Missouri Department of Natural Resources

Detecting Illicit Storm Water Discharges - Fact Sheet Series

Water Protection Program fact sheet

2/2007

The Water Protection Program has created this series of fact sheets to help managers of municipal separate storm sewer systems understand basic and technical information about detecting illicit storm water discharges. There are two documents in this series.

1. *Detecting Illicit Storm Water Discharges* -- PUB2209-1
2. *Water Quality Parameters Useful in Detecting Illicit Storm Water Discharges and Determining Overall Stream Health* -- PUB2209-2

Recycled Paper

PUB002209

Missouri Department of Natural Resources

Detecting Illicit Storm Water Discharges - #1 in series

Water Protection Program fact sheet 2/2007

Detecting illicit storm water discharges for managers of municipal separate storm sewer systems (MS4s)

The 2003 Storm Water Regulations require affected communities to develop and administer a storm water management program. One requirement is to identify and correct illicit storm water discharges. This fact sheet provides regulated communities with a definition of illicit discharges, potential sources and how to look for them. More detailed technical references are provided at the end of this document.

An illicit storm water discharge is a release of non-storm water to the storm water drainage system. Examples are untreated sewage, industrial waste, improperly disposed oil or similar contaminants discharged into a storm water drainage system that then drains to a stream, river or lake. An illicit discharge may also be illegally piped directly to the water body. The results are high levels of pollutants such as heavy metals, oils, greases, solvents and bacteria.

Most storm water drainage systems are designed to quickly carry rainwater away from developed areas and solid surfaces such as roadways, rooftops and parking lots, to natural drainage channels such as rivers and streams. In general, storm water systems provide little-to-no treatment of the water that flows through them. Therefore, untreated domestic sewage, industrial wastewater or other waste streams must not be discharged to the storm water system. Those waste streams must be discharged to a municipal wastewater treatment system that is permitted under Missouri's National Pollutant Discharge Elimination System (NPDES) permit program.

Few cities have accurate historical records that show the location of all their storm water drains, cross-connections between sanitary and storm sewers, and combined sewer overflows (CSOs.) Therefore, one of the first steps a regulated community must take is to locate, identify and map the storm drains, municipal sewer lines and combined sewer overflows, including informal outfall points such as holes in the sides of manholes. They must then use procedures to detect and eliminate illicit discharges. Developing a good mapping system, and performing dye and smoke testing of the storm water pipe system will be necessary. Basic field screening tools and visual screening methods will be useful in detecting potential discharges from outfalls and wet weather drainage areas.

Some useful, yet inexpensive, screening measures to start with are conductivity, pH and temperature. A portable meter or water quality test kit can measure these field-screening parameters on-site. The information obtained should be used as a screening tool to locate problem areas during non-rain events. If these parameters show readings significantly higher or lower than pre-determined background readings, it is an indication of an illicit discharge somewhere up stream in the storm water system. Visual and odor observations should also be noted to help determine the nature of the discharge (e.g. characteristics such as suds, oil sheens, stains, smudges, and other abnormal or odorous conditions.)

A flow data logger, placed in the drainage area, can collect useful information to determine if discharges take place during non-rainfall events. For example, if the discharge contains fecal coliform along with an elevated biochemical oxygen demand (BOD), it would be reasonable to search for some type of connection to domestic sewage. This may be a small subdivision or restaurant. If the discharge contains heavy metals, an illicit discharge from an industry might be the suspect. Further investigation will usually require monitoring when the discharge is actually occurring. Additional field investigations can include asking questions and conducting site surveys.

Monitoring equipment can be expensive, but some items are inexpensive and accurate. For example, individual conductivity and pH pens cost between $50 to $100 and are available from various laboratory suppliers.

Additional publications in this series

For an overview of water quality indicators, see *Water Quality Parameters Useful in Detecting Illicit Storm Water Discharges and Determining Overall Stream Health* -- PUB2209-2, which is part 2 of this *Detecting Illicit Storm Water Discharges - Fact Sheet Series*. PUB2209-2 contains more technical information for managers of Municipal Separate Storm Sewer Systems.

Online publications

The following documents provide information on how to develop an illicit discharge detection and elimination (IDDE) program. They also provide details on measuring and interpreting conductivity and other parameters. The IDDE manuals are especially useful, as they were developed purposely to assist Phase II MS4s in meeting IDDE requirements:

- *IDDE Manual* - Center for Watershed Protection
  www.cwp.org/IDDE/IDDE.htm
- *IDDE Manual* - New England Interstate Water Pollution Control Commission
  http://www.neiwpcc.org/iddemanual.htm
- *Illicit Discharge Detection and Elimination Minimum Control Measure: Non stormwater discharges* - EPA fact sheet
  www.epa.gov/owm/mtb/nonstorm.pdf
- *"Sherlocks of Stormwater" Effective Investigation Techniques For Illicit Connection And Detection* - Dean C. Tuomari/Susan Thompson, Wayne County Department of Environment
  www.epa.gov/owow/nps/natlstormwater03/40Tuomari.pdf
- *Source Verification Procedure* - University of Alabama
  www.cwp.org/IDDE/Source_Verification_of_Inappropriate_Discharges.pdf

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Missouri Department of Natural Resources

Water Quality Parameters Useful in Detecting Illicit Storm Water Discharges and Determining Overall Stream Health - #2 in series

Water Protection Program fact sheet 2/2007

An illicit storm water discharge is a release of non-storm water to the storm water drainage system. Examples are untreated sewage, industrial waste, improperly disposed oil or similar contaminants discharged into a storm water drainage system that then drains to a stream, river or lake. An illicit discharge may also be illegally piped directly to the water body. The results are high levels of pollutants such as heavy metals, oils, greases, solvents and bacteria.

This fact sheet describes how illicit discharges may impact the health of a receiving stream. Data comparisons can be made to specific criteria listed in the Missouri Water Quality Standards (10CSR 20-7) available on the Secretary of State's Web site at www.sos.mo.gov/adrules/csr/current/10csr/10c20-7b.pdf. If criteria are not available for certain parameters, data can be compared to background water quality, meaning that samples can be compared to analyzed samples of nearby, similar-sized streams that are relatively unimpacted by pollution sources.

Visual and odor screening methods

Color and odor can be good indicators at the outfall point. They are also useful when searching wet weather drainage areas for potential sewage, washwater and industrial or commercial liquid wastes. Examples include visible sewage, oil sheen or suds. Odor or discoloration may accompany the sewage, oil or suds. (Note: suds and surface oil sheen may also occur in natural systems.) Dye and smoke testing can also be used in detecting leaks throughout the piped portion of sewer and storm drainage systems.

Field parameters

Many of these parameters can be analyzed with water quality test kits:

Acidity

Acidity of water is its quantitative capacity to react with a strong base to a designated pH. Acidity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known *(19th Edition, Standard Methods, 1995).*

Alkalinity

The alkalinity or the buffering capacity of a stream refers to how well it can neutralize acidic pollution and resist changes in pH. Alkalinity measures the amount of alkaline compounds in the water, such as carbonates, bicarbonates and hydroxides. These compounds are natural buffers that can remove excess hydrogen (H+) ions *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Conductivity
Conductivity is a measure of how well water can conduct an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, ammonia, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum, etc. The presence of these substances in illicit discharges, storm water runoff, leachate, sewage bypasses, etc. increases the conductivity of a body of water over normal background levels. Non-polar organic substances like oil, alcohol, and sugar do not conduct electricity very well and thus do not change the conductivity of receiving water's appreciably *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Depending upon the geographic region and seasonal conditions, conductivity values in storm water runoff can be elevated. This is mainly prevalent during the winter months when ice-melting agents are in use (e.g. sodium chloride and calcium chloride).

Dissolved Oxygen (DO)*
The amount of Dissolved Oxygen (DO) in water is expressed as a concentration.
A concentration is the amount of weight of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen gas present, in milligrams per liter of water. Milligrams per liter (mg/L) can also be expressed as parts per million (ppm).

The concentration of dissolved oxygen in a stream is affected by many factors:

- **Temperature:** Oxygen is more easily dissolved in cold water
- **Flow:** Oxygen concentrations vary with the volume and velocity of water flowing in a stream. Faster flowing white water areas tend to be more oxygen rich because more oxygen enters the water from the atmosphere in those areas than in slower, stagnant areas.
- **Aquatic plants:** The presence of aquatic plants in a stream contributes to the dissolved oxygen concentration via photosynthetic activity. Photosynthesis occurs during the day when the sun is out and ceases at night. Oxygen is removed from the water by respiration and decomposition of organic matter.
- **Human activities affecting DO:**
    - √ Removal of riparian vegetation may lower oxygen concentrations due to increased water temperature and increased suspended sediments. However, the removal of riparian vegetation also increases light penetration to the stream, which can result in increased algal growth and a subsequent increase in dissolved oxygen to supersaturation levels. Also, as bacteria break down the algae, they can deplete the dissolved oxygen. Both excessively high and excessively low levels of dissolved oxygen can be harmful to organisms.
    - √ Typical urban human activities may lower oxygen concentrations. Runoff from impervious surfaces bearing salts, sediments and other pollutants increases the amount of suspended and dissolved solids in stream water.
    - √ Organic wastes and other nutrient inputs from sewage and industrial discharges, septic tanks and agricultural and urban runoff can result in decreased oxygen levels.

√ Dams may pose an oxygen supply problem when they release waters from the bottom of their reservoirs into streams and rivers. Although the water on the bottom is cooler than the warm water on top, it may be low in oxygen if large amounts of organic matter have fallen to the bottom and have been decomposed by bacteria.

√ In streams that have been impacted by any of the above factors, summer is usually the most crucial time for dissolved oxygen levels because stream flows tend to lessen and water temperatures tend to increase.

Hardness

Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (temporary hardness), largely combined with bicarbonate and carbonate, and with sulfates, chlorides and other anions of mineral acids (permanent hardness) *(Limnology, Wetzel, 1983)*.

Hardness can affect the toxicity of other chemicals present in storm water runoff.

pH*

pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organisms biochemical reactions by either harming or killing the stream organisms.

Streams generally have pH values ranging between six and nine, depending upon the presence of dissolved substances that come from bedrock, soils, photosynthetic activity and other materials in the watershed.

Changes in pH can change the aspects of water chemistry. For example, as pH increases, ammonia becomes more toxic to fish. As pH decreases, the concentration of metal may increase because higher acidity increases the ability of metals to be dissolved from sediments into the water *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Temperature*

Water temperature is a controlling factor for aquatic life. It controls the rate of metabolic activities and reproductive activities. If stream temperatures increase, decrease or fluctuate too widely, metabolic activities may speed up, slow down, malfunction or stop altogether.

There are many factors that can influence the stream temperature. Water temperatures can fluctuate seasonally, daily and even hourly, especially in smaller sized streams. Spring discharges and overhanging canopies of stream vegetation provide shade and help buffer the effects of temperature changes. The quantity and velocity of stream flow also influence water temperature. The sun has much less effect in warming the waters of streams with greater, swifter flows than of streams with smaller, slower flows.

Storm water discharges that drain a high percentage of impervious surface can have a dramatic effect on the temperature of a receiving stream. In arid and temperate climates, during the mid-summer months, impervious surfaces (such as pavement) can raise to temperatures in excess of 100 °F. During a mid-summer rainfall event, the rainwater becomes heated as it runs off parking lots and roadways and enters the receiving stream, river or lake system.

Temperature affects the concentration of dissolved oxygen in a water body. Oxygen is more easily dissolved in cold water, and as a result, more available. *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Turbidity

Turbidity is a measure of the cloudiness of water. Cloudiness is caused by suspended solids (mainly soil particles) and plankton (microscopic plants and animals) that are suspended in the water column. Moderately low levels of turbidity may indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the food chain. However, higher levels of turbidity pose several problems for stream systems. Turbidity blocks out the light needed by submerged aquatic vegetation. It can also raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight.

Suspended soil particles may also carry nutrients, pesticides and other pollutants throughout a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen. High turbidity may result from sediment bearing runoff or nutrient inputs that cause plankton blooms *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods).*

Analytical parameters

Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand is the amount of oxygen consumed by bacteria in the decomposition of organic material. It also includes the oxygen required for the oxidation of various chemicals in the water, such as sulfides, ferrous iron and ammonia. While a dissolved oxygen test tells you how much oxygen is available, a BOD test tells you how much oxygen is being consumed and is an indirect measure of the biodegradable organic material content of a sample *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Carbonaceous biochemical oxygen demand (CBOD)

Carbonaceous biochemical oxygen demand measures the amount of demand that is oxidized by carbonaceous compounds (but excludes reduced forms of nitrogen such as ammonia and organic nitrogen). CBOD is a fraction of the BOD that excludes the nitrogenous oxygen demand by the addition of nitrogen inhibitors during the analysis *(19th Edition, Standard Methods, 1995).*

Chemical Oxygen Demand (COD)

The chemical oxygen demand is used as a measure of the oxygen equivalent of organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant *(19th Edition, Standard Methods, 1995).*

Fecal Coliform/E. coli*

Fecal coliform, enterococci and E. coli bacteria are present in the digestive systems of all warm-blooded animals and are not usually disease-causing agents themselves. However, high concentrations suggest the presence of fecal matter, which may contain disease-causing organisms. Fecal coliform, enterococci and E. coli bacteria are used as indicator organisms; they indicate the probability of finding pathogenic organisms in a stream. The strains of E. coli bacteria present in all warm-blooded animals, including humans, should not be confused with a particular strain of E. coli that is often found in cattle and can contribute to E. coli tainted beef *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Fecal coliform and E. coli should be measured with caution. Storm water discharges can have elevated bacteria levels during runoff events from pet and other animal waste that enter into the storm water system.

Metals*
The effects of metals in water and wastewater range from beneficial to troublesome to dangerously toxic. While some metals are essential, others may adversely affect water consumers, wastewater treatment systems and receiving waters. Some metals may be either beneficial or toxic, depending on concentration *(19th Edition, Standard Methods, 1995).*

In urban runoff, low concentrations of metals in storm water discharges are often related to vehicle exhaust, worn tires, roofs or downspouts; however, elevated concentrations may indicate an illicit industrial discharge.

Nitrogen
Nitrogen is important to all life. Nitrogen in the atmosphere or in the soil can go through many complex chemical and biological changes. It can be combined into living and non-living material and return back to the soil or air in a continuing cycle called the nitrogen cycle.

The following three nitrogen compounds are interrelated through the process of nitrification, the biological oxidation of ammonia to nitrate. In this process, nitrite is produced as an intermediate product.

Order of decreasing oxidation state:
NH_3 (ammonia) ⇨ NO_2 (nitrite) ⇨ NO_3 (nitrate)

In relatively stable, oxygenated natural water systems, the oxidation of nitrite to nitrate is rapid, but the conversion of NH_3 to NO_2- is the rate limiting step in the total process *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Nitrogen as Ammonia (NH_3)*
It is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature and its ubiquity in surface water systems. It is discharged in large quantities in industrial, municipal and agricultural wastewaters. In aqueous solutions, ammonia assumes two chemical forms: NH_4+ - ionized (less toxic or nontoxic) and NH_3 - unionized (toxic).

The relative concentration of ionized and unionized ammonia in a given ammonia solution are principally a function of pH, temperature and ionic strength of the aqueous solution *(Fundamentals of Aquatic Toxicology, 1985).*

Nitrogen as Nitrate (NO_3-)
Generally occurs in trace quantities in surface water. It is an essential nutrient for autotrophs (photosynthetic) and at times can be the growth-limiting nutrient. In effluent of nitrifying biological treatment plants, nitrate may be found in concentrations up to 30 mg/L nitrate as nitrogen *(19th Edition, Standard Methods, 1995).*

Nitrogen as Nitrite (NO_2-)
Nitrite is extremely toxic to aquatic life. However, it is usually present only in trace amounts in most natural freshwater systems because it is rapidly oxidized to nitrate. In sewage treatment plants using nitrification process to convert ammonia to nitrate, the process may be impeded, causing discharge of nitrite at elevated concentrations into receiving waters.

Nitrogen as Total Kjeldahl
Organic nitrogen and ammonia can be determined together and have been referred to as "Kjeldahl nitrogen (TKN)", a term that reflects the technique used in their determination *(19th Edition, Standard Methods, 1995).* TKN is an indicator of the remaining oxygen demand of nitrogen compounds.

Nitrogen, Organic
Organic Nitrogen is the byproduct of living organisms. It includes such natural materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials. Typical organic nitrogen concentrations vary from a few hundred micrograms per liter in some lakes to more than 20 mg/L in raw sewage *(19th edition, Standard Methods, 1995).*

Phosphorus and Inorganic Phosphorus
Phosphorus is often the limiting nutrient for plant growth, meaning it is in short supply relative to nitrogen. Phosphorus usually occurs in nature as phosphate, which is a phosphorous atom combined with four oxygen atoms (PO_4^{-3}).

Phosphate that is bound to plant or animal tissue is known as organic phosphate. Phosphate that is not associated with organic material is known as inorganic phosphate. Both forms are present in aquatic systems and may be either dissolved in water or suspended (attached to particles in the water column) *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*.

Total Solids
Total Solids is a measure of the suspended and dissolved solids in a body of water. Thus, it is related to both conductivity and turbidity *(1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods)*. *Revised Dec. 11, 2006*

* Parameters with an asterisk are subject to the water quality criteria listed in Missouri's Water Quality Standards (10 CSR 20-7), which are available on the Secretary of State's Web site at www.sos.mo.gov/adrules/csr/current/10csr/10c20-7b.pdf.

Additional publications in this series

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