CHAPTER 2 – AN OVERVIEW OF THE STUDY DESIGN PROCESS

In This Chapter . . .

Why Write a Study Design?

Study Design Steps

A study design is a written document that describes the choices you make about why, what, where, when, who and how you intend to monitor the waters of interest. These choices are organized into a 10-step process.

Step 1: What Is Already Known About Your Watershed?

Step 2: Why Are You Monitoring?

Step 3: What Will You Monitor?

Step 4: What Are Your Data Quality Objectives?

Step 5: How Will You Monitor?

Step 6: Where Will You Monitor?

Step 7: When Will You Monitor?

Step 8: What Are Your Quality Assurance Measures?

Step 9: How Will You Manage, Analyze and Report the Data?

Step 10: What Are the Tasks and Who Will Do Them?

By answering these questions, you will produce a study design. In this chapter, we'll walk you through the process of preparing a study design document, using worksheets in Appendix 6. Here we focus on the *process* of making study design choices. Chapters 3, 4 and 5 contain information that relates to the *content* of those choices.

Why Write a Study Design?

Preparing a study design may be the most important step in organizing your whole monitoring effort.[1] Think of it this way: in 10 years someone will look at your water quality data and want to know how you came up with those numbers. This person should be able to find out by reading your study design document. Besides documentation, a study design serves some very important purposes for your group and to the people you hope will use your data.

- It forces you to focus on what you are trying to accomplish with your monitoring program;
- It prevents waste of time and money on equipment and procedures that are inappropriate for your group or goals;
- It allows you to select the most appropriate monitoring strategy to address the issues that are important to you and your community;
- It allows everyone who might use your data to assess the quality of your results since you clearly document your sampling and analysis methods and quality assurance procedures;
- It minimizes the impact of changing personnel on the continuity of your monitoring activities because anyone can read your study design and "pick up the threads;"
- It allows your group to re-evaluate your monitoring study every year in an orderly manner and make changes as needed; and
- If you are using federal funds to monitor your waters, you will be required to prepare a "Quality Assurance Project Plan" (QAPP). You can very quickly and easily convert your study design document into a QAPP.[2]

How to Use the Worksheets

This chapter and the worksheets in Appendix 6 are organized by the steps described above. For each step, there are either questions or tables that prompt you to enter the appropriate information. Some questions or information requested in the tables may not be relevant to your monitoring program. If so, leave them blank. When you've filled out all the relevant worksheets, you've produced a study design. (The worksheets are also available as a Microsoft Word© file that you can edit according to your needs. You can call CVMP staff at (717) 787-5259 to request a copy of the file.)

The following sections will take you through the worksheets, step by step. The significance and meaning of each question and table in the worksheet are explained, as well as how and where to find the information requested.

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[1] For information on how to organize a monitoring program, see River Watch Network's "Program Organizing Guide," Montpelier VT 1995.

[2] Guidance for volunteer monitoring groups on preparing QAPPs can be found in: U.S. Environmental Protection Agency's "The Volunteer Member's Guide to Quality Assurance Project Plan", 1996.

Step 1: What Is Already Known About Your Watershed?

Start out by collecting existing information on the conditions and issues in your watershed. To help you do this, and to help with the rest of your study design, we suggest that you form a technical committee. See Step 10 for information on how to do this.

The worksheets in Appendix 6 prompt you for the following information:

1A: Describe your group.

This will give the reader a sense of who your group is and what it does. It provides the organizational context for your monitoring program. Hopefully, you have this information readily available.

1B: Background on the watershed.

This is a basic description of the geography of your watershed to give the reader a sense of place. Include any information on ecoregions, physiographic regions, hydrology, topography and climate that will give the reader a sense of the watershed. Include a map.

Table 1B: Background on waters of interest.

This table is a list of the waters of interest and some basic information about each.

1) **Waters of Interest**: List the major rivers, tributaries, streams, lakes, ponds, etc. that your group is interested in, regardless of whether you have any plans to monitor them. Get a map of the watersheds within your area. These are available from 1-800-USA-MAPS or local sporting goods stores. We suggest that you pick a watershed that you will be able to adequately cover with your assessment, considering your group's resources, time availability and energy. Delineate this on a topographic map, and use this map as your reference map.
2) **Watershed/Drainage Area/Communities**: For each body of water, fill in the major watershed it is located in, the drainage area in square miles and the municipalities it flows through or that it lies in. Drainage areas of watersheds can be found in the Pennsylvania Gazetteer of Streams.[3]
3) **Rivers***:* For a river, list the largest water body that it flows into (e.g. a larger river, lake, the ocean, etc.) before, or near, where it leaves your area of interest.

   Lakes: List the rivers or streams that flow into and out of your lake or pond.
4) **Land Use Types:** List the different land use types, then list the percentage of the land area located in each type in the watershed for each water of interest. Use the following list: unmanaged forest, managed forest, cropland, grazing land, urban, rural residential, industrial, commercial. This information could be provided by the County Conservation District or County Planning Commission.

Table 1C: Current status of your waters of interest.

This table prompts you to list your waters of interest and various aspects of their status under the water quality standards. The information in this table comes out of four sources:

1) The Pennsylvania Water Quality Standards (Pa. Code, Title 25, Environmental Protection, Chapter 93);
2) DEP Water Quality Assessment Maps;
3) Current Section 303(d) list (DEP); and
4) Your own experience.

[3] Pa. DEP, 1989 Pennsylvania Gazetteer of Streams.

You will need copies of the first three from DEP staff at (717) 787-5259.

Pennsylvania reports to EPA and Congress every two years with a list of all the waters in the state, and the extent to which they support their designated uses under the state water quality standards. As part of this process, the Commonwealth develops a list of all its waters and delineates whether they fully, partially or do not support their protected uses as described in the "305(b)" list.

Impaired waters that do not meet the water quality standards appear on the "303(d)" list. For these waters, "Remediation Plans" must be developed in which pollution loading is allocated among various sources through "total maximum daily loads" or TMDLs. Not all waters that are listed as impaired on the 305(b) list will necessarily appear on the 303(d) list. There are three reasons why this might occur:

1) A pollutant as defined by the Clean Water Act does not cause the impairment. DEP does not place these waters on the list since there is no pollutant to allocate through the TMDL process.
2) Impairments are being, or will be, addressed through existing enforcement and compliance pollution control efforts.
3) The waterbody already has an EPA-approved TMDL developed for identified causes of impairment.

Following is a brief explanation of each of the columns in Table 1C (on page A6-4):

1) **Stream and Zones of Interest:** Refer to the index map in Chapter 93[4] (on p. 93.32 at the end of Section 93.9) and find the basin (A-Z) that contains your waters of interest. Find the drainage list (A-Z) that contains your waters of interest. In the "Stream" column of the list, find the river, stream, creek, run or brook that includes your waters. They are listed in "hydrological order" with the number to the left of the name representing its rank: (1 is the most downstream, 2 is a tributary to 1, etc.). "Zone" refers to all (basin) or part (beginning and end points) of your water of interest.
2) **Water Uses Protected:** Identify the protected uses of the water – such as recreation, water supply and aquatic life – that are to be achieved and protected. They are listed (abbreviated) in the "Water Uses Protected" column of the drainage list. The abbreviations are as follows:
   a. Aquatic Life
      - Cold Water Fishes (CWF)
      - Warm Water Fishes (WWF)
      - Migratory Fishes (MF)
      - Trout Stocking (TSF)

   b. Water Supply
      - Potable Water Supply (PWS)
      - Industrial Water Supply (IWS)
      - Livestock Water Supply (LWS)
      - Wildlife Water Supply (AWS)
      - Irrigation (IRS)

   c. Recreation
      - Boating (B)
      - Fishing (F)

[4] Pennsylvania Code Title 25, Environmental Protection Department of Environmental Protection Chapter 93. Water Quality Standards or www.pacode.com

- Water Contact Sports (WC)
- Esthetics (E)

d. Special Protection

- High Quality Waters (HQ)
- Exceptional Value Waters (EV)

e. Other

- Navigation (N)

3) **Actual Uses and Values:** Based on your experience, list the uses that are actually occurring in each water of interest. Here you don't need to limit yourself to the above list of uses. List any types of water uses (e.g. sightseeing, picnicking) and values (e.g. aesthetics, historical) that you can think of or from community workshops you can hold (see below).

4) **Waters Assessed:** Check the water quality assessment maps to see whether your waters have been assessed. If not, you might want to flag these waters for your own monitoring needs.

5) **Uses Supported:** Check the water quality assessment maps to see whether your waters support their designated uses. If not, these waters are considered *impaired.*

6) **NPS Pollution:** Check the water quality assessment maps to see whether nonpoint source (NPS) pollution is present in your waters.

7) **Source of Impairment:** For impaired waters, check the 303(d) list to see the activities that are causing the impairment. List these here.

8) **Cause of Impairment:** For impaired waters, check the 303(d) list to see the contaminant(s) which are causing the impairment. List these here.

9) **Known Problems, Conflicts or Threats:** If you know of problems, conflicts among or threats to the protected uses, list these here.

10) **Known Efforts to Address Problems:** If you know of any efforts to address the problems listed in columns 3 or 4 of this table, list them here. Note especially if there are any remediation plans or TMDLs in process.

Uses, Values and Threats Workshops

Public workshops are a great way to involve watershed residents in your program, to learn about how your stream or lake is being used, what people think is important and problem areas. They are also a good way to build a list of potential monitoring volunteers. After all, they came to your workshop, they must be interested in the water!

Give members of your watershed communities an opportunity to help you identify water-related uses, special attributes and problems by holding one or more *Uses, Values and Threats Workshops.* At these workshops, explain your program ideas and assemble the topographic maps, or some other clear base maps, that cover your watershed. Invite participants to identify and locate water use areas, special attributes and problem areas using labeled or color-coded "post-it" notes. You can learn a surprising amount about your water body through this exercise.

1D: State the most pressing water quality issue(s) facing your waters of interest:

Based on your research, briefly describe the issues that will need to be addressed in order for your stream or lake to support designated and identified uses and values, deal with the threats and solve the problems. Issues can be existing or a potential conflict among these uses and values.

Issues can also be concerned with the existing or potential impacts of these threats on uses and values. A few examples might be:

- Loss of riparian or lakeshore habitat to development;
- Recreation impairment caused by pollution from inadequate or failing on-site septic systems;
- Shoreline erosion due to clearing and development; or
- Aquatic life impairment due to sedimentation.

Step 2: Why Are You Monitoring?

At this point, you've learned about the "official" status of your waters of interest under the state's water quality standards. You've listed uses, values, problems, conflicts and threats. You've stated the water quality issues you need to address. Now you are ready to decide your reasons for monitoring. What information do you need to address the issues? What is the purpose of your monitoring? What specific water-related questions are you trying to answer? Who do you expect will use your results and for what reason? The worksheets in Appendix 6 prompt you for the following information:

Table 2A: Information needed to address issues

Think about the key issues you identified above. What information might you need to address them? What information would you need to restore riparian or lakeshore habitat, for example? Identify the key characteristics, conditions and processes that you wish to monitor and where you wish to monitor them. Try to identify some of the general conditions and processes you might want to monitor in the field. For example, your research might turn up the fact that there are fish kills in the late summer in a particular stream reach or lake embayment and the causes are unknown. You may want to focus on those areas and processes that affect fish health.

2B: Monitoring questions

We suggest that any monitoring program should start with one or more questions, the answers to which provide essential information that address issues faced by decision-makers in your watershed. Your monitoring activities should then be designed to answer these questions. For example, if the issue you're concerned about is a conflict between a waste discharge and swimming at your favorite swimming hole, you might frame the following monitoring question: *Is swimming in the swimming hole a health risk?* If your issue is the threat of polluted runoff from a large paved area on a river, you might frame the following question: *What is the impact of the parking area on the ecological health of the river?* If the loss of lakeshore vegetation is your issue of concern, you might frame the following question: *What is the impact of the loss of shoreline vegetation on aquatic plants and animals in the littoral zone?* Questions can be framed many ways, but the more specific the better.

Chapter 4 of this manual suggests questions that volunteer watershed monitoring can or should address in Pennsylvania. These questions are listed on the worksheet. Check one or frame your own.

2C: Monitoring purposes

Unless you have lots of free time on your hands, you want your monitoring effort to collect the most useful information with the least amount of time and expense. An important first step is to identify why you want to collect this information: the purpose of your monitoring. According to recent guidance for effective state monitoring programs[5], there are five general purposes for monitoring:

1) Define present watershed conditions;
2) Characterize existing and emerging problems by type, magnitude and geographic extent;
3) Provide information to help design strategies to reduce and control pollution and to manage land and water;
4) Provide information for evaluating the effectiveness of reduction, control and management strategies; and
5) Reveal trends in watershed quality.

[5] Yoder, 1997.

These are general reasons to collect watershed information. We suggest that, in addition to these reasons, you consider who you expect to use this information, and what you expect them to use it for. In Chapter 3, we suggest four purposes for monitoring in Pennsylvania:

Purpose A: Community Education and Awareness

Purpose B: Baseline Data Collection

Purpose C: Community and / or Watershed Level Assessment

Purpose D: State and Federal Agency Assessment

Table 2D: List the intended uses and users of the information you collect

Identify the decision-makers who are (or should be) interested in the answers to your questions. See the lists in the table in Chapter 3 for examples of uses and users of monitoring information. Find out what actions they might take or decisions they might make as a result of your information. List these decision-makers (users) and the actions or decisions (uses). Consult with the decision-makers to find out if and under what circumstances they will use your information.

Step 3: What Will You Monitor?

Streams are very complicated systems of inter-related physical, chemical and biological characteristics, often referred to as "indicators.[6]" Which indicators you choose to monitor will depend upon the questions you are asking as well as your available human and financial resources.

There are literally hundreds of indicators that you could measure. Rather than list them all here, we'll organize them into two broad categories and give you a few examples from each: 1) watershed ecosystem indicators, and 2) public health indicators.

1) Watershed Ecosystem Indicators

Biological Indicators: This includes living things like bacteria, fish, insects, plants and others living in the water column or on the bottom of a water body or in the riparian area.

Physical Water Column Indicators: This includes factors like temperature, turbidity, clarity and other physical characteristics of the water column.

Chemical Water Column Indicators: This includes factors like dissolved oxygen, pH, alkalinity, nutrients and other elements and compounds found in the water column.

Flow Regime: This includes all the factors that affect the amount of water in the system, such as land use, precipitation, runoff, groundwater and current velocity.

Habitat Structure: This includes the physical structure of the channel, shorelines and riparian area that supports life, such as riparian vegetation, bottom composition, bank stability, gradient, instream cover, current, channel form, siltation and width / depth.

Energy Source: This includes the various factors that provide energy to watershed organisms such as sunlight, organic matter inputs, nutrients, oxygen and carbon dioxide production.

The different indicators listed above each tell us something different about the stream or lake. One way to think about these differences is to think about those factors that stress the watershed, the exposure of the watershed to that stress, and how it responds. This stress, exposure and response way of thinking is similar to how people who study the occurrence of disease think about their work.

- **Watershed Stress Indicators:** These are measures of activities which have the potential to affect the ecosystem, (e.g. pollution, land uses, water uses, climate, etc.).
- **Watershed Exposure Indicators:** These are measures of changes in indicators that suggest the magnitude and duration of exposure to a stressor (e.g. the concentration of suspended sediment over a period of time, the duration of low flow and / or high temperature events.).
- **Watershed Response Indicators:** These are measures of the ecosystem's response to exposure to a stressor (e.g. changes in the river channel, changes in biological community composition or abundance).

This is a useful way to think about indicators because it helps you select appropriate indicators based on how you will use the information. For example, just because you measure higher-than-normal nutrient concentrations, doesn't mean you have discovered a problem (unless there is a violation of water quality standards). To assess that, you will need to measure a response indicator, to see if those higher-than-normal concentrations are actually causing problems for aquatic life.

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[6] The Intergovernmental Task Force on Monitoring Water Quality (ITFM) defines "environmental indicator" as follows: "A measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality." ITFM, 1993 Report, Technical Appendixes, Appendix A.

2) Public Health Indicators

You can think of public health indicators in much the same way as watershed health: stress, exposure and response. In this case, stress would be the presence of disease-carrying organisms in the water (high levels of *E. coli* bacteria in water used for swimming or drinking). Exposure would be the extent to which people come in contact with disease-carrying organisms (e.g. the extent to which people are drinking or swimming in contaminated water). Response would be the extent to which people who are exposed to contaminated water get sick (e.g. number of illnesses in people who drink or swim in the water with high levels of bacteria)

In this handbook, we have simplified the task of choosing indicators by packaging them into "assessments." These assessments are described in Chapter 5. In Step 3 (What Will You Monitor?), you will tentatively select one or more assessments to carry out. Then you will select a set of indicators from the "Monitoring Options" table for each assessment. Consult with your technical committee and / or DEP's Citizens' Volunteer Monitoring Program staff to help you determine which assessment and indicators will best help you answer your questions.

3A: Select an assessment (see Chapter 5)

Chapter 5 contains a list of the various assessments we recommend. Briefly scan the information about each assessment and decide which one(s) seems to best fit your questions, purposes and capabilities. You can select more than one. For example, we strongly recommend that all groups carry out assessment A1 (Watershed Inventory on pages 5-6 to 5-8), either by itself or as a first step in conjunction with one or more other assessments. Check the assessment(s) you will carry out from the list. This is a tentative selection.

Table 3B: Select indicators

For each assessment you have selected, select the indicators that are most relevant and practical for your water body and your capabilities from the recommended list of indicators in the "Monitoring Options" table. Remember that the indicators listed for each assessment are a menu – you don't have to monitor all of them! Your human and financial resources and expertise may limit the indicators you can monitor. Find out how much time, money, equipment and expertise are required to monitor each indicator. You'll need to consult with DEP staff and / or members of your technical committee, who are familiar with how these indicators are sampled and analyzed. You can also look at Appendix 2 of this handbook to get a sense of what is involved to analyze the indicators.

You may want to revisit your selections after you have determined your data quality objectives and methods (in the next section). Remember that selecting indicators is a logical process that considers your specific monitoring question and your capabilities. And, you have set up a technical committee to help you make these choices (right?). Here are some things to consider when selecting indicators:

Scientific Considerations:

- Does it help answer your question?
- Can you observe or measure and quantify it?
- Does it respond to changes over a reasonable time period?
- Does it respond to the impacts you're evaluating?
- Can you isolate the conditions that cause it to change?
- Does it integrate effects over time and space?
- Does it respond to changes in other indicators?
- Is it a true measure of an environmental condition?

- Is there a benchmark or reference condition against which to evaluate it?
- Does it provide early warning of changes?

Practical and Program Considerations:

- Do you have the human and financial resources to measure it?
- How difficult is it to monitor?
- Does it help you understand a major component of the ecosystem?
- Is it understandable/explainable to your target audience?

For each assessment type, list the indicators you will monitor in Table 3B.

Step 4: What Are Your Data Quality Objectives?

Data quality objectives are the quantitative (numerical) and qualitative (narrative) terms you use to describe how good your data needs to be in order to be useful. You will need to establish data quality objectives for both *sampling* of each sample type and *analysis* of each indicator. The objectives guide you in your selection of sampling and analytical methods – you match your methods to your data quality objectives.

Table 4A: Data Quality Objectives for Sampling

These apply to your overall process for collecting samples, including your sites and frequency. They help you:

- Decide how many samples and at what frequency you want to collect them;
- Select the number and types of sites to sample; and
- Determine the specific sampling places at each site.

You will need to revisit your data quality objectives for sampling after you have decided on sites and frequency (study design steps 6 and 7).

Following are the categories of data quality objectives for sampling that correspond to the column headings in Table 4A:

1) **Sample Type:** Type of sample you will collect such as water or stream bottom.
2) **Completeness:** The percentage of the total number of samples that you must actually collect in order to consider your data set "complete." For various reasons, your volunteers will likely not collect samples at every site on every date. If there are too many of these "holes" in your data, analysis will be difficult. So you need to set a target.
3) **Representativeness:** The extent to which the samples you collect reflect the true environmental condition or population you are monitoring. This relates to where you take your samples in the stream system, water column or lake cross section. It may also relate to the number of samples you take at a site. Data quality objectives for representativeness can be narrative and / or numerical.
4) **Comparability:** The extent to which data from one study can be compared with past data from the same study or another one. You may want to compare your data with that collected by DEP last year. Or you may want to compare your data this year with data you collected five years ago. This is a narrative, rather than a numerical objective.

You set data quality objectives for sampling for each type of sample you will collect (for example water or stream bottom):

Sample Type	Completeness	Representativeness	Comparability
Type #1	# of samples or percentage of total number	Narrative and / or numerical objective	Narrative objective
Type #2	# of samples or percentage of total number	Narrative and / or numerical objective	Narrative objective

Table 4B: Data Quality Objectives for Analysis

These apply to each indicator you are monitoring. They help you select an appropriate analytical method for each indicator.

1) **Indicator:** List the indicator such as pH, dissolved oxygen, conductivity, etc.

2) **Accuracy:** How close a measurement of an indicator is to the “true” or expected value. This tells you how close to being “right” your measurements are, assuming you know what the true value is. True values can be a known concentration of an indicator that you or the lab make up and you analyze. Or, the true value can be the results of the measurement of an indicator in a sample by a certified professional or government lab. Here, you are assuming that their results are the true value. If you and the lab analyze the same sample, you would compare your results with theirs to determine your accuracy. In either case, you don’t know with 100 percent certainty that the known concentration or the results from a certified lab are the true value, since errors in making up concentrations or measurements can occur even in the best laboratory.

   Another way of assessing accuracy is through an “expected” value. In this case, a portion of a real stream or lake water sample is treated by adding a known amount and concentration of the indicator being measured, then measuring the concentration. This should increase the concentration in the sample relative to an untreated portion of the same sample by a predictable, or expected, amount. Accuracy is usually expressed as ± (plus or minus) a given level.

3) **Precision:** The degree of agreement among repeated measurements of the same indicator on the same sample. This tells you how consistent and reproducible your field and laboratory methods are. Precision is usually expressed as either ± (plus or minus) a given level or as a relative percent difference (RPD). For example, a precision objective of ± 0.1 mg/l means that two measurements of the same sample should not be greater or less than each other by more than 0.2 mg/l (example 10 ± 0.1 gives a range of 9.9 – 10.1). A precision objective of 5 percent Relative Percent Different (RPD) means that the RPD calculated for two replicate sample results should be within 5 percent.

4) **Detection Limit/Measurement Range:** The detection limit is lowest concentration of a given indicator that your methods or equipment can detect and report as greater than “zero.” Any reading below this point is considered unreliable and would instead be reported as less than the detection limit itself. For example, if your detection limit is 0.01 mg/l and your result is 0.003 mg/l, you would report your result as <0.01. The detection limit you set should be based on levels you need to be able to measure in order to detect problems or changes over time, depending on your monitoring question(s).

   The measurement range is the range of reliable measurement of an instrument or measuring device. Any reading above the upper limit or below the lower limit (your detection limit) is considered unreliable. The measurement range should include the range of levels that you need to be able to measure for each indicator.

This can also be set up as a table. For example:

Indicator	Accuracy	Precision	Detection Limit/Measurement Range
Indicator 1	± (reporting units)	± (reporting units) or RPD (%)	lowest reliable reading – highest reliable reading
Indicator 2	± (reporting units)	± (reporting units) or RPD (%)	lowest reliable reading – highest reliable reading

A Note About Setting Data Quality Objectives

Setting data quality objectives may be the most challenging part of designing your monitoring program. In part, it’s a “chicken-and-egg” situation. How do you know what you can do before you try? In fact, unless you are preparing a Quality Assurance Project Plan (QAPP), you may not need to set objectives before you start monitoring. You may be able to experiment and then assess your capabilities. So, we recommend the following:

1) Determine whether you need to set data quality objectives for your data users. If you are using federal funds and preparing a QAPP, you will need to set objectives. If you are not preparing a QAPP, consult with your most rigorous data users to find out if they require you to set objectives.
2) Consult with your most rigorous data users and find out if they have established data quality objectives for each of your sample types and indicators. If so, consider using their objectives.
3) Consult with your technical committee and / or DEP staff to help you determine if you need to set data quality objectives. At this point, you may not need to set data quality objectives. Your technical committee and / or DEP staff may recommend that you get a season's worth of sampling under your belt, then set objectives based on your actual capabilities.
4) If needed, establish preliminary data quality objectives for each type of sample and for each indicator with your technical committee and / or DEP staff. Consult Chapter 5 for a list of recommended methods for the assessment you have selected. Consult with people who have experience in these methods to help you set preliminary objectives.
5) Revisit your data quality objectives after your first sampling season. Did you meet them? Can you meet them?
6) Adjust your data quality objectives (and possibly your goal) according to actual experience. You may need to adjust your data quality objectives to meet your capabilities. Be sure to consult with your technical committee and data users to confirm that your adjustments are acceptable. If not, you may have set unrealistic expectations for your program and you may need to revisit your overall data quality goal.

Step 5: How Will You Monitor?

Determining how you will monitor involves making choices about the appropriate sampling and analytical methods, both in the field and in the lab, that meet your data quality objectives. Recommended methods for each indicator are listed in the "Monitoring Options" tables for each assessment in Chapter 5. Tables 5A and 5B in Appendix 6 (on page A6-11 and A6-12) list the information to include in your study design.

Following is a brief description of each of the information items requested.

Table 5A: Sample Collection Methods (see Appendix 2: "Guide to Indicators and Monitoring Methods" for descriptions of possible sample collection methods for various indicators)

This table deals with the details of how you will collect samples for each indicator:

What will be sampled: This refers to the specific thing that will be sampled. Here are some of the options:

- stream or lake water
- groundwater
- habitat
- algae
- phytoplankton
- rain
- benthic macroinvertebrates
- sediment
- maps
- zooplankton
- stormwater
- discharge
- fish
- macrophytes
- periphyton
- wastewater

Sampling containers or devices/preservation: What type of container or devices will be used? Will the sample be preserved and, if so, how? Some examples:

Sampling Containers or Devices

- plastic bottle
- collection net
- acid-rinsed glass
- meter
- BOD bottle
- rock basket
- Surber sampler
  secchi disk
- glass bottle
- Whirl-pak bag
- Dredge
- integrated depth sampler

Preservation Methods

- acidified
- formalin
- fixed
- refrigerated
- alcohol
- dark

Quantity of sample to be collected: How much of the sample will be collected? This is determined by the needs of your analytical method. Some examples:

- milliliters
- cubic centimeters
- # of organisms
- # of transects
- area sampled
- # of measurements

Number of samples to be collected per site: How many samples will be collected at each site?

Methods Reference: Cite a specific method and the source. For example, "grab sample per Standard Methods 9500A." A variety of methods for each indicator can be found in Appendix 2.

Water samples can be collected in various ways:

- *Grab Samples*: Samples are collected in some type of container by dipping the container in the water and filling it to some pre-determined level.
- *Integrated Samples*: Samples are collected from various depths or locations across a transect and are combined into one sample for analysis.
- *Multiple Depth Samples*: Individual samples are collected at various depths and analyzed separately.
- *Direct Measurement*: The indicator is measured directly from the water without collecting a sample.

Benthic macroinvertebrate samples can be collected in many different ways:

- *Qualitative Net Collection*: A sample is collected directly off the bottom using a net. The level of effort is not standardized.
- *Semi-Quantitative Net Collection*: A sample is collected directly off the bottom using a net such as a D-net. The level of effort is standardized by collecting from a specified area in front of the net. Since the area is not precisely delineated, the method is not strictly quantitative.
- *Quantitative Collection*: A sample is collected by using a Surber sampler or by placing rock-filled baskets on the stream bottom and allowing them to be colonized. The time the rock-filled baskets are left out is standardized at six weeks and the colonization area in each basket is roughly the same. A Hess sampler or Hester Dendy multiplate sampler can also be used instream. Quantitative algal samples from lake water column can be collected using a plankton net of known diameter being pulled through the water column at a known speed for a known distance.

Habitat is typically sampled in one of two ways:

- Visual estimates of each of the habitat characteristics; or
- Field measurements of each of the habitat characteristics.

Public health is sampled for exposure and for the incidence of disease. Exposure is typically sampled as follows:

- Water Samples: Analyzed for the contaminants of concern; or
- Fish or Shellfish Samples: Analyzed for the contaminants of concern.

Table 5B: Sample Analysis Methods (see Appendix 2: "Guide to Indicators and Monitoring Methods" for descriptions of possible sample collection methods for various indicators)

This table deals with the details of how you will analyze samples for each indicator:

How Sample Transported to Lab: How will the sample get from the field to the lab for analysis. For example, samples may be transported by car in coolers.

Maximum Holding Time: The maximum amount of time that the sample can be held before it must be analyzed. Some holding times for common water column indicators are listed in the "Sample Handling Requirements (from Standard Methods)" table at the beginning of Appendix 2 (page A2-1). Some indicators don't have a limit on the amount of time they can be held. For these, fill in "NA" for "not applicable."

Methods Reference: Cite a specific method used and the source. For example, "Standard Methods 9500A." A variety of methods for each indicator can be found in Appendix 2.

Brief Description of Method: Briefly describe the method. For example: "Membrane filtration and incubation for two hours at 35° C followed by 18 – 24 hours incubation at 44.5° C."

Reporting Units: In what units the results will be reported. Some common units are:

- mg/l
- NTUs
- cfu per 100 mL
- °C or °F
- cubic ft/sec
- meters or feet

Since the assessments in Chapter 5 list monitoring methods appropriate for each indicator, your job is fairly simple after you have selected appropriate indicators. For some indicators, more than one method is recommended. So, you still may need to make some choices on methods. Here are some things to consider:

Scientific Considerations:

- Does it meet your data quality objectives?
  - How accurate is it?
  - How precise (reproducible) is it?
  - What is its detection limit?
- Will it measure the indicator in the range that you need?
- What lab facilities are required?
- What equipment is required?
- Does it yield samples that are representative?
- Is it comparable to methods used by agencies collecting similar information?

Practical and Program Considerations:

- Do you have the human and financial resources to do it?
- How difficult is it?
- How time-consuming is it?
- Will it produce data useful to the target audience?

Step 6: Where Will You Monitor?

In Step 1, you identified your waters of interest. Now it's time to identify the specific locations where you will collect monitoring information.

First, refer to Chapter 5 for the site selection considerations for each type of assessment you selected. Consult with your technical committee and / or DEP staff to help you refine these considerations into criteria you will use to select your sites to answer your questions. Next, use a topographic map to do a preliminary selection of sites that appear to meet your criteria. Determine how many of these sites you can monitor. Consider safety, accessibility, your human resources and how many samples you can analyze. Field check each site for accessibility, representativeness, safety and appropriateness. Record directions to the site, a brief description of the site and other relevant information in a site log notebook. *Get landowner permission to use sites on private property.* Drop the sites where you cannot obtain permission. Finalize your list of sampling sites. Photograph each site at the sample collection point and place the site description and the photograph in a loose-leaf binder for permanent archiving. Locate each final site on your topographic map. Finally, identify the laboratory where the analysis of samples will be performed.

Table 6A: Sampling Site List

This table is your list of all your sampling locations chosen through a site selection process. When researchers select sampling locations they will monitor, they may use complex statistical approaches that are geared to producing sites that are representative of the area being monitored. Describing these methods is beyond the scope of this handbook. However, we describe types of sampling sites below and site selection considerations for each of the assessments in Chapter 5.

- **Site Number**

  Assign a unique number to each site. There are various site numbering schemes available. Pick one that allows you to easily add sites. In general, a site numbering system based on a water body Identification such as the Pennsylvania Stream Code[7] and the distance of the site from the mouth seems to work best. An example for Conneaut Creek is 62719-0.1. The number 62719 is the Pennsylvania stream code for Conneaut Creek and "0.1" means the site is located one tenth mile from the mouth of Conneaut Creek.

- **Brief Description of Location**

  Include a brief phrase that describes the location of the site. Also, include the Pennsylvania Stream Code[7] for the segment that includes the site.

- **How and Where the Site Will Be Sampled**

  Describe the sampling technique (see Step 5) and where the sample will be taken at the site. For example: "grab sample taken from boat in mid-channel."

  For water sampling, the two main issues are where in the water column and where across the stream you will collect samples.

  Where In the Water Column (what depth)?

  In streams, the main thing to consider is whether the water is evenly mixed from surface to bottom. If not, water quality may vary quite a bit at different depths, due to different water velocities. This is especially true for sediment in deep rivers with smooth bottoms. In this case, the different velocities at different depths would each be capable of carrying certain size

[7] United State Department of the Interior Geological Survey 1999. Pennsylvania Gazetteer of Streams.

particles in certain quantities. In these rivers, you may need to collect samples from multiple depths, depending on the indicator you are monitoring. Otherwise, a sample collected about eight inches below the surface may be sufficient. In shallow, high velocity, turbulent streams, we generally make the assumption that the water mixes fairly evenly from top to bottom. In these streams, water samples should be about half way between the surface and the bottom.

Lakes are usually not homogenous throughout the water column. Generally, lakes stratify into three layers determined by the different density of water at different temperatures. These are the *epilimnion*, the *metalimnion* and the *hypolimnion*, from surface to bottom. So, for some indicators, such as dissolved oxygen and nutrients, samples should be collected at regular intervals (usually every meter or so) down through each layer. These samples may be analyzed separately if your questions concern conditions at each layer. If not, the samples may be combined into a depth-integrated sample.

Where Across the Transect?

Water, habitat and aquatic communities can also vary significantly across the stream or lake transect (across the water) due to uneven mixing of the indicator you are measuring. So, where you decide to collect the sample is important.

In streams, we recommend that water samples and most measurements be collected in the main stream current and away from the banks, at sites where the stream seems to be evenly mixed. Uneven mixing across streams occurs where tributaries join, downstream of structures such as dams or diversions, and at meanders. In these cases, you may want to collect samples at regular intervals across the stream. These samples can be analyzed separately, if you wish to measure the variation across the stream, or combined into an integrated sample to “average” the variation.

Lakes vary even more dramatically than streams. This is especially true when the lake has many bays and coves. We recommend the deepest part of the main lake and bays for overall characterization and near shore areas for water use assessment and aquatic weed monitoring.

What Type of Micro-Habitat for Benthic Macroinvertebrates?

For the most part, we recommend sampling the cobble-bottom micro-habitats at riffle macro-habitats (an area within a riffle that has cobble in the substrate), largely because they contain the most abundant and diverse communities. However, if riffles and cobble are not available, rock baskets can be suspended in the water column in “run” type macro-habitats. Other micro-habitats can be sampled directly, including aquatic vegetation, large woody debris, leaf packs and root wads along the banks. A similar habitat should be sampled at each station for meaningful comparison.

- **Type of Site**

  These are described in the next section, titled “Types of Monitoring Sites.” Decide the type of site and indicate it in this column.

- **Indicators**

  List the indicators that will be monitored at this site.

  Instructions for filling out the worksheet follow this background information.

Table 6B: List where each indicator will be analyzed

In this table you list where you will analyze the samples as well as the indicators to be analyzed at each location.

- **Place of Analysis**

  List the specific location where samples will be analyzed. List the name of each lab or write "field" if samples will be analyzed at each site.

- **Indicators Analyzed**

  List all the indicators that will be analyzed at that location.

Types of Monitoring Sites

First, we will describe the different types of monitoring sites. Note that appropriate types of sites for each assessment are listed in the "Site Location Considerations" section of the assessments in Chapter 5. Then we will describe some site-specific sampling location considerations – where to collect samples, measurements or observations at the site. Next, we will describe some practical considerations that you need to consider when selecting sites. Finally, we will cover the basic options for locations to analyze samples.

In this section, we will discuss four different categories of monitoring sites:

1) *General Watershed Assessment Sites*

These sites would be relevant to several of the assessments described in Chapter 5, where the focus is on an entire watershed or tributary watershed.

Watershed Reference Sites: Sites located in the least-developed parts of the watershed that represent "least-impaired" conditions.

Stream Impact Assessment Sites: These sites include upstream reference, impact and recovery sites that bracket some sort of human alteration of the river system. See Section 2 below for a description of each. Locate these three sites wherever you wish to assess impacts in the watershed.

Fish Habitat Area Sites: There may be various types of habitat areas, including areas designated as "cold water" and "warm water" habitats, and others which may be used by fish as spawning, nursery or resting areas.

Benthic Macroinvertebrate Macro-Habitats: Riverine sites that include riffles, runs and pools:

- **Riffle Sites**: Shallow (1-2' deep), fast moving (0.4 - 2.5 feet per second), cobble bottom areas.
- **Run Sites**: Deeper (>2' deep), moderately fast moving (0.4 - 2.0 feet per second), sand and gravel bottom areas.
- **Pool Sites**: Deep (>2' deep), slow-moving (<0.4 feet per second), mud-bottom areas.

Within these larger macro-habitat areas and at each site, there will also be *microhabitats* that include different types of habitat structures: cobble bottoms, large woody debris, aquatic vegetation and submerged bank vegetation.

Water Use Sites: These are sites where various types of human water use occur, such as swimming areas (formal and informal), boat launch areas, fishing access areas and water supply intakes.

Tributary Impact Assessment Sites: These sites assume that the tributary may be considered a pollution discharge to the main stem of the stream (see figure 1 below). The idea is to bracket the mouth of each tributary assessed with four sites:

1. **Tributary Reference Sites:** These sites are in the main stem of the stream, upstream of the confluence with the tributary. They represent conditions in the main stem prior to the impact of the tributary.
2. **Tributary Impact Sites:** These sites are in the main stem of the stream, downstream of the confluence with the tributary, where the water from the tributary is completely mixed with the main stem[8]. Impact sites represent conditions in the main stem after the impact of the tributary.
3. **Tributary Recovery Sites:** These sites are in the main stem of the stream, downstream of the impact site. They represent conditions in the main stem after the impacts of the tributary have begun to diminish.
4. **Tributary Integrator Sites:** These sites are at the mouth of the tributary. They represent the condition of the tributary, integrating all the upstream impacts, before it enters the main stem.

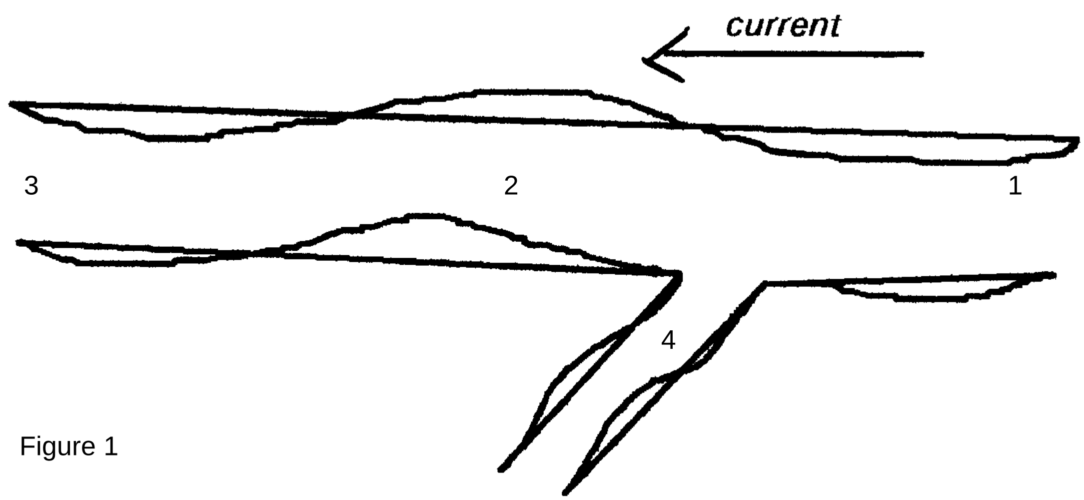

Figure 1

Lake Assessment Sites: The main differences between monitoring lakes and monitoring streams are that the water flow through lakes is much slower, and lakes tend to be deeper. Frequently, in summer and winter, lakes stratify into layers of similar temperature that don't mix until spring and fall. So, in order to know what is going on in a lake, you need to look vertically in the water column as well as in different parts of the lake. Following are some different types of lake assessment sites that account for the horizontal and vertical variations:

- **Deepest Sites:** The water in the deepest places in the main lake and in embayments tends to be the most representative of critical conditions in the lake. At these sites, you need to decide at what depth(s) you will take samples in order to assess the condition of different layers.
- **Mouths of Tributaries (Inlets):** These are the same as the "tributary integrator sites" described above. They represent the condition of the tributary before it enters the lake.
- **Lake Outlet:** These sites are located where the lake spills over a dam or enters a stream. They represent the conditions of the water as it leaves the lake.

[8] This is not easy to determine. It depends on the current velocity, the distance from the tributary outlet to the farthest bank, the depth of flow and the hydraulic forces across the stream. You may need to actually sample across the stream at various distances downstream of the tributary to determine where complete mixing occurs.

- **Water Use Sites:** These are sites where various types of human water use occur, such as swimming areas (formal and informal), boat launch areas, fishing access areas and water supply intakes. The idea is to assess conditions that affect these uses at these sites.
- **Near Shore Areas:** Sites near the lakeshore are frequently the most heavily used and biologically productive areas of the lake. Many of the water use sites are located here as are many of the places most suitable for nuisance aquatic weed growth.

2) *Stream Impact Assessment Sites*

These include at least three sites that bracket some sort of human alteration of the stream system. These sites would be relevant to the impact assessments described in Chapter 5 (on pages 5-23 to 5-35 and 5-66 to 5-79).

- **Upstream Reference (Control) Sites:** These sites are upstream of some sort of human alteration of the stream. They represent conditions in the stream prior to the impact of the alteration.
- **Impact Sites:** These sites are downstream of some sort of human alteration of the stream. They represent conditions in the stream after the impact of the alteration.
- **Recovery Sites:** These sites are downstream of some sort of human alteration of the stream. They represent conditions in the stream after the impacts of the alteration have begun to diminish.

3) *Public Health Monitoring Sites*

The focuses for these sites are areas where people are coming into contact with the water or aquatic life. Examples include:

- swimming areas (formal and informal);
- boat launch areas; and
- fishing access areas.

The idea is to collect samples of water at these recreation sites to assess whether they are contaminated. These sites are most relevant to the “Recreational Waters Uses and Water Supply Assessment” described in Chapter 5 (on page 5-61).

4) *Habitat Assessment Locations*

Habitat assessments can be carried out anywhere in the watershed, depending on the habitat of the organisms you are assessing. For the most part, habitat assessments focus on the channel and/or the riparian area:

- **Channels:** The channel carries the water during various magnitudes of flow in streams and lakes. It provides the physical structure and foundation for life in the stream or lake.
- **Shorelines and Riparian Areas:** As you move upland from the channel itself, there is a gradation to shorelines, riparian areas and the watershed itself. This is the land that drains into the stream or lake, from the top of the banks, to the floodplain, to upland areas.

Step 7: When Will You Monitor?

In this step, you will put together your sampling schedule. Scheduling depends on the type of assessment you are doing and your specific monitoring question(s). Since the time of day, frequency, and time of year, and weather sampled greatly affect your results, consider each of these when you establish the sampling schedule. This handbook suggests the frequency, time of day and year, and weather conditions for each assessment in Chapter 5. Work with your technical committee to help devise a sampling schedule that will answer your monitoring questions and match your capabilities.

Table 7A: Sampling Schedule, Frequency, Times and Weather

In deciding when to monitor, you should think in several time scales: the time of year you wish to monitor; how many times you will sample during the year (frequency); the time of day you will collect samples; and the weather conditions you want to capture.

Indicator(s)

The sampling schedule may be different for different indicators. If that is the case, list the indicators that share a common schedule.

Sampling and Analysis Dates

This boils down to deciding on time of year and sampling frequency, then picking sampling dates that reflect your choices. Specific guidance on how frequently and when you should monitor is given for each assessment in Chapter 5. Here are some general principles:

Time of year: Human use and aquatic ecosystems change with the seasons. Water flows, temperatures, chemistry, food sources and the level of biological activity all vary with seasonal cycles. So, in the ideal study, you would sample during all seasons to determine how your ecosystem varies. However, this is not practical, nor necessary, for most volunteer programs. Consider sampling during critical periods when the ecosystem is under the most stress (such as summer hot, dry periods) to capture worst-case conditions. Consider sampling during periods when the ecosystem is under the least stress as a benchmark. Consult with your technical committee to determine critical and benchmark sampling periods for your program. For monitoring that is based on the use of the water body, you need only monitor during the time of year when the use is occurring (for example, during the summer for swimming), though you may want to sample immediately before and after the season in order to establish a benchmark.

Frequency: How many times should you sample? As with everything else, it depends on the question(s) you have asked, as well as the indicator. If you are trying to establish baseline conditions or monitor impacts, you should collect water samples as often as practical, in as many different conditions, and for as many years as possible. For other types of assessments, once per year is enough. For example, you may only need to collect benthic macroinvertebrate samples once per season, or possibly only once per year, since these organisms integrate impacts over relatively long periods of time (months). There are statistical methods to help you determine how many samples from a given area you should collect to be able to quantify the relationships among the different indicators you are monitoring. These methods are beyond the scope of this handbook. For practical purposes, your financial and human resources will probably dictate your sampling frequency.

List the dates that this indicator (or group of indicators) will be sampled and analyzed.

Time of Day Sampled

Certain indicators, like dissolved oxygen and pH vary according to the time of day. In order to understand this daily variability, you may have to sample these indicators at different times of the day, perhaps even hourly, over several 24-hour periods. For others, like benthic macroinvertebrates, the time of day is not important.

List the time of day that this indicator (or group of indicators) will be sampled.

Special Weather Conditions

Weather affects aquatic ecosystems in profound ways – for some, it reduces stress and for others, it causes stress. Since weather varies with the season, see the “Time of Year” section above for the general considerations. Within seasons, consider sampling a variety of weather conditions: storm events, droughts, “normal” conditions, relatively hot weather, relatively cool weather, etc. Since weather changes can occur without much warning, sampling to capture different weather events is challenging. However, you can learn a lot about how your stream or lake responds to these changes.

If you are monitoring storm events, you might want to sample before, during and after the event. The idea is to see how the stream or lake responds hydrologically and how levels of indicators in the water column change. This might mean obtaining a set of samples as follows:

- Before the event begins, to establish background conditions;
- As water levels rise (and polluted surface runoff enters the stream or lake);
- As water levels fall after the storm; and
- When water levels return to pre-storm conditions.

Of course, this requires that you have an accurate prediction of when the storm will begin and end. You then analyze your results to see if the storm event seemed to cause the levels of the indicators to change.

List any special weather events you will try to capture with your monitoring.

Step 8: What Are Your Quality Assurance Measures?

Quality assurance is a system you put into place to ensure that your data will meet standards of quality that you define. Essentially, it's the way you try to determine and ensure that your data meet the data quality goals and objectives we described in study design Step 4 ("What Are Your Data Quality Objectives?" page 2-12).

Your quality control management system includes most aspects of your monitoring program:

Organization and Planning: This includes much of the basic organizational work described in more detail in the "What is Already Known About Your Watershed?" (page 2-3) and "What Are the Tasks and Who Will Do Them" (page 2-32) study design steps. It includes things like your training requirements, written job descriptions, how the paid and volunteer personnel are organized, and the basics of managing your volunteers. For quality assurance, the main relevance is the documentation of these elements, which you will do in your study design. Training recommendations for each type of assessment can be found in Chapter 5.

*Sampling and Analysis Facilities, Equipment and Supplies***:** The actual sampling and analysis of your water body will include your needs for laboratory and storage facilities; how you will care for, calibrate (prepare for measurement) and maintain your monitoring equipment; and how you will manage your monitoring supplies. For quality assurance, the main relevance is the documentation of these activities.

Data Management: Quality assurance for data management includes the measures you take to ensure that the data are properly recorded on field and lab sheets and accurately transferred to a computer or summary sheet (data entry and validation) for analysis. Procedures for data management are described in more detail in study design Step 9 "How Will You Manage, Analyze, and Report the Data?" (page 2-28).

Documentation: Putting everything in writing is a very important quality assurance measure. It helps you keep track of your procedures, it provides a written reference for your volunteers, and it provides a resource for people outside your program to discover what's behind your results. Things that you should put into writing include manuals, equipment and supplies records, sampling locations, field and lab sheets, your study design and a QAPP (if required). Documentation can also include a set of procedures known as chain of custody. Chain of custody refers to identifying and documenting each person that handled the sample. Unless your data is going to be used in some legal or regulatory proceeding, you don't have to worry about rigorous chain of custody. For most programs, it can be as simple as having places on your field and data sheets for samplers and analysts to sign when they take custody of and complete their work on a sample.

Reporting: Based on your evaluation, you decide which data you will report. If you didn't meet your data quality objectives, you may decide not to report certain data or you may decide to report it but note your lack of confidence in its accuracy, precision or completeness. You also decide what will go into your reports, how frequently you will produce them and who receives them.

Table 8A: Quality Control Measures

These are specific measures you will take during the collection and analysis of your samples to ensure the *accuracy* (how close to the real result you are) and *precision* (how reproducible your results are) of your monitoring. The purpose of quality control procedures is to let you know right away if you have a problem, so that you can correct it. Quality control procedures include both *internal measures* analyzed by the project field volunteers, staff and lab, and *external measures* analyzed by people and / or labs (also known as a "quality control lab") outside of your program.

Consult with your technical committee and / or DEP staff to help you determine the general quality assurance measures you will use. Next, consult Chapter 5 and Appendix 4 for recommendations on internal and external quality control measures for the assessment(s) you selected in study design Step 5. General Quality Assurance / Quality Control (QA / QC) requirements are listed with each assessment in Chapter 5. Tables 1 and 2 in Appendix 4 list specific quality control measures for each indicator for basic and advanced assessments. Determine which quality control measures you have the resources and capabilities to carry out and select these for your program. Your human and financial resources and expertise may limit your ability to do quality control measures. Your resources may also limit the water quality indicators for which you can do adequate quality control.

This table focuses on the quality control aspects of quality assurance. General QA / QC approaches for each assessment are recommended in Chapter 5. Specific quality control measures for each indicator are recommended in the tables in Appendix 4.

Indicators

Many quality control measures are unique to specific indicators. Other measures apply to all, or some indicators. List the indicator (or group) to which quality control measures will be applied.

Internal Quality Control Measures

These are measures that are taken by your project's volunteers and staff in the field and in the lab. See Appendix 4 (page A4-2) for a list and definitions of each. List the measures in the table.

External Quality Control Measures

These are measures that involve people or labs outside of your program. If you will be carrying out external quality control measures, locate a quality control lab – an independent lab that can run external quality control measures for you. Private labs, state environmental labs, federal labs and wastewater treatment plant labs are some common examples of quality control labs. See Appendix 4 (page A4-3) for a list and definitions of each. List the measures in the table.

Percent Quality Control Samples

There percent of the samples you analyze will be considered quality control samples. Typically, 5-10 percent of the samples are quality control samples.

Table 8B: Evaluation of Quality Control Results

Evaluation (sometimes known as quality assessment) is your assessment of how accurate and precise your data actually are after you have collected and analyzed the samples. This involves calculating the accuracy and precision of your quality control samples and comparing them to your data quality objectives (See study design Step 4, "What Are Your Data Quality Goals and Objectives" for definitions of these terms page 2-12). Decide which statistical tools you will use to evaluate your quality control results. See the list of tools in Appendix 4, *"A Closer Look At Quality Control and Evaluation"* (page A4-1). Were the data accurate and precise? Was your data set complete enough to allow reliable analysis?

In the table, list each type of quality control measures you will run (e.g. duplicate samples, split samples) and the statistical tools you will use to evaluate each (e.g. relative percent difference, standard deviation).

8C: Quality Control Response Actions

If you find errors, or don't meet your objectives, you need to describe what measures you will take to improve data quality. Examples might include steps to identify the source of the problems or error and listing corrective actions taken:

- validate the data;

- evaluate volunteer performance;
- audit field and lab procedures;
- do not use some (or all) of flawed your data;
- change laboratory methods, equipment, or field procedures;
- require more training; and
- change your field or lab sheets, etc.

Finally, if all else fails, you can change your data quality objectives. Remember, you set them and you can change them. You should consult with your technical committee and data users to be sure this is acceptable.

8D: Training

Describe the training for field and lab staff and volunteers. What type of training sessions will be run? Who trains whom? Describe this both for the initial personnel and for those who come on board later.

8E: Training Manuals

List the manuals that field and lab personnel will use.

Step 9: How Will You Manage, Analyze and Report the Data?

Dealing with data involves converting raw data into useful information that sheds light on the answers to your monitoring questions. That process has three main steps: 1) data management; 2) data analysis; and 3) data reporting. Managing data includes recording it, entering and validating it and summarizing it. We highly recommend using a computer to manage your data, with either a spreadsheet program or a database, depending on your computer resources and skills. Analyzing data includes making sense of it and finding the story. Reporting data involves telling the story in various ways to various audiences.

The worksheets in Appendix 6 are organized according to these tasks; and in filling them out you describe how you will carry out each of these tasks.

9A: Data Management: Recording Data

Raw field and lab data will be recorded on field and lab sheets. Describe the information that will be recorded on these sheets. We suggest the following:

Field Sampling Data Sheet Information

General

- site location name
- sampling date
- monitors' names
- surface water conditions
- additional descriptive comments
- water body or watershed
- tidal stage or flow
- precipitation within last 12, 24, 48 hrs.
- general visual observations
- current weather conditions

For each sample or measurement

- the time each sample or measurement was taken
- unique ID number for each container
- depth of sample or measurement
- type of sample collected
- note if a Quality Control Sample
- type of sample container used
- site number where sample was taken
- sample preservation technique (if any)
- field measurement results

For when the sample is delivered to the lab

- time the sample arrived at the lab
- who checked in the samples at the lab

Lab Data Sheet Information

General

- waterbody or watershed
- lab analysis date
- computer data entry person
- additional descriptive comments
- name of lab
- who checked in the samples at the lab
- data proofer

For each sample

- bottle number or sample ID number
- time sample was collected
- time sample analysis was begun
- analysis results (raw)
- depth or type of sample
- who performed the analysis
- quality check results
- site number for each bottle
- time sample was received at lab
- time sample analysis was finished
- analysis results (converted to final reporting units)
- quality checks performed
- note if a Quality Control sample

9B: Data Management: How Field and Lab Sheets Will Be Handled

In this section, describe how the field and lab sheets will be handled: How will field sheets get to the lab? How will the field and lab sheets get from the field samplers and lab analysts to the data entry person? How will the sheets be checked for proper recording and missing data? How and where will they be stored before and after data entry?

9C: Data Management: Entering and Validating Data

Identify the computer hardware and software you will need to manage your data. Generally, either a computer database program and/or a spreadsheet program are used to enter, store and retrieve data for analysis. If your data management skills are limited, or if your anticipated data set is small, you should probably start with a spreadsheet.

Data entry involves taking the numbers from the field and lab sheets and entering them into a computer database or spreadsheet either in raw numbers (e.g. quantity of a titrant used or a hydrometer reading) or in final reporting units (e.g. concentration in milligrams per liter).

Data validation involves checking the data entered into the computer against the data on the field and lab sheets to assure that it has been entered correctly. Ideally, this should be done by someone other than the person who entered the data, and entries should be checked to assure correct entry and that the results are possible (e.g. a pH of 31 is not possible) or within an acceptable range. It is good practice to indicate on each data sheet that it has been validated.

Describe how the data your program gathers will be entered and validated by answering the four questions asked on the worksheet.

9D: Data Analysis: Summarizing Data

In order to analyze your data, they need to be in a form that allows you to view the entire data set, or the relevant parts, in a way that reveals patterns and trends. A table, if it's not too large, is a good place to start. However, for large data sets, you will need to reduce this mass of numbers to something more manageable. Statistical summaries can help. If you have a large data set or data from several years, presenting all of it will be cumbersome and your story will be buried amidst the numbers. Statistics are simply descriptions of a set of data. Using some simple statistics, you can reduce the volume of data to relatively few numbers that summarize the data set. Commonly used statistics include *averages* (known as arithmetic means), *geometric means*, *medians*, *ranges* and *quartiles*. Be aware, however, that these summaries become highly un-representative of your data with just a few data points. A minimum of five data points is recommended to calculate any of the statistical summaries.

Your study design should describe which statistical summaries you will use to reduce your data set to a manageable size.

9E: Data Analysis

You posed one or more monitoring questions in study design Step 2 ("Why Are You Monitoring" page 2-7). The data analysis step is where you use your monitoring results to answer your question(s), and where you use your quality control data to evaluate whether you met your data quality goal and objectives. Evaluating your quality control data is described in study design Step 8 ("What Are Your Quality Assurance Measures?" on page 2-25). Here, we will focus on your monitoring results.

Almost all of the questions we suggest for monitoring involve comparing your monitoring results with *reference conditions*. Reference conditions can be actual conditions at a designated reference site, or general theoretical statements about what the condition of the water body should be like in a region.

Conditions at reference sites are used as benchmarks, against which conditions at the other sites are assessed. For baseline monitoring, these sites represent the least impaired conditions in a watershed. For stream impact assessments, these sites are upstream controls, representing conditions before the impacts are integrated into the stream.

Theoretical reference conditions describe expected conditions based on historical data or commonly accepted requirements of human health or aquatic life, as opposed to actual conditions at a reference site. In this case, you are comparing your results for each indicator with the expected value for that indicator. You determine whether it is above or below that value (for some indicators, above is good; for others, below is good) or within an acceptable range. The state water quality standards[9] would be a common example of theoretical reference conditions. The *water quality criteria* within the standards describe the conditions that need to be achieved in order to support human and aquatic life uses designated for a particular water body. These conditions are described for various water quality indicators such as bacteria, temperature, dissolved oxygen, pH, etc.

Your study design should describe what you would use as reference conditions to analyze your data. It should also describe your data analysis process. We suggest the following data analysis process:

1) Review and interpret the data "in-house" to develop preliminary findings, conclusions, and recommendations.

   Findings: Findings are observations about your data, based on your statistical and visual summaries, and comparison of your data with reference conditions.

   Conclusions: Conclusions are your explanation of why the data look the way they do (e.g. why they don't look like reference conditions) and how they relate to your study question(s).

   Recommendations: Recommendations are based on your findings and conclusions. They can take two forms: *actions* that should be taken, and *further information* that should be gathered.

2) Review the data and your interpretation of it with your technical committee. They can verify, add to or correct your interpretation of the results.

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[9] Pa. DEP – Chapter 93. Water Quality Standards

3) Review the data and your interpretation of it with the people who will use your data – for example, the public, waterbody users and government officials.

9F: Data Reporting

Once you have analyzed your monitoring data, decide who you will report it to, how you will report it and what formats you will use. By "reporting," we mean presenting your results to your intended audiences.

Who Is It For? The audiences for your data are your intended users. Remember them? You identified them back in study design Step 2 ("Why Are You Monitoring?" page 2-7). They can range from the general public to resource managers and regulators in federal and state agencies.

What Type of Report? There are many ways to report your results: through video, written reports, the Internet, oral and slide presentations and others. You should tailor your reports to your audience. If you try to present the same report to the general public in the same way that you presented it to resource managers and regulators, you're not going to reach them very effectively. We recommend that you at least produce a written report that summarizes your work and the results for your most rigorous audience. This is the basic foundation for all your other presentations. When you have completed your most comprehensive written report, you can prepare different types of presentations for different audiences.

What Type of Format for Your Written Report? We suggest that your written report summarize your monitoring activities and results, state your findings and conclusions and make recommendations for actions to address problems or changes to your sampling program, if needed. Some programs produce an annual "state of the watershed" report that summarizes and analyzes the results of the year and all previous years. Many highlight trends, clean-up progress, new trouble spots, etc.

Remember that the style, length and content of your report should be geared to the audience you are addressing. We recommend the following generic report format that can be adapted to different audiences:

I. **Introduction:** Brief description of both the area and your program (including maps)

II. **Project Description:** Brief summary of your study design

III. **Results**

   A. How Were the Data Analyzed?

   B. Findings

   C. Conclusions

   D. Recommendations

Acknowledgments: Who made your program possible?

References: What information sources did you use to prepare your report?

Appendices: Include your summarized data and any other information that you wish to include, but would detract from your narrative report.

Step 10: What Are the Tasks and Who Will Do Them?

Describe the major tasks and key program personnel that might be associated with a monitoring program.

Table 10A: Major Monitoring Tasks

This table is set up to help you keep track of the tasks and who will do them.

Major Project Tasks

Organizing your monitoring activities involves a set of tasks that produces and builds on the technical decisions you have made in your study design. Here is a list of many of the major tasks:

- Find a lab (if needed);
- Purchase equipment;
- Recruit and organize volunteers;
- Train field and lab volunteers;
- Monitoring;
- Quality assurance;
- Analyze your results;
- Report your results;
- Present your results; and
- Evaluate your study design.

Who Will Carry Out (Position Title)

The scope of your monitoring program will determine how many and what kind of people you will need to carry it out. Following are some possible positions that you might recruit volunteers to do. Note that some may become paid positions, if the workload is such that it's unreasonable to expect a volunteer to do it. The major responsibility of each position is described briefly.

Possible Program Coordination Positions

These positions carry much of the responsibility for making sure that there are people in place to carry out the monitoring. They may become paid positions.

Program Coordinator: Oversees all the monitoring program tasks listed in the previous section to see that they are carried out.

Volunteer Trainer: Trains the volunteers on how to carry out their jobs. Note that this might be the program coordinator, lab coordinator, volunteer coordinator, data management coordinator or a consulting person or organization.

Lab Coordinator: Oversees and coordinates the lab analysis of samples and does the training of any laboratory volunteers. If you have recruited an outside lab to run your analyses or quality control samples for you, be sure to identify the person in that lab who will be responsible for reporting to you and answering any questions you may have.

Quality Assurance Officer: Responsible for seeing that your quality assurance measures are carried out. If you have produced a Quality Assurance Project Plan, this person would be responsible for seeing that it is carried out. Note that this could be the program coordinator the lab coordinator, or a person outside of your program.

Volunteer Coordinator: Assures that volunteers are in place to carry out the tasks, including recruiting and scheduling volunteers, communicating with them on a regular basis to be sure that they are having a good experience and thanking or rewarding them for the work they are doing.

Data Management Coordinator: Assures that all the field and lab data are computerized for summary and analysis. This may include setting up the software for data entry, and producing the data summary, while also overseeing volunteers that enter the data, validating the data.

Technical Committee: Provides advice and assistance to the program coordinator in preparing the study design, troubleshooting problems and interpreting your results (see study design Step 1, “Getting Started” for more information on organizing a technical committee).

Possible Monitoring Positions

Field Monitor: Collects and records samples, observations and measurements in the field and drops them off at a sample drop-off point or a lab.

Sample Runner: Transports samples from a sample drop-off point (if you have one) to the lab. Note that this may be unnecessary in a small watershed where samplers drop their samples off at the lab.

Laboratory Analyst: Analyzes and records the results for field samples. Lab analysts work under the supervision of the lab coordinator.

Data Entry Volunteer: Enters the field and lab data into a computer. Works under the supervision of the data management coordinator. May also validate data entered by another volunteer.

Speaker: Makes public presentations about the program and the monitoring results

You should develop job descriptions for each of these positions *before* you recruit people to fill them.

10B: Technical Committee

Form a technical committee of people who can provide you with advice and assistance in preparing your study design and by collecting information on the resource conditions and issues in your watershed.

Sample Job Description: Technical Committee

Role: Advise project staff on the technical aspects of the program.

Responsibilities:

- Decide on data use goals and data quality objectives to address the program goals and objectives;
- Develop study questions;
- Review and comment on the study design;
- Recommend, review and comment on quality assurance / quality control procedures;
- Assist staff in solving technical problems with the monitoring;
- Review and comment on drafts of manuals and training materials;
- Review protocols annually and recommend changes as needed;
- Assist staff in interpreting the results;

♦ Review and comment on reports;
♦ Attend two meetings and be available as needed for advice; and
♦ Commit to about 20 hours per year to review documents, attend meetings and provide telephone consultation.

Ask the resource people you identified in study design Step 2 (page 2-7) to serve on the committee. Give or send them a copy of the job description and be clear as to what is expected of them in terms of their time and expertise. Remember, you're asking professionals to donate services. The least you can do is let them know the extent of the donation you are requesting so they can decide if it's something they can do.

Areas Of Expertise

Determine what expertise you need on your technical committee. Suggested areas of expertise include:

- stream / lake biology
- stream / lake hydrology
- local river / lake uses and problems
- data management
- field and lab methods
- stream / lake chemistry
- how state agencies work
- data interpretation
- business environmental compliance
- laws and regulations

Members

Identify the resource people you will approach to be on your technical committee. Don't forget local businesses. They often have environmental compliance staff who can provide good expertise and good connections with the business community.

Study Designs and Quality Assurance Project Plans

If your program is using U.S. Environmental Protection Agency (EPA) funds, you must have an EPA-approved Quality Assurance Project Plan (QAPP) before sample collection begins. The QAPP is a written document that outlines the procedures a monitoring project will use to ensure that the samples participants collect and analyze, the data they store and manage and the reports they write are of high enough quality to meet project needs. EPA guidance on the preparation of QAPPs is available from EPA's Office of Wetlands Oceans and Watersheds in *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (ask for document #EPA 841-B-96-003).

So, what's the difference between a QAPP and a study design? Let's take a look at the content:

The Study Design

The study design is a technical document, formatted and written to be understandable to you and your group, and anyone who wants to know the design of your monitoring effort. It's focused on documenting your choices in a consistent manner, but in less detail than the QAPP. The Study Design has 10 steps which document the choices you will make:

Step 1: What Is Already Known About Your Watershed?

Step 2: Why Are You Monitoring?

Step 3: What Will You Monitor?

Step 4: What Are Your Data Quality Objectives?

Step 5: How Will You Monitor?

Step 6: Where Will You Monitor?

Step 7: When Will You Monitor?

Step 8: What Are Your Quality Assurance Measures?

Step 9: How Will You Manage, Analyze and Report the Data?

Step 10: What Are the Tasks and Who Will Do Them?

The QAPP

A QAPP is a technical document formatted to meet the needs of EPA reviewers and designated data users targeted by your program. It is focused on documenting the choices in a consistent manner among a wide variety of program types across the country. The QAPP has 23 elements:

Project Management

1) Title and Approval page
2) Table of Contents
3) Distribution List
4) Project / Task Organization
5) Problem Identification / Background
6) Project / Task Description
7) Data Quality Objectives for Measurement Data
8) Training Requirements / Certification

Measurement Data Acquisition

9) Sampling Process Design
10) Sampling Methods Requirements

11) Sample Handling and Custody Requirements
12) Analytical Methods Requirements
13) Quality Control Requirements
14) Instrument/Equipment Testing, Inspection and Maintenance Requirements
15) Instrument Calibration Frequency
16) Inspection/Acceptance Requirements for Supplies
17) Data Acquisition Requirements
18) Data Management

Assessment and Oversight

19) Assessment and Response Actions
20) Reports

Data Validation and Usability

21) Data Review, Validation and Verification Requirements
22) Validation and Verification Methods
23) Reconciliation with Data Quality Objectives.

As you can see, a QAPP is very thorough and detail-oriented. It describes all the details of your field and lab procedures.

Should You Do a QAPP or a Study Design?

Unless you are required to do a QAPP, we strongly suggest that you start with a study design. We think that the preparation is easier, more intuitive, and you are less likely to get lost in the forest of details that a QAPP requires. In short, you will be able to focus on making good choices, rather than all the details.

Once you have done a study design, it's a fairly easy step to a QAPP. Most of the elements required by a QAPP will be in your study design, but perhaps not in as much detail. To make it easier for you, if there is a QAPP in your future, we have cross-referenced the study design steps in this workbook to the QAPP elements listed in the in *The Volunteer Monitor's Guide to Quality Assurance Project Plans.*

If you follow the guidance in this handbook, you should be able to fairly easily prepare a QAPP, should you need one.

STUDY DESIGN	***QAPP***
Step 1: What Is Already Known About Your Watershed?	Element 4: Project/Task Organization Element 5: Problem Identification/ & Background
Step 2: Why Are You Monitoring?	Element 4: Project/Task Organization Element 5: Problem Identification/ & Background
Step 3: What Will You Monitor?	Element 6: Project/Task Description Element 10: Sampling Process Design
Step 4: What Are Your Data Quality Objectives?	Element 7: Data Quality Objectives
Step 5: How Will You Monitor?	Element 10: Sampling Process Design Element 11: Sampling Methods Requirements Element 12: Sample Handling and Custody Requirements Element 13: Analytical Methods Requirements
Step 6: Where Will You Monitor?	Element 10: Sampling Process Design
Step 7: When Will You Monitor?	Element 10: Sampling Process Design
Step 8: What Are Your Quality Assurance Measures?	Elements 8, 9, 15, 19, 21 General Element 14 QC Measures Element 20 Evaluation Element 19 Response
Step 9: How Will You Manage, Analyze, and Report the Data?	Element 19: Data Management Element 21: Reports Element 22: Data Review, Validation and Verification Requirements
Step 10: What Are the Tasks and Who Will Do them?	Element 6: Project/Task Description Element 4: Project/Task Description