Session 8: Basic Water Quality Monitoring Techniques for TMDLs

In This Training Session

Acronyms

ADCP– Acoustic Doppler Current Profiler
DNR – Department of Natural Resources
FWMC – Flow Weighted Mean Concentration
TMDL – Total Maximum Daily Load
USGS – United States Geological Survey

Introduction

With a monitoring plan in hand, you may now be ready to head into the field to gather new data. This module will familiarize the reader with basic water quality data collection techniques and equipment, and describe how newly gathered data can be brought together to provide useful information for a TMDL study.

The module will explain in general terms:

- why new water quality data may be needed for a TMDL study
- what new data may be needed
- when water quality samples should be collected
- where water quality samples should be collected
- how samples are collected and with what kinds of equipment

Why Monitor?

Very simply, monitoring and data collection will allow you to fill the data gaps you have previously identified as a result of the Data Inventory.

By collecting new data, you may be better able to answer critical questions regarding the severity of the impairment, the conditions under which the impairment occurs and the relative contributions that point and nonpoint sources make to the overall pollutant load to the waterbody.

Good data is the foundation of any TMDL study. Without good quality data, your judgments about the causes and sources of pollution may, in reality, be nothing more than a hunch. Poor quality or inadequate data could lead your team to make erroneous conclusions and spend time and resources trying to address the wrong pollution problems and sources.

If monitoring is done well and with adequate forethought, you can sometimes accomplish more than one data collection goal at a time. In the end, this could save considerable staff time and resources.

Your monitoring plan should allow you to answer the following series of questions. Check your work against the questions and information presented below to ensure that all important issues have been considered.

What Do You Monitor?

"What" to monitor will depend on the goals and objectives you have developed for your data collection effort. **For purposes of this training module, we will assume the need to estimate existing pollutant loads in a waterbody.** Note that this module will present a basic overview of methods used to estimate loads. Actual methods that might be employed in a TMDL study might be more complex and are beyond the scope of this module.

As an example, the following data collection goal and objectives have been developed:

Sample Data Collection Goal:

Determine existing pollutant loads

Sample Data Collection Objectives:

(1) Collect 25+ samples (including high and low flows) at appropriate time periods
(2) Conduct accurate stage tracking within 7/100ths of a foot
(3) Develop a well-defined, up-to-date rating curve
(4) Use a certified laboratory when analyzing all samples

When Do You Monitor?

Since our data collection goal involves determining existing pollutant loads to the waterbody, we will need to characterize pollutant concentrations based on flow and time.

As we determine exactly when to collect water quality samples, we must be certain to consider the following:

- When monitoring to determine pollutant load, sampling activities must take place during event flows, such as snow melt and rain runoff in the pre-canopy season (March/April through part of June) to obtain samples representative of flow conditions and volume.
- To characterize the range of pollutant concentrations present in a stream, pollutant concentrations, samples must be collected across the spectrum of flows (base flow, event flows, and in between) and seasons. To get more detail, ensure samples are gathered on the rising limb and falling limb of the hydrograph.
- Timing and frequency of sampling will depend on size of the stream/river and the length of its hydrograph. For example, a small stream has a typical event hydrograph that lasts one day; whereas, the Minnesota River event hydrograph lasts several weeks.
- Whenever possible, watershed studies should include more than one year of monitoring data so that the effect of climatic variations on water quality can be observed. Time and resources constraints, however, may not always make that feasible.

Where Do You Monitor?

Where to monitor will again depend on the goals and objectives you have developed for your project; however, in general:

- Select “representative” sites – possibly based on drainage area, stream type, land use, etc.
- Monitor near the mouth of the watershed when determining pollutant loads.
- Conduct a longitudinal study and/or “network” study of tributaries when characterizing streams.
- Select representative sites so that they have a well- mixed water column, and no direct inputs to the receiving water (pipe outfalls, ditch outlets, etc.) that could bias results.
- Select sites that are safe (no traffic, steep banks, etc.).
- Choose a site with a stable cross-section for flow gauging studies by avoiding areas affected by vegetation, shifting sediment beds, etc.
- Contact the local Minnesota Department of Transportation, the city, county, and township to determine whether the bridge locations you have selected for taking flow measurements and samples can be used throughout the monitoring season.

In some cases, the bridges you would like to use for monitoring activities may be slated for repair or replacement in the near future.

To determine existing pollutant loads, we must be able to solve this equation:

Flow x Pollutant Concentration = Load (mass)/unit time

How Do You Gather the Data?

Solving this formula requires that the following information be collected in the field:

1. **Flow data**, consisting of:
   - flow measurements from the field
   - continuous stage measurements
2. **Water quality samples of pollutants of concern** to provide pollutant concentration data

(Note: If either of these data sets are absent, collected incorrectly, or compromised by an inadequate number of samples, your results will likely be erroneous.)

First, Determine Flow

Flow is an essential piece of information when calculating existing pollutant loads to a waterbody. Calculating flow requires the collection of a certain number of flow measurements in the field, while also collecting continuous stage data with automated in-situ sensors.

The US Geological Survey (USGS) regularly gathers flow and stage data for a number of streams in Minnesota. However, there are many streams that have not been studied. For those streams, flow data must be gathered for the TMDL study using USGS methodologies and protocols (Techniques of Water-Resources Investigation Reports, found at the following Web site: http://pubs.usgs.gov/twri/).

Contact other agencies that do flow work (USGS, Minnesota DNR, etc.) to determine the best course of action for monitoring at a particular site. Consider whether there would be adequate staff and resources to support long-term monitoring at the site before committing your resources.

The basic steps required to collect flow data are:

1. **Collect a finite number of flow measurements in the field.**
2. **Use measurements to develop a rating curve.**
3. **Use rating curve and measured and recorded stage data to calculate flow.**

Obtaining Flow Data

Experienced hydrologists first take field measurements of stream velocity. This involves taking multiple stream velocity measurements across the entire cross section of a river or stream.

Flow = ∑*V (average velocity) x the cross section area*

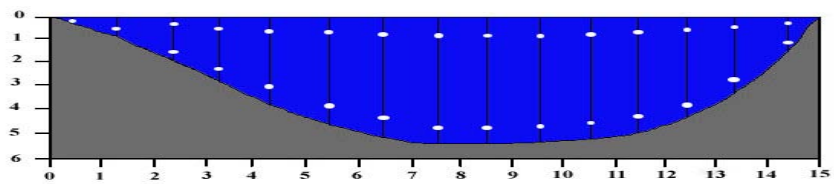

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Figure 1: A river cross section is divided into multiple vertical segments where flow measurements are taken.

Equipment for Measuring Flow Within a River/Stream

Flow measurements are taken in the field by a trained professional using various tools

Figure 2: Wading Rod being used to determine flow.

If the stream is shallow enough, the technician wades across the entire stream using a wading rod to measure depth and a current meter to measure velocity at multiple points along the stream’s cross section.

Figure 3: Bridgeboard and Weight being used to determine flow

If the stream is too deep to wade, flow measurements can be made with a “bridgeboard”. The bridgeboard is a free-standing support with a sounding reel used to raise or lower a current meter over bridge railings. Current meters are attached to torpedo-shaped weights of up to 30 lbs. so the vertical depth of cross sectional areas can be measured.

Figure 4: Bridge Crane and Weight used to determine flow

A bridge crane is used to measure flow where water velocities are too fast for smaller equipment. Weights of over 100 pounds can be used with this apparatus. Be aware that current will push “undersized weights” away from true vertical, resulting in exaggerated stream depths**.**

Figure 5: Acoustic Doppler Current Profiler being used to determine flow

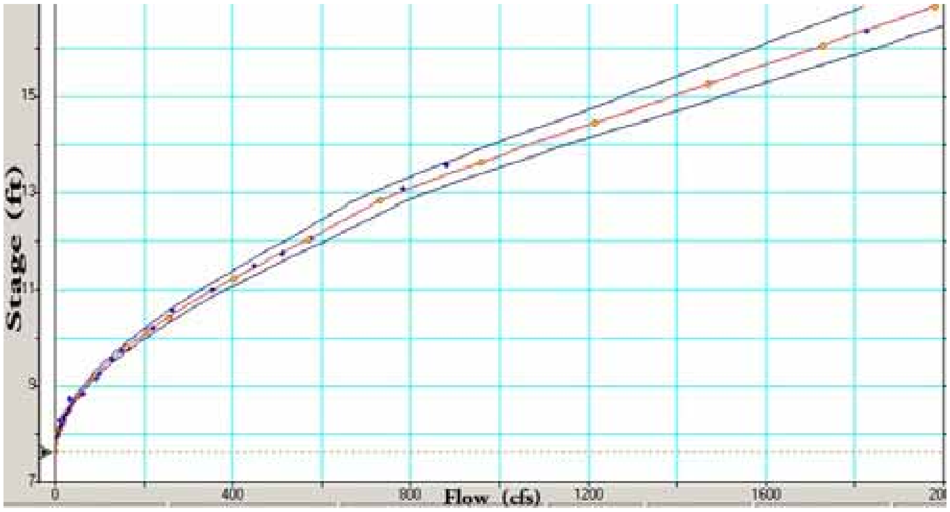
The newest and most technologically advanced equipment for measuring flow is the Acoustic Doppler Current Profiler (ADCP). Using three or more acoustic beams, the ACDP measures discharge when pulled back and forth across a stream's cross section.

Some units can be mounted "in situ" or in stream, to give real time discharge readings.

A rating curve is a tool that is developed by statistically analyzing both flow measurements and associated stream stage. Flow measurements are derived from measurements of a river's cross-sectional velocity, stage elevation, and width measurements. A rating curve converts field measurements to a line of best fit when regressing stage against flow.

Figure 6: Rating Curve for Hawk Creek – Maynard

Obtain an Accurate Flow Value



Rating Curves

A rating curve is an extremely useful tool since it allows us to convert stage data (collected automatically and continuously) into flow data in a reliable manner using a mathematical formula, however, they require ongoing management.

To develop a rating curve, hydrologists must collect sufficient flow measurements. Existing rating curves must be validated every year by collecting additional data, at least every 4-5 weeks throughout the monitoring season and throughout the range of flows.

Floods, vegetation, stream channel widening, downcutting, agrading, degrading can all affect a rating curve. Stage data should be adjusted for temporary shifts. A new rating curve should be developed for permanent shifts.

A Word About Rating Curves

A rating curve is considered “preliminary” until 2 years of flow measurements have been collected.

River stage is the measurement of a river’s elevation. Stage data is collected continuously by automatic measurement equipment.

Measuring Stage in a River / Stream

Stage measurements are typically recorded at 15-minute to one-hour intervals. Output from these devices is recorded and stored in an on-site data logger (like a small computer).

River Stage is measured with any one of the following automated tools:

- Submerged pressure transducer
- Ultrasonic transducer
- Float and weight assembly
- Pressure bubbler system

The later two tools are often placed in decrease interference with the equipment.

Equipment Used to Measure Stage

Figure 7: Device for measuring stage

The site in figure 7 incorporates data logger, stage recording radar sensor, rain gauge, velocity meter and solar panel for power. The site also uses telemetry to transmit recorded data.

Figure 8: Bridge showing monitoring set-up

Water Quality Monitoring

By measuring flow and stage, we are able to calculate flow at any point in time monitored. Flow values are usually compiled to calculate a daily average flow for a river using a rating curve. However, in order to calculate **existing pollutant loads** (our data collection goal), we must also gather water quality data to determine existing pollutant concentrations.

Flow x Pollutant Concentration = Load (tons)/unit time
(determined) (to be determined) (to be determined)

Water quality monitoring involves collecting water samples from the stream for lab analysis. A certified laboratory analyzes the sample for the specific pollutant(s) of concern to determine concentration. Field measurements are also usually taken at the same time water quality samples are collected (dissolved oxygen, turbidity, pH are usually measured).

Remember these points when collecting needed water quality samples:

- Results will be poor at best if an inadequate number of samples are taken.
- Moderate to high flow periods are the most critical periods within which to take samples.

- During very low flows, one sample taken every two weeks is often adequate.
- Ensure that sampling activities are staggered along the hydrograph.

The number of samples that need to be taken may depend on the requirements of specific models you may be using. Be certain to check with your technical team to evaluate and determine the appropriate number of samples needed.

Water quality samples are taken in one of two ways:

Water Quality Monitoring Equipment

Figure 9: Staff taking a grab sample using a bucket and rope

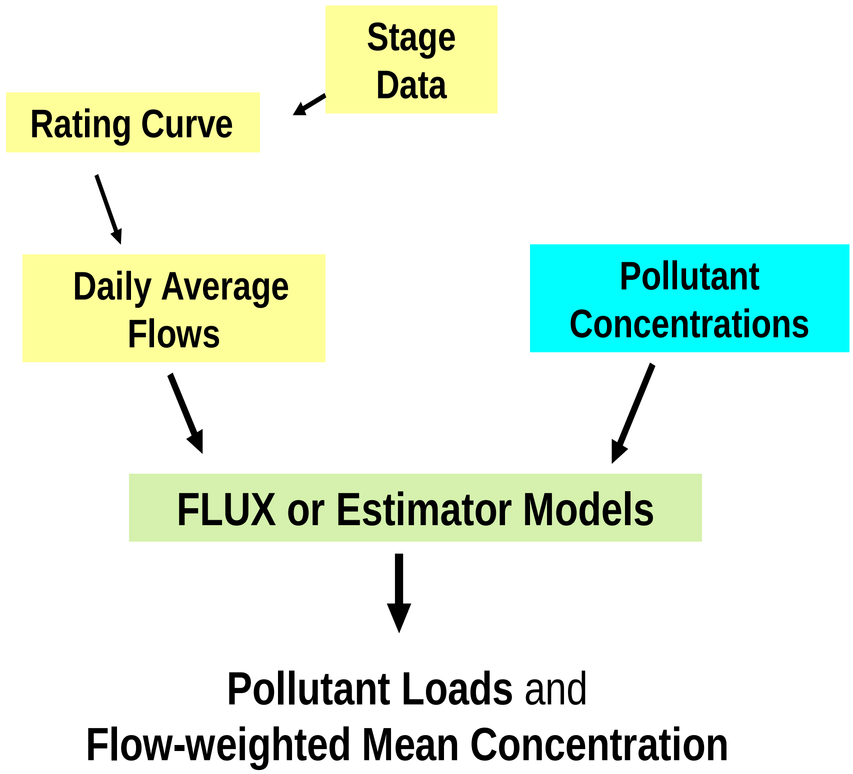
Grab samples are collected in the field by trained staff. Samples are collected at specific points along the hydrograph.

Figure 10: Stilling Well with Automated Sampling Equipment

Where higher frequency monitoring is desired, an automated water quality sampler can be used. The downsides of using this kind of equipment are that samplers require an experienced operator, need continual maintenance and often break down during critical sampling periods. The samples must also be preserved properly using refrigeration.

Assuming that the required number of water quality samples has been collected and analyzed by a certified lab, pollutant concentration data can be used in conjunction with the flow data you have collected to compute the load (mass) and the flow-weighted mean concentrations (FWMCs) for a specific pollutant.

Figure 11: Using a variety of data to estimate pollutant loads



FLUX and Estimator are models used to estimate the load of pollutants in a waterbody during a monitoring period based on daily flow records and sample concentrations and associated flows. Results can also be computed and reported as a flow-weighted mean concentration for the monitoring period. In some cases, daily load estimates can be made for the days that were not sampl

Pollutant load information provides us with the amount of a pollutant that is currently being discharged to a waterbody over a given period of time. If standardized monitoring procedures are used, it is possible to compare loading between different sites and streams. Estimated loading rates are only valid and defensible if there are several years of data to account for climatological variations.

Flow-weighted mean concentration is a valuable piece of information because it represents the average concentration of a pollutant that has passed by a particular monitoring site during a monitoring season or on an annual basis.

It is the equivalent of routing all waters passing a monitoring site into a huge basin, mixing it well and collecting one sample to represent the concentration of a pollutant within this total flow volume. The flow-weighted mean concentration helps to determine an accurate picture of the total mass of a specific pollutant a watershed yields, usually expressed in tons per acre.

We have provided an example of the ways in which a critical data gap could be filled by collecting new data in the field. Each TMDL study will have different data gaps and different data collection goals based on the unique circumstances within a watershed and on the amount of information that has already been collected.

While the focus of this module has been on collecting water quality data, of equal importance is the collection and analysis of biological, geomorphological, and land use data sets, as needed. Data collection techniques for these types of data will be addressed in subsequent chapters.

Summary

- Monitoring and data collection will allow you to fill data gaps and meet the data collection goals you have developed as part of your monitoring plan.
- Good data, gathered in accordance with a specific monitoring plan should become the foundation of any reliable TMDL study. Without good quality data to work with, your conclusions could be erroneous.
- Exactly where and when you choose to conduct your monitoring activities will depend on your data gaps and monitoring goals.
- Depending on the data collection goals you have developed, “what” to monitor can vary significantly. You may need to collect all or some of the following kinds of data:
  - Flow
  - Stage
  - Water quality samples of pollutants of concern
  - Biological
  - Geomorphologic
  - Land use

- This module provided one example of how you might collect additional water quality data in the field
- Work with your team to determine exactly what additional information is needed
- Ensure that proper procedures and protocols are followed when collecting new water quality information

Expected Time Commitment

Collecting existing data is not a quick or linear process. To develop a plan for gathering existing data and to complete a data inventory will likely take months to years.

Revisit Initial Assumptions

Once you have completed the data inventory and conducted an initial analysis of the data, review Worksheet 6-1. Did you learn anything new? Were your initial assumptions correct? Do you need to change the direction of your project? What new data is needed?

Identify those data gaps that require development of a monitoring plan and those that could be satisfied by conducting a literature review, etc.

Prepare to Develop a Monitoring Plan

TMDL studies typically require a targeted data collection effort to fill critical data gaps. Before gathering additional data, a monitoring plan should be developed. Monitoring plans encourage project staff to think the project through carefully before any work is done in the field.

The monitoring plan establishes a plan of action so that field work is efficient and effective at gathering the critical information needed to complete the TMDL study. The monitoring plan is a working, living document that is revisited throughout the duration of the project.

The monitoring plan:

- Describes the water body
- Describes the basic TMDL study design
- Outlines reasons for collecting additional data (if applicable)
- Describes the means by which data will be interpreted
- Identifies data-reporting mechanisms
- Provides statistical means of testing new ideas
- Ensures the project purpose remains clear despite personnel changes

The monitoring plan allows you to test a working hypothesis about water quality impairments, with an expectation that your hypothesis could be wrong.

When developing a monitoring plan, document your decisions regarding what data you decided to gather or not to gather. For example, gathering some kinds of data may be cost prohibitive. Documenting your decisions will allow others to follow your thinking and understand why the study may have had certain limitations. Chapter 7 addresses monitoring plans in much greater detail.

Resources

Contact:
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