain is different probably due to differing intestinal environments. This contrast is what will help determine if polluted waterways are actually contaminated with human sewage or animal waste runoff.

The first step in DNA testing requires the building of a library of fingerprints, or isolates, taken from humans, wildlife and domestic animals. For example, waste samples must be obtained from cows, horses, deer, waterfowl, dogs, cats or any other known potential pollution source and analyzed. A few hundred isolates are needed per source to build a large enough library and the larger the library, the easier it is to match isolates. Dr. Samadpour's laboratory, who developed the MST method, has subtyped more than 65,000 *E. coli* strains. Unfortunately, libraries from other geographical areas should not be relied upon due to possible genetic variances. After the reference library is built, bacteria samples from unknown origins can then be compared to the library for



identification. Antibiotic resistance analysis (ARA) is also recommended to be used in conjunction with the DNA ribotying to make the results more reliable. ARA uses *E. coli* samples to determine antibiotic resistance. Humans having a higher resistance.

Currently, the number of laboratories set up to analyze these types of samples are limited and the cost per test is significant. If starting from scratch, laboratory costs, including building the library and running DNA and ARA tests, are expensive. For example, the City of Albuquerque compiled a library of eight (8) different animals, including humans, and sampled 16 sites two (2) times each. Their costs were approximately $100,000 and their results were not absolute. (Over the next two years, the State of New Mexico will be conducting a study on eight (8) different sites testing for ARA and ribotyping). Additionally, highly trained personnel are required to performed the tests due to the risk of error.

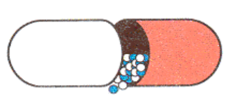
2. Caffeine

Caffeine was investigated as a tracer for leaking sanitary sewer lines because it passes through the digestive system virtually unchanged and is persistent in the environment. Caffeine is generally found in human sewage only but may be detected in certain plants such as watermelon. Presently, sample analysis is running about $100.00 per test which makes it financially infeasible for smaller cities and utility districts. Bench top methods may be run in-house but have a large margin of error.

A study conducted in Puget Sound found caffeine present in more than 160 of the 216 samples collected. Contaminated samples were even found at depths of 640 feet. Scientists believe this wide spread contamination is due to Seattle motorists and coffee cart operators dumping cold coffee along streets and into storm drains. The city has since withdrawn plans to use caffeine as an indicator but there is every indication that caffeine testing may be beneficial for other cities.

3. Pharmaceuticals/Drugs

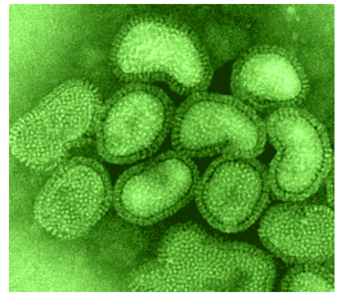
Pharmaceuticals are being investigated due to increased awareness of their presence in major waterways. The FDA has begun asking pharmaceutical manufacturers what ecological effects may be caused by their products. The U.S. Geological Survey (USGS) reported finding "95 pharmaceutical hormones and other organic chemicals in U.S. waters." Most importantly,



endocrine disrupters which change, imitate or block hormonal functions have been found in these waterways. During a 5-year study in London, England, the environmental agency investigated a decline in human male fertility. In conjunction with findings, male fish in nearby rivers were found to be changing sex due to ethanol estradiol (a synthetic estrogen in urine of women using birth control pills) found in the waters. The decline in male fertility was suggested to be caused by men ingesting ethanol estradiol via drinking water. The chemical is thought to remain active for a month and surface water is the main source of drinking water in the study area. Therefore, it is very possible that the chemical causing male fish to change sex could also be linked to male infertility.

4. Viruses

Researchers have discovered human adenoviruses contaminating surface water along the California coastline. The methodology used to identify the viruses in coastal waters was originally used to trace pathogens in sewage. The presence of these viruses in such waterways supports the idea that the source of contamination is from human waste discharging into waterways. Unfortunately, it is not known whether the viruses are virulent. Interestingly enough, there are no significant correlations between the presence of viruses and bacterial indicator levels (total coliforms, fecal coliforms and Enterococci). This news has serious implications so California has been asked to re-examine their water quality standards for recreational areas. The standards do not address the viral quality of those same waters. This concern brings rise to the question, "Should every state be re-examining their own water quality standards in regards to viral quality?"



5. Infrared heat detection systems (IHDS)

Arkansas Department of Health employee, John Church, devised a technique for locating leaking septic systems while watching the television show COPS. Infrared heat detection systems (IHDS) detect changes or variations in temperature. Based on the theory that human waste is going to be significantly warmer than the ambient ground, the detection system can easily give a visual picture of a leaking septic system. In turn, this system can be used for bodies of water, such as lakes, to locate areas that are slightly warmer possibly due to wastewater inflow. This detection system tends to work best in colder seasons when the warm septic effluent or wastewater can be detected easier. The effectiveness of this system has not been tested in southern states with warmer climates. Nor has a hand held system been tested during ground surveillance. Church also used a state police helicopter with a Forward Looking Infrared (FLIR) imaging system, global positioning system (GPS), video equipment, and maps. Using the IHDS in aerial reconnaissance seemed to be cost effective if usage of the helicopter was donated.

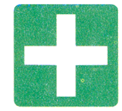
IV. Sampling

As previously stated, sampling is conducted at the time that a dry weather flow is found or when priorities indicate an area needs to be resampled. Sampling and detailed investigations are best conducted in the morning when there are greater sanitary sewer flows from residential areas, during or after high use periods such as tourist season or holidays, or while tides are ebbing or at their lowest, if applicable. Determine the approximate number of samples to collect on a particular day by considering:

Physical proximity of dry weather flows to office or laboratory. How much time will be spent driving to and from the field sampling area?

Accessibility to the dry weather flows. Must the investigator walk from outfall to outfall or can he/she drive? Can the opening of the outfall be easily reached for sampling or does an upstream manhole have to be sampled?

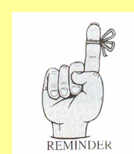
Many analytical tests have maximum holding times before they must be delivered to the lab and analyzed.
Some laboratories limit the time when samples can be received for same day analysis and/or require pre-notification of plans to sample.
What has the weather been like? (See Section III. Initial Dry Weather Flow Survey.) All outfall sampling should occur only during periods of dry weather.



- Take and consume plenty of drinking water.
- Use sun screen repeatedly.
- Use insect repellent as needed.
- Use safety lights on vehicles, safety cones, and safety vests when working along a roadway.

A. Preparing to Sample

Once a sampling event is planned and scheduled, notify the laboratory as needed.
Gather the appropriate type and number of bottles for the intended tests including extra bottles required for lab duplicates, etc. See Appendix I .
Check bottles for cracks or splits, verify the “sterilized” tab is in-tact.
Follow established standard operating procedures (SOP) for sample preservatives. Acid preservation is placed in the sampling containers at the lab before departure or in the field using an acid kit.
Pre-label bottles, if possible, using a water proof pen or marker. Include sample site i.d., date, preservation information, and analysis requested. Time of sampling and collector’s name will be added in the field.
Assemble coolers with ice for sample preservation and transportation. The ice chests must be able to keep the samples at 4 °C or less for delivery to the lab.
Gather field meters and pre-calibrate according to approved methods. Document calibration and maintenance activities in permanent calibration logs developed for each meter used.



- Pre-rinse the bucket 3 times using the dry weather flow before collecting water to fill sample containers.
- The turkey baster or pump & tubing should be sanitized between outfalls using a dilute chlorine solution. Rinse with dry weather flow before sampling.

B. Collecting Samples

Travel to an outfall with a dry weather flow. If receiving water and dry weather flow are mixed and backing up into the drainage pipe, sample at the first upstream storm drain manhole where mixing does not occur.
Complete field sampling sheet or make observations before sampling. See Appendix J.
Collect dry weather flow directly into the sample containers or use a bucket or telescoping

sampling pole to collect the water sample. If the flow is too small and/or if the flow does not "fall" into the container or bucket, use a turkey baster, small hand pump or another such device to collect the water.

Preserve samples if still needed.

Immerse filled sample containers in ice for transportation to lab. Deliver samples to lab within required time limit.

Check in samples at lab, complete chain-of-custody papers,

Enter field data into the proper database for later use.

Figure 15. Collecting a sample using telescoping sampling pole.

C. Using the Sample Results

After lab results are obtained:

Label each outfall flow as pathogenic, toxic, nuisance, and/or aquatic life threatening for record keeping purposes. See Appendix K for "Summary of Illicit Connection Investigation."

Determine priorities for conducting detailed investigations of the underground storm drain system upstream of the outfalls experiencing a contaminated dry weather flow.

- pathogenic and/or toxic problems should be addressed first due to human health risks.
- use the pre-determined screening levels for each parameter plus flow data to identify which discharges pose the greatest threat.

• Enter confined spaces with required training and appropriate equipment only.
• Use proper tool for removing and replacing manhole lids.

Use a combination of physical, biological and chemical tracers to conduct each detailed investigation. Multiple tracers will give a more detailed picture of what is occurring underground. Table 1 in Appendix L indicates the most common pollution sources associated with each tracer. Refer to Section III for specific "how to" instructions for each tracer.

Make an enlarged map of the underground "watershed" for each storm water outfall to be investigated.

Assemble equipment used to perform detailed investigations. Refer to the Investigation Check List in Appendix M.

Begin the investigation by comparing current outfall and discharge conditions with previous information. If the same, choose the "best fit" tracer(s) and begin tracking upstream. Move systematically from manhole to manhole or sample each storm water manhole immediately upstream and downstream of where a sanitary sewer line crosses the storm sewer system. If the flow in the manhole is obviously contaminated, skip to the next upstream location to save time.

Make notations on the underground "watershed" map indicating flows and directions or the lack of flow. Other observations are noted on additional Illicit Discharge Connection Field Investigations Sheets (See Appendix C)
Make observations about above ground conditions such as large trees, broken or shifted concrete or asphalt. Tree roots and shifted pipes are common causes of illicit connections.
Compile all information from "Illicit Discharge Connection Field Investigations Sheets" onto a "Tracer Summary Sheet" found in Appendix N. Use this summary sheet to determine the area of concern.
After localizing the area of concern, initiate dye testing or request the sewer line be televised to confirm the exact location of the illicit connection.
Notify the responsible party to make the necessary repairs.
Once a repair is made or a pollution source is eliminated, resample any continuing flow from the outfall to verify there are no additional problems impacting the same storm sewer line.
Repeat investigation efforts if samples are unacceptable.

Case Study #12: Using multiple tracers in a detailed investigation.

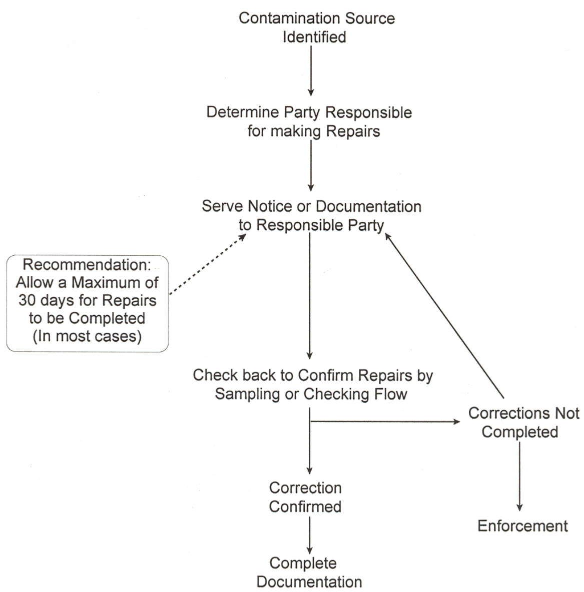
> While investigating one particular outfall, a total of thirteen (13) tracers plus other observations were used. They included six (6) physical tracers (color, odor, turbidity, water temperature, flow, and other observation), one biological tracer (*E.coli*), four (4) chemical tracers (pH, chlorine, ammonia, & phosphates) and three (3) confirmation techniques (dye testing, optical brighteners, and televising). Of the thirteen tracer used, only five (5) were helpful in identifying the area of concern in this situation. Dye testing the houses one-at-a-time identified the problem.

V. Documentation and Reporting

Documenting all steps of an investigation is absolutely essential regardless of whether an investigator reports to a supervisor only, implements enforcement action or writes annual reports for a regulatory authority. Good record keeping will enhance the success and timely corrections of most identified illicit connections. Numerous sheets of paper will be generated during the mapping, surveying and detailed investigation activities. All of this information should be organized, evaluated, and summarized with the idea that legal enforcement action is a possibility.

The process for eliminating identified illicit connections is shown in the flow chart on page 32. After confirming the existence and location of the illicit connection, some type of notice must be issued to the responsible party. The notice may be in the form of a work order to a city/district department or a notice of violation (NOV) delivered to a private citizen. Whatever the case, someone or some entity is responsible for making necessary repairs. The notice must include a time frame in which the repairs need to be made. Next, the investigator should conduct a check

Figure 2: Flow Chart for Corrective Action



back inspection at the end of the time allowed. Should repairs not be complete and/or the contaminated flow continues, several questions must be answered to determine which strategy to use next. Investigators may find that there is a second illicit connection in the same MS4 or they may choose to issue a second NOV for extenuating circumstances or they may decide that enforcement is the next step towards resolving the problem. If the problem is resolved, all documentation should be completed for reporting purposes.

If enforcement is the option chosen, the investigator has several options. First, city ordinances may be written to mandate repairs and enforcement procedures. Second, cities/districts may have the option of turning the case over to a county agency with enforcement capabilities; or third, the case may be referred to the state environmental agency for enforcement. Every program should create a standard operating procedure (SOP) so all cases are handled consistently and efficiently.

Every illicit connection to the MS4 is an "unauthorized discharge" to the waters of the state and is a violation of the Texas Water Code §26.121. If the discharge is intentional for the purpose of avoiding pretreatment or disposal costs, immediate enforcement with repairs and mitigation may be the appropriate process. Unintentional discharges such as a cracked pipe caused by shifting soils is still an unauthorized discharge but is usually handled quite differently. Regardless, when wastewater from the sanitary sewer escapes into the MS4 it is considered to be a by-pass of the treatment works and it is a reportable incident. The owner/operator of the sanitary sewer collection system has the responsibility of reporting the discharge as such.

An illicit connections investigator will generate at least three types of reports from the data collected. First, if the municipality or utility district is responsible for making repairs, then work orders for the same should be written and given to the appropriate personnel. Second, periodic summary reports need to be sent to immediate supervisors for management purposes. Third, annual reports on eliminating illicit connections must be compiled for the state regulatory agency, the Texas Commission on Environmental Quality (TCEQ) formerly known as the Texas Natural Resource Conservation Commission (TNRCC).

At this time, each entity determines what their reports will look like and what they will include, however, a sample supervisor's report has been developed and provided in Appendix K.

Project References & Literature Cited

Bacterial Source Tracking. Virginia Tech Website.
www.bsi.vt.edu/biol-4684/BST/BST.html

Billups, Andrea L, *DNA Techniques Allow Scientists to Become Pollution Detectives*, University of Florida, 1996.

CH2M Hill, *Dry Weather Screening Analysis Protocol, Training Manual*, Colorado, 1990.

Dates, Geoff, *Monitoring Optical Brighteners: Detergent Ingredient Helps Track Bacteria Sources*, The National Newsletter of Volunteer Water Quality Monitoring, Vol. 11, No.2, Fall 1999.

Galveston Bay Estuary Program, *The Galveston Bay Plan: The Comprehensive Conservation and Management Plan for the Galveston Bay Ecosystem*, Publication GBNEP-49, April 1995.

Glanton, T. S., M. T. Garrett, and Bill Goloby, *The Illicit Connection,* Houston, 1991.

Glanton, T.S., M.T. Garret, Zaki Ahmad, and Bill Goloby, *Non Storm Water Discharges to the Storm Water Conveyance System: There Discovery and Significance*, Unpublished paper presented at the Hazardous and Solid Waste Symposium, Houston, 1991.

Guertin & Associates, Inc, *Eliminating Illicit Connections to Storm Drains,* Massachusetts, 1998.

Jaing, Sunny, Rachel Noble, and Weiping Chu, *Human Adenoviruses and Coliphages in Urban Runoff-Impacted Coastal Waters of Southern California*, Applied and Environmental Microbiology, Vol. 67, No. 1, January 2001, pp. 179-184.

Johnson, Barry, M.S., P.E., Camp Dresser & McKee, Dean Tuomari, *From Theory to Implementation: Finding Illicit Connections*, Wayne County Department of Environment, Michigan, 1998.

Kolbe, Christine M. and Mark W. Luedke, A Guide to Freshwater Ecology, Texas Natural Resource Conservation Commission, Austin, 1993.

Maryland Department of the Environment, Water Management Administration, *Dry Weather Flow and Illicit Discharges in Maryland Storm Drain Systems*, Baltimore, 1997.

Pomeroy, Christine and Kelly Cave and Dean Toumari, *Summary of Illicit Connection Detection Programs in Michigan*, RPO Technical Memorandum-NPS01A-TM01.00, February 1996.

Sargeant, Debby, *Fecal Contamination Source Identification Methods in Surface Water*, Ecology Report #99-345, Washington State Department of Ecology, 1999.

Sargent, Dave and Wayne Castonguay, *An Optical Brightener Handbook,* Massachusetts, 1998.

"Coffee Fouls Up Pollution Testing: Too much Java in the Sound to use it as a Tracer," *Seattle Post-Intelligencer*, The Associated Press, July 2000. Seattlepi.nwsource.com/local/coff03.shtml

Texas Engineering Extension Service, Training Division, *Basic Wastewater Operations*, Texas A&M University Service, Texas, 1994.

Texas Natural Resource Conservation Commission, Water Quality Division, *Surface Water Quality Monitoring Procedures Manual*, Texas, 1999.

Tracey, Patrick, *Ecological Risks and Pharmaceuticals*, Bureau of National Affairs, Washington, D.C., March 2002.

Tuomari, Dean, *The Do's and Don't's of Implementing a Successful Illicit Connection Program*, Wayne Coutny Department of Environment, Michigan, 1992.

Turner, Collie, and Braden Inc., *Phase II Model Storm Water Management Program*, Houston, 2001.

U.S. EPA, Federal Register, *National Pollutant Discharge Elimination System Rules and Regulations*, 40 CFR Parts 9, 122, 123, and 124, Vol. 64, No. 235, December 8, 1999.

U.S. EPA Office of Water, *Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems: A User's Guide*, EPA/600/R-92/238, Washington, D.C., 1993.

Wayne County Rouge River National Wet Weather Demonstration Project, *Guidance for Preparing a Program for the Elimination of Illicit Discharges*, Wayne County, Michigan, 1997.

Sangal, Suresh K., Pradeep K. Aggarwaiand, Dean Toumari, *Identification of Illicit Connections in Storm Sewers: An Innovative Approach Using Stable Isotopes*, Rouge Program Office, 1996.

Samadpour, Mansour, Dr., *Description of Microbial Source Tracking Methods. Appendix E.* Thurston County Department of Environmental Health.

Glossary

Adenovirus (Human)
A DNA virus that affects the respiratory system (fever, sore throat, runny nose), gastrointestinal tract, or the eye (conjunctivitis). The virus may be latent then become re-activated at a later time. The virus can be passed through contaminated water.

Anaerobic decomposition
Biological metabolism or decomposition in the absence of oxygen.

Conductivity
The measure of a liquid's ability to carry an electrical charge. Expressed in micromhos per centimeter (µmhos/cm) at 25 °C. It is dependent on the presence of ions, the total concentration of the ions, their mobility and valence as well as the temperature of the solution.

Deposits or stains
Any type of coating or discoloration that remains at an outfall as a result of dry weather discharges.

Direct Connection
Physical connections of sanitary, commercial, or industrial piping which carry untreated wastewater to a storm sewer system. A direct connection is usually unauthorized and may be accidental or intentional.

Discharge
The volume of water that passes a given point within a given period of time.

Dissolved Oxygen
The oxygen freely available in water. Dissolved oxygen is vital to a fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

Dry Weather Discharge
The flow of a liquid from a storm water outfall during dry weather.

Effluent
Treated wastewater that flows out of a treatment plant or industrial outfall (point source), prior to entering a water body

Eutrophication
The accelerated growth of aquatic plant life in a body of water due to excessive dissolved nutrients. Ultimately it results in lowered or depleted dissolved oxygen levels.

Floatables

Floating materials (plastic containers, condoms, sanitary napkins, tissues, corks, paper containers, wood, leaves, detritus, grease balls, oil films, slimes, scum, etc.) that are either part of the inappropriate waste streams discharged to a storm water system or are collected by flows which enter a storm water drainage system.

Illicit Connection

Any discharge to a MS4 that is not composed entirely of storm water and is not authorized by an NPDES permit. (One exception is fire fighting activities).

Indicator Organism

An organism, species, or community that indicates the presence of a certain environmental condition or conditions.

Infiltration

The process whereby water or waste water enters an underground storm drainage system through such means as defective pipes, pipe joints, connections, manhole walls, etc.

Inflow

The process whereby water enters a sanitary wastewater collection system from surface locations (including but limited to depressed, perforated manhole covers, yard drains, area inlets, or roof leader)

Lateral

A drain or sewer that has no other drains or sewers discharging into it, except for service connections or house laterals.

MS4

Municipal Separate Storm Sewer System. A conveyance or system of conveyances which includes roadway and drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains. See 40 CFR 122.26(b)(8) Classification: Large MS4 have a population > 250,000, a medium MS4 has a population of 100,000 to 250,000, and a small MS4 is any other system not regulated under Phase I.

NPDES

National Pollutant Discharge Elimination System. A permitting program that regulates polluted storm water runoff from MS4's, construction sites, and industrial activities.

Nuisance and aquatic life threatening pollutant

A constituent which will cause in impairment in surface waters such as low dissolved oxygen levels, excessive algal growth, floatables, color change, odor, and/or turbidity. The origins of this pollutant is from sanitary wastewater, laundry wastewater, construction sites, automobile wash waters, or lawn runoff.

Nutrient

Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

Outfall

The point at which a storm water drainage system discharges from a pipe, ditch, or other conveyance to a receiving water. There is sometimes a concrete structure or retaining wall at this location to protect the end of the discharge pipe and prevent erosion of the receiving water bank.

Pathogenic or toxic pollutant

A constituent that by itself or in combination with others may cause illness through contact, ingestion, and/or inhalation. Sources include sanitary, commercial, or industrial wastewater plus improper disposal of household hazardous materials, fertilizers and pesticides, and other sources of the like.

pH

The measurement of hydrogen-ion activity of water caused by the breakdown of water molecules and presence of dissolved acids and bases. Simply: the measure of a solution's acidity or alkalinity.

Phosphorus

Essential nutrient to the growth of organisms and can be the nutrient that limits the primary productivity of water. In excessive amounts, from wastewater, agricultural drainage and certain industrial wastes, it also contributes to the eutrophication of lakes and other water bodies. The nutrient screening level for total phosphorus is 0.2 mg/l. Anything over this is considered high for a body of water.

Photosynthesis

The process used by green plants to use light energy to convert carbon dioxide and water to simple sugar and oxygen.

Point Source

A single, identifiable location or source from which pollution may be discharged to surface waters (example: a pipe or a ship).

Pollutant

Any material, substance, organism, or condition which can alter the physical, thermal, chemical or biological quality of water and render it harmful, detrimental or injurious to humans, animal life, vegetation or property, or to the public's health, safety or welfare, or impairs the usefulness or public enjoyment of the water for any lawful or reasonable purpose.

Potable Water

Water which has been treated or is naturally safe for drinking. It contains no toxic constituent which would make it harmful for human consumption.

Raw sewage

Untreated wastewater from all sources not permitted to discharge to an MS4.

Receiving Water

A river, stream, lake, estuary, or other body of water, natural or manmade, into which storm water or treated wastewater may be discharged.

Run-off

That part of precipitation or irrigation water which runs off the land into surface waters or waters of the state.

Sanitary sewer

A series of underground pipes which carry sanitary waste or process wastewater to a treatment plant.

Septic odor

Rotten egg smell produced by decomposing organic matter and the lack of oxygen.

Sewage

Sanitary wastewater or wastewater generated by commercial or industrial operations but does not include storm water.

Sewer

A pipe, conduit or drain, generally closed, but not normally flowing full, for carrying sanitary, industrial and commercial wastewater or storm water flows.

Storm drain

A pipe, ditch, or natural or manmade channel that is designed to carry storm water, surface runoff, street wash water, and other drainage from a specific area/source to receiving waters.

Storm Water

Water resulting from precipitation which either infiltrates into the ground, impounds/puddles, and/or runs freely from the surface, or is captured by storm drainage, a combined sewer, and, to a limited degree, by sanitary sewer facilities.

Surface Waters or **Waters of the State**

Groundwater (percolating or otherwise), lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Gulf of Mexico inside the territorial limits of the state, and all other bodies of surface water, natural or artificial, inland or coastal, fresh or salt, navigable or non-navigable, and including the beds and banks of all watercourses and bodies of surface water, that are wholly or partially inside or bordering the state or inside the jurisdiction of the state.

Tracer

A distinct component, or combination of components, of a polluting source which is identified in order to confirm the entry of a pollutant to a storm drainage system.

Turbidity

The lack of clarity in the water usually caused by suspended particulate and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. It is measured by interference to light penetration.

Urbanized Area (UA)

A land area containing one or more central places. The residential population is at least 50,000 with at least 1,000 people per square mile.

Watershed

A confluence of streams or rivers that drain a geographical area to a specified point.

Illicit Discharge/Connection Field Investigation Sheet

Field Site Description

Outfall ID: Tributary/Drainage Ditch:

Location:

Land Use: Residential Commercial Industrial Agricultural

Discharge Observations

Flow: Yes/No (If yes, estimate flow)_________ GPM Tide:___________

Time:__________ Days Prior Rain:__________

Odor: None Musty Sewage Sulfide (Rotten Eggs) Other ______________

Color: Clear Green Brown White Blue Grey Other ______________

Turbidity: Clear (Lt) Cloudy (Mod) Opaque (Hvy) Suspended Solids Other ___________

Vegetative Growth: None Inhibited Growth Algae Sewage fungus Excessive Growth Other ___________

Deposits/Stains: None Sediment Garbage Oily Color________ Other__________

Floatables: Paint Sanitary Waste Surface scum Debris Other ___________

Structural Materials: Concrete Metal Plastic Other___________

Structural Conditions: Undamaged Caved-in Corroded Cracked Other ___________

Biological Activity: Fish (list)________________ Turtles (list)_________________ Others ______________
Waterfowl/Wading birds (list)_________________________________

Picture Taken: Yes/No Film/ Digital

Field Analysis (Parameters Optional)

Air Temp:__________(°C) Water Temp:________(°C) Dissolved Oxygen(DO):_________(mg/l)

pH: ________ Ammonia:________ (mg/l) Chlorine:__________(mg/l)

Phosphate(PO_4):________(mg/l) Detergents (O.B's): _________ Other:____________

Lab Analysis (Parameters Optional)

Bacterial counts:__________________ Other:

Comments:

Inspector Data

Investigator: Signature: Date:

Charcoal Packet Processing

Equipment List

Charcoal: Activated, Coconut, 8-12 Mesh,
(Use 5 grams per packet)

Packets: Fiberglass mesh (18 x 14)
Cut into 3.25" x 5.5" pieces, fold in half, fill with charcoal and heat seal or staple closed

KOH Solution: 5% potassium hydroxide dissolved in 70% isopropyl alcohol
Elute each charcoal packet in 20 ml of solution

Liquid Tracing Dye: Fluorescein

Latex gloves

30 ml glass vials with screw caps

6 ounce whirl pack plastic bags (write on and puncture proof)

Black light

Packet Placement

- Background charcoal packets need to be placed one week prior to dye testing
- Packets are placed at areas where dye is suspected to surface and should be in a shaded or dark location
- Background packets are retrieved and replaced with new test packets, dye is then introduced into the system. Background packets can be analyzed or frozen for later laboratory analysis

Packet Retrieval

- Test packets are retrieved after one week and replaced with a second set of test packets
- Use new latex gloves at each site to prevent cross contamination
- Place each test packet in a separate whirl pak bag
- Label bag with the name of property or resident, retrieval date, and address or exact location

Charcoal packet processing and elution

- Cut corner of test packet and empty charcoal into 30 ml glass vial. Add 20 ml KOH solution to vial
- Label vial with name of property or resident, date, and location with indelible ink
- Visually read the vial for the presence/absence of fluorescent dye within 24 hours of the elution. Take a second reading within 48 hours. This should be done for each packet, therefore there will be two (2) readings for each packet. The first and second reading should be done by different staff persons.
- If the results are difficult to determine, shine a strong beam of light through the sample, in a dark room, to look for fluorescence. Record the results as positive, flashlight positive, or negative.

Quality Control

- When the KOH solution is prepared, use the following control procedure:
  1- Fill a 250 ml beaker with 150 ml of cold tap water. Submerge a charcoal packet in the beaker for 15 minutes
  2- Fill a second 250 ml beaker with 150 ml cold tap water and a drop of fluorescent dye. Submerge a charcoal packet in this beaker for 15 minutes
  3- Follow the elution instructions for both packets
  4- Record the results. The packet in the tap water should produce a negative result and the packet in the dye water should produce a positive result. If any other results are observed the quality of the KOH solution, charcoal, dye, etc. should be checked.
- Field duplicates should be completed on 10% of the samples. This means that two (2) packets should be placed together and the results compared for consistency. Place test packets side by side, not one in front of the other.
- All supplies that come into contact with the packets or elutant should be analyzed for tracer dyes prior to packet placement, ie. Placement anchors, glass vials, tape, markers, labels, etc.
- Charcoal packets should be constructed and stored in a way so they are not contaminated

Optical Brightener Kit Checklist

For field:

Small, dark (non-transparent) rubbermaid container (to hold contents below)
Untreated cotton pads
½ in. Wire mesh cages
Monofilament fishing line (high test)
Tent stakes
Wire cutters
Cable ties
Zipper seal sandwich bags
Hand sanitizer/ rubber gloves
Unexposed, non-fluorescent labels

For interpreting results in office:

Long wave U.V 4-6 watt fluorescent lamp

For cleaning:

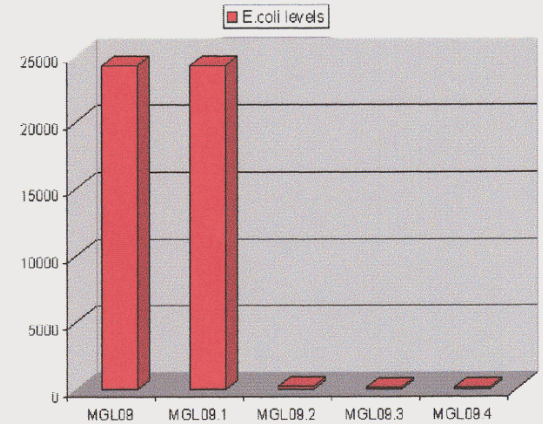
Bucket
Clorox
Cleaning brush

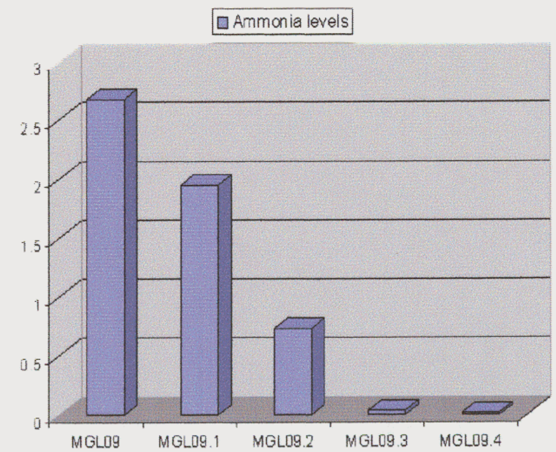
Optical Brightener Data Sheet Subwatershed Area: Collected by:

Site ID	DOP	DOR	No. days	Flow (GPM)	O.B. +/-	Total Rain	Observations

Optical Brightener Observation Form

DATE	SITE ID#	Observer %	Observer Initials	QAQC %	QAQC Initials





Magnolia Creek
Station MGL 09

Sampling Equipment Checklist

Field Maps

Field data sheets

Waterproof marker

Handheld GPS (if available)

Sampling Bottles

Ice chest / Ice

Meters: YSI (DO), pH

Thermometer

Deionized water for cleansing meters after calibration

Bucket with rope

Telescoping sampling stick with attached sampling bottle

Rubber gloves and/or hand sanitizer

High beam cordless spotlight

Rubber boots / Waders

Manhole hooks

Traffic cones / Safety Vests

Spray paint

Cell phone / Two-way radios

Camera/film or Digital

Sunglasses, sunscreen, and bugspray

Other___________________________

Other___________________________

Other___________________________

Run: **Collector:** **Rain:** **Wind Dir:**

Date: **Sunrise:** **Days Prior (72053):** **Wind Spd:**

Station												
Time												
Color (0080)												
Turbidity (82078)												
Sample Depth												
Flow (00061)												
Flow Severity(01351)												
Salinity (00480)												
Conductivity (00094)												
DO (00300)												
pH (00400)												
Air Temp. (00020)												
Water Temp.(00010)												
Observations												

Data Entry Signature: ______________________ QA/QC Signature: __________________________

D:\4J-FieldSamplingSheet.wpd

Summary of Illicit Connection Investigation

Location of Illicit Connection (Address):

Contamination Effect: Pathogenic Toxic Nuisance
(Circle all that apply)

Type of Connection: Direct Infiltration Inflow Other_______
Comments:

Flow: Continuous Intermittent GPM's _________
Comments:

Source of Flow: Sewage Potable Water Swimming Pool Other_________
Comments:

Land Use: Residential Commercial Industrial Agricultural
(Circle all that apply)

What tests were used:

What supplies are needed to fix the problem:

What are the estimated costs of remediation:

Responsibility: City/County/MUD Resident(Customer)
Comments:

Name of Responsible Party:

if Resident Responsibility: Address: Phone #:

Who Discovered Flow: Citizen Complaint Inspector City Crew Other________
Comments:

Investigator: Date: Total Manhours:

Table 1. Field Survey Parameters and Associated Non-Stormwater Flow Source Categories

Parameter	Natural Water	Potable Water	Sanitary Wastewater	Septic Tank Effluent	Industrial Water	Wash Water	Rinse Water	Irrigation Water
Odor	-	-	+	+	+	+/-	-	-
Color	-	-	-	-	+	-	-	-
Turbidity	-	-	+	+	+	+	+/-	-
Vegetation	-	-	+	+	+	+/-	-	+
Deposit/Stains	-	-	+	-	+	+/-	+/-	-
Floatables	-	-	+	-	+	+/-	+/-	-
Structural Damage	-	-	-	-	+	-	-	-
Temperature Change	-	-	+/-	-	+	+/-	+/-	-
pH	-	-	-	-	+	-	-	-
Ammonia	-	-	+	+	-	-	-	-
Surfactants	-	-	+	-	-	+	-	-
Fluorescence	-	-	+	+	-	+	-	-
Conductivity	-	-	+	+	+	+/-	+	+

+ High Concentration Association
- Low Concentration Association
+/- Variable Concentration Association

*Turner, Collie, and Braden Inc.

Investigation Checklist

Field Maps
Field data sheets
Telescoping sampling stick with attached sampling bottle
Meters
- Ph meter
- DO / Specific Conductivity

Parameter Kits
- Chlorine
- Ammonia
- Phosphate
- Optical Brightener

Fluorescent Tracing Dye
Thermometer
Dye
Manhole hooks
Rubber gloves and/or hand sanitizer
High beam spotlight
Rubber boots
Traffic cones
Cell phone / Two-way radios
Sunglasses, sunscreen, and/or bugspray
Camera/film or Digital
Other________________________________
Other________________________________

Illicit Connections Detection and Elimination Tracer Summary Datasheet

	SITE:					
	TIME:					
	DATE:					
Flow (GPM)	*Value*					
Turbidity	*Value*					
Odor	*Pos/Neg*					
Color	*Pos/Neg*					
Air Temp	Value					
Water Temp	*Value*					
pH level	*Value*					
Ammonia	*Value*					
Chlorine	*Pos/Neg*					
PO4	*Pos/Neg*					
Ecoli	Value					
OB's	*Pos/Neg*					
Dye Test	*Pos/Neg*					
	Observation					