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NON-STORMWATER DISCHARGES INTO STORM DRAINAGE SYSTEMS

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ABSTRACT: This paper summarizes the first phase of an EPA sponsored research project to develop a manual of practice to investigate non-stormwater discharges of polluted waters into storm drainage systems. A number of past projects have found that dry-weather flows discharging from storm drainage systems can contribute significant pollutant loadings to receiving waters. If these loadings are ignored (by only considering wet-weather stormwater runoff, for example), little improvement in receiving water conditions may occur with many stormwater control programs. These dry-weather flows may originate from many sources, the most important sources may include sanitary sewage or industrial and commercial discharge cross-connections, failing septic tank systems in storm sewered areas, and venicle maintenance activities. After the outfalls are identified that are affected by polluted dry-weather flows, additional survey activities are needed to locate and correct their sources.

KEY WORDS: Non-stormwater discharges, cross-connections; stormwater; dry-weather flow.

Introduction

This paper is a preliminary summary of the first phase of a current EPA research project to:

- o develop investigative techniques to assist local governments in identifying the magnitude and sources of non-stormwater discharges to their storm drainage systems; and
- o present case studies of techniques used by selected municipalities in identifying these non-stormwater discharges.

Discharges from storm drainage outfalls can be a combination of dry-weather base flows; stormwater runoff; snowmelt water; intermittent discharges of debris, wash-waters, and other waste materials into storm drains; and the relatively continuous discharges of sanitary and industrial cross-connected wastes. These discharges include stormwater that contains the washoff of pollutants from all land surfaces during rains,
including washoff of pollutants from areas such as industrial material and waste

storage areas, gas station service areas, parking lots, and other industrial and commercial areas, etc. Therefore, the quality of urban runoff can vary greatly with time (dry versus wet-weather, cold versus warm weather, etc.) and location.

The discharge of sanitary and industrial wastes into storm drainage (non-stormwater discharges) can lead to serious water pollution problems. In many cases, storm drain discharges are badly polluted by stormwater alone, without the additional pollutant loadings associated with sanitary or industrial non-stormwater discharges. The addition of sanitary wastes increases the concentrations of organic solids and nutrients, and increases the potential of pathogenic microorganisms in the runoff. Industrial wastes can be highly variable, but can substantially increase the concentrations of many filterable heavy metals in runoff, as an example. In many cases, annual discharge loadings from stormwater outfalls can be greatly affected by dry-weather discharges.[1,2,3]

Dry-weather and wet-weather urban runoff flows have been monitored during many urban runoff studies that have found that discharges observed at outfalls during dry weather were significantly different from wet-weather runoff. Warm and cold weather runoff was also contrasted during some studies and was also found to be quite different. During the Castro Valley, California, Nationwide Urban Runoff Program (NURP) study, Pitt and Shawley found that the dry-weather flows were very hard and had very few nonfilterable pollutants, while the stormwater runoff was quite soft and had substantial nonfilterable metals.[1] The dry-weather flows were found to contribute substantial quantities of many pollutants, even though the concentrations were not high. The long duration of baseflows in many areas of North America (about 95 percent of the time) off-set their lower concentrations and lower flow rates as compared to wet-weather (stormwater) flows.

The Bellevue, Washington, NURP project summarized the reported incidents of intermittent discharges and dumpings of pollutants into the local storm drainage system.[4] During a three year period of time, about 50 citizen contacts were made to the Bellevue Storm and Surface Water Utility District concerning water quality problems. About 25 percent of the complaints concerned oil being discharged into catchbasins. Another important category of complaints was for aesthetic problems, such as turbid or colored water in the creeks. Various industrial and commercial discharges into the storm drainage system were detected. Concrete wastes flushed from concrete trucks at urban job sites were a frequently occurring problem. Cleaning establishment discharges into creeks were also a common problem. Vehicle accidents also caused spills of gasoline, diesel fuel, hydraulic fluids, and lawn care chemicals from damaged trucks that commonly flowed into the storm drain inlets. Pitt also monitored both dry- and wet-weather discharges from stormwater outfalls in Bellevue and found significant pollutant yield contributions associated with dry-weather discharges from residential areas.[2]

Dry-weather flows in a monitored Toronto residential area were found to have high pesticide concentrations, while a monitored industrial area had dry-weather flows that had high concentrations of organic and metallic toxicants.[3] This Toronto project also found substantial differences in warm and cold weather dry- and wet-weather runoff. More than 50 percent of the annual discharges of water volume, total residue, chlorides, and bacteria, from the monitored industrial, residential, and commercial areas, were associated with dry-weather discharges. Substantial metal discharges, especially from the industrial area, were also found to be associated with dry-weather discharges.

Gartner Lee and Associates, Ltd. conducted an extensive survey of dry-weather storm drainage in the Humber River watershed (Toronto) in an attempt to identify the most significant urban runoff pollutant sources.5 About 625 outfalls were sampled two times during dry-weather, with analyses conducted for many pollutants, including organics, solids, nutrients, metals, phenols, and bacteria. About 1/3 of the outfalls were discharging at rates greater than 1 L/sec. The dry-weather flows were found to contribute significant loadings of nutrients, phenols, and metals, compared to upstream conditions. About 10 percent of the outfalls were considered significant pollutant sources. Further investigations identified many industrial and sanitary sewage non-stormwater discharges into the storm drainage. An apartment building with the sanitary drains from eight units illegally connected to the storm drainage system was typical of the problems found. Other problem areas were found in industrial areas, including liquid dripping from animal hides stored in tannery yards and washdowns of storage yards at meat packing plants.

Methodology

A specific objective of this project is to identify the most promising techniques to identify, quantify, and locate non-stormwater discharges of sanitary and industrial wastes entering storm drainage systems.

As noted above, non-stormwater discharges can take multiple forms. Many non-stormwater discharge problems are associated with intermittent discharges. These intermittent discharges occur during wet weather as runoff from storage areas, or as illegal dumping or washing operations that occur during dry or wet weather. Other non-stormwater discharge problems are caused by continuous connections that can occur during both wet and dry weather. These can be associated with "non-contact" cooling water discharges (which frequently contain a variety of chemicals, including algicides and corrosion inhibitors), other industrial wastewater connections, and sanitary sewage waste connections, for example.

This project is identifying procedures that can be used to identify the significance and type of either intermittent or continuous discharges occurring during dry weather. The pollutant contributions associated with non-stormwater discharges can be distinguished by unique characteristics based on water types and typical pollutants. As an example, the major water types (major ions) of the flow components could vary substantially: the water supply source could be either groundwater or surface water (this water type would represent many of the wastewater types), while an uncontaminated baseflow source could be from local springs, groundwater, or from regional surface flows. Knowing the specific water source for each flow component could enable the relative mixture of uncontaminated baseflow and the other non-stormwater discharges to be calculated.

Potential Dry-weather Discharge Sources

The following list summarizes the potential contaminated residential area non-stormwater discharge sources being evaluated:

Sewage sources:
- o raw sewage from directly connected or leaky sanitary sewerage
- o septage from improperly operating septic tank systems

Household automobile maintenance:
- o car washing runoff
- o radiator flushing
- o engine de-greasing
- o improper oil disposal

Residential irrigation sources:
- o over-watering runoff
- o direct spraying of impervious surfaces

Roadway and other accidents:
- o fuel spills
- o spills of truck contents
- o pipeline spills

Other:
- o washing of ready-mix trucks
- o laundry wastes
- o improper disposal of other household toxic substances
- o dewatering of construction sites
- o sump pump discharges
- o contaminated surface and groundwaters

Commercial and industrial dry-weather discharges are being considered in a separate study conducted by Triad Engineering of Milwaukee. The results of the Triad study are being incorporated into the complete EPA manual. The commercial and industrial approach is stressing differentiating industrial categories used in the industrial discharge permit program.

The natural baseflow raw water source flows, along with the sewage related sources and many industrial sources, would be relatively continuous in flow duration. The other sources would be intermittent. As a drainage area increases in size, however, the probability also increases that dry-weather discharges associated with individual intermittent activities would appear continuous at the outfall. Most of the studies referenced previously found flows at the monitored outfalls most of the time during dry weather, even though the flows were very low at times. The quality of the flows also changed dramatically at different times of the day for the monitored Toronto industrial outfall.3 Some trends were also noted for dry-weather outfall flows for different times of the year.

This study is identifying unique physical, biological, or chemical characteristics that would distinguish the different flow sources.

Monitoring Approach

The purpose of the monitoring procedures is to separate the outfalls into three general categories (with a known level of confidence) to identify which outfalls need further analyses and investigations. These categories are: (1) pathogenic or toxic pollutant sources, (2) nuisance and aquatic life threatening pollutant sources, and (3) unpolluted water sources. The pathogenic and toxic pollutant source category would be considered the most severe and could cause disease upon water contact or consumption and significant impacts on receiving water organisms. They may also cause significant water treatment problems for downstream consumers, especially for soluble metal and organic toxicants. These pollutants may originate from sanitary, commercial, and industrial non-stormwater discharges. Other residential area sources (besides sanitary wastewater), such as inappropriate household toxicant disposal, automobile engine de-greasing, vehicle accident clean-up, and irrigation runoff from landscaped areas excessively treated with chemicals (fertilizers and pesticides) may also be considered in this most critical category.

Nuisance and aquatic life threatening pollutant sources can originate from residential areas and may include laundry wastes, landscaping irrigation runoff, automobile washing, construction site dewatering, and washing of ready-mix trucks. These pollutants can cause excessive algal growths, tastes and odors in downstream water supplies, and highly colored, turbid or odorous waters.

Clean water discharged through stormwater outfalls can originate from natural springs feeding urban creeks that have been converted to storm drains, infiltrating groundwater, infiltrating domestic water from water line leaks, etc.

The proposed monitoring approach is separated into three phases:

- o initial mapping effort
- o initial field surveys
- o confirmatory chemical analyses.

These three initial phases will be followed by detailed storm drainage and site investigations to identify specific pollutant contributors and control options.

An important requirement of the methodology is that an initial field screening effort would require minimal effort and would have little chance of missing a seriously contaminated outfall. This screening program would then be followed by a more in-depth analysis to more accurately determine the significance and source of the dry-weather pollutant discharges.

Mapping. The most important step in a non-stormwater discharge problem investigation is in preparing and studying drainage and land use maps. In addition to mapping, aerial photographs and general site investigations may be very useful. The most important objective of the mapping activities would be to identify the locations of all of the stormwater outfalls. Finding the outfalls is not trivial. In the case studies examined, repeated trips typically uncovered additional outfalls that could not be located during earlier excursions. In Toronto, for example, most outfalls were located during the first field trip, but two more trips were needed before all of the outfalls were located.5 Similarly, additional outfalls were periodically found that were not identified on the city storm drainage maps. It is very difficult for communities to maintain up-to-date mapping of drainage facilities.

Another important objective of the initial mapping activities is to outline the drainage areas discharging to the outfalls. These drainage maps should identify the predevelopment streams that may have been converted to storm drains (indicating the likelihood of natural uncontaminated baseflows) and the current and past land uses. Specific land use categories to be indicated should include commercial and industrial land uses, plus other activities that may contribute runoff problems (such as land fills). Any industrial activities having significant potential of contributing flows to the storm drainage system, as indicated by Triad's analyses, need to be specifically identified and located.

Further drainage area investigations would be conducted after the outfall studies have indicated dry-weather discharge problems. These would include drainage system and industrial and commercial site studies (such as dye and smoke studies) to locate specific non-stormwater discharges. Additionally, aerial photography can be very useful during later phases of non-stormwater discharge control projects. As an example, aerial photography can be very useful in identifying areas having failing septic systems located in residential areas served by storm drainage systems. Aerial photography can also be used to identify continuous discharges to surface drainages, such as sump discharges, and to identify storage areas that may be contributing significant amounts of pollutants during rains.

Initial field surveys. The initial field surveys are to be used as a screening effort: to identify the outfalls needing more detailed investigations which would identify pollutant sources and control options. These initial surveys would include physical and limited chemical evaluations of outfall conditions and would be conducted to minimize "false negatives" (outfalls actually having important discharges, but falsely classified as not needing further investigation).

Different flow and pollutant characteristics of the potential discharge sources can be used to identify and quantify non-stormwater discharge problems. The initial surveys to obtain this key information should be repeated at all outfalls over several seasons. Many of the dry-weather discharges are intermittent and may not be noted during any one investigation. Various physical characteristics near the outfall can provide evidence that inappropriate discharges periodically occur. However, repeated trips to the outfalls significantly increase the probability of identifying problem outfalls.

It is difficult to develop a procedure that will separate the outfalls into clear "problem" and "no problem" categories. In some of the case studies investigated, only correcting problems at the most critical outfalls resulted in insufficient receiving water quality improvements. It may be important to eventually correct all non-stormwater discharge problems throughout a city, not just the most severe problems. This screening procedure should therefore be considered as just an initial effort that needs to be followed-up with more detailed confirmatory investigations at the outfalls and receiving water monitoring to document improvements after different stages of the control program.

Candidate parameters. Many different analytical methods are being evaluated as part of this project. The initial screening effort should include the following:

- o placement of outfall identification number;
- o outfall discharge flow estimate;
- o floatables, color, oil sheen, and odor characteristics of water;
- o other outfall area characteristics, such as stains, debris, damage to concrete, corrosion, unusual plant growth, or absence of plants;
- o water temperature;
- o conductivity;
- o fluoride concentration;
- o ammonia and/or potassium concentrations; and
- o surfactant concentration.

These characteristics can be relatively easy to obtain at the outfall location, depending on the needed detection limits for the chemical analyses and potential interferences. The selection of the procedures to use to obtain the tracer concentrations will depend on many conditions, most notably the expected tracer concentrations in the uncontaminated base flows and in the potential non-stormwater source flows, along with the needed probabilities of detection at the minimum contamination level. Other factors affecting procedure selection include ease of use, analytical interferences, cost of equipment, training requirements, and time requirements to conduct the analyses.

Simple outfall estimates of discharge, and noting the presence of oil sheens, floatables, color, odors, etc. will probably be the most useful indicators of outfall problems. These observations will need to be repeated several times, especially if non-continuous discharges are likely. The presence of stains and structural damage will greatly assist in identifying significant non-continuous discharges.

Notably absent from the above list are pH and dissolved oxygen. These have been included in several previous non-stormwater discharge studies, but with limited value. These two parameters have not been found to be extremely useful in identifying or categorizing pollutant sources. However, in areas having known industrial sources, pH may be an important parameter that would have to be added to this list.

Specific conductance and temperature can be quickly and easily measured using a dual dedicated meter. Water color can be quantified using a comparative colorimetric meter or spectrophotometer in the field.

Fluorides can be detected using a variety of methods in the field, including field colorimetric kits having detection limits of less than 0.15 mg/L. This detection limit may not be sufficient to detect low dilutions of contaminants with adequate precision. Dedicated specific ion meters for fluorides are available having very low detection limits (2 ug/L) that would be quite capable of detecting very small dilutions. Neither of these methods are "direct reading" and require some time at the site to conduct the analysis and/or calibrate the meter.

Ammonium forms of nitrogen can be measured in the field using indicator paper, with detection limits of about 10 mg/L. Field colorimetric kits having detection limits of about 0.1 mg/L are available for total ammonia. Ion selective electrodes can be used in the field, with detection limits of about 0.01 mg/L for ammonia. Only the indicator paper method is a direct measurement procedure, but it probably does not have a low enough detection limit to permit the detection of low dilutions of non-stormwater contaminants. The other methods require some sample preparation, but would be much more useful.

Potassium can be measured in the field using ion selective electrodes having detection limits as low as 0.01 mg/L. Portable spectrophotometers can also be used, with detection limits of about 0.1 mg/L. Either of these methods can be useful in a non-stormwater discharge study.

Detergents (or surfactants) can be detected in the field using a comparative colorimetric method (having a detection limit of 50 ug/L) or with a recently developed auto titration method having very few interferences and much lower detection limits.

In addition, the following optional characteristics may also be obtained at each outfall, depending on probable pollutant sources:

o hardness;
o toxicity screening; and
o specific metals.

Hardness can be easily determined in the field using field titrimetric kits or even indicator papers, with varying sensitivities and interferences. Toxicity screening tests require laboratory analyses and some can be conducted in several hours. The toxicity tests would be useful in areas known to have commercial or industrial activities. Some individual metals (especially copper and chromium) could also be used in areas having these land uses. In most cases, it will probably be necessary to conduct a variety of carefully selected tests because of the large number of potential pollutant sources that probably occur in most drainage areas.

This scheme should allow an efficient determination of the general category (toxic/pathogenic, nuisance, or clean) of the water being discharged. In many cases, fluorides can be used to separate untreated water from treated water sources. Untreated water sources may include discharges from natural waters or untreated industrial waters. If the treated water has no fluoride added, or if the natural water has fluoride concentrations close to treated water fluoride concentrations, then fluoride may not be an appropriate indicator. Hardness can be used as an indicator if the clean water source is likely groundwater, while the treated water source is from surface supplies. Specific major ions could also be used to separate groundwater and surface water sources. Specific conductance may also serve as a rough indicator of major water source.

Water from treated water supplies (that test positive for fluorides, or other suitable tracer) can be relatively uncontaminated (domestic water line leakage or irrigation runoff), or it may be heavily contaminated. In areas having no industrial or commercial sources, sanitary wastewater is probably the most important non-stormwater source. Surfactants may be useful in determining the presence of sanitary wastewaters. However, surfactants in water from treated water sources could indicate sanitary wastewaters, laundry wastes, car washing water, or other waters having detergents. Fabric whiteners (as measured by fluorescence using a fluorimeter in the laboratory or in the field) may also be a useful test for laundry and sanitary wastes.

If the surfactants were not present, then the treated water could be relatively uncontaminated (such as from domestic water line leaks or irrigation runoff), or it may be from rinsing ready-mix trucks or other rinsing activities (such as accident scenes). Sanitary wastewater would have the most consistent characteristics (volume and characteristic) compared to most of the other potential sources. Ammonia (or ammonium) nitrogen and potassium have been studied in several previous studies as an indicator of sanitary wastewaters. If the surfactant concentrations were high, but the ammonia and potassium concentrations were low, then the contamination is likely from laundry water. If they were all high, then sanitary wastewater is the likely source. Obviously, odor and other physical appearances (such as turbidity, foaming, color, and temperature) would also be very useful in separating major sanitary wastewater flows from rinse water or laundry water sources.

Several confirmatory outfall analyses could be conducted to verify the more significant sources of non-stormwater discharges. These analyses require highly trained personnel and specialized equipment that would not be available in most laboratories. It may not be feasible to analyze samples from each of several hundreds of outfalls several times a year for these materials. These analyses can be very useful to check for false negatives and for more specific results on a random basis. These confirmatory analyses may include:

- trihalomethanes
- specific bacteria
- coprostanol

Trihalomethanes (THMs) are formed when chlorine reacts with certain natural organics present in waters. The detection of these compounds in groundwaters has been used as a positive indication of treated city water leakage.6 Chloroform and dichlorobromethane are the THMs most frequently used because of their very low detection limits and specific indicators of treated domestic water.

Bacteria are usually poor indicators of the source of cross-connection water. Past use of fecal strep. to fecal coliform ratios to indicate human versus nonhuman bacteria sources in mixed and old wastewaters (such as most nonpoint waters) has not been very successful. There may be some value in investigating specific bacteria types, such as fecal strep. biotypes, but much care needs to be taken in the analysis and interpretation of the results. A more certain indicator of human wastes may be the use of certain human-specific molecular markers, specifically the linear alkylbenzenes and fecal sterols, such as coprostanol and epicoprostanol.[7]

Detailed outfall analyses. After the initial outfall surveys indicate the presence of serious contamination, additional pollutants associated with local commercial and industrial activities need to be monitored. This monitoring will assist in identifying the classes of commercial or industrial activities responsible for the contamination.

Watershed analyses to locate specific sources. In order to identify the specific contaminant sources in the drainage system, further detailed analyses are needed. These may include:

- drainage system surveys (tests for specific pollutants, visual inspections, and smoke and dye tests)
- in-depth watershed evaluation (including aerial photographs)
- industrial and commercial site studies

Conclusions

Many urban runoff projects have found that dry-weather discharges from stormwater outfalls can contribute significant pollutant loadings. Ignoring these loadings can lead to improper conclusions concerning stormwater control requirements.

Municipalities that have recognized the importance of dry-weather flows have investigated their sources using various methods. Unfortunately, most municipalities have very large numbers of outfalls and an efficient method is needed to separate the outfalls creating the most severe problems. This project is examining three categories of outfalls: pathogenic/toxicant, nuisance and aquatic life threatening, and clean water. The most important category is for outfalls contributing pathogens or toxicants. These are most likely originating from sanitary wastewater or industrial non-stormwater discharges. An initial screening analysis at all outfalls should have a high probability of identifying all outfalls in this category.

The first step of this procedure is an extensive mapping effort to identify the locations of all outfalls for sampling and to outline the drainage areas contributing to each outfall. The screening analyses at the outfalls include several visual measures (color, turbidity, oil sheens, floatables, etc.) along with measurements for fluorides and surfactants. Fluorides indicate if the water originated as treated domestic water (instead of infiltrating untreated groundwater). This may indicate sanitary sewage non-stormwater discharges or other waste waters. Surfactants can help in identifying sanitary sewage connections, in contrast to landscaping irrigation runoff or rinse waters, or industrial waters. The drainage area maps need to be studied to determine the presence of potential industrial or commercial cross-connection sources.

More sophisticated analyses are available to confirm the potential sources, but they most likely cannot be employed for all outfall samples because of the required highly skilled analysts and expensive equipment.

Future project phases will evaluate these outfall procedures in test conditions and will result in refinements to the manual of practice. Procedures to identify and correct specific non-stormwater discharges will also be summarized in these future project phases.

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