Storm Water Sampling Guidance for Total Phosphorus & *E. coli*

November 24, 2009

Introduction

National Pollutant Discharge Elimination System (NPDES), Municipal Separate Storm Sewer System (MS4) permits require regulated public entities located within urbanized areas that discharge storm water from an MS4 to a water body designated with a Total Maximum Daily Load (TMDL) to demonstrate progress toward meeting Water Quality Standards (WQS). If the TMDL was written for *E. coli* or Total Phosphorus (TP), the MS4 permits further require permittees to collect representative samples of storm water discharges from their regulated MS4s to those water bodies.

What is a TMDL?

When a lake or stream does not meet WQS, the Federal Clean Water Act requires that a TMDL be developed. Studies shall be completed to determine what is impacting the water body and to develop goals so the water body can meet the standards.

A TMDL describes the process used to determine how much of a pollutant a lake or stream can assimilate and sets pollutant reduction targets for that water body.

Specifically, the MS4 permits state:

"Within three years of COC issuance, the permittee shall take at least one representative sample of a storm water discharge from at least 50 percent of the major discharge points discharging directly to surface waters of the state within the portion of the TMDL watershed in the urbanized area. A major discharge point is a pipe or open conveyance measuring 36 inches or more at its widest cross section. At a minimum, the sample shall be analyzed for (*E. coli* or Total Phosphorus).

The permittee shall use these results and other available information, which may include results from a well-designed ambient monitoring program, to develop and prioritize actions to reduce the discharge of (*E. coli* or Total Phosphorus) to be consistent with the TMDL. These prioritized actions shall be reported to the Department in the second progress report, with implementation targeted during the five-year permit cycle that begins in 2013."

This guidance document details the essential elements of a wet weather monitoring study design which will provide an accurate representation of the storm water discharge from the MS4 to address TMDL concerns and meet permit requirements. The guidance consists of two parts detailing different strategies for conducting a wet weather monitoring program. Part One of this guidance walks MS4 permittees through a comprehensive study design that involves multiple sampling over a variety of storm events and is focused on getting the best quality data to define representative wet weather discharges. Part Two provides a basic study design for sampling a single storm event as required by the MS4 permits.

Because storm water discharge quality may vary widely, a monitoring plan aimed at defining a 'representative sample' needs to encompass the normal range of conditions with the expectation that those storms are generating the normal range of runoff conditions. A representative sample, as considered in this document, is a suite of samples assumed to characterize discharge quality over a range of seasons, storm size, and storm duration (see Selection of a Storm Event for Monitoring for additional discussion).

Without knowing the normal range of storm water discharge quality under a variety of conditions, permittees who opt for the single-sample monitoring plan run a significant risk of generating data that fails to capture the realistic range of variability of the parameters of concern in the discharge, and is therefore unlikely to be truly representative. The permittee will then be left with unreliable data upon which future decisions and actions will be based. Additionally, it should be recognized that if single sample monitoring is conducted (Part Two), any subsequent questions or doubt with regard to data reliability for *any* portion of the data should be viewed as doubt for *all* data collected.

A detailed study design carefully considers sample site location, sample collection numbers, collection methods, quality control procedures, and data interpretation ensuring the success of a wet weather monitoring program. While more time consuming and costly up front, investing in a comprehensive monitoring plan, as described in Part One, will result in a more accurate, representative, and confident characterization of the storm water discharge, upon which future decisions can be based. The monitoring results will help permittees make sound storm water management and land use decisions and prioritize potentially expensive and intensive actions necessary to make progress towards meeting WQS in TMDL areas.

It is recognized that the Part One guidance often recommends actions that are scientifically sound, but in practicality may be difficult to achieve in some instances. It will be up to the individual communities using the Part One guidance to understand the goals of their monitoring strategy and make all practical efforts to gather the highest quality data that they reasonably can. The Department is available for input or review if there is a need to scale back monitoring from the guidance goals laid out in Part One.

The Role of this Guidance

These recommendations should be viewed as an 'ideal', to guide the development of a high-quality monitoring plan. This guidance may present logistic and budgetary challenges if fully implemented.

It is recognized that a final monitoring program will have to balance the need for accurate and representative data with available resources, and that reduced efforts may be necessary.

Michigan has two NPDES permitting options for discharges from MS4s: the Watershed Permit (MIG610000) and the Jurisdictional Permit (MIS049000). Both permits allow an alternative approach to address the TMDL requirement. Under the alternative approach option, an existing monitoring plan, with prioritization and pollutant controls, can be submitted to the Department for approval.

In addition, the Watershed Permit also allows an "Elective Option" (Part I.A.4.b.1)c)). The Elective Option requires a collaborative effort with other

watershed partners to implement a monitoring program based on minimum design elements which are defined in the permit. The Department recommends that permittees who opt to pursue the Elective Option use Part One of this document to develop the collaborative monitoring program. More information on the alternative approach and elective option can be discussed further with Department District staff on a case by case basis.

Keep in mind, the Department is available for consultation and input on monitoring plans as needed.

Finally, this document was not developed for Illicit Discharge Elimination Programs (IDEP), which require dry-weather screening. There are considerable guidance documents already available for such activities. However, that does not mean these two program components are not interconnected. Therefore, the Department recommends that, where feasible, both the wet and dry weather monitoring programs work together to effectively reduce the discharge of pollutants from MS4s to waters of the state.

Goals and Challenges of a Wet Weather Monitoring Program

The primary goal of monitoring is to quantify pollutants in wet weather discharges to waters of the state with approved TMDLs. The data are used to understand which discharge points, and their associated catchments (area drained), are most likely to contribute the pollutants of concern within the TMDL watershed. After the initial study, additional monitoring upstream may be necessary to further identify sources, or there may be enough information to effectively develop and prioritize actions to reduce the pollutants of concern.

Monitoring storm water discharges presents many challenges:

- Rain events, and timing and volume of runoff, are highly variable.
- Pollutant concentrations can be highly variable, so a number of samples (and therefore chemical analyses) are required to characterize storm water quality
- Runoff events often occur at inconvenient times (e.g. Sunday at 2:00am).
- Runoff events are difficult to predict, resulting in “false alarms” for monitoring staff.
- Sample collection can be physically difficult, depending on the situation.

Despite the challenges, a well-designed monitoring program can be invaluable for achieving goals, such as:

- Identifying the source(s) of pollutant loads to streams and lakes.
- Assisting in the selection and design of storm water best management practices (BMPs).
- Assessing the effectiveness of storm water treatment practices.

Part One

This section describes recommendations for conducting a comprehensive assessment of storm water quality including the collection of multiple wet-weather samples from individual MS4 storm water discharge points. The recommendations are in operational order and are intended to be executed in

that order. Additional information on storm water sampling can be found in Law *et al*. (2008), especially under *Design 1 – Quality of Storm water at the Outfall*.

1. Selection of Discharge Points

The selection of discharge points for sample collection is a multi-step process that involves desktop analysis and site visits. Utilization of land use maps, topographic maps, watershed plans, high resolution aerial photographs, and storm water sewer system maps -- aided by GIS -- can greatly reduce the amount of field work necessary for the site selection process. Locations may also be prioritized based on existing ambient monitoring data or on information gathered as a result of illicit discharge investigations. An ambient monitoring program aimed at systematically sampling relevant portions of the TMDL watershed or upstream drainages may help to inform and focus discharge point monitoring. Reaches or tributaries for which ambient data has demonstrated elevated levels of the parameter of concern can be given a higher prioritization when developing a monitoring program for MS4 wet-weather discharges.

A. **Determine scope of the monitoring area.** Certificates of Coverage (COC), issued under the General MS4 Permits, will identify the specific TMDL(s) the permittee shall address. At a minimum, the monitoring area shall include the TMDL reach and contributing watershed within the urbanized area. However, any sections of the TMDL reach and contributing watershed outside the urbanized area should also be included in a comprehensive monitoring plan.

> Information on a specific TMDL can be found at: www.michigan.gov/deq. Click on the 'Water' tab, then 'Water Quality Monitoring', then 'Assessment of Michigan Waters', then 'Total Maximum Daily Loads

B. **Locate the MS4 discharge points that discharge to the monitoring area.** To identify all discharge points, regardless of size, it is recommended that storm sewer system maps and as-built drawings of storm water infrastructure be reviewed, interviews with public works personnel and facility staff be conducted, and field inspections be performed. In some instances, the identified TMDL reach may also be a MS4. This can occur when the TMDL reach, a surface water of the state, is also a designated county drain (a MS4). In these cases, the County agencies should identify their MS4s which discharge into the TMDL reach, even if that reach is also considered their MS4. A surface water of the state includes the Great Lakes and their connecting waters, all inland lakes, rivers, streams, and wetlands.

> **What is a Discharge Point?**
> The MS4 permits define a discharge point as any location on the MS4 owned or operated by the permittee that discharges directly to a surface water of the state, or that discharges to any other separate storm sewer system before discharging to a surface water of the state.

C. **Determine catchment characteristics of the identified discharge points**. Characteristics to identify include (in part from Law, 2008):

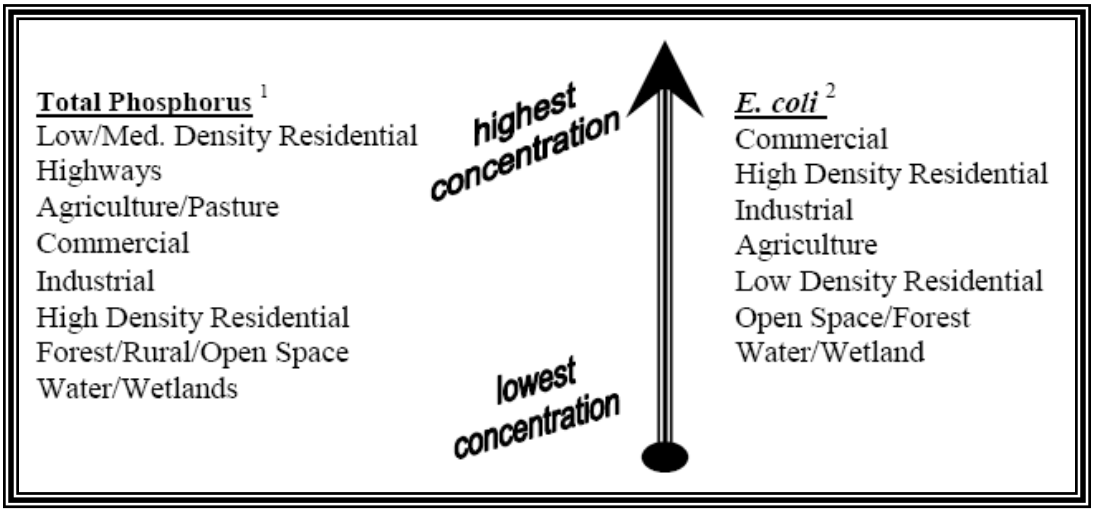
- Catchment size and boundaries
- Predominate land use type and distribution across catchment
- Land cover distribution (e.g. percent impervious cover, forest, wetland)
- Type of conveyance (open or enclosed channel; curbs and gutters or swales)
- Development characteristics (e.g. age, traditional versus low impact)
- Presence and type of storm water treatment practices
- Discharge point cross-section
- Age and maintenance of BMPs

D. **Develop a prioritized list of catchments to target for monitoring**. The following criteria should be considered:

- Catchments with higher potential to generate pollutants of concern based on land use. Figure 1 shows a ranking of urban land uses with regard to potential TP or *E. coli* discharge concentrations[1, 2].
- Age of development (older areas have a higher potential for illicit discharges) and age/maintenance of BMPs.
- Previous Illicit Discharge Elimination Program (IDEP) data.
- Specific local information. For example, golf courses may discharge high phosphorus while areas with known failing septic systems may contribute *E. coli*.
- Site conditions that may affect sampling include adequate safe access for sampling and housing equipment with a minimum potential for vandalism.
- Discharge points that are in close proximity to each other for sampling efficiency.

Ultimately, the prioritized list should be based upon the likelihood of the land use, or catchment, to contribute the pollutant of concern and its dominance in the monitoring area.

Figure 1. Ranking of urban land use potential to discharge TP and *E. coli*.



1. TP from research by the Rouge River National Wet Weather Demonstration Project, Technical Memorandum RPO MOD TM34.00.
2. *E. coli* from Purdue University's L-THIA Basic Model for relative fecal coliform loadings based on land use; cobweb.ecn.purdue.edu/runoff.

E. **Determine the number of discharge points to be sampled.** Since the number of discharge points can vary from less than 10 to hundreds, it is not practical to recommend a specific number to sample. The sample size of discharge points should be sufficient to understand storm water characteristics from all potential sources to the TMDL reach.

General recommendations for choosing sample sizes and their distribution include:

- The permit requires sampling a minimum of 50% of major discharge points (≥ 36"). It is recommended that smaller discharge points also be sampled, particularly if they drain land uses thought to be major pollutant sources.
- Sampled discharge points should represent catchments in which one land use predominates (ideally > 80%). If the jurisdiction covered by the permit is large, and contains multiple catchments with similar land uses, sample several discharge points for each major land use type. If such homogenous catchments can be identified, data from a subset of them can be extrapolated to other, similar catchments.
- Stratified random sampling can be used to select sampling sites, as described in the following steps:

1. Divide the jurisdiction into catchments with distinct dominant land uses (the 'strata'; first column in Table 1).
2. Number each discharge point in each strata (second column).
3. Select enough random numbers (in Excel or other random number generator) for <u>each</u> land use strata to identify the desired number of discharge points to be sampled (third column). The number of random numbers (= samples) selected for each strata should be proportional to the number of discharge points in each strata compared to the total number of discharge points; e.g., if 30% of the total discharge points occur in Industrial catchments, approximately 30% of the samples should be allocated to the Industrial catchments.

Table 1. Example of Using a Stratified Random Design to Select Sampling Sites.

Catchment & Land Use	Discharge Points	Randomly Generated Numbers for Each Land Use (= Discharge Points to be Sampled)
High Density Residential #1	HDR 1 HDR 2 HDR 3 HDR 4	2, 3, 6, 7 (So sample HDR 2, HDR 3, HDR 6, & HDR 7)
High Density Residential #2	HDR 5 HDR 6 HDR 7	
Commercial	C 1 C 2 C 3	2 (So sample C2)
Industrial #1	IND 1 IND 2 IND 3 IND 4	1, 3, 4, 8 (So sample IND 1, IND 3, IND 4, & IND 8)
Industrial #2	IND 5 IND 6 IND 7 IND 8	
	Total = 18 (50% = 9)	Number of discharge points sampled = 9

See Gilbert (1987) for additional details on stratified random sampling.

F. **Determine the sample collection technique.** The sample will be from the storm water, at or before the discharge point, not ambient waters after the discharge mixes with the water body. Storm water samples can be collected by either automated sampling or manual sampling. Automated sampling, in which samples are collected using programmable automated samplers ("auto-samplers"), is preferred for most monitoring programs, especially in larger catchments. There are several options for collecting samples with auto-samplers (NRC, 2008); however, flow-weighted composite sampling is the recommended method for storm water. Flow-weighted composite sampling yields a single sample for analysis, whose concentration is the Event Mean Concentration (EMC).

Manual "grab" sampling, in which samples are collected by filling sample bottles by hand, is usually not recommended for storm water sampling for logistical reasons; the necessary sampling frequency (see below) is very labor-intensive and limits the number of stations that can be sampled, and the increased number of samples greatly increases analytical costs. However, manual sampling may be necessary for certain pollutants which cannot be collected using automated samplers due to cross-contamination concerns; these include bacteria, oil and grease, and volatile organic compounds. Manual sampling across the hydrograph is also the only way to assess pollutant discharge dynamics (e.g., first flush vs. peak flow discharges), and if this is a goal of the sampling program, a

flow-weighted EMC can be calculated from manual sample data. If manual sampling must be performed, the following is recommended:

- Record the water level at each station during each sampling period.
- Collect at least 6 samples at each station during a rain event; 2 or more during the beginning of the storm, 2 or more near peak flow, and 2 or more after peak flow. Since hydrograph timing cannot be known during runoff, it is often necessary to collect additional samples that are discarded after runoff is complete.
- Pollutant concentrations are sometimes highest at the beginning of runoff (first flush). This is often true for small catchment areas of less then 400 acres and especially in smaller, paved areas (Law et. al., 2008) as well as for commercial and industrial land uses (NRC, 2008), but not so in larger catchments where the highest pollutant loads are normally observed during peak flow. If first flush data are desired, collect samples within the first 30 minutes to 1 hour of the start of runoff.

Like samples collected by auto-samplers, grab samples can be analyzed individually (the most appropriate method for *E. coli*) or combined to create a flow-weighted composite (appropriate for TP and other constituents). Additional information on automatic and grab sampling or flow and precipitation monitoring can be found in the California Department of Transportation guidance manual (2000).

It should be noted that if submerged discharge points are to be sampled, it may be necessary to use the nearest up-pipe manhole access, provided there are no concerns for additional pollutant input between that point and the discharge point.

G. **Determine the sampling period duration.** Given the variability of all storms, data from a single runoff event are of very limited use. For many study purposes it is desirable to sample at least 5 to 10 runoff events of varying intensities and durations, spread over the seasons, which can equate to at least 1 or 2 years of sampling effort. In addition, some pollutants exhibit roughly predictable season patterns (e.g., chloride inputs in the late spring, or coliform bacteria during the summer and fall), which should be accounted for.

> <u>It cannot be stressed enough:</u>
> Regardless of the sampling program, it is essential that monitoring be conducted by competent personnel who understand safety issues, environmental sampling, and will ensure data collected are reliable, and of acceptable quality.

2. **Other Data Needs**

Rainfall and Flow. To determine the minimum amount of rain that will cause a runoff event, and therefore what minimum storm event can be sampled, it is recommended that historical precipitation records be reviewed early in the process to provide a basis upon which to establish targets for sampling.

Monitoring rainfall amounts can be accomplished a number of ways ranging from establishing a network of inexpensive graduated “direct reading” rain gauges throughout the MS4 watershed that can be maintained by competent volunteers to establishing self-recording electronic “tipping bucket” rain gauges that enable computerized uploads. Permittees should be mindful that

there may already be established gauges that can be used throughout a watershed at schools, colleges/universities, news station weather departments, and citizen-based weather station networks, among others. Regardless of the approach used, it is important that information be collected on a scale fine enough to have some confidence in the amount of rainfall that fell in a discharge point's catchment.

Rain gauges should be as close to the sampled catchments as possible, and in larger monitoring areas multiple rain gauges may be necessary. For a small watershed, a recording gauge would be best. But, if the sampling points are dispersed and resources are limited, at least three manual rain gauges should be used (National Research Council, 2008). Ideally, several locations throughout the sampling area should be used and compared to a recording gauge.

Flow should also be measured or estimated at each water sampling location. Similar to water sample collection, flow monitoring can be performed manually or with automated equipment. The lack of flow data can greatly hinder the resulting assessment and interpretation of the sampling information collected (National Research Council, 2008).

3. Selection of a Storm Event for Monitoring

The goal of representative monitoring is to establish an understanding of storm water quality under a typical range of wet-weather conditions. Consequently, some guidelines should be used to define when sampling crews prepare and when sampling should begin. While this guidance attempts to define conditions under which MS4 discharge points are likely to discharge, there will be times when permittees have a better understanding of local conditions and how their systems respond to rain.

As a general guide, sampling should only occur following a dry period of 72 hours or more. Additionally, it is recommended that a storm of 0.25 inches or more within a 24-hour period be used as a minimum for sampling. A range of storm events (size and duration) will help establish the expected discharge quality, with the focus on the typical range of storms seen annually. Unusually heavy or severe storms similar to a 100-year 24-hour event may not be sampled at all and very common small rain events (e.g. < ½ inch) should not be over-represented in a sampling plan with the goal of understanding discharge quality over a range of conditions. .

Ideally, if local rainfall is, or can be, divided into categories that represent rain depth, rain intensity, seasons, and/or dry periods, the use of stratified random sampling of storm events is recommended. A sufficient number of representative storm events under each of those categories need to be sampled.

If possible, an open line of communication or collaborative agreement should be established with local weather monitoring source to aid in forecasting incoming storms and screening them for potential monitoring events. A reliable source of storm tracking and forecasting will help reduce the number of 'false starts' for monitoring crews when a storm doesn't fully form or doesn't produce enough rain to generate a discharge event.

In *Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Storm water Monitoring Studies Using Six Example Study Designs*

(Law, 2008) it is mentioned that at least two years of monitoring is needed to get about 20 to 30 representative wet weather events. In addition, it was noted that samples from about half of the storm events have the potential of being discarded due to unexpected conditions and sampling errors.

4. Analytical Methods

Analysis of all samples should be conducted by well-trained, competent staff in a laboratory with rigorous quality assurance and quality control procedures. In some communities, the local publicly owned wastewater treatment facility may have such a laboratory that is able to analyze samples at a reduced cost.

A. **Total Phosphorus (TP):** The recommended method for measuring TP is EPA Method 365.4 – Automated Colorimetric Block Digester method. A copy of this method is available at: www.epa.gov/waterscience/**methods**/**method**/files/365_4.pdf.
Alternate methods that achieve the same detection limit and range of 0.01 to 20 milligrams per liter (mg/L) are also acceptable. Test kits for TP should not be used, as their detection limit (~ 1 mg/L) is too high.

i. **Quantification Limit for Total Phosphorus**. The analytical method for TP cited above has several variations, some of which have different quantification limits (the lowest concentration of phosphorus that can be reliably quantified). A quantification limit of 0.01 mg/L – equivalent to 10 micrograms/liter (µg/L) -- is most suitable for identifying elevated phosphorus in storm water. Not all analytical laboratories achieve this quantification limit. Therefore, this needs to be confirmed when choosing a laboratory. Higher quantification limits (20-50 µg/L) may be acceptable depending on study objectives.

B. ***E. coli:*** Two methods are recommended for measuring *E. coli*:

i. **EPA Method 1103.1** -- Membrane filtration using mTEC agar -- is available from: http://www.epa.gov/waterscience/methods/method/biological/

ii. **The Colilert procedure** is available on the IDEXX web site: http://www.idexx.com/water/colilert/moreinfo.jsp

The pros and cons of the *E. coli* analyses include:

i. EPA Method 1103.1:
- More expensive, and requires a more highly trained operator
- More accurate for highly contaminated samples
- Yields fewer “too numerous to count” results

ii. Colilert:
- Cheaper, and can be performed by less experienced personnel
- More accurate for less contaminated samples
- Maximum value = 2,400 colonies/100 mL, unless sample is diluted

5. Quality Control Procedures

Preparation of a Quality Assurance Project Plan (QAPP) is always a good idea prior to sample collection, and may be required depending on the monitoring program funding source. A QAPP provides a detailed framework for deciding how data will be collected to achieve specific objectives, and describes the procedures that will be implemented to obtain data of known and adequate quality. EPA provides guidance on preparing QAPPs, which is available at http://www.epa.gov/QUALITY/qapps.html

Several important aspects of sampling quality assurance are outlined below.

A. **Sample preservation and hold times.**

i. ***E. coli*** samples should be immediately placed on ice. The hold time for *E. coli* – from the time the sample is collected until the start of analysis -- is 6 hours. This can be significantly limiting. Samples shall be delivered to the laboratory within this 6 hour window for the subsequent data to be useful.

ii. **Phosphorus** samples are preserved in the field with sulfuric acid, to a pH of 2, and placed on ice. Preserved samples shall be refrigerated at 4 °C in the lab, for no more than 28 days prior to analysis.

B. **Duplicates and blank samples.** Precision and accuracy of sampling are accounted for partly through sampling of duplicates and blanks.

i. **Duplicate samples** are simply a second sample collected as close in space and time to the initial sample as possible. Field duplicates can be collected by holding two bottles in the discharge stream simultaneously, or by filling the two bottles within a few seconds of each other. Typically a duplicate is collected for every 20th sample.

a. The precision target for TP duplicates is a relative percent difference (RPD) between the two values of ≤ 20 percent. RPD is calculated as follows:

[(difference of the two values)/(mean of the two values)] x 100%

b. The precision target for *E. coli* duplicates is calculated differently, and the latest edition of *Standard Methods for the Examination of Water and Wastewater* should be consulted for details.

ii. **Blank samples** do not have to be collected if the discharge samples are collected directly into the bottle that will be submitted to the lab. If the sampled discharge is collected with a sampling device in one bottle and then poured into another bottle, it is necessary to collect a field blank to check for cross-contamination, and to decontaminate the sampling device between samples. Decontamination procedures are:

a. Total phosphorus: Rinse the sampling device 3 times with distilled water before collecting a sample at a new station.
b. *E coli*: Rinse the sampling device with a 10% bleach solution, followed by 2 rinses with distilled water, followed by 2 rinses with "station water" (the water to be sampled next).

A blank for TP is generated by rinsing the sampler four times with distilled water and collecting the fourth rinse in a sample bottle for analysis. A blank for *E. coli* is generated by rinsing the sampler three times with distilled water and collecting the third rinse for analysis. If a blank is desired for sample bottles used to directly draw samples, rather than collecting in a sampling device first, distilled water is used as the blank.

The optimal precision targets for blanks is a value less than the method detection limit for TP (usually 0.01 mg/L), and less than 10 colony forming units per 100 mL for *E. coli*. Higher values may be acceptable if they are lower than the lowest value of the set of environmental samples. Blanks should be collected at the same frequency as duplicates; one for every 20 samples.

Hold times for duplicates and blanks are the same as for regular samples.

6. Data Interpretation and Format

A. **Interpretation.** The summarization, comparison, and interpretation of the data collected through discharge point monitoring shall be done mindful of the applicable TMDL and associated goals. Data for each discharge point should be analyzed to understand the central tendency of the storm water quality for concentration and load. If permittees are not familiar with descriptive statistical analysis and programs to conduct them, they should seek out assistance to analyze their data. Because the monitoring and characterization of MS4 discharge points is ultimately focused on informing the prioritization of activity, any data analysis should be aimed at summarizing individual discharge point data so that all discharge points can subsequently be ranked and addressed as appropriate to meet TMDL goals.

Individual storm event data are most useful in the context of a larger data set for a particular discharge point. The larger data set is used to demonstrate the quality of the storm water over a range of storm conditions at the particular discharge point. Data for each discharge point should be summarized over all storm events to understand the median, mean, standard deviation of concentration and/or load. Box and whisker plots of the data, grouped by discharge point, can be helpful in graphically representing storm water quality and ranking discharge points so that priorities for future actions to address TMDL goals can be established. Standard deviation information will help clarify the discharge points with the most confident data characterizations, while those with broad deviations may indicate discharge points that need additional monitoring.

For those unfamiliar with summary statistics, such as those previously mentioned, Chapter 7 of Storm water Effects Handbook (Burton and Pitt, 2001) provides an overview of basic statistical analyses relevant to storm water data and some software options available for conducting such analyses.

B. Data Storage/Submittal Format. All data shall be submitted to the Department Water Bureau (WB) with the second progress report. Data

should be organized and electronically stored in such a way the information may be easily transferred to the Department or other end user interested in storm water data. In keeping with the format and information used by the National Stormwater Quality Database (NSQD), a spreadsheet template similar to that in Table 2 will be useful for submittal of the data, if required. The example provided in Table 2 is not exhaustive, but provides the needed data for incorporation into the NSQD.

C. Comparing Data to TMDL Goals. While it is not possible to address all future scenarios of TMDL goals, the following offers a general approach that may be useful for a majority of situations.

i. ***E. coli* TMDL.** Typically the numeric targets for an *E. coli* TMDL involve meeting the *E. coli* water quality standards found in the Part 4 Rules that correspond to attainment of the relevant designated uses. That target is 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to attain the Total Body Contact designated use from May 1 through October 31, and 1000 *E. coli* per 100 ml as a daily maximum year-round to attain the Partial Body Contact designated use. Keep in mind, these targets are in-stream *E. coli* concentrations.

Based on this, data should be summarized to allow for comparison of *E. coli* concentrations for individual storms, and range of storms, in order to understand where concentrations exceed the target, where the exceedance is consistent, and the degree of exceedance. Load estimations can be used to prioritize locations with consistent and proportionally larger inputs. For example, if *E. coli* data from two discharge points consistently show exceedance of the target, but one discharge point is several times larger in volume than the other, the larger could become a higher priority for remediation.

ii. **Total Phosphorus TMDL.** Primary numeric TMDL targets for TP may focus on either concentration and/or load and so the comparison of discharge data may need to be done for one or both measurements. Similar to *E. coli* prioritization, ranking discharge points by mean TP concentration can be a first step, followed by comparison of loads to identify those discharge points with disproportionally large loads and higher concentrations. Because data will have to be analyzed and compared to TMDL-specific goals, the Department can assist in identifying a reasonable approach for evaluating results.

D. Pollutant Source Tracking. The sampling recommendations described above provide information on the concentration and quantity of pollutants entering a stream during wet weather events, but do not provide much information on the source of the pollutants. Identifying pollutant sources can be time-consuming and expensive, but one relatively simple approach is to sample upstream (within the storm water system) of a discharge point known to be a significant pollutant source. In storm water systems this often entails collecting samples from the downstream end of junctions that isolate branches of the system draining discrete neighborhoods, industries, etc.

Table 2. Example spreadsheet format for data recording, storage, and transmittal.

Unique Discharge Point Identifier	Date	Long (dd)	Lat (dd)	% impervious	Drainage Area	Rainfall Amount	Type of Sample[1]	Flow Volume	Parameter Data (TP &/or *E. coli*)

1. First flush, flow weighted, grab, composite

Part Two

This section provides guidance for a single wet weather event sample collection to meet the very minimum MS4 permit requirements.

A representative sample is assumed to characterize discharge quality over a range of seasons, storm size, and storm duration. Without knowing the normal range of storm water discharge quality under a variety of conditions, permittees who opt for the single-sample monitoring plan run a significant risk of generating data that fails to capture the realistic range of variability of the parameters of concern in the discharge, and is therefore unlikely to be truly representative. The permittee will then be left with unreliable data upon which future decisions and actions will be based.

> "At least one representative sample of a storm water discharge shall be taken from at least 50 percent of the major discharge points discharging directly to surface waters of the state within the portion of the TMDL watershed in the urbanized area."

1. **Selection of Major Discharge Points** (Refer to Part One, Section 1 for more details)

   A. For this requirement, a major discharge point is defined in the MS4 permits as a pipe or open conveyance measuring 36 inches or more at its widest cross section that discharges to surface waters of the state.

   B. The sample will be from the storm water, at or before the discharge point, not ambient waters after the discharge mixes with the water body.

   C. The Department recommends permittees prioritize sample locations and timing specific to the TMDL. Emphasis should be on sampling discharge points draining areas with the highest concentration of *E. coli* and/or TP and capturing first flush of TP. Keep in mind, some permittees have both TMDLs. See Part 1, Figure 1, for a ranking of urban land uses with regard to potential *E. coli* and TP discharge concentrations.

   D. The focus area is within, or contributing to, the listed TMDL reach. The municipality's jurisdiction may include land and discharge points upstream of this area. In this case, sampling of discharge points upstream of the TMDL reach should be included, thereby providing valuable information on water quality influences. Upstream sampling is often vital in identifying and addressing pollutant sources and a thorough sampling plan should incorporate this concept by considering discharges upstream of the TMDL reach when identifying and prioritizing the discharge points to be sampled.

> Information on specific TMDL reaches can be found at: www.michigan.gov/deq. Click on the 'Water' tab, then 'Water Quality Monitoring', then 'Assessment of Michigan Waters', then 'Total Maximum Daily Loads (TMDLs)'.

2. **Sample Event Timing** (Refer to Part I Section 3 for more details)

> TMDL related storm water sampling shall be completed within three years of COC issuance.

   A. Because of the difficulties with cold-weather sampling, the Department

recommends samples be collected between May 1 and October 31.

B. Sampling wet weather should occur only after it has been dry for at least 72 hours.

C. Very small storm events may not generate significant runoff. Therefore, wait until there has been at least ¼ inch of rain within a 24 hour period. The simplest way to measure rain is with an accurate rain gauge placed in an obvious area, such as at the office of the individual in charge of the sampling.

   There will be times when a suitable event has been forecast, causing monitoring efforts to begin, only to have to cancel due to insufficient precipitation.

D. Sampling should be conducted as soon as possible following the start of discharge from targeted discharge points to capture a sample of the 'first flush'. First flush is defined as the runoff discharge at the beginning of a storm event and is assumed to consist of a significant amount of pollutants.

E. Synchronized sampling should be done as often as possible. Synchronized sampling is when several discharge points are sampled at or near the same time. If enough trained staff are available, all sites should be sampled during the same time period.

> Regardless of the sampling program, it is essential that monitoring be conducted by competent personnel who understand safety issues, environmental sampling, and will ensure data collected are sufficient, reliable, and of acceptable quality.

3. Analytical Data (Refer to Part I Section 4 and 5 for more details)

A. Develop and follow Quality Assurance and Quality Control procedures to ensure samples are collected, preserved, and analyzed properly.

B. Estimate and record the flow of the discharge at the time of sampling.

C. Collect *E. coli* or Total Phosphorus as single grab samples. Three samples are not needed for *E. coli* because mixing in the discharge is assumed.

D. Samples shall be analyzed for the TMDL pollutant, *E. coli*, Total Phosphorus, or both by a reputable laboratory that uses EPA approved methods as discussed further in Part One.

E. All data shall be submitted to the Department's Water Bureau (WB) with the second progress report. Data should be submitted in the electronic format provided by the WB.

> Don't forget, *E. coli* shall be delivered to the laboratory within 6 hours of collection.

References

1. Burton, G. A. Jr. and Pitt, R. 2001. Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers. Lewis Publishers, New York, NY. 911 pp.

2. California Department of Transportation. 2000. *Guidance Manual: Stormwater Monitoring Protocols*. Second Edition. 303 pp. Available at: www.nap.edu/catalog.php?record_id=12465

3. Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York, NY. 320 pp.

4. Law, Neely L; Fraley-McNeal, Lisa; Cappiella, Karen; Pitt, Robert. 2008 *Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs*. Center for Watershed Protection Ellicott City, MD. Available at www.cwp.org.

5. National Research Council, 2008 *Urban Stormwater Management in the United States*. The National Academies Press, Washington, D.C.

6. United States Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA-Office of Water. EPA 841-B-97-003.

Appendix A

Training and Safety Considerations

Sampling can be hazardous, especially if there are high flows, considerable vegetation, deep pools, or soft sediments. However, most hazards can be avoided by the use of automated samplers, careful site selection and timing, as well as proper training. Therefore, it is important that sampling and safety training be instituted right away.

1. **Safety recommendations:**

    1. Always sample in pairs
    2. Carry 2-way radios or cell phones
    3. Have personal information on you that includes:
        - Emergency contact information
        - Identification
        - Medical alerts
    4. Try to collect all samples from land, especially if during heavy rains.
    5. If you must enter the water, do so cautiously and be prepared to make a quick exit
    6. Never enter a stream where footing is unstable
    7. Never enter a stream where the water is too deep (about 2 feet)
    8. Never enter a stream where the water is too fast (more than 2.5 ft/sec)
    9. Use common sense

2. **Safety Equipment.** Much of the equipment you will need is probably already in your possession or easily bought. The following is a list of items needed for all monitoring:

    1. Boots or waders
    2. Walking stick of known length for balance, probing, and measuring
    3. Long sleeves and pants that are thorn-resistant
    4. Protective gloves
    5. Insect repellent
    6. Sunscreen and hat
    7. Flashlight and extra batteries
    8. Whistle in case of an emergency
    9. Drinking water and snack
    10. Information with location and numbers to call in case of emergency
    11. First aid kit
    12. Rope
    13. Dog/animal repellant
    14. Weather radio (if necessary)
    15. Life jacket (if necessary)
    16. Hand sanitizer or wipes

3. **Monitoring Equipment.** Different equipment for specific chemical and biological monitoring should be reviewed before going into the field. Further information on equipment can be found in the USEPA Volunteer Stream Monitoring: A Methods Manual. Each chapter has a list of equipment needed for specific samples. For all monitoring, the following items should be included:
    1. Camera, Pencil, and field notebook
    2. Measuring tape
    3. Sampling pole
    4. Cooler and ice