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Listening to Watersheds

A Community-Based Approach to Watershed Protection

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River Network and U.S. Environmental Protection Agency

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Forward

I am a member of the Otter Family located in the Tribal Community of Mashpee. As it has been since before our human memory, this is the Territory of the Wampanoag Federation our Homelands include what are now "massachusetts" and eastern "rhode island." My great Honor is to be the blood of my Ancestors, who seen themselves as the flesh and bones of Nitimigaho, the First Mother of All. Among my most profound and sustaining experiences, is the awareness of Spirit-Beings, known as Manitou. They are everywhere, in all things Seen and Unseen, inhabiting dimension and place, and having no limitation in form, time, and space. Collectively and personally, Manitou connects to us thru ceremony. Ceremonies heighten our awareness and enlightenment, as we become more spiritually alert to Life in a fuller capacity. Manitou has shown and revealed that the Great Mysteries are plentiful, awe inspiring, and beautiful beyond Belief. Among those whom we regard as Manitou, is the Water. Such a phenomenal substance, and every much a Living Being.

The Manitou of this Living Being is known to us as, Nipinapezik and regarded as one of our Great Mothers. She is a central presence in our Ceremonies and we sing Songs of Honour to Her. Usually, the Women will address Her on the behalf of the People gathered in Community/Ceremony. Wampanoag Spirituality acknowledges that Womankind carries forth the Life of All Beings on the Earth. Our Ceremonies provide the relationship to the Feminine l qualities of Creation and Life. Preponderantly, Womankind is reflected in most of our Ceremonial Practice, Beings, and the Sacred. I see in myself, service to Manitou and the Great Mothers of Life.

In the common secular experience, Water is truly one of the few essential ingredients. necessary for planetary Life, the other essentials being Food/Sustenance, and Air. An Elder once shared these thoughts, that, ...human Beings can live about 60 days without food, about 10 days without water, about 5 minutes without air; that is the order of human survival.... We should always approach Water with such awareness. All Living Beings have a tremendous regard for the presence of water. I have seen ants, snakes, and bees drinking water. We certainly appreciate water when we do not have it. Many times in our Fasting, water has been the most honored, prayed to, Being, as well as the most enjoyable fruit in breaking our Fasts. When consuming water, I am conscious of giving Thanks to Her for all that She is.

Aside from the obvious human need for water, watersheds, marshes, flood lands, and swamps are equally, indispensable to the Wampanoag, other First Nations, and to all Natural Life of Creation. While in our common lives, supermarkets and pharmacies are primary sources of medicines and food; these marshy wetlands, historically and in modernity, provide our People with medicine, food, sacred space, and refuge. Our hunting, fishing, gathering and harvesting places predominately are located in these types of areas.

In these spaces, Ntonqasinwame, All Who are Our Relatives, are equally provided with such life essentials, including housing. The natural process of Life – the interaction of living matter and beings on Earth's surface, creates aquifers. Aquifers, the main source of water in our homes are now feeding and facing annihilation through industrial activity.

With such importance of water and watersheds, human preoccupations with economy must become more mindful and inclusive of devising protection and understanding of art dependence on watersheds.

It is incomprehensible to consider any destruction of watersheds. Without trees, fertile earth, clean air, water, the integrity of life cannot be maintained. Based on humanities blind willingness to continue mindless, thoughtless pursuits of economic frontiers at all costs, will inevitably manifest the augury that there will come the time when our Great Cosmic Mother, the Earth, will no longer be able to sustain humanity and be able to care for All Life.

As long as human avarice dictates the corporate land-based development as the primary source of economic wealth, Life in its natural being, inclusive of humanity, will be confronted by annihilation. Continued obtuse human manipulation of the balanced ecological interdependency of Creation, through thoughtless, unknowledgeable human activity will likely produce this most probable outcome. When the trees are gone, as the practice of clear cutting will produce, the watersheds filled and obliterated, the desertification of our forests and our Lives will result. More personally, this process of desertification includes what we are doing to our Bodies. Our bodies, much like the earth, are 75% water-based. Our body tissues or water saturated, our blood, brain, eyes, bone marrow, organs all require water in order to maintain and sustain function. In fact, there is no bodily function that is not based on the use of water. I believe that this is basically true for the Way of Creation, the Earth, and Life. We do not presently consume enough water intake. In most homes in our community, people consume a water-based beverage rather than just water; for instance, coffee, juice, and pop are consumed more regularly than water. I sense that this is true throughout human societies in western industrial states. Additionally, the quality of water we do consume is by large, the composition of a number of carcinogens, particularly in cities and densely populated areas. Over the long-term, we are submitting ourselves to the desertification progression.

The effort put forward by this handbook and guide to sustaining our waterways and watersheds, represents the important work of our time as First Nations. This sensible approach of bonding western scientific procedure and the traditional scientific knowledge of First Nations will lend the necessary support and enhancement of the traditional tools to protect, work and learn from, that have enabled First Nations to survive. These tools include our sovereignty, original jurisdiction, and political basis of our historic, inherent Life as a People. This work will also provide people, generally, with the potentials to move beyond governments' and businesses' willingness to circumvent common sense. Destruction of All Life by human destruction, is not, after all, and can never be the legacy of humanity.

gkisedtanamoogk
Wabanaki Nations
January 2001

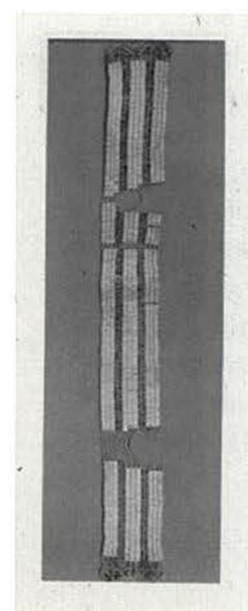
Note: Uncommon capitalization of words is reflective of Wampanoag Cosmology, and is not to be construed as grammatical error.

Preface

The purpose of this guidebook: a community-based approach to watershed management

Our focus in writing this guidebook is to begin a dialogue with Native communities about having their knowledge and beliefs central to a watershed assessment process, producing better assessments and healthier watersheds. Just as the Colonists used the Haudenosaunee Great Law of Peace as a guide to craft the United States Constitution[1], the purpose of this guidebook came to be, with permission, modeled after their Two-Row Wampum Belt (Kaswentha). The purpose is to "recognize that each People is to travel down this river together, side-by-side, but each in their own vessel." Kaswentha records a treaty that the Haudenosaunee made with the Dutch over 400 years ago and this guidebook attempts to embody the same spirit by understanding that neither is "to steer the other's vessel" but listen and "help each other, from time-to-time, as people are meant to do."[2]

We recognize that the Native peoples of this continent understood the concept of watersheds and the interconnections necessary for good health long before modern scientific theories were developed. And as suggested by Louie Wynne, member of the Spokane Tribe, we all need to know how to listen before we can understand anything – especially the knowledge and lessons contained in the teachings of Native legends. Thus, we have begun the process of listening.

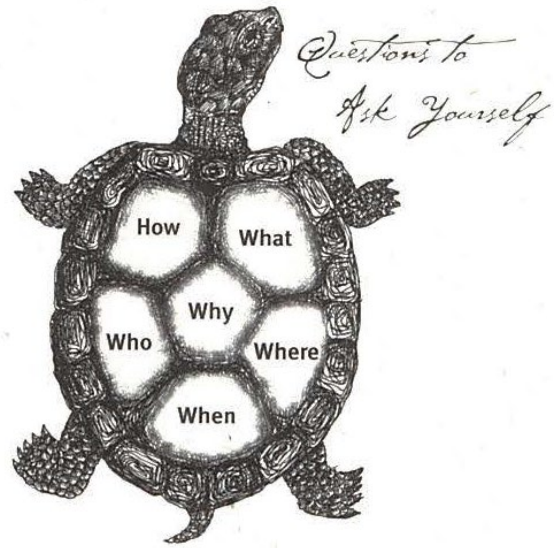


The two parallel rows of purple wampum beads (made from shells) represent two vessels traveling down a river – the spirit of the Haudenosaunee (a birch-bark canoe) and the Dutch (a ship). The three rows of white wampum beads separating them symbolize peace (respect), a good mind (equity) and the power of a good mind (empowerment).

In our experience, we have seen the success of a community-based approach in developing solutions to problems. River Network has promoted and trained Native and non-Native people in watershed assessment across the Country for over 10 years. In this guidebook, we Present what we've learned from our Native partners and advisors about a watershed assessment that has the community's knowledge at the center of the process. It is our hope that this approach will start to make Native and non-Native "scientific" knowledge accessible, understood and used by staff and community members within a cultural context. We make no pretense that the is document has captured the wide range of knowledge and beliefs of Native communities. However, it is our hope that the examples we use will reveal our acknowledgement, respect and commitment to this process.

"In the pueblo worldview, the message from the spiral is that interconnections are a vital part of our world, and we see evidence of that from the patterns in our fingerprints, the way hair grows on a baby's head, to spirals in galaxies and in DNA. The lesson that can be drawn from this is to look at watershed protection as one tool that Indian communities can use to revitalize themselves." –Robert Gomes, Taos Pueblo

The organization of this guidebook



In honor of Turtle Island, we created a turtle that serves as the carrier of the watershed assessment process. In addition, "the turtle's pace reminds people to slow down and pay more attention as we interact with the world."[3] This is a very important aspect of designing a watershed assessment. Each of the chapters is represented in one of the plates on the turtle's shell. The steps in a watershed assessment have been organized into six chapters – *Why, What, Where, When, Who* and *How* – representing the major categories of questions in which we hope decisions will be made. Because the question Why is the most crucial, it is placed at the center with the other five questions building on it in a spiral pattern. The other five interconnected questions are the only ones suggested for regular evaluation in the iterative process of watershed assessment.

The Endnotes and Resources for each chapter are found at the back of this book.

Using this guidebook

Producing watershed assessment guidance in written format means that the is document is, by default, much more linear than the actual process. Consequently, there will be some overlap between the different parts of this document. But you should be able to use each part of this document separately, while understanding that the decisions being made are intricately linked to each of the other parts. For example, the decisions you make about data quality are influenced by your definition of healthy data analysis methods chosen and how you expect to use the data. If you decide that the level of one parameter in a healthy watershed should be pretty low, you might want to collect and analyze samples using methods that capture the low range of values. And if you will be testing for significant differences between sites, it is necessary to take enough replicate samples to compare the variability within each site to the variability between each site. Finally, your analyses might lead you to change what you are measuring, bringing the assessment full circle and changing the course of the next round of monitoring.

> Each Native community will use this document differently and weave the assessment of science and process into its own pattern. It is suggested that "in some sense, every reader 'finishes' every book according to his or her experiences and needs and beliefs and potential."[4] We hope that you will do the same with this document by taking possession of what you are reading. Take the time to underline, comment and question. When you "finish" this document, the process will be your own.
>
> Most of all, we hope you see this document as open to your influence and observation, and join the dialogue that will help to improve upon these ideas and methods in future editions.

Watershed assessment is a continuous combination of developing, testing and re-evaluating methods for evaluating watershed health. Thus, we hope that regardless of where you start in this document, you will move back and forth between the other chapters to continually remind yourself of where you are going and the path that has taken you there.

The audience for this guidebook

The audience is primarily intended to be tribal environmental departments that are just beginning to design their watershed assessment programs and need some guidance on doing the science within a program that involves the larger Native community. Programs that have extensive experience doing watershed assessments may also benefit from exploring more community involvement in their programs. Finally, agencies and nonprofit organizations that are working with, or interested in working with Native communities may benefit from learning about the cultural context.

Introduction

What is a watershed assessment?

There are many definitions of watershed assessment in various guidance documents. In this guidebook, we use our own definition that paraphrases what most others seem to have in common.

For our purposes, **a watershed assessment** is: **a long-term, on-going process of trying to understand the changing conditions of watershed health**.

Watershed assessment is part of the overall process of caring for the watersheds (often called "watershed management").

Importance of Assessment Design

Billy Frank Jr., Chairman of the Northwest Indian Fisheries Commission (www.nwifc.wa.gov), writes in their newsletter, "People need to slow down and look ahead." Although it can be easy to get caught up in all of the details and fast-paced lifestyle of today, Billy provides a reminder that "Indians traditionally believe that decisions we make today should be based on the impact to the next seven generations." The first part of doing a watershed assessment can be a great time for this reflection, to return to basic values and to think about why the work is being done. During this process, take the time to listen to the tribal members.

Designing your assessment may be the most important step in understanding the watershed. Think of it this way, if you want to tell anyone why you did the work or how you came up with the information, you can share your assessment design. Besides documentation, an assessment design serves some very important purposes for the tribe and other people with whom you share your information, including the following:

- It helps the tribe to focus on what it is trying to accomplish with the assessment,
- It allows the tribe to select the most appropriate strategy to address the issues that are important,
- It gives the tribe time to decide what information will be shared and with whom, and to develop a process for ensuring that privacy is respected,
- It prevents waste of time and money on equipment and procedures that are inappropriate,
- It provides authorized users and those who might question the tribe's data with a way to assess the quality of the results,

- It allows new personnel to "pick up the threads" and minimizes the impacts on the continuity of monitoring activities,
- It allows the tribe to re-evaluate monitoring efforts every year in an orderly manner and make changes as needed, and
- It provides information that can be quickly and easily translated into a Quality Assurance Project Plan (QAPP), if necessary.

Like assessment itself, the design is an ongoing process where you revisit your design and change it as needed.

Assessment Design Process

We've simplified the assessment process into the following steps:

1. **Establish you Expectations**
2. **Determine Current Conditions** *(Watershed Assessment)*
3. **Move Your Data to Information**
4. **Use the Information to Tell the Story**

1. **Establish Your Expectations**

   What are your goals for a healthy watershed and its community? How will you know when you've achieved them? These expectations will provide the benchmarks against which you compare current conditions. Processes for establishing your expectations include:

   - Exploring the tribal members' traditional ecological knowledge about healthy watersheds,
   - Integrating tribal members and their knowledge into the basic ecological understanding of the watershed(s) and the process of making decisions about the necessary connections in a healthy watershed,
   - Incorporating all of this knowledge into their monitoring purposes.

2. **Determine Current Conditions**
   (Watershed Assessment)

   Determine current conditions by:

   - Gathering existing information on stressors and watershed response indicators,
   - Gathering new information by measuring or observing stressors and watershed response indicators, including aquatic life, water quality, hydrology, channel, erosion, vegetation, etc.

3. **Move Your Data to Information**

   Move your data to information by:

   - Comparing current conditions with expected conditions,
   - Synthesizing what seem to be the differences,
   - Identifying healthy waters,
   - Identifying impaired waters.

4. Use the Information to Tell the Story

Use your assessment results to develop a protection/restoration plan to:

- Share some of the knowledge gained from your listening experiences,
- Use your assessment results to develop a plan to protect healthy waters or restore impaired waters.

Why

Perhaps the most important step in listening to watersheds is deciding why: why does the tribe want to assess the health of the watershed(s) and waters that live within them? One of the central reasons might simply be that water is life. Both the quantity and quality of water in rivers and their watersheds is important for their life and the life they bring to all relations. The Haudenosaunee believe that "the Creator made the river, not just as H20, but he made the rivers a living entity," and that this living entity is a part of the entire living whole of the earth. This traditional perspective saw that "those rivers of Mother Earth and lakes will be the blood veins of our Mother, our beautiful Mother" and that the rivers had a responsibility to cleanse and purify Mother Earth and carry sustenance to the rest of Creation. Understanding this interconnectedness meant the clear responsibility of the people to water and all other relations. This is exemplified by the notion that people must make sure that the waters are always healthy so that "there will not be a heart attack someday to our Mother."[5]

Unfortunately, modern human society has detrimentally affected the balance of interrelations in watersheds, and therefore all other relations within. For instance, Native communities have seen the impacts of dams on water flow and how that has decreased and contaminated their sources of food and places to gather medicinal plants. Native communities also know what it is like to have their ceremonial water so contaminated that they are afraid to drink or bathe in it. Consequently, Native people have become especially susceptible to the human health effects of pollution.[6]

Measuring the health of watersheds, and how humans affect them, can add a lot to what tribes already know. Combining these measurements with traditional knowledge and values can provide the tribe with critical information needed to restore and protect its waters and watersheds. This section describes a process for incorporating the Native knowledge and culturally significant uses and values of water and watersheds into a watershed assessment.

This process involves:

1) Gathering Existing Knowledge

2) Developing a Watershed Vision

3) Setting Assessment Goals for Gathering New Knowledge

4) Establishing Your Expectations

5) Generating Assessment Questions

The suggested combinations of traditional and Western science will produce better assessments, healthier watersheds and help connect more people to their waters.

Gathering Existing Knowledge

Over the past ten to fifteen years, the international community has begun increasingly to appreciate the value of traditional knowledge as a tool in assessing and protecting local environments and in addressing the environmental problems of today.[7] Terry Williams, Fisheries and Natural Resource Commissioner for the Tula lip Tribes, emphasizes the relationship between Indigenous Peoples and their environment as the basis for traditional knowledge.

> The **EPA's Watershed Analysis and Management (WAM) Guide for Tribes** describes gathering existing and new knowledge as levels of effort:
>
> **Level 1 Assessments** are "qualitative" and rely on sources of existing information, which are broad-based, such as maps and reports.
>
> **Level 2 Assessments** gather new data using quantitative methods and involve more time and resources.

"For tens of thousands of years, Indigenous Peoples inhabited massive land bases. During this extensive period of time, we discovered that the natural world provided us with all that we needed, including our medicines, our health and our prosperous economic viability. We incorporated this natural world into our cultural ceremonies. To this day, it is through our ceremonies that we give thanks and appreciation to all of Creation for sustaining us and shaping who we are."

Every community has developed its own system for understanding and relating to its environment. The system is often stored, practiced and passed on through the customs, stories and activities of Indigenous People and their community. One or more listeners collect this "Story" by talking with members of the tribe and preserving their accounts.

The process of getting information about what tribal members, elders or leaders want for their waters and watersheds may be difficult – they may have forgotten what it is like to have someone actually ask them. They may also be reluctant to share this knowledge because so much of it has been taken and/or exploited in the past. Be clear about how this information will be used and protected. Be flexible about how much people are willing to share. Consider how members communicate with one another, discuss the most effective and respectful means of communication and develop ways that make sense to you.

The "Cultural Ecosystem Story"

A "Cultural Ecosystem Story"[8] could serve as your primary source of culturally specific information when determining what the Native community wants for its waters and watersheds. It may also guide your decisions as to what new information you may need to gather.

The financial resources and time allocated to gathering a "Cultural Ecosystem Story" may be different every time it is carried out. It may range from a personal interview of a few purposefully selected community members to interviewing many individuals and extensively documenting the uses of many resources over time. For a watershed assessment, the listener could attempt to seek the knowledge of those in the community whose activities depend on certain resources in the watershed. These resources may include clean free flowing water for spiritual cleansing, certain wetland plants used by basket weavers or rivers that provide suitable spawning habitat for salmon. The longer a community member has observed and directly interacted with one or more resources, the more important that person's knowledge will become to the "Story."[9]

Other Sources of Knowledge About the Watershed

Information about your waters may have been gathered by state and federal agencies, schools, community groups and others. Even though it may not directly relate to your waters of interest, there may be valuable information about impacts and conditions upstream and downstream. And even though there will be gaps in the existing information, it may also alert you to areas of contamination about which you were not aware! Doing your own watershed assessment is a perfect opportunity to fill those gaps and generate new perspectives with your own information.[10]

Information you might find useful include:

- Base maps of land use, surface water and groundwater *(historic and current, digital and hard copy)*
- Photographs *(historic and current, aerial and regular)*
- Lists of wastewater discharges, toxic dumps and other potential contamination sites
- Rare plants and animals and their habitats

Possible sources of this information include:

- State and federal agency monitoring programs
- State water quality assessments under the Clean Water Act ("305b" reports)
- State lists of which waters support their designated uses ("305b" lists)
- State lists of impaired waters ("303d'' list)
- U.S. Geological Survey flow data and National Water Quality Assessment reports
- Volunteer and school monitoring programs
- Local, regional or state watershed assessment reports

After collecting all of this information, you can consider what the existing watershed data says about the status of your waters, and whether existing protection efforts are meeting the needs of the tribe. Combined with traditional knowledge, this information can be a very useful foundation for developing a watershed vision and identifying information needs that might serve as the goals of your assessment.

Developing a Watershed Vision

Geographical and cultural differences will lead each community to develop a unique vision and set of assessment goals for the water and watershed(s). As Pauline Pascall-Flett speaks for her people in the Spokane Tribe:

"Our hope is even though the land was once flooded and even now though the river gets dammed up, even though the river gets polluted, our great grandfather, the wise one, will have mercy upon us and once again chase the salmon upriver to us in nice pure water. The salmon was once our livelihood, providing not only our staple but allowed us to gain other varieties of food in trade from other Tribes, those who had elk, moose and buffalo. We were once salmon people and we long and pray to become the salmon people we once were."

A vision synthesizes the values and beliefs of the community and how the members would like to see those practiced. A good starting point is the knowledge you gathered in the previous step. Based on that knowledge, you can begin to develop summary vision statements by asking tribal leaders, elders and other community members to help you answer these related questions (adapted from the 7 Generations Manual)[11]:

Where did we come from? Where are we now? Where are we going? Where do we want to be?

1) **Where did we come from?** Define how the "Story" reflects the resources with which the community has most closely been involved, how members use those resources, and the values, beliefs and ways of looking at the world that affect that use.

2) **Where are we now?** Build an environmental picture of the community by identifying which resources described in the "Story" are important today, how people interact with and benefit from them, what uses work and don't work, and how the health of those resources might be affected. Use all of the forms of existing knowledge to describe generally the condition of the resources today and what is impacting them.

3) **Where are we going?** Talk about and define what the community thinks will happen to the environment and themselves, if they continue to use resources as they do now and the impacts are not removed.

4) **Where do we want to be?** Talk about and define what the community, wants the health of its people and the resources to look like in the future. Compare this with the answers. to Questions 1 and 2. Highlight anything that should stay the same and anything that might need to change in order to be consistent with the associated value and vision for the future.

Sources of pollution in modern society that might stress the health of the watershed:

Pollution from specific locations ("Point sources")

- Acid mine drainage
- Impoundments
- Injection wells
- Direct sewage discharge
- Leaking underground storage tanks
- Water withdrawals

Resulting from sources such as:

- Wastewater treatment plants
- Food processing plants
- Large animal feedlots
- Pulp or paper producing plants
- Power plants
- Mines
- Dams

Pollution from land areas ("Non-point sources")

- Fertilizers
- Herbicides and pesticides
- Raw sewage
- Exotic plant and animal species
- Petroleum residues
- Soil
- Metals

Resulting from sources such as:

- Lawns
- Farms
- Recreation and tourism
- Underground and above ground storage tanks
- Air pollution
- Landfills
- Unofficial or abandoned dump sites
- Failing septic systems
- Automobiles
- Poor forestry practices
- Paved surfaces
- Construction sites
- Removal of streamside vegetation
- Stocking and planting of non-Native species

Example: Columbia River Inter-Tribal Fish Commission

The Umatilla, Nez Perce, Yakama and Warm Springs Tribes created their own collective vision of what they want for the Columbia River Basin in their work together through the Columbia River Inter-Tribal Fish Commission (CRITFC).

Their summary document (http://www.critfc.org/legal/vision) broadly states that the tribal vision for the future of the Columbia River Basin is: "...one in which people return to a more balanced and harmonious relationship with the environment. It is a vision for the future based both on past tribal teachings and practices and on current science. It is a vision where science serves our teachings and practices but does not overshadow them."

More specifically, the tribes state that: "The tribal vision for the future of the Columbia River Basin respects and reflects upon the tribal memories of the past. It simultaneously looks ahead, with a vision filled with images of Indian and non-Indian use and enjoyment of clean air and water, healthy lands, fish, wildlife, plants and other resources. The tribal vision calls for recognition and appreciation of the spiritual values of these not merely to extract and exploit them for monetary or other economic value they may hold, but to restore and sustain them to bless the human spirit."

"Tribal sustenance is achieved most simply and directly through activities that are termed "harvest" in non-tribal language. But this word, and its more commonly understood meaning, do not fully nor accurately represent the connection between Indian people and the "resources" the earth gives to us for our well-being. It suggests a relationship that is somehow unequal – too one-sided.

For the tribes, "taking fish," and wildlife and plants, cannot be separated from the obligation to "take care of fish" and wildlife and plants. In our past, promises were made and exchanged – and kept. We would provide for each other, we could provide for ourselves – the people and the fish. There have been other promises made, by and to Indian people, in words and on paper. We do not take any of these promises lightly. The tribal vision for the future of the Columbia River Basin is one where, once again, promises made are promises kept."

Setting Assessment Goals for Gathering New Knowledge

Use the tribal watershed vision to develop and prioritize goals for your assessment activities. Revisiting your goals frequently allows you to evaluate the interconnections in your work and see whether other issues are surfacing. Goals can also help your assessment work collect the most useful information with the least amount of time and expense. Use the following questions as a starting point for developing specific goals for your assessment:

What does the tribe want to do with the information collected?

Consider how much information and knowledge the tribe wants to share, with whom, how and for what purpose. Who makes decisions that affect the issues that are important to you? At what scale? Information may or may not be shared with the non-Native community.

The ways in which you might use your information include the following:

1. **Education and awareness**

The goal is to collect data that will be used to increase the understanding and appreciation of the way watersheds work, by bringing together traditional and contemporary knowledge. The information will be used to raise awareness of watersheds as living communities, promote watershed stewardship, give participants experience in exploring and sharing their own knowledge and the process of scientific inquiry, and improve awareness of the impacts of decisions (including cumulative impacts) on the watershed. Data quality is not as important.

2. **Baseline data collection**

   The goal is to collect data that will be used at the community or watershed level to track trends over a relatively long period of time to see if conditions are improving, staying the same or getting worse. The data could be used to quickly identify either problems or successes, in order to assess the need for some corrective action, further study or promote positive efforts. The data quality needs to be sufficient to detect changes in indicators at appropriate levels, and scope of time and space.

3. **Planning watershed restoration and protection efforts**

   The goal is to collect data that will be used to assess current conditions, identify the nature and extent of problems, identify high quality or culturally significant waters for protection, and develop protection and restoration plans. The data collected needs to accurately represent current conditions, and sensitive enough to identify existing and emerging problems – especially if you expect to change people's behaviors or ask them to spend money on finding solutions.

4. **Enhancement of state agency water quality assessments**

   The goal is to collect data that will be used by a state agency in conjunction with its own, to either flag problems for follow-up or identify impaired waters under the Clean Water Act (CWA). Data quality for flagging problems needs only be sufficient enough to detect them. Data quality for identifying impaired waters needs to meet or exceed state requirements. For example, if the data shows that the water(s) don't meet state standards, it may provide enough information to put them on the impaired waters list [303(d)], forcing the development of plans to correct problems (e.g., a Total Maximum Daily Load – TMDL – study). This may be an important step in getting the agency to address issues in non-Native areas that affect Native waters.

5. **Development of culturally specific water quality standards**

   The goal is to collect data that will be used to develop benchmarks or water quality criteria that will be the basis of water quality standards. The quality of the data needs to be sufficient to capture critical levels needed to support designated uses. The data collected will help determine cultural and ecological relationships, existing connections, their conditions and causes both on and off Native lands, the life that is supported and changes necessary to reach goals of the tribe. Water quality standards can play an important role in contemporary society by providing the regulatory and legal basis for water quality based controls that are enforced outside of Native lands.

6. **Designing and evaluating the effectiveness of watershed restoration and protection efforts**

The goal is to collect data that will be used to help differentiate between the problems (e.g., altered hydrology) and symptoms (e.g., eroding riverbanks) and evaluate the effectiveness of implemented solutions. Information on the conditions of selected watershed characteristics before, during and after restoration and/or protection Plans are carried out, will give you valuable feedback about what's working and what's not working. Based on this, you may choose to revise your plans.

Starting with the end in mind, these uses will help you develop goals for the type and quality of information you will want to collect in your assessment. These suggested uses are not mutually exclusive; rather, data collected for one use might be used for several others.

What other information might affect your watershed assessment goals?

- **Treaty Rights:** Consider any treaty rights and to what quantity and quality of water, food or materials the tribe is "legally" entitled and the interactions of these. When you discuss the desired state of the watershed, consider both the quantity and quality of water needed for both traditional and contemporary uses of water by tribal members. Even if the fish don't contain any toxins or heavy metals, there must be enough water in the river to support their entire life cycles. Native communities often have rights to a quantity of water under the Winters Doctrine.

  In Winters v. United States, the Supreme Court held that the 1888 agreement establishing the Fort Belknap Reservation in Montana implicitly reserved the right to use the waters of the Milk River. The resulting doctrine applies to "Indian country" areas whether created by treaty, agreement, executive order, statute or order of the Secretary of the Interior, and has been held to apply to groundwater, as well as surface water. The Winters Doctrine may also include the protection of a degree of water quality as well as water quantity.

- **The Clean Water Act:** If your tribe is receiving any money from the U.S. Environmental Protection Agency (EPA) already, you may have heard your funding referred to simply as a number like 319 or 106. Or maybe you are dealing with whether your waters are on the "303(d)" list? Have you ever wondered whether your program needs to write a "305(b)" report? During all of this you may have asked yourself the common question – what the heck do all these numbers stand for? Well, these are all sections of the Clean Water Act.

  The CWA Act is the first major holistic legislative effort toward understanding, protecting and restoring water quality, and it uses watershed assessment data as the basis of its regulatory actions and voluntary cooperative efforts. The CWA can be an important source of federal funding and regulatory enforcement (e.g., federally recognized tribal water quality standards) for Native communities to undertake watershed health assessment, restoration and protection. However, in order to receive federal funds, there are requirements (described in the next section) that some Native communities may feel are a compromise of their government-to-government relationship with the United States as a sovereign nation.

- **Federal Recognition and "Treatment in a Manner Similar to a State" (TAS):** The first requirement that tribes must fulfill in order to receive federal funds is federal recognition as an "Indian Tribe." However, this may not be something that the tribe is interested in pursuing because since time immemorial, long before the concept of federal recognition by the U.S.

government, Native people occupied all of what became the United States, practiced self-governance and lived according to their own customs and practices. Today, Native communities must reach their own balance of cultural water quality goals and the requirements of federal funding they are willing to accept, if any, in order to get federal help reaching them.

Once federally recognized, tribes must go through another process (sometimes repeatedly) in order to participate in many of EPA's major grant or regulatory programs – "Treatment in a Manner Similar to a State" (TAS)."[12] The CWA[13] authorizes TAS, if certain requirements are met. TAS is what the U.S. government requires of tribes in order to recognize the tribe's authority over its waters to be eligible for federal funding. This is also required in order for the tribe to develop "federally recognized" tribal water quality standards for waters running through tribal lands and enforceable outside of those lands *(described more in the next bullet)*.

Perhaps the most important part of the TAS process is the determination of whether what the tribe wants to do is within its jurisdiction. EPA asks tribes that are applying for regulatory programs to show that they have adequate jurisdiction over the areas to be regulated. It is usually relatively simple and uncontroversial to demonstrate jurisdiction over trust lands or lands owned by a tribe, because tribes almost invariably have inherent sovereign authority to regulate both their members and their territory (although specific statutes may have affected this general principle for some tribes). A more complex and controversial issue is whether a particular tribe has jurisdiction over nonmember activities on nonmember-owned fee lands within the boundaries of an Indian reservation. Updates on that on-going controversy are beyond the scope of this document, so tribes are advised to remain informed about the current rulings and associated implications for tribal work. EPA has not construed the Clean Water Act as a delegation of federal authority to a tribe. Rather, under these statutes, EPA looks to see whether a tribe has adequate inherent authority to run a program.

Although controversy continues to surround the status of Alaska Native villages, their authority and their lands, EPA determines their eligibility for authority similar to all other tribes – on a program-specific basis. The Alaska Native Claims Settlement Act of 1971 (ANCSA), did not terminate the tribal governments, the federal relationship or the federal trust responsibility. EPA's policy is to regard only the governmental entities listed by the Bureau of Indian Affairs (BIA) as the federally recognized tribes under the EPA National Indian Policy and other federal laws and regulations applying to Indian tribes [63 FR 71941 (December 30, 1998)].

- **Tribal Water Quality Standards and EPA Promulgation:** Tribes already have the right to develop and enforce their own standards on reservation land but, under current regulations, even those are supposed to meet the minimum federal water quality standards set by EPA. Enforcing tribal water quality standards outside of reservation land requires federal recognition of them, which comes with the requirements described above and lots more work: If you haven't already developed your own "federally recognized" tribal water quality standards, consider your unique goals and the pros and cons of this process, including the necessary financial and technical resources.[14] Find out which tribes have undertaken the development of federally recognized standard (list available from EPA) and talk to them about their experience. But also talk with. tribes who have chosen not to take that route and discuss their reasons.

If the tribe chooses not to pursue developing their own standards (either now or at all), you will need to think about the core water quality standards that EPA is considering putting in plate (promulgating) for all tribes. Discuss with the community whether the same set of standards for all tribes in what is now the United States will adequately address their needs. Inform EPA of your conclusion and the reasons. Some tribes are concerned that, despite its well-meaning intention, this type of action by EPA represents a paternalistic approach and is inconsistent with the government-to-government relationship between tribes and the United States.[15] Furthermore, and perhaps more importantly, if the standards do no{ incorporate traditional knowledge and law, they may fail to protect the unique concerns and cultural needs of individual tribes and potentially promote further assimilation by replacing traditional practices.

EPA feels that the primary benefit of core federal standards would be to ensure that all areas of Indian country currently without EPA-approved Tribal standards have direct water quality-based protection under the Clean Water Act. Many of the CWA's mechanisms for protecting water quality rely on standards, and that without them, these mechanisms are limited. As of January 14, 2000, it is EPA's intent to allow a reasonable amount of time for tribes that "opt out" of the promulgation of core standards to achieve the protection of water quality standards (WQS) under the CWA for their waters. EPA would ultimately intend to promulgate the core standards for those waters, if this goal is not met. Keep up to date on the current status of this effort.

Example: The Yukon River Inter-Tribal Watershed Council

The Yukon River Inter-Tribal Watershed Council (YRITWC), which grew out of the collective watershed vision of 36 villages along the river, is working on prioritizing issues of concern and implementing a watershed assessment plan that will allow them to drink from anywhere in the Yukon River within 50 years. This process began at the historic Yukon River Summit in December of 1997 in Galena, Alaska, when Chiefs and representatives from the Tlingit, Gwich'in and Koyukon Athabascan, and Yup'ik Nations gathered to share stories and perspectives on protecting the many diverse human and animal populations that depend on the Yukon River. From elevated rates of human cancers and leukemia, to documented physical and behavioral abnormalities in the fish and wildlife upon which Indigenous Peoples depend, it became clear to the Summit participants that the Yukon River watershed – one of the largest, most remote and still intact ecosystems in the world – was in peril. The commitment from all participants to initiate culturally based environmental and watershed education and protection efforts in all communities in the watershed is reflected in their mission: "We, the indigenous Tribes/First Nations from the headwaters to the mouth of the Yukon River, having been placed here by the Creator, do hereby agree to initiate and continue the cleanup and preservation of the Yukon River for the protection of our own and future generations of our Tribes/First Nations and for the continuation of our traditional Native way of life." And their guiding principles further emphasize a collaborative effort. Everyone agreed to be inclusive, consensual, fair and equal, honest, trustworthy, patient, not judgmental, bold, tenacious and flexible. Everyone also agreed to listen, have integrity, share wisdom and make timely decisions and responses.

Establishing Your Expectations

How will you know if your waters are healthy or protect community health? You need some reference or benchmark against which to compare the conditions you find in your watershed. In short, you need to define what you expect to find in a healthy watershed. These expectations are sometimes known as "reference conditions."

There are two main types of reference conditions:

- **Actual conditions** are those that you find and can observe or measure at real locations. These locations are selected to represent healthy waters. A common example is the use of "reference sites" – selected to represent the waters in the absence of or minimally affected by pollution or other impacts.
- **Theoretical conditions** that you establish, based on scientific theory or summaries of data from similar waters, need to describe the desired state of your waters. A common example is the use of "water quality standards." These contain descriptions, either numerical or narrative, that define the conditions you want under the Clean Water Act or tribal law.

In either case, assessing a watershed compares what you measure or observe at the places you are assessing, with the reference conditions (at actual sites or in water quality standards) that you establish.

Traditional knowledge can be very helpful in establishing your expectations for a healthy watershed. Traditional knowledge may contain information about the natural variability of different ecological processes, the conditions they create throughout the watershed and how people lived with them. Describing your expectations for a healthy watershed will provide you with a general "reference condition" – a description to which you can refer, if you observe any differences or changes. For example, tribal elders may describe a river's past condition as providing enough fish for everyone to eat. They may also know how many tribal members include "everyone."

Traditional knowledge can also help you identify places where the watershed is healthy – reference sites. Community members and programmatic staff know the watershed best. Listen to people who have lived there for many years. Take people out into the field and discuss what you both know about healthy places. Ask them about the connections you may have found in creating the Cultural Ecosystem Story. Ask people to explain why things live where they do and how they are connected to each other. Listen to what all of your senses tell you when you are out there and choose reference sites that fit best with your culturally-specific vision of a healthy watershed.

Your expectations may be narrative statements, for example, "enough fish for everyone to eat, without depleting them." You may also choose to quantify that: "enough fish to provide 1000 tribal members with 3 pounds of fish per week during the fishing season."

You might also go a step further and describe the types of habitats and the water quality that would support this level of harvest. Either expectation might prompt you to determine how many pounds of fish are in the river during the season.

Generating Assessment Questions

Based on the knowledge you gathered and your assessment goals, frame one or more specific questions that your program will answer. These questions will guide your decisions on all aspects of your monitoring program. *Some examples include:*

- Is the watershed healthy? Has the health of the watershed changed over time? If so, how has it changed?
- Is it safe to harvest plants and animals for medicine and sustenance? If so, how much and from where?
- Where are the traditional places with unique cultural values that should be protected? Do the surrounding areas impact those places?
- How does our current lifestyle affect the health of the watershed? What can we change?
- Does the watershed support a healthy fish population large enough to sustain the tribe? If not, why and what needs to be done?
- Where are the impaired waters that should be a high priority for restoration? What's causing these impairments?
- Is it safe to ingest or bathe in untreated water for ceremonial purposes?
- Is water quality affecting the health of the terrestrial animals on which we depend for sustenance?

Now that you have developed your assessment questions, the next step is to decide what type of assessment and respective indicators will best answer them.

What

A "Cultural Ecosystem Story" speaks the "language of the subtle signs, qualities, cycles, and patterns"[16] of a landscape learned from thousands of years of observing and communicating with all parts of the natural world. Similarly, a watershed assessment will add to your knowledge of how watersheds behave, what is impacting their health and how best to understand those impacts.

This chapter focuses on selecting appropriate *indicators* to answer your questions. These are measurable features, which provide clues about the current health of the watershed, as well as trends over time. The results can be used to make decisions about the use, protection and restoration of the watershed (ITFM, 1995). Some indicators are specific watershed features, such as dissolved oxygen, the make-up of the river bottom or lakebed, the presence or absence of fish, etc. Others are calculations using several indicators, such as flow, which is calculated from the width of a stream channel, the speed of the water and the depth.

Indicators are used in several ways, depending on your reasons for the assessment:

- If you are interested in trends over time, select indicators that give you **early warning of ecosystem change.**
- If you have a plan for watershed restoration or protection, select indicators that tell you **whether you've achieved your objectives.**
- If you are trying to address problems, select indicators that provide insight into the **causes of problems.**

There are an almost endless number of indicators of watershed health. This section should help you narrow the field and make some preliminary choices that will start to address your questions. From this point, all of your watershed assessment design decisions will be affected by *variability* and *scale.* Subsequent decisions you make (about where, when, how and who) build on, and may affect the priority of what you choose to assess.

Since the overall scope of the assessment is affected by the extent to which your indicators may vary over time and space, we'll start with a brief summary of variability and scale.

Variability

Variability is a measure of how much something changes over time and space. For example, the difference *over a year* between your highest and lowest results at a *single site* for a given indicator is a type of variability over time. The difference between the results for a given set of sites on the same date is a type of variability over space.

Watershed assessment is all about measuring change. But it's critical to understand why changes occur:

1. **Some changes occur as part of natural cycles or processes:** A watershed is not static. It changes from minute to minute, day to day, and over seasons and years. For example, dissolved oxygen varies in response to the photosynthetic activity of green plants, which produces oxygen. This varies with the daily and seasonal cycles of the sun. Biological communities will change in response to natural upstream to downstream changes in habitat.
2. **Some changes are due to human activities:** Because modern society has greatly impacted watershed processes, human activities add another source of variability on top of those resulting from natural processes. For example, nutrients from runoff or sewage can generate higher than normal aquatic plant production.
3. **Some changes are due to errors in sampling or analysis:** In the process of assessing the watershed, you will introduce sources of variability in the ways that you collect and analyze samples. For example, measuring dissolved oxygen at two sites on the same day, but changing the calibration of the probe between the sites.

You are going to collect data that might be explained by any of these three. *Naturally-occurring changes and those caused by human activities give you a true picture* – they reflect what's really happening in the watershed. Assuming you can distinguish between the two, you can use this information to make protection and restoration decisions. *Changes due to errors in sampling or analysis give you false signals.* You might see a trend that isn't there, conclude that conditions are worse (or better) than they really are, etc. So, it's very important to select indicators that can be measured using methods that minimize this type of change (see the "How" chapter).

Assuming you minimize measurement errors, you're left with the challenge of distinguishing between the natural and human-caused changes you measure. If you intend to make management decisions based on your assessment, this is the main challenge in how you design your whole assessment, from selecting indicators through deciding where, when, and how you will carry it out.

Variability and Scale

Variability also depends on the scale, the relative size or extent of the area you are assessing:

- **Watershed:** An area of land that drains water, sediment and dissolved materials to a common outlet.
- **Stream Corridor:** The stream channel and plant communities on either side of the stream.
- **Stream:** The stream itself and its channel.

- **Stream Reach**: A relatively homogenous segment of the stream with relatively homogenous physical, chemical and biological characteristics. (FISRWG, 1998)

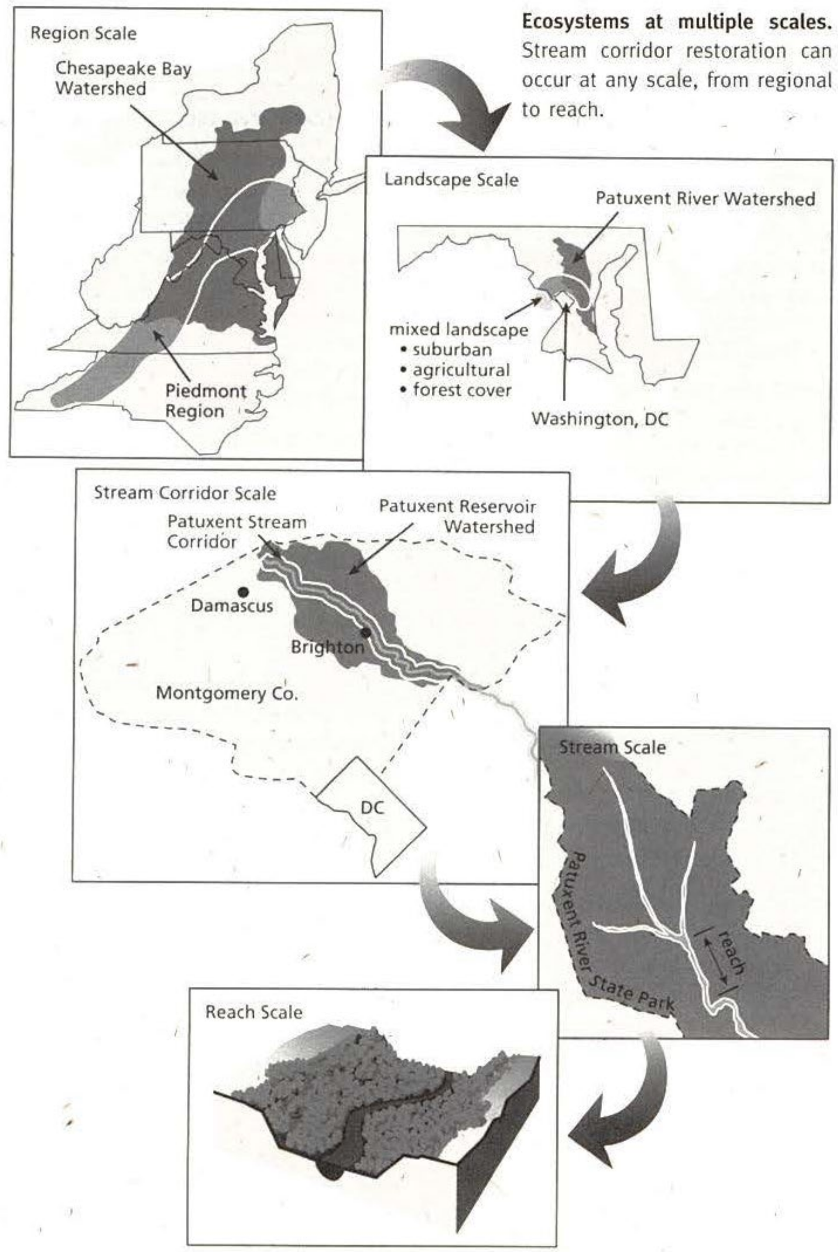
These different scales are not all well-defined. For example, watersheds range in size from a few square miles (your local creek) to tens of thousands of square miles (the Yukon). To make matters even more confusing, other scales like "landscape" and "eco-regional," are often used. Like watersheds, these can be large or small. They are usually defined as an area with similar climate, natural biological communities, geology and other characteristics. These may cut across watershed boundaries. You may have several in your watershed. Knowing this may help you define your expectations of the changes that take place within your watershed as you move downstream.

Then there are areas defined by political boundaries, such as states, reservations, EPA regions, etc. These are not as useful in under-standing your watershed as natural boundaries. But they may be critical in defining the scale at which decisions about your watershed are made.

Typically, as the size of the assessment area increases, there will be a greater amount of variability to account for in the analysis of your results. For example, at the stream reach scale, the factors that might affect the amount of sunlight to which the water is exposed and the consequent temperature of the water (e.g., elevation, stream width, canopy cover, aspect) don't vary as much as they do at the watershed scale. So if you are comparing sites from different parts of the watershed, you might have to group them by similar characteristics before you draw any conclusions about a change you measured.

For every indicator you will have to consider the effects of scale on:

- **Natural variability:** For example, at the stream scale, high elevation headwater streams are typically colder and have more shading than streams at lower elevations. If you found a measurable difference in dissolved oxygen levels when comparing a high and low elevation stream, it could be primarily a result of this natural variability.
- **Human-induced variability:** For example, at the watershed scale, smaller watersheds may have fewer differences in land use activities than a large watershed, making it easier to pinpoint the source(s) of nutrients coming into a stream.
- **Sampling and analysis variability:** For example, dissolved oxygen levels will naturally increase as the day progresses due to increasing photosynthesis by plants as the sun gets higher in the sky. If you are sampling many sites throughout a large watershed, it will be difficult to measure dissolved oxygen levels at all the sites, within small enough period of time, so that the level of sunlight doesn't affect your results. Thus, even if the sites are similar, measurable differences might be caused by time of day.



Choosing the Scope of Assessment

Choose the scope of assessment that will best address each of the questions you generated. Here are two basic assessment scopes (U.S. EPA, 1997):

1. **Comprehensive**

   This is an assessment that collects information, at the watershed scale, to get an idea of the general condition of watershed health over space and/or time. This assessment is concerned with the integrated "bottom line" ***effect*** of all the processes in the watershed. Thus, you would not be specifically looking to determine or measure the cause of any problem. The comprehensive assessment is designed to be *representative* of all the different types of waters and lands within the watershed ("unbiased"). There would be a very large number of possible indicators to measure. A good place to start is to select indicators for which you have established benchmarks *(criteria)*. You would compare your results for each indicator to your water quality or health benchmarks for each indicator to determine the condition of the watershed (see "Why" chapter: Establishing Your Expectations).

2. **Targeted**

   This describes an assessment that collects information at the stream reach scale and/or the watershed scale. Unlike the comprehensive assessment (which strives for an unbiased sample of watershed conditions) the targeted approach focuses intentionally on one or more problem sources known (or suspected) to be causing problems. The information is used to assess the ***effect*** on the resource or people and the ***cause*** of the impact (pollution source or alteration). At the stream reach scale, you might target a pipe that is discharging pollutants into the river by assessing the water quality and/or aquatic life above and below it You would select indicators that directly measure pollution levels, as well as, indicators that respond to those pollutants. At the watershed scale, you might assess the effects of sediment loading (e.g., from erosion and deposition) on the watershed by measuring one. of the major causes (e.g., % impervious surfaces) and the watershed's response (e.g., sediment loading, aquatic life or channel stability). You could also investigate whether or not there may be a connection between environmental contamination and human health problems. Direct assessment of the impact allows you to compare measurements and have what some would consider a better defense for a cause-and-effect relationship.

Selecting Indicators

The web of watershed life has many features that can serve as indicators of health. The key is to select those that tell you the most about what's going on in your watershed.

Ways to look at watershed indicators:

Stress Indicators

These are measures of activities or processes (stressors) that can cause stress on any aspect of watershed health, including humans (e.g., pollution, land uses, water uses, climate, etc.).

Exposure Indicators

These indicators link the stressors (e.g., pollution sources) with the response indicators (e.g., aquatic life). They measure the extent (magnitude and duration) to which the response indicators are exposed to the stressors (e.g., bacteria counts, chemical or sediment concentrations, duration of low flows and high temperatures).

Response Indicators

These are measures of the effect on watershed health – the response to exposure to a stressor (e.g., cancer rates, changes in the river channel, changes in biological community composition or abundance).

This stress, exposure and response way of thinking is similar to how people who study the occurrence of disease think about their work – disease-causing organisms are stressors. The number of these organisms in your body indicates exposure. Whether or not you get sick is your response.

This approach applies to watershed health, as well as human health. For most comprehensive assessments, it's important to select indicators from each of these groups.

Example: Watershed Indicators

For example, if one of your watershed goals is a healthy fishery, it makes sense to be assessing the fish themselves (in general, or specific species) as your response indicator. Next, select an indicator of pollution that can be measured in the water (and/or on the bottom) where the fish would be exposed to it (for example, sediment in spawning areas). Finally, try to select indicators that tell you something about the source of the pollutant (for example, the percentage of watershed land that is highly, erodible). If you don't measure some sort of response indicator, you might not know whether there is a problem. Instead, you might measure an indicator of the stress and incorrectly assume that any higher-than-normal levels reveal a health problem. The following table lists the indicators that would be relevant for different types of stressors.

		Stressors:							
		Impoundments	**Water Withdrawal**	**Sewage**	**Toxins**	**Urban Runoff**	**Acid Mine Drainage**	**Agriculture**	**Grazing**
	Watershed Indicators								
Exposure Indicators	Presence of Life				X		X		
	Presence of Disease or Death			X	X		X		
	Dissolved Oxygen Concentrations	X	X	X				X	
	Temperature	X	X	X		X		X	X
	Streamflow	X	X			X			X
	Fecal colif. | *E. coli* bacteria			X					X
	Bottom Composition	X	X			X			
	Embeddedness	X				X			X
	pH				X	X	X		
	Metal Concentrations *(in sediment, water & fish tissue)*				X	X	X		
	Turbidity					X		X	X
	Algal Abundance			X				X	X

		Stressors:							
		Impoundments	**Water Withdrawal**	**Sewage**	**Toxins**	**Urban Runoff**	**Acid Mine Drainage**	**Agriculture**	**Grazing**
	Watershed Indicators								
Stress Indicators	Number & Characteristics of Discharge			X	X				
	Number & Characteristics of Impoundments	X							
	Location of Non-Point Source Pollution					X			
	Volume of Water Withdrawn		X					X	
	Spill Locations					X		X	
	Amount and Type (e.g., invasive exotics) of Streamside Vegetation							X	X

We suggest that you consider this stress-exposure-response perspective as a way to clarify the role of each indicator in your assessment. The ideal is to measure indicators that play each one of these roles.

Types of Indicators

The stress-exposure-response approach is one of many ways to categorize indicators. Another way to think about them is by the part they play in the watershed ecosystem.

The Stream Corridor Restoration Guide (FISRWG, 1998) describes four categories of indicators:

1. **Hydrologic and hydraulic processes** (e.g., flow, channel "roughness")
2. **Geomorphic processes** (e.g., channel type and stability)
3. **Chemical processes** (e.g., nutrients, alkalinity)
4. **Biological characteristics** (e.g., benthic macroinvertebrate community structure)

Indicators in each of these categories are used to measure and analyze current conditions.

The WAM Guide lists 8 categories (which are called "technical modules") based on major components of the watershed ecosystem:

Resource Modules

1. **Community resources** (e.g., number of hunting/fishing licenses sold)
2. **Aquatic life** (e.g., fish community)

3. **Water quality** (e.g., dissolved oxygen)
4. **Historical conditions** (e.g., subsistence fishing locations)

Process Modules

5. **Hydrology** (e.g., flow)
6. **Channel** (e.g., width/depth ratios)
7. **Erosion** (e.g., measures of bank loss)
8. **Vegetation** (e.g., % forest cover)

These modules are selected to provide a holistic view of the watershed.

EPA Recommended "Core" Indicators

There is no one set of indicators which will be useful everywhere. However, as a starting point, consider the list of EPA "core" indicators (EPA, 1997): for comprehensive assessments of watershed health. This menu of stress, exposure and response indicators addresses many components of watershed health:

Aquatic life *(Response Indicators)*

- Fish
- Invertebrates
- Algae

Physical Habitat *(Exposure/Response Indicators)*

- Geomorphology
- Flow
- Substrate quality
- Riparian vegetation

Water Column Characteristics *(Stress/Exposure Indicators)*

- Temperature
- Turbidity
- pH/Alkalinity
- Conductivity
- Dissolved oxygen
- Bacteria
- Transparency

Note that some of these indicators can be measured directly (e.g., pH turbidity), while the results for others are calculated from direct measurements. For example, "stream stability indices" are calculated for geomorphology and "indices of biological integrity" for fish and invertebrates. Not all assessments will use all of these indicators. But, we think it's a reasonable starting point (or menu) from which to choose indicators relevant to your assessment.

None of the choices you make about watershed indicators are necessarily final at this point. You may want to revisit your selections after you've determined your data quality objectives and methods, because it's entirely possible to select an indicator that is too expensive or too difficult to monitor.

Choosing Indicators

There are literally thousands of indicators that might be useful. How do you decide?

Some things to consider when selecting indicators:

- Is there a benchmark or reference condition against which to evaluate it?
- Is it a stress, exposure or a response indicator?
- Does it help answer your question?
- Is it culturally appropriate?
- Can you observe or measure it?
- Over what time period does it respond to changes?
- Does it respond to the impacts you are assessing?
- Can you isolate the conditions that cause it to change?
- Does it integrate effects over time and space?
- Is it affected by changes in other indicators?
- Is it a true measure of an environmental condition?
- Does it provide early warning of changes?
- 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?

Where

"Understanding that the driving mechanism behind Indigenous Peoples has always been the environment is to begin to understand Indigenous Peoples. Through the ages, Indigenous Peoples have followed the rhythms and cycles of nature. By following the seasonal grasses and berries, herbs and animals to different locations, we established areas, which were defined by available species and their migratory patterns. Our travels followed these migratory patterns, and naturally shaped our trade routes and our heritage. They have, in fact, defined us." –Terry Williams

Deciding where you will conduct your assessment work is also a process of following the resources that are important to the people and selecting monitoring sites that will be most helpful to them. Since you can't monitor everywhere, it helps to choose a set of sites that will best address your questions, which represent your values and address your goals. Site selection is generally an exercise in deciding the number of sites you can realistically monitor and their locations that will provide useful and representative information.

Variability

As described earlier, a larger assessment area typically means there will be a greater amount of variability to account for in your data analysis. This means that it's especially important to understand the natural changes in a watershed. Site selection may be the most important tool you have to distinguish among the three types of variability:

1. **Natural Variability**

Sites that represent the "least altered" conditions in the watershed are known as *reference sites*. Having a good set of reference sites that reflect the natural condition of different types of waters throughout the watershed is a great way to get a handle on natural variability upstream to downstream. By monitoring these sites, you can actually find out what the natural variability is, because you actually measure it. For example, high elevation headwater streams are typically colder and have more shading than streams at lower elevations. If you find a measurable difference in dissolved oxygen levels when comparing a high and low elevation stream, it's likely a result of the natural variability from upstream to downstream. Variability also happens within the water column. For example, the water column of many lakes "stratifies" into layers of different temperature. In the warmest months, the upper water layers warm up and don't mix with colder layers below. So where in the water column you take your measurements can affect your results.

2. **Human-caused Variability**

   Site selection to isolate this type of variability usually involves "bracketing" a pollution source: one site directly upstream of the source, and two sites downstream. Differences in conditions between the upstream and downstream sites are a sign that pollution from this source is likely the cause of the change. To minimize the effects of natural variability, when possible, choose sites with relatively uniform conditions (e.g., thorough mixing of the water, equal exposure to sunlight).

3. **Sampling and Analysis Variability**

   Proper site selection can help minimize and isolate errors in collect samples. For example, some sites may be more difficult to sample than other's and sampling errors may be more likely. Sites may have complex flow patterns that make it difficult to sample. Deciding where at that site to collect a representative sample is a challenge, since conditions may vary across the channel. This makes it more likely that you will collect samples that are not representative of the entire site.

   Generally, if you are doing a comparison among sites, their characteristics should be as similar as possible (e.g., geology, flow, size) in every way but the indicator you are measuring. This helps you to isolate the cause of any differences in results.

Selecting Sites Basic Approaches

Two general approaches to picking sites reflect the scope of the assessment discussed earlier. If a broad assessment of the probable status of your water bodies in a large area is your goal, then the comprehensive assessment is likely your best choice. If your focus is on finding and restoring impaired waters, then the targeted assessment is probably best.

Comprehensive Assessment

Sites are either chosen to represent as many of the conditions in the watershed as possible or located randomly. For example, "Cultural Ecosystem Story" may define sites throughout the watershed that support healthy fish populations, possibly at different times of the year. If so, start there! You could also randomly locate your sites using a probabilistic design. This design is used to assess conditions at the landscape or watershed scale, and the number of sites is chosen using statistical methods. Sites are placed into relatively homogenous groups, based on their geology, chemistry, aquatic life, etc. A relatively small number of sites are chosen that represent each group. Then they are placed in one of two types:

1. **Reference Sites** are locations that reflect minimal change from natural or unimpacted conditions.[17] These sites are used as benchmarks against which the conditions of the assessment sites are compared. In a comprehensive approach, reference sites are selected for each waterbody type. Ideally, you determine the condition of your assessment sites by comparing the results to those at the reference sites and determining the degree of change (usually a percent similarity, e.g., the assessment site is X% like the reference site).
2. **Assessment Sites** are locations used to assess the degree of change from expected or desired conditions resulting from the impact or process in which you are interested. Conditions at these sites are compared with those at reference sites or with water quality standards.

The comprehensive assessment will provide an overall sense of the watershed's health, but the information is not typically detailed enough to assess specific problems at specific locations. Examples of the comprehensive assessment design using statistical site selection methods include some state water quality assessments,[18] the USGS National Water Quality Assessment (NAWQA), and EPA's Environmental Monitoring and Assessment Protocol (EMAP).

Targeted Assessment

Sites are chosen to assess a particular problem source, source such as a discharge pipe, disturbed land area, eroding bank, etc. These problem sources may be suspected, presently known or upcoming. Problem, sources may be at specific locations, but sometimes involve an area of disturbed land, such as an extensive construction site or paved urban area. The targeted approach usually focuses on, assessing conditions at the reach scale, and provides information that can be used to identify or confirm problems, develop site-specific solutions or restoration strategies, and assess their performance. Because of this location-specific focus, the results do not really represent the current status of all waters.

In targeted assessments, sites are chosen to "bracket" a specific known or suspected pollution source:

- **Control Sites** are locations that represent the condition of the indicators being measured before they enter the problem area. These are sites that reflect minimal change from natural conditions. These sites are used as benchmarks against which the conditions at impact and recovery sites (see column to the right) are compared.

  In a targeted design, control sites are usually located just upstream of the problem area to be assessed. However, sometimes it's not possible to locate a good control site upstream of the problem area. In that case, the control site may be located on another reach that is similar in all respects to the reach being assessed. In either case, you determine the condition of your assessment sites by comparing the results to those at the control sites and determining the degree of change (usually a percent similarity, e.g., the assessment site is X% like the reference site).

- **Assessment Sites** are locations used to assess the degree of change resulting from the impact or process in which you are interested. Conditions at these sites are compared with those at control sites. Or, if you can't find workable control sites, use the water quality standards.

Two common types of assessment sites are:

1. **Impact Sites**

   These are sites where the conditions have been altered by impacts such as point or non-point sources of pollution or a particular tributary. You compare the values from these sites to the control sites in order to assess the effect of the impact. Impact sites are typically located either immediately downstream or just outside of the source of the problem where the impact is thoroughly mixed into the water.

2. **Recovery Sites**

   These sites are located further away or downstream of the impact source, where it is assured that water quality has begun to recover from the impact(s). The values from these sites are compared to the impact sites in order to assess whether the water quality has improved, and also compared to the reference sites in order to assess whether the water quality is anything like it was before the impact.

Your "Cultural Ecosystem Story" might help locate potential assessment sites that the community feels have been significantly impacted.

Selecting Sites General Considerations

Once you've decided on a basic approach, the next step is to select specific reference and assessment sites geared toward it. The following table lists some different categories of sites and general criteria on site selection for both comprehensive and targeted assessments.

	ASSESSMENT TYPE SELECTION CRITERIA:	
	Comprehensive *Reference and Assessment Sites*	**Targeted** *Control, Impact and Recovery Sites*
Site Categories		
Waterbody Type	Representative sites on all water-body types in the watershed: lakes, rivers, wetlands and groundwater	Sites focused on problem are in the water of concern: lakes or rivers or wetlands or groundwater
Human Uses	Representative of all human uses: ceremonial, drinking, bathing, swimming, travel, fishing	Sites focused on problem areas that affect the use(s) of concern
Aquatic Life Uses	Representative of all aquatic life uses: fish, invertebrates, algae, aquatic vegetation	Sites focused on problem areas that affect the aquatic animals or plants of concern
Physical Habitat	Representative of all: habitat types: lakes, ponds, wetlands, streams/rivers (riffles/runs/pools), cold and/or warm water processes that	Representative sites on all waterbody types in the watershed: lakes, rivers, wetlands and groundwater

	create and maintain them: geomorphic classes, hydrology, substrate types (rocky to muddy), riparian vegetation	
Water Column	Representative of different water column types: deep/slow, deep/fast, shallow/fast, shallow/slow	Representative sites on all waterbody types in the watershed: lakes, rivers, wetlands and groundwater

Site Specific Sampling Location Considerations

As you would at any scale, you want to choose a sampling location at the site that accurately reflects conditions there. Note that specific sampling locations at the site may differ depending on the indicator.

The two main things to consider at any one of these particular sampling sites are:

1. **How far down in the water?**

   The main thing to think about is whether the water is evenly mixed from surface to bottom. If not, water quality may vary quite a bit at different depths. In rivers, this can be due to different water velocities. Generally, lakes stratify into three layers determined by the different density of water at different temperatures. You may want to sample each layer. Or you may want to sample only the layer that contains an indicator of concern in that layer (e.g., dissolved oxygen near the lake bottom).

2. **How far across?**

   Because water, habitat and aquatic communities can also vary significantly across a stream, lake or wetland, it is best to set up transects (a string of sampling locations spread across the water). This allows for multiple regularly spaced samples that will reflect any uneven mixing.

Practical Considerations for Site Selection

Accessibility and Safety

Avoid steep, slippery or eroding banks or sites where landowner permission cannot be obtained.

Time-sensitive Sampling

Make sure any difference in values between sites is NOT a result of natural variation in time of day. For example, because dissolved oxygen levels can naturally increase in a short period of time in the morning, measurements or samples at all of your sites should be taken within a fairly narrow window of time.

Distance Between Sites

You will also have to consider distance between sites when you are taking samples that have short holding times. For a period of time, financial and staff resources may also limit the number of sites and how far apart they can be.

Previously Collected Information

Where possible, it helps to choose sites that have been previously assessed in order to build on that information.

Once you have chosen a potential set of sites, use a topographic map to do a preliminary evaluation of them to see if they appear to meet your criteria. This is when GIS technology can be immensely helpful. Even if the tribe doesn't have its own GIS capabilities, it is usually easy to get access to information and assistance. A GIS can help select sites by:

- Making calculations and measurements of watershed area, percentage of different land covers and distances much easier.
- Showing the locations of discharges and land uses that may cause (or threaten to cause) impacts.
- Graphically displaying historic assessment data and relating it to other information that's in the GIS database.

Checking and Documenting Your Sites

Once you have chosen the sites you would like to sample, you will need to determine how many of these sites you will actually be able to monitor. Once again, consider safety, accessibility, your human resources and how many samples you can analyze. It helps to go out in the field and check each site for accessibility, representativeness, safety and appropriateness. *Depending on the situation, you might need landowner permission to use sites on private property*. If you can't presently get permission, drop those sites and decide whether future efforts toward getting permission are necessary. Finalize your list of sampling sites.

For each site you decide to include, give it a unique number, record directions to the site, a brief description of the site and other relevant information in a site log notebook. In general, a site numbering system based on a waterbody ID and the distance of the site from the mouth seems to work best. 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. If you have access to Global Positioning System (GPS) receiver, consider going to your sites and determining their location using the radio signal sent from satellites.

"East of my grandmother's house the sun rises out of the plain. Once in his life a man ought to concentrate his mind up on the remembered earth, I believe. He ought to give himself up to a particular landscape in his experience, to look at it from as many angles as he can, to wonder about it, to dwell upon it. He ought to imagine that he touches it with his hands at every season and listens to the sounds that are made up on it. He ought to imagine the creatures there and all the faintest motions of the wind. He ought to recollect the glare of noon and all the colors of the dawn and dusk." *–N. Scott Momaday, Kiowa*

When

At this point, you have used your assessment questions to decide what and where to monitor. Now it's time to decide when, because each of the indicators you are assessing varies over time as well as space. Living with and understanding the cycles of the natural world is a powerful source of knowledge you can use to schedule your assessment work.

We have endured

The ordeal of winter

The hunger

The winds

The pain of sickness

And lived on.

We grieve for those

Grandparents

Parents

Children and

Lovers

Who have gone.

Once again we shall

See the snows melt

Taste the flowing sap

Touch the budding seeds

Smell the whitening flowers

Know the renewal of life.

–Morton and Gawboy, 2000

Variability

Watershed conditions vary over periods of time from hours to years.

Natural Variability

Watershed conditions change over the course of a day, seasonally and annually in response to sunlight, precipitation and other natural cycles. The response to these natural cycles differs dramatically depending on the indicators you are measuring. For example, dissolved oxygen varies hourly, especially at sunrise and at dusk. On the other hand, aquatic life integrates changes in conditions in time periods ranging from a matter of hours (say from a flood) to multiple years (say from a multi-year drought). There may also be dramatic differences in different regions, say between temperate, wet New England to the arid southwest.

Human-induced Variability

Human activities can cause impacts that range from minutes to years. For example, a toxic spill might kill critters almost instantly. On the other hand, land development may gradually change the way water behaves as impervious surfaces gradually reduce the ability of the land to soak up water. As with natural variability, this varies with region.

Sampling and Analysis Variability: When you collect your samples you may also increase the probability of errors. For example, sampling bottom-dwelling critters or sediment during high flows can be very challenging.

When to Carry Out the Assessment

Think about the information you are trying to collect on each indicator and what you know about the variations over time that might occur at each site and influence your results. Monitoring at the right frequency and time frame can help you understand the short and long-term natural cycles of watershed behavior. With that understanding, you can assess the impact of human activities on those cycles and the watershed response. Once again, the main challenge is to figure out whether changes are due to natural causes (e.g., climate), human causes (e.g., pollution events) or errors in your sampling and analysis. By using the timing of your assessment to account for how the indicator varies, you will make it easier to differentiate the causes of change.

Assessment Approach

Comprehensive

A comprehensive assessment should include a range of samples for each indicator that represent the various cycles of time and sources of variability described below.

Targeted

A targeted assessment is generally focused on a particular process or location that will dictate the frequency of sampling (e.g., sampling below a sewage discharge before, during and after a rain event). However, if you don't have a basic understanding of how a process or conditions at a location vary, you might need to start with a more comprehensive approach in order to learn.

Time of Day

The sun's daily cycle affects every place on the planet. When the sun comes up, the plants start photosynthesizing and producing oxygen for all life. So if you are trying to assess the lowest levels of dissolved oxygen that a river experiences in a day, you will need to take samples before the sun comes up. But, if you want to know a broad range of oxygen levels that a river experiences in a 24-hour period, you could take measurements every hour over the entire day. Decide on the time of day you will assess every indicator.

Time of Year

The sun's annual cycle also affects every place on the planet – some more variably than others. If you want to assess the lowest levels of dissolved oxygen that a river experiences in a year, you will need to take samples during the lowest flow and/or the highest temperature. If you want to know a broad range of oxygen levels that a river experiences in a year, you could take measurements on the same day every month. Decide on the time of year you will assess every indicator.

Multiple Years

Because no two years are exactly alike, the best assessment of watershed health includes many years of information. This information will give you a better understanding of the range of conditions that a watershed experiences, from droughts to floods. The lowest dissolved oxygen levels between years might vary considerably, if water levels fluctuate dramatically. Decide on the number of years you plan to collect information.

Weather

Because weather can affect a watershed in profound ways, you might also want to assess the impacts of various types (e.g., storm events, droughts, "normal" conditions, relatively hot weather, relatively cool weather). For example, you might want to assess the sediment load in a river after a big rainstorm. If so, you want to consider getting samples before the storm, as water levels rise, as water levels fall and after pre-storm conditions return. This requires that you have an accurate prediction of when the storm will begin and end; and since weather can occur without much warning, this can be challenging. Decide on any special weather events you will try to capture with your monitoring.

Human Use and Impacts

The use of water and watersheds by humans also varies over time – some of which fluctuate with regularity and others do not. You might want to consider the following uses and the influence of their timing on your assessment:

- **Ceremonies**
- **Hunting**
- **Fishing**
- **Dam Releases**
- **Water Withdrawals for Things such as:**
    - **Irrigation**
    - **Snow-making**
- **Recreational Tourism**
- **Farming**

Who

Who will complete each of the tasks you have listed? Describe the major tasks, key program personnel and timeline that might be associated with your monitoring program. Either of these assessments can involve tribal members. Elders have had the time to develop a long-term perspective of the changes over time. Involving both elders and youth might build support for protecting current conditions and restoration of others.

Major Project Tasks

Make a list of tasks that help you accomplish the goals and the dates that you expect to finish them.

Major tasks typically include:

- **Collecting and synthesizing traditional ecological knowledge**
- **Hire staff**
- **Train field and lab staff**

- **Purchase equipment**
- **Find a quality-control lab (if needed)**
- **Collect information on current conditions**
- **Quality assurance**
- **Analyze results**
- **Report results**
- **Present results**
- **Evaluate study design**

Key Program Personnel

The scope of your monitoring program will determine how many and what kind of people you will need to carry it out. Financial resources may dictate that many of these responsibilities be carried out by the same person. But remember that you may also be able to solicit volunteer help as well (e.g., internships sponsored by Native organizations, local tribal members, federal volunteer programs, non-Native public).

Some of the possible positions, and their major responsibilities, you might think about having include:

- **Program Coordinator:** Oversees all of the program tasks to see that they are carried out.
- **Lab Coordinator:** Oversees and coordinates the lab analysis of samples and does the training of any laboratory staff. If you use an outside lab to run your 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.
- **QA Officer:** Responsible for seeing that your quality assurance measures are carried out. This could be the program coordinator, lab coordinator or a person outside of your program.
- **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 overseeing volunteers that enter the data, validating the data and producing the data summary.
- **Speaker(s):** Makes public presentations about the program and the monitoring results.
- **Field Technicians:** Collect and record samples, observations and measurements in the field and drops them off at a sample drop-off point or a lab.
- **Laboratory Technicians**: Analyze and record the results for field samples. Lab technicians work under the supervision of the lab coordinator.
- **Data Entry Technicians:** Enter the field and lab data into a computer. Work under the supervision of the data management coordinator. May also validate data entered by other staff.

Take the time to develop job descriptions for each of these positions before you recruit people to fill them. A Technical Committee could provide advice and assistance to the program coordinator in preparing the study design, troubleshooting problems and interpreting your results.

How: Part 1

Now that you've decided what indicators to measure, and where and when to measure them, the next step is to decide ***how*** to measure them. In previous chapters, we discussed the types of variability in watershed assessments (natural, human activities and experimental) and the need to determine how each affects your results. Measuring the variability due to natural and human activities is hard enough!

You don't want to confuse the issue by introducing experimental variability: that which results from your data gathering methods. Unfortunately, you can introduce additional sources of variability at every step in sampling and analysis. Your goal is to be able to assume that any difference in watershed condition you see in your assessment is a result of the actual difference in the indicator (in time and/or space), rather than from differences you caused in sampling and/or analysis. Fortunately, you actually have some control over experimental variability by setting your own data quality objectives, choosing the right collection and analytical methods, and putting a quality assurance program in place to let you know whether you're meeting your objectives.

The purpose of this chapter is to help you choose the appropriate methods to meet your needs and capabilities. How do you choose the "appropriate" method?

We suggest the following three steps:

1. **Set data quality objectives** so that data you gather is useful and meets your needs of being complete, representative, comparable, accurate and precise.
2. **Select sampling and analysis methods** that meet your data quality objectives and match your capabilities.
3. **Design a quality assurance/quality control (QA/QC) program** to find if you've met your data quality objectives.

The methods you choose will depend on a number of things:

- Your capabilities and resources
- The nature of your questions (Refer to "Why" chapter)
- How you are going to use the information you gather

The next section provides a brief overview of this very complex step.

Set Data Quality Objectives

There is more than one way to measure most indicators. How do you choose among the myriad methods? One of the key things to decide is: What quality of data do you need to produce in order to use it for your purposes?

Data quality objectives (DQOs) are statements and/or numerical descriptions of the benchmarks you set for your sampling and analysis methods. While data quality objectives are not your only consideration, they can help you identify the methods that most closely match your needs.

In this section, we'll briefly review some of the basic concepts. EPA has produced detailed guidance for developing data quality objectives.[19]

Data quality objectives serve two purposes:

1. Before you collect any field data, they help you select appropriate methods.
2. After you've begun collecting field data, they help you track whether the methods are working.

Setting data quality objectives before you've gathered field data may be the most challenging step in the assessment process. In part, it's a "chicken-and-egg" situation because it is difficult to know whether the objectives are reasonable before you've taken any measurements.

You may decide to collect measurements during a "testing phase" to establish a record of whether your methods can meet your DQOs. You can also consult with other tribes or agencies, to see if their experience can help you set reasonable objectives. You may not need to set data quality objectives.

Three reasons to set DQOs include:

1. You are **using federal funds,** and preparing a Quality Assurance Plan (QAP) – DQOs are required.
2. You are **letting others use your data,** and they require DQOs.
3. You want to **collect data** of a particular quality.

Data quality objectives are an integral part of a Quality Assurance Plan, which may be required if you are using federal money for monitoring (See the “Designing a Quality Assurance/Quality Control” section in the “*How: Part 1*” chapter). In a QAP, you set up quality control checks. These checks are designed to test your sampling and analytical processes, and produce data which you compare with your objectives.

A word of caution: As of this writing, most of the guidance for setting data quality objectives is aimed primarily at collecting and analyzing samples of chemical indicators in the water itself. Some methods, such as those that involve observation, may not lend themselves to numerical objectives.

Before developing specific objectives, it's usually helpful to come up with an overall objective that describes how you will use the data. This can be a simple narrative statement.

Overall Data Quality Objective

Your data quality objectives will describe in more detail how you will meet this overall objective. Detailed DQOs will help you select the right methods, both for collecting samples and analyzing them.

Data Quality Objectives for Collecting Samples

Sampling is the process of collecting a sample(s) of something (e.g., water) and preparing it (them) for the measurement of the indicators you've chosen.

Data quality objectives for sampling describe your targets for:

Completeness

How many measurement samples will you need for a complete data set?

EXAMPLE

-**Data Quality Objective**-

Suppose you want to evaluate the impact of an upstream municipal wastewater treatment plant on tribal waters.

Your data quality objective might be: ***To produce data that the tribe can use to determine whether the treatment plant is impairing aquatic life and ceremonial uses of tribal waters.***

Representativeness

How many samples will you collect, and where will you collect them to ensure that they represent the actual environmental condition or population you are sampling? This is important because, in most cases, you are only sampling a very small part of the watershed.

Comparability

How comparable will your data be to previously collected data? There are statistical methods for setting data quality objectives for sampling, but they are beyond the scope of this guide.[20]

EXAMPLE

-**Analysis Data Quality Objective**-

- To produce results within 10% of known metal concentrations *(accuracy)*
- To produced results within 10% between multiple tissue samples *(precision)*

Data Quality Objectives for Analysis

Analysis is the process of measuring the indicators you've chosen. Measurements can be done in the field (for example, by using a field meter) or the lab. Data quality objectives for analysis describe the quality targets you must hit in order to provide useful data.

These targets are:

Detection Limit: the lowest concentration of a given indicator that your method 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.

Accuracy: how close a measurement of an indicator is to the "true" or expected value, though you may never be totally sure what the "true" value is. Accuracy is usually expressed as ± (plus or minus) departure from the "true" value.

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).[21]

Detection Limit/Measurement Range: 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.

Revisit your data quality objectives after your first round of data collection. Did you meet them? Can you meet them? Don't be afraid to adjust your data quality objectives (and possibly your goals) according to actual experience.

Once you've set your data quality objectives, the next step is to find sampling and analysis methods that are likely to meet them.

Selecting Sampling Analysis Methods

There is usually more than one way to collect the information you're after. Sample collection and analysis methods range from simple and inexpensive, to complex and cost-prohibitive. On one end of the spectrum, systematic observations or photographs may be all you need to document obvious pollution problems. At the other end, you may need to use difficult and expensive methods to find a very low concentration of a pollutant that is causing the problem. To add to the confusion, equipment manufacturers want to sell you equipment, and people who have used a certain method for a long time may be biased and recommend methods that won't meet your needs or capabilities.

Collecting Samples

Choosing the right collection and analysis methods involves a number of decisions, including:

1. **What you are going to sample?** (e.g., the water column, the bottom of the lake, riparian habitat, etc.)
    - Samples are collected in some type of container by **dipping the container** in the water and filling it to some predetermined level.
    - Rainfall might be measured by recording the water level in a **gauge.**
    - Abundance of waterfowl might be estimated with **counts.**
    - Human health might be assessed by taking **blood or hair samples** to analyze the amount of the contaminant that has been absorbed or deposited.
    - pH of the **water column** will be measured.
    - Trends in the smell of fish might be assessed by **direct observation and narrative descriptions.**
    - Stream flow or discharge might be measured by using information about **the area of the channel** and **the velocity of the water.**

-Types of Samples-

Integrated Depth Samples: Samples are collected from various depths or locations across a transect that are combined into one sample for analysis.

Multiple Depth Samples: Individual samples are collected at various depths and analyzed separately.

Artificial Substrate: A sampler is placed in the water column or on the bottom and colonized by critters or plants.

Direct Measurement: The indicator is measured directly from the water without collecting a sample.

2. **What you will use to collect samples?** (e.g., your eyes, a meter, sample container type, etc.)[22]
    - Invertebrates might be collected with a **kick net.**
    - Bacteria might be collected in a **Whirl-pak bag.**
    - Fish might be collected by **electro-shocking.**
    - Water samples might be collected in a **plastic bottle.**
3. **Whether and how you will preserve samples?** (e.g., freezing, acidification, immersing critters in alcohol or some other preservative)
    - Invertebrates might be preserved with **alcohol.**
    - Bacteria samples taken downstream of a wastewater treatment plant should be mixed with **sodium thiosulfate** in order to preserve colony numbers.

- Dissolved oxygen samples, being analyzed with the Hach Azide Modification of the Winkler titration method, will need to be "fixed" in the field using **manganous sulfate, alkaline iodide-azide and sulfamic acid.**

4. **How you will transport the samples to the lab, and how long can you keep the samples before they must get there?** (e.g., in coolers within six hours)
    - Samples taken for bacteria analysis will need to be **refrigerated** so that the number of colonies does not change.
    - Dissolved oxygen samples will need to be kept in a **dark container**.
    - Samples taken for pH analysis typically need to be analyzed **as soon as possible.**
5. **How many samples and how much?** (e.g., two 500 mL samples of the water column, three 1 square-meter samples of the bottom of the lake, one observation of 300 feet of riparian habitat. etc.)
    - You might collect 500 ml water samples at **three different depths**.
    - You might assess the habitat of one riffle in **ten different locations**.
    - You might assess the smell of **five different fish from one spot.**
    - You might collect **two secchi depth readings** at each lake site.
    - You might need to collect at least **three benthic macroinvertebrate samples** from 1 square meter of river bottom.
    - You might count waterfowl at **ten locations** to get a good average.

-General Terms Used In Water Analysis Methods-

This section describes the basic laboratory methods used to analyze water samples. These methods are referred to in the next section on methods for each indicator.

Titration

Determining the concentration of an indicator in a sample by adding to it a standard reagent of known concentration in carefully measured amounts until a color change or electrical measurement is achieved, and then calculating the unknown concentration. Common indicators measured this way are dissolved oxygen and alkalinity.

Colorimetric

Determining the concentration of an indicator in a sample by adding to it a reagent that causes a color change in direct proportion to the concentration of the indicator being measured. The intensity of the color (as measured by the extent to which it absorbs or transmits light) is either read with a visual color comparator or measured using a meter, and either read directly in appropriate reporting units or read in "% absorbance" or "% transmittance" units and converted to reporting units. Common indicators measured this way are nutrients.

Electrometric

Determining the concentration of an indicator in a sample by using a meter with an attached electrode, which measures the electric potential (millivolts of the sample. This amount of electric potential is a function of the activity of ions or molecules in the sample and proportional to the concentration of the indicator being measured. The electrode is selected based on its response to specific ions (known as an "Ion Selective Electrode" (ISE), general ionic activity (conductivity) or molecules (for example, a Membrane Electrode). The meters can display results in either millivolts (mV) or in appropriate reporting units. Common Indicators measured this way are dissolved oxygen, pH, conductivity and nutrients.

Gravimetric

Determining the concentration of an indicator in a sample by filtering a specified quantity of the sample and determining the weight of the material retained on the filter. Common indicators measured this way are total solids and total suspended solids.

Nephelometric

Determining the clarity of a sample by measuring the intensity of light scattered by panicles in the sample and comparing this with a known solution. The higher the intensity of the scattered light, the higher the turbidity, reported in nephelometric turbidity units (NTUs).

Membrane Filtration and Incubation

Determining the bacteria concentration of a water sample by filtering a specified quantity through a specified gridded membrane filter, which retains the bacteria and other particles larger than 0.45 microns. After filtration, the membrane containing the bacterial cells is placed on a specific nutrient medium and then incubated at a specified temperature for a specified length of time. Colonies of a specified color growing on the filter are then counted.

Analyzing Samples

1. **What is the maximum time a sample can be kept before it must be analyzed?**
    - Bacteria samples must be analyzed within **eight hours** of collection.
    - Macroinvertebrate samples preserved in alcohol may be kept **indefinitely.**
    - Chlorophyll must be analyzed within **30 days**.
2. **How and where will you analyze the samples?** (e.g., a meter in the field, visual observation in the field, membrane filtration in a lab, etc.)
    - The alkalinity of a water sample can be measured by **titration** – adding a standard reagent of known concentration in carefully measured amounts until a color change or electrical measurement is achieved, and then calculating the unknown concentration.
    - Dissolved oxygen can be measured in the field using a meter that employs an **electrometric method** – a meter with an attached electrode which measures the electric potential (millivolts) of the sample, which is a function of the activity of ions or molecules in the sample and proportional to the concentration of the indicator being measured.
    - The concentration of bacteria in a water sample can be measured by counting the number of colonies captured during **filtration** – filtering a known quantity of water through a membrane filter on which the colonies will grow when given the appropriate food source.
    - Macroinvertebrate samples are sometimes **sub-sampled**, if the number of organisms exceed certain limits, and the **taxonomic level of identification (family, genus, species**) is typically geared toward the calculation of particular summaries.
3. **How will you report the results?** (e.g., as a concentration of mg/L, # of critters in each family, percentage of habitat in each vegetative type, etc.)
    - Bacteria results are typically reported as **number of colonies per 100 milliliters (cfu/100ml**).
    - Benthic macroinvertebrate results are usually expressed as the **number of critters of each type (taxon).**
    - Abundance of waterfowl might be reported as **number per square area.**
    - Medicinal plants, invasive species or dead fish might be reported as **present or absent.**

Your assessment design should document each of these decisions for each indicator. Where do you find this information? There are many sources of information about methods. We've listed a few in the sidebars on the following pages. Each of these sources describes how each of the steps listed above should be done. Of course, you may decide to modify them to meet your own needs. If so, you will need to document where you depart from the original method.

If your goal is to meet the methods requirements of federal agencies, such as the EPA and USGS, there are two options:

1. Use a method **prescribed** by the agency (such as EPA's *Methods for Chemical Analysis of Water and Wastes*).
2. Demonstrate that an **alternative** method meets established performance criteria (performance-based methods)[23] being developed by the National Methods Board of the National Water Quality Monitoring Council.

Otherwise, select methods that meet your data quality objectives and are within your capabilities. Cite a specific method of analysis and source for each indicator sampled and provide a brief description. *(See examples for more methodology sources.)*

Selecting Methods for a "Core'' Assessment

Back in the "What" chapter, we described a core set of indicators that you might consider as a starting point to assess overall watershed health: the following tables list each of the core indicators and sources of methods that are described in more detail in the corresponding sidebars.

-Biological Response Indicators-

Indicators	**Examples of Methods**	**Source**[24]
Fish	*Sampling:* Electro-shocking *Analysis:* Identify species *Results:* # of fish in each species	2.1
Benthic Macroinvertebrates	*Sampling:* Net or artificial substrate *Analysis:* Identify major groups, families, genera, or species *Results*: # of critters in each taxon	2.1-2.5
Periphyton	*Sampling:* Scrape off rocks *Analysis:* Identify species *Results:* # of algae taxa	2.1
Plankton (*Phytoplankton, Zooplankton*)	*Sampling:* Whole water sample or net *Analysis:* Identify types and various lab methods *Results:* # of algae in each taxon	1.1
Aquatic Plants	*Sampling*: Visual survey *Analysis:* Identify Types *Results:* Map of areal extent	1.1, 1.7

Examples of Sources for Fish, Macroinvertebrates and Periphyton Used by ***Government***

1.1 APHA, 1992. *Standard Methods for the Examination of Water and Wastewater,* 18th ed. American Public Health Association, Washington, D.C.

2.1 Barbour, Michael, et al. 1999. *Rapid Bioassessment Protocols for Use In Wadeable Streams and Rivers,* EPA-841-B-99-002. U.S. EPA, Office of Water 4503F, Washington, D.C.

2.2 State monitoring protocols or standard operating procedures.

Examples of Sources for Fish, Macroinvertebrates and Periphyton Used by ***Community-Based Programs***

1.7 U.S. EPA, 1991. *Volunteer Lake Monitoring: A Methods Manual,* EPA 440/4-91-002. U. S. EPA, Office of Water, Washington, D.C.

2.3 Dates, Geoff and Byrne, Jack, 1997. *Living waters: Using Benthic Macroinvertebrates and Habitat to Assess Your River's Health.* River Watch Network (now River Network), Montpelier, VT.

2.4 Murdoch, T. and Cheo, M., 1996. *The Streamkeeper's Field Guide.* Adopt-A-Stream Foundation, Everett, WA.

2.5 U.S. EPA, 1997. *Volunteer Stream Monitoring: A Methods Manual,* EPA 841-8-97-003. U.S. EPA, Office of Water 4503F, Washington, D.C.

2.6 Volunteer monitoring protocols developed by state or regional watershed monitoring programs.

-Physical Habitat Response Indicators-

Indicators	Examples of Methods	Source[24]
Geomorphology	*Sampling:* Field measurements *Analysis:* Dimensionless ratios, gradient, channel profile *Results:* Comparison to reference reach	3.5, 3.6
Flow	*Sampling:* Field measurements of current velocity, channel cross section *Analysis:* Calculation of flow *Results*: Cubic feet per second	3.4, 3.5, 3.7
Bottom Quality (Chemical)	*Sampling:* Dredge bottom sediment *Analysis:* Lab tests *Results:* Depends on chemical	3.7
Riparian	*Sampling*: Visual survey *Analysis:* Identify Types *Results:* Areal extent, #	3.1, 3.2, 3.5, 3.6, 3.8, 3.10, 3.11

Examples of Sources Used by ***Government***

3.1 Bain, M. and Stevenson, N., 1999. *Aquatic Habitat Assessment: Common Methods.* American Fisheries Society, Bethesda, MD.

3.2 Barbour, Michael, et al, 1999. *Rapid Bioassessment Protocols for Use In Wadeable Streams and Rivers*, EPA-841-8-99-002. U.S. EPA, Office of Water 4503F, Washington, D.C.

3.4 Gordon, Nancy et al, 1992. *Stream Hydrology: An Introduction for Ecologists*. John Wiley & Sons, New York, NY.

3.5 Harrelson, Cheryl C., 1994. *Stream Channel Reference Sites: An Illustrated Guide To Field Technique,* U.S. Forest Service General Technical Report RM-245. Fort Collins, CO.

3.6 Hunter, Christopher J., 1991. *Better Trout Habitat*. Island Press, Washington, D.C.

3.7 U.S. Geological Survey, 1977. *National Handbook of Recommended Methods for Water-data Acquisition*. Office of Water Data Coordination, Reston, VA.

3.8 State monitoring protocols or standard operating procedures.

Examples of Sources Used by ***Community-Based Programs***

3.9 Dates, Geoff and Byrne, Jack, 1997. *Living Waters: Using Benthic Macroinvertebrates and Habitat to Assess Your River's Health.* River Watch Network (now River Network), Montpelier, VT.

3.10 Murdoch, T. and Cheo, M., 1996. *The Streamkeeper's Field Guide*. Adopt-A-Stream Foundation, Everett, WA.

3.11 U.S. E.P.A., 1997. *Volunteer Stream Monitoring: A Methods Manual*, EPA 841-8-97-003. U.S. EPA, Office of Water 4503F, Washington. D.C.

3.12 Volunteer monitoring protocols developed by state or regional watershed monitoring programs.

-Water Column Exposure Indicators-

INDICATORS	Examples of Methods	Source[24]
pH	*Sampling:* Water sample *Analysis:* Titration *Results:* mg/L as $CaCO_3$	1.1-1.8
Temperature	*Sampling:* Direct measurement using probe or thermometer *Analysis:* Direct read *Results*: Degrees Fahrenheit or degrees Celsius	1.1-1.8
Conductivity	*Sampling:* Direct measurement using probe and meter *Analysis:* Direct read *Results:* mhos/cm	1.1-1.8
Dissolved Oxygen	*Sampling*: Direct measurement or collect water *Analysis:* Direct read or titration *Results:* mg/L or % saturation	1.1-1.8
Turbidity	*Sampling*: Water sample *Analysis:* Turbidimeter *Results:* NTUs	1.1-1.8
Transparency	*Sampling*: Direct measurement or water sample *Analysis:* Secchi disk or turbidity tube *Results:* Depth in feet or meters	1.1-1.4, 1.7
Bacteria	*Sampling*: Water sample in sterile container *Analysis:* Membrane filtration, incubation *Results:* Colony forming units/100mL	1.1-1.4, 1.5, 1.8

Examples of Sources Used by ***Government***

1.1 APHA, 1992. *Standard Methods for the Examination of Water and Wastewater*. 18th ed. American Public Health Association, Washington, D.C.

1.2 U.S. EPA, 1993. *Methods for Chemical Analysis of Water and Wastes.* EPA-600/4-79-020. Environmental Monitoring and Support Laboratory, Cincinnati, OH.

1.3 State monitoring protocols or standard operating procedures.

1.4 U.S. Geological Survey, 1977. *National Handbook of Recommended Methods for Water-data Acquisition.* Office of Water Data Coordination, Reston, VA.

Examples of Sources Used by ***Community-Based Programs***

1.5 Behar, Sharon, 1995. *Testing the Waters*. River Watch Network (now River Network), Montpelier, VT.

1.6 Murdoch, T. and Cheo, M., 1996. *The Streamkeeper's Field Guide*. Adopt-A-Stream Foundation, Everett, WA.

1.7 U.S. EPA 1991. *Volunteer lake Monitoring: A Methods Manual*, EPA 1140/4-91-002. U.S. EPA, Office of Water, Washington, D.C.

1.8 U.S. EPA, 1997. *Volunteer Stream Monitoring: A Methods Manual*, EPA 841-8-97-003. U.S. EPA, Office of Water 4503F, Washington, D.C.

Scientific Considerations in Selecting Methods

Here are some things to consider when selecting methods:

- 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 in Selecting Methods

- 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?

Designing a Quality Assurance/Quality Control

As we described in the "Where" chapter, there are natural, experimental and human-caused sources of variability in watershed ecosystems. A good quality assurance program will help you identify and minimize the variability that is caused by your sampling and analytical procedures.

Quality assurance is the set of principles and procedures to put into place to ensure that your data is of the quality that you defined – helping to meet your data quality objectives.

Quality control defines the specific steps needed to take during information collection and analysis that ensures you follow your quality assurance principles.

Probably the most important part of QA/QC is to document, document, document! It helps you keep track of your procedures, it provides a written reference for your staff, and it provides a resource for people outside your program to discover what's behind your results. While this section provides a brief overview of the major concepts, a more detailed description can be found in the EPA document *"Integrating Quality Assurance Into Tribal Water Programs."*

Aspects of Quality Assurance

Organization and Planning: Describe your training requirements, written job descriptions, how the staff is organized and the basics of managing staff.

Sampling and Analysis Facilities, Equipment and Supplies: Describe your 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.

Data Management: Describe 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.

Associated Documentation: Describe what you have for documentation, including: manuals, equipment and supplies records, sampling locations, field and lab sheets, your assessment design, QAP (if required) and a chain of custody. A chain of custody simply identifies and documents each person that handled a sample. If your data is going to be used in some legal or regulatory proceeding, it might be good to have a rigorous chain of custody.

Reporting: Describe which data you will report, why you are reporting it, what will go into your reports, how frequently you will produce them and who gets them. 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.

Aspects of Quality Control

Quality control is a way to let you know right away if you have a problem assessing your indicators – allowing you time to correct it. Many quality control measures are unique to specific indicators. Others apply to all, or some. Define the indicator (or group) to which quality control measures will be applied. Try to focus on the quality control measures that your resources (human and financial) and capabilities will allow.

QC measures can be either internal or external:

- **Internal** – certain sample collection and analysis done by your staff in the field and lab.
- **External** – sample analyses done by people and/or labs outside of your program. If you will be having external quality control samples analyzed, be sure to locate an independent "quality control lab" that meets your needs.

Sampling Quality Control

These samples are taken to assess any changes you may have caused by treating them differently in their collection, transportation or storage (e.g., collecting at different depths, leaving one out of the cooler, exposing one to the light). By recording the name of the person taking the sample, you can also flag differences between people's sampling techniques.

Examples of these QC samples include:

- **Blanks –** de-ionized water, which is poured into a sample container in the field, as if it were a water sample. The water is assumed to contain none of the constituent you are measuring, so you shouldn't be able to detect any.
- **Duplicates** – a second sample collected and processed by an independent sampler or team at the same spot at nearly the same time.

The results of two samples that were sampled and treated exactly the same way (duplicates) should be close in value – as close as you set in your analytical DQOs. If they are not similar, you might have a problem somewhere in either your sampling or analysis process. Because all samples need to be analyzed, it is impossible to completely isolate sampling variability. This does not mean that sampling variability can be ignored, just that it is difficult to estimate. The best way to estimate its magnitude is to combine methods for assessing sampling and analytical variability. For example, you can split each of the duplicates and compare the results. If the split results from one duplicate are comparable (limits defined by you), the analytical variability is low. If all the split results from both duplicates are comparable, the sampling variability is also low.

Analytical Quality Control

- Negative Plates
- Positive Plates
- Splits
- Calibration Blanks
- Spikes
- Calibration Standards (Knowns and Unknowns)

These samples are taken to assess any changes you may have caused by analyzing them differently (e.g., not calibrating the meter regularly, using different batches of reagents, stirring some samples more than others, etc.). By recording the name of the person analyzing the sample, you can also flag differences between people's analytical techniques.

Examples of these QC samples include:

- **Negative plates** (for bacteria) are a type of blank created by filtering sterile water in the same way as a water sample and then testing whether there is any contamination from processing previous samples, equipment, etc.
- **Positive plates** (for bacteria) are created by filtering water known to contain bacteria (such as wastewater treatment plant influent) in the same way as a sample to confirm that your procedures can grow bacteria.

- **Splits** are created by dividing one whole sample into two or more sub-samples that are analyzed separately as distinct units. When analyzed internally, these will determine the precision of your analytical method; alert you to any inconsistencies in equipment performance and analytical techniques of one person, or between two or more people. When analyzed externally, these will determine the accuracy of your laboratory methods.
- **Calibration blanks** are samples made of distilled or de-ionized water processed like the other samples and used to "zero" the instrument, ensuring that you are not getting falsely high or low readings that would result from the instrument starting above or below zero.
- **Calibration standards** are samples of a known concentration of the indicator being analyzed and are used to calibrate the instrument at different levels, ensuring accurate readings around those levels.
- **Spikes** are sub-samples that are treated with a known amount and concentration of the indicator being analyzed, increasing the concentration by a predictable amount. When the spiked and un-spiked samples are analyzed the same way, the results help detect the presence of substances that might interfere with the chemical reactions in your method, evaluate how well staff and the equipment is able to detect an increase of a known amount, and determine the accuracy of your lab procedures.
- **Knowns** are samples labeled with the known concentrations of selected indicators sent by an outside lab for you to analyze. Your results should be within an acceptable level of difference defined in your data quality objectives and are used to assess how accurately staff and your equipment are able to measure that indicator.
- **Unknowns** are samples of unlabeled concentrations of selected indicators sent by an outside lab for you to analyze. After analysis, comparison of your results with the revealed concentration should be within an acceptable level of difference defined in your data quality objectives.

How Many Samples Should Be Quality Control Samples

Define the percentage of the samples you analyze that will be quality control samples. Typically, 5-10% of the samples are quality control samples.

How To Evaluate Quality Control Results

You will need to see how accurate and precise your information actually is after you've collected and analyzed it. This involves calculating the accuracy and precision of any quality control samples and comparing them to your data quality objectives.

Common statistical tools used to calculate accuracy and precision include (See EPA document, "Integrating Quality Assurance Into Tribal Water Programs," for more detailed descriptions and formulas for these calculations):

- **Standard deviation**
- **Coefficient of variation**
- **Relative percent difference**
- **Percent recovery**

List the types of quality control you will have and the methods you will use to evaluate them.

Quality Control Response Actions

You will also need to describe what measures you will take to improve data quality, if you find errors or don't meet your DQOs.

Examples of how to identify the source of the problems or error include:

- Validate the data
- Evaluate staff performance
- Audit field and lab procedures

Examples of possible corrective actions include:

- Don't use some (or all) of your data
- Change laboratory methods, equipment or field procedures
- Require more training
- Change your field or lab sheets, etc.

Finally, if all else fails, you can change your data quality objectives. Because you set them, you can change them. Just make sure that you will still be able to meet any associated requirements you might have.

Training and Manuals to be Used

Describe the training for field and lab staff. 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. List the training manuals that field and lab personnel will use.

Data Management Procedures

It helps to make as many decisions as you can about the way you will manage your data before you start collecting it. This gives everyone a standard procedure and makes it easier to convert your results from raw data into information, and then into a report or proposal. In this section we'll just list the basic steps. See *"How: Part II – Making Sense of Data"* for descriptions of each step.

1. **Recording Data:** Describe the information that will be recorded on your data sheets.
2. **Handling Data Sheets:** Describe how the field and lab sheets will be handled.
3. **Entering and Validating Data:** Describe how the data will be entered and validated.
4. **Credibility:** Describe the criteria you will use to determine whether your data are credible and can be used for their intended purpose.

Data Analysis Methods

This section should describe how you will make sense of your data, including what benchmarks you will use and how you will do the comparison.

1. **Summarizing your data:** Describe which statistical summaries, if any, you will use to summarize your data set and the data that is required to make inferences from those summaries.
2. **Interpreting your results:** Describe how you will use your data summaries to answer your questions and develop findings.
3. **Developing conclusions and recommendations:** Describe how you will use the story to develop conclusions and recommendations.

How: Part 2

When you are finished collecting your information, you may have many different forms with numbers and words on them (e.g., interviews, field and lab sheets, watershed summaries, other studies). Somewhere in there the answers to your study questions should be found. In fact, one of the most helpful roles of an assessment design is to remind you of your original set of questions and that your information was collected so that you could answer them. *Nobody remembers all of the details* – especially after collecting lots of information or at the end of a chaotic field season.

Where to start? In the introduction, we boiled watershed assessment down into four basic steps:

1. **Establish your expectations.** (See the "*Why*" Chapter.) Develop benchmarks that reflect your vision, goals and objectives for the watershed.
2. **Design and carry out a program** to gather existing and new information. Discover the current condition of the watershed by carrying out field and lab measurements and/or observations.
3. **Find the Story** – Move your data to information. Use new and existing knowledge to make appropriate comparisons. Use the results of these comparisons to develop findings, conclusions and recommendations.
4. **Tell the Story**. Inform others by telling the story to the community, your decision-makers and any other appropriate people.

The first two steps were covered in the previous chapters. In this chapter, we'll delve into finding the story and telling it.

Finding the Story – Move Your Data to Action

The first step in finding the story is to review your assessment questions and your expectations for a healthy watershed. The story will hopefully be in the answers to your questions and whether current conditions meet your expectations.

There are many ways to move data to information. Three simple steps include the following:

1. Get your data into a manageable form.
2. Make the appropriate comparisons.
3. Develop findings, conclusions and recommendations.

Get Your Data Into a Manageable Form

Any data you collected from the field may still be in raw form or they may have been converted into final reporting units (e.g., bacteria filter counts have been converted from colony forming units for the quantity filtered to colony forming units per 100 mL). It is helpful to have all of your information in a form that can be easily manipulated, summarized and analyzed.

One way to manage your data is to use a computer, and there are many different types of software from which to choose. Many people use a spreadsheet, database. geographic information system (GIS) or some combination of these.

-Data Management Methods-

Databases organize data in tables, but you typically interact with them through data entry screens. These screens make sure that you follow the database structure when you enter data and can automatically check that the correct type (numbers versus text) or range of data (such as pH must be greater than 0 and less than 14) is entered. Although databases take a considerable amount of preparation time, once this is done it is very easy to enter, store, retrieve, perform relational queries and report the data. "Off the shelf" databases include Access (Microsoft), Approach (Lotus), Filemaker (Claris), Paradox, Rbase and Dbase.

GIS software gives you another way to store and display your data that combines simple database and graphing functions with the power of putting data directly onto a map of the watershed. This system allows you to easily sort and combine any of your data to perform visual analyses, simple calculations based on the location of the sample point in the river or watershed and the value of your sample, and create reports. You could also enter any locations mentioned in a Cultural Ecosystem Story with a description and plot them on a map according to, for example, their traditional use. Most GIS software also easily imports other kinds of data formats into a table to which the spatial information can be linked.

Spreadsheets organize data in tables (rows and columns) that you manually construct and can directly rearrange, sort, search and use to perform many calculations and statistical and graphical analyses. Common spreadsheet programs include Excel (Microsoft), Lotus 123 (IBM) and Quattro Pro (Word Perfect).

STORET (short for STOrage and RETrieval) is a data management system (based on the "Oracle" data base) developed by the EPA that contains raw biological, chemical and physical data on the nation's surface and groundwater. EPA actually maintains two data management systems containing water quality information for the nation's waters: the Legacy Data Center (LDC), and STORET. The LDC, contains historical water quality data dating back to the early part of the 20th century and collected up to the end of 1998. STORET contains data collected beginning in 1999, along with older data that has been properly documented and migrated from the LDC.

Data for STORET are collected by tribes, federal, state and local agencies, volunteer groups, academics and others. For further information, visit the STORET homepage at www.epa.gov/storet, call the STORET technical assistance line at 1-800-424-9067, or send an email to STORET@epa.gov.

Make the Appropriate Comparisons

Having your data in a manageable form makes it easier to begin making comparisons and sense of all the information! Your assessment questions will generally dictate the appropriate comparisons, but some that are typically made include:

- One or more indicators at the same site over time
- One or more indicators at different sites
- Indicators relative to reference or control sites, with variations including:
    - Determining whether the result is higher or lower than a single number,

    - Dividing the result at your assessment site by the result at the reference site to come up with a percent similarity to the reference site,
    - Using complex predictive statistical models.
- Indicators relative to the criteria used in establishing expectations or developing water quality standards, determining whether designated uses are, for example:
    - **Fully supporting:** all uses supported
    - **Partially supporting:** uses supported but threatened
    - **Not supporting:** one or more uses not supported (See *Sample "Use Support Status" Determinations* for more information.)
- Quality assurance results with expected results, answering questions like the following (For information on using the actual statistics to answer these questions, see the U.S. EPA *Integrating Quality Assurance Into Tribal Water Programs*):
    - **Split, duplicate and replicate samples:** How close were the two results? Does that difference meet your expectations?
    - **Spiked, known and unknown samples:** How close did the actual results come to the expected results? Does that difference meet your expectations?
    - **Blanks:** Was the result "0" or "below your detection limit?"
- Some combination of these.

Looking at a spreadsheet or database table can be a good place to start making comparisons. Depending on the amount of data, this process may be enough to reveal patterns and trends. For large data sets, you may want to summarize this mass of numbers in order to make comparisons.

Some commonly used summaries include: (See the “Commonly Used Data Summaries” table in the “*How: Part 2*” chapter for definitions for each of these summary terms.)

- **Range** (minimum and maximum)
- **Average** (arithmetic mean)
- **Median**
- **Quartiles and the Interquartile Range**
- **Geometric Mean**

Some Indicators You Might Want to Compare	
Flow v. any Indicator	May indicate polluted runoff or may explain low values (due to dilution)
Precipitation v. any Indicator	May indicate polluted runoff or may explain low values (due to dilution)
Secchi Transparency v. Chlorophyll	May indicate that transparency is a surrogate for chlorophyll (which would be handy, since it's much easier to measure)
Secchi Transparency v. Apparent Color	May indicate that transparency is a surrogate for apparent color (it is also easier to measure)
Conductivity v. Nutrients	May indicate that conductivity is a surrogate for nutrients (easier to measure)
Conductivity v. Suspended Solids	May indicate that conductivity is a surrogate for suspended solids (easier to measure)

Turbidity v. Suspended Solids	May indicate that turbidity is a surrogate for suspended solids (easier to measure)
Depth v. Temperature	Indicates extent of mixing zone at freshwater inflows; extent of tidal salinity "wedge" in estuaries; may indicate presence of pollutant plumes or cells; may indicate stagnant water layers in well-protected embayments
Depth v. Oxygen	See depth v. temperature
Depth v. Salinity or Conductivity	Indicates origin of water – ocean or river

Sample "Use Support Status" Determinations	
Aquatic Life	
Fully Supporting	Sustainable assemblages of fish, macroinvertebrates, or algae which are not significantly different from the reference condition.
Partially Supporting	At least one assemblage is moderately different from the reference condition.
Not Supporting	At least one assemblage has been severely modified from the reference condition.
Note: The definitions of "significant," "moderate" and "severe" are developed by the Tribe and can be defined when the community is establishing their expectations for a healthy watershed.	
Physical Habitat	
Fully Supporting	Reliable data indicate natural channel morphology, substrate composition, bank/riparian structure, and flow regime of region. Riparian vegetation of natural types and of relatively full standing crop biomass (i.e., minimal grazing or disruptive pressure).
Partially Supporting	Modification of habitat slight to moderate usually due to road crossings, limited riparian zones because of encroaching land use patterns, and some watershed erosion. Channel modification slight to moderate.
Not Supporting	Moderate to severe habitat alteration by channelization and dredging activities, removal of riparian vegetation, bank failure, heavy watershed erosion or alteration of flow regime.
Special Considerations for Lakes	
For lakes, Consider DO, pH, and temperature standards for both upper and lower levels of the water column. In addition, States should consider turbidity and lake bottom siltation.	

The story might be in the minimum and maximum values measured, such as the number of times a measurement may exceed a set level or the range of readings throughout a given day. Or, it may be helpful to use one of the other values for comparisons between sites, or between months, seasons or years for the same site. The purpose behind the average, geometric mean and the median is to summarize the data by calculating a value that is "representative" or "typical" of the values being summarized. (Be aware, however, that with just a few data points, these summaries do not accurately represent your data. A minimum of 5 data points is recommended to calculate any of these statistical summaries.) The purpose of the quartiles is to show how the data are spread above and below that representative value.

Which statistical summaries you use depends upon the type of data you are summarizing. For temperature and dissolved oxygen, it is good to calculate seasonal medians and quartiles because these two indicators vary naturally with the seasons. If your monitoring spans more than one season (e.g., spring into summer), try calculating separate summaries for summer and spring. If your monitoring data is always collected during one season or some other continuous period, calculate one set of quartiles for the whole data set. Other indicators may vary over other continuous periods, such as ice-free periods or periods when the water body stratifies. In any case, be sure that you're comparing data sets that are for the same period, season or otherwise.

A Good Graph Has...

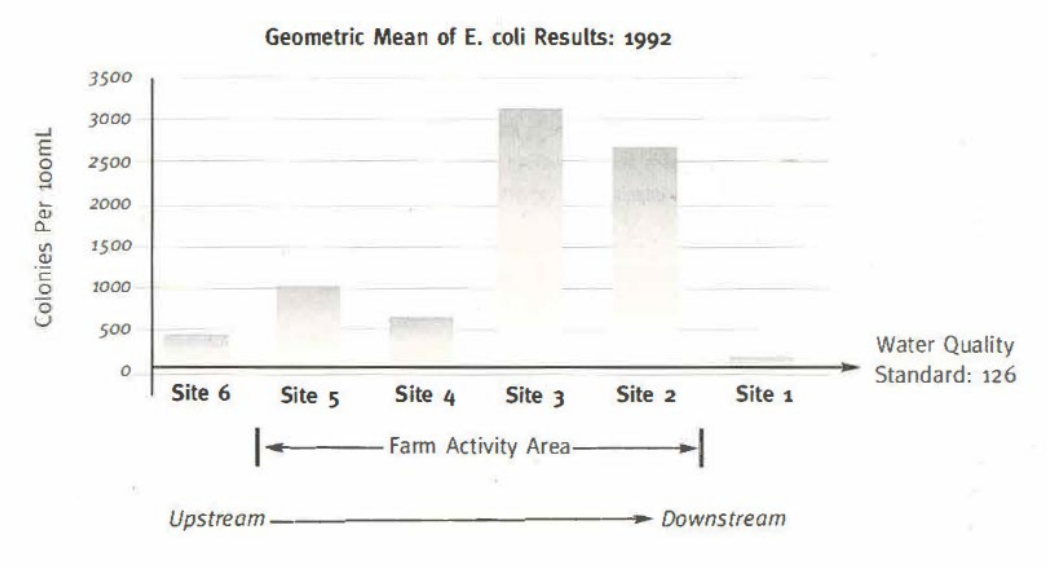
- Enough information to "stand on its own," if separated from supporting materials, including:
    - A clear title
    - Simple clear labels on axes
    - A scale that reveals trends
    - A legend that explains the elements of the graph
    - Clearly shown reporting units
- A story that is apparent
- Information that allows the reader to get the point, for example, levels of concern
- The minimum number of elements to tell the story – avoid clutter

In general, it is best to use the median instead of the average, if your data contain atypically high or low numbers. If they don't, the median may be close to the average anyway – so you could use either. Note that for dissolved oxygen (as % saturation) and salinity, you may be able to use averages, if the results don't fluctuate much.

Whether using summaries or not, it may help to make comparisons by creating visual displays of the data. Often, patterns in the data can be easier to see in a graph, as in the two examples on the following pages.

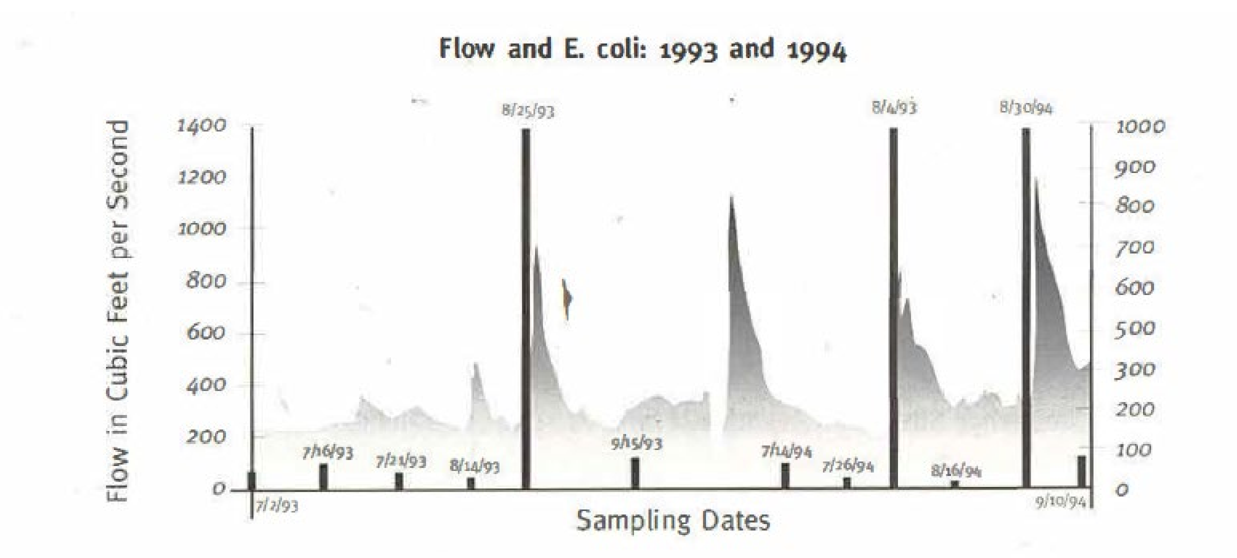
Example 1

This bar graph compares the geometric mean of one indicator to: 1) the same indicator at different sites and 2) a water quality standard. You can easily see at a glance that the highest bacteria levels in 1992 were consistently at Sites 2 and 3. It also shows you that all sites, except Site 1, were usually higher than the water quality standard.



Example 2

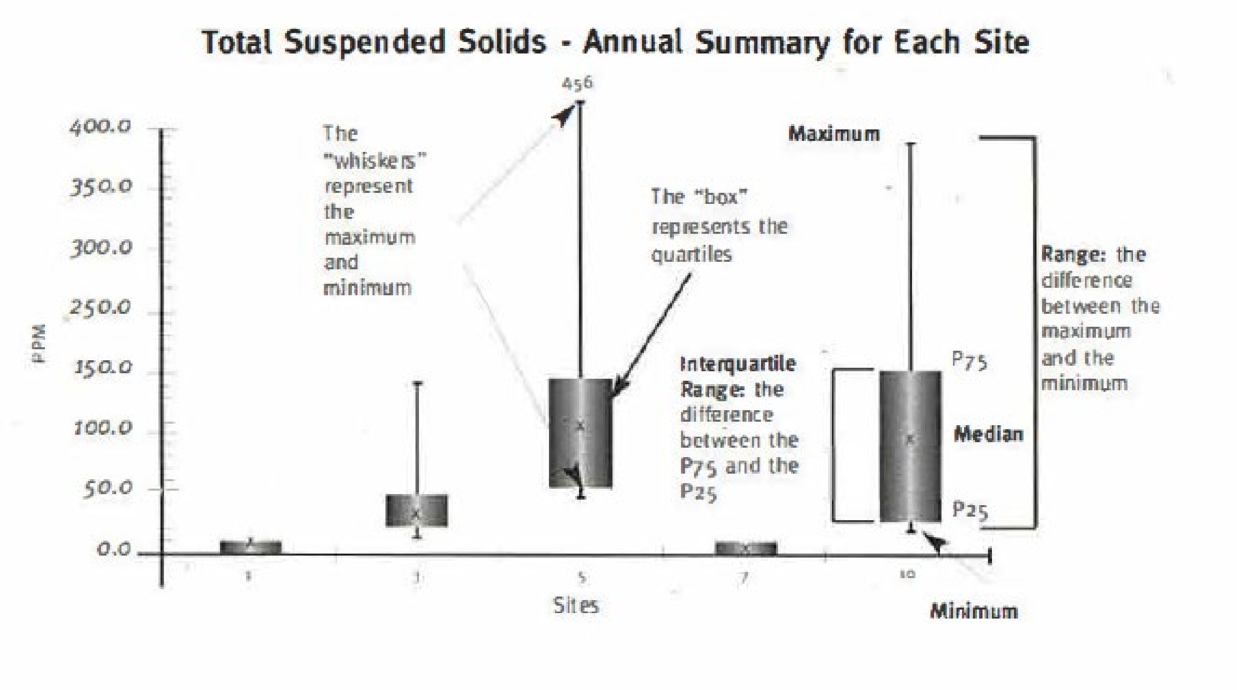
As you can see in this combination graph, you could also compare how one indicator relates to: 1) another indicator and 2) over time. Here is a combination of *E. coli* results (bars) compared with flow (gray area). Like a line graph, the gray area emphasizes either a relationship or a trend among data points, rather than individual data points. A word of caution: emphasizing the continuity and relationship between data points implies that you know the relationship between the values found at each site. This may or may not be the case, so line or area graphs can be misleading, unless you have enough data points to feel confident that the trend implied is valid. In the case of the flow example here, this is appropriate, since these are average daily flows and thus, "continuous" measurements.



Example 3

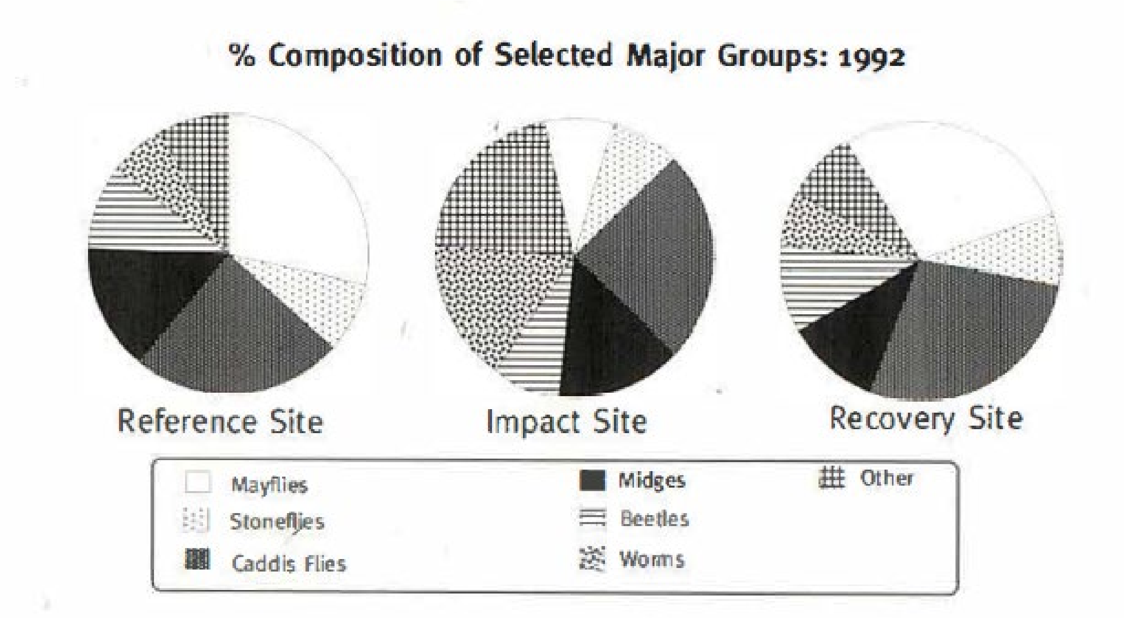
You may also want to look at the variability of your data and whether there are meaningful differences among the results at your samples sites. In this case, a "box and whisker" plot showing the quartiles and interquartile range might be helpful. This sample "box and whisker" plot shows you that the results varied most (largest range and interquartile range) at Sites 5 and 10 and least at Sites 1 and 7.

The more overlap of the "boxes" (the interquartile range) between two sites, the more confident you are that the results are similar. If your analysis involves a comparison between assessment sites and reference sites, this is a relatively simple way to actually "see" the difference or similarity. If there is little or no overlap, there is likely a meaningful difference. For example, the interquartile ranges for Sites 5 and 10 overlap between 60.0 and 158.0 mg/L. This is very easy to see just by looking at the boxes. In contrast, the interquartile ranges for Sites 1 and 5 don't overlap at all.



Example 4

Pie charts, like this example, are commonly used to show percent composition of the data. They easily display the percentage of a sample or a data set that is composed of different groups. For example, they can show the percent of a sample that is composed of different water quality indicators, pollution sources or taxonomic groups. They can show the percent of the total number of samples that fell within certain ranges.



-Commonly Used Data Summaries- Water Column Data	
Indicator	**Summary**
Temperature	Seasonal Average[1] Seasonal Median Maximum Range Quartiles
Turbidity	Median Maximum Quartiles
Dissolved Oxygen (as mg/l)	Seasonal Median Minimum Quartiles
DO (as % saturation)	Seasonal Average[2] Seasonal Median Quartiles
Transparency (water clarity)	Seasonal Average Seasonal Median Maximum and Minimum Range Quartiles
Bacteria (water contact safety)	Geometric Mean Quartiles
Bacteria (shellfish)	Geometric Mean % greater than 49[3] Maximum Standard Deviation[4]

	P90[5]
Specific Conductivity or Salinity	Average[6] Median Quartiles
pH	Median or Average[7] Quartiles Minimum
Alkalinity	Median Quartiles Minimum

[1]*Calculate the median on a seasonal subset of the data.*

[2]*Since % saturation is corrected for temperature and salinity fluctuations; this may be fairly stable allowing you to use the average.*

[3]*This is the percent of the total number of samples which exceed a fecal coliform result of 49.*

[4]*This is the standard deviation, a measure of the distribution or variability of the data set around the mean.*

[5]*This is the value below which 90% of the data lies (also known as the 90th percentile).*

[6]*Salinity in estuaries may be fairly stable allowing you to use the average.*

[7]*The average is acceptable in well-buffered systems (especially estuaries) where fluctuations are not extreme. It also is acceptable if you measure pH to the nearest 0.1 unit. If you measure to the nearest 1.0 unit then use the median.*

-Commonly Used Data Summaries-

Range *(maximum and minimum)*

Range is the difference between the maximum value and the minimum value in your data set. If the difference is large (a wide range), it means that there is a lot of variation in your data. This is useful information when you're trying to determine if there is a trend over time or space, because it will give you an idea of the amount of variation that typically occurs. The maximum and minimum values themselves may also be important. For example, dissolved oxygen standards are frequently expressed in terms of minimum concentrations that will support fish. Bacteria levels are expressed in terms of maximum levels that will pose an acceptable risk to public health.

Average *(arithmetic mean)*

Averages take the sum of all the values in your data set and divides it by the total number of values to get a value that is representative or typical of the rest. Averages are especially useful, if you know that the variation in your data is relatively low, and you don't want to show all of the numbers. For example, you might want to present the average size of a certain species of fish caught at a particular location. Just remember that very high and very low numbers (outliers) can greatly affect the average value and potentially distort the findings. You might choose to leave either really large or small fish out of the average and describe them separately (using additional information to help explain their size difference).

Geometric Mean

Like the median, the geometric mean reduces the influence of the very high and very low numbers on the data set. To calculate it, a set of data is transformed to the logarithmic values of each data point. These values are averaged and then transformed back to the original units. It is commonly used to summarize bacteria data, since many state water quality standards are expressed in terms of the geometric mean of sampling results taken over a 30- or 60-day sampling period. Again, your spreadsheet or data base will most likely calculate this for you.

Median

Medians are frequently more representative than the average, because the median is the value in the center of a set of values arranged from lowest to highest. This means that half of the numbers are greater than the median and the other half are less than the median. If the set has an even number of values, then the median is the average of the two central values:

13.1 13.6 15.3 25.1 26.5 32.6 35.4 45.3 48.5 52.2 136. 7 151.6

The median is 34, the average of the two central values. The median is more representative especially when the set contains one or two very high or low numbers because changing the magnitude of any of the other values won't affect it at all, as long as they don't change their position in the line up.

Quartiles

Quartiles describe the range of values around the median, making it much more informative. Quartiles use the median to split each half of the data set into half again, just like a dollar can be divided into 4 quarters (see the "Graphs" section below for a graphical example). In effect, quartiles show you the typical value and the range of 50% of your data. By trimming the highest 25% and lowest 25% of your data, you eliminate the influence of the outliers, which may not be representative of the bulk of your data *(but as you see in the "Graphs" section, these data can be included as the "whiskers" on the graph)*.

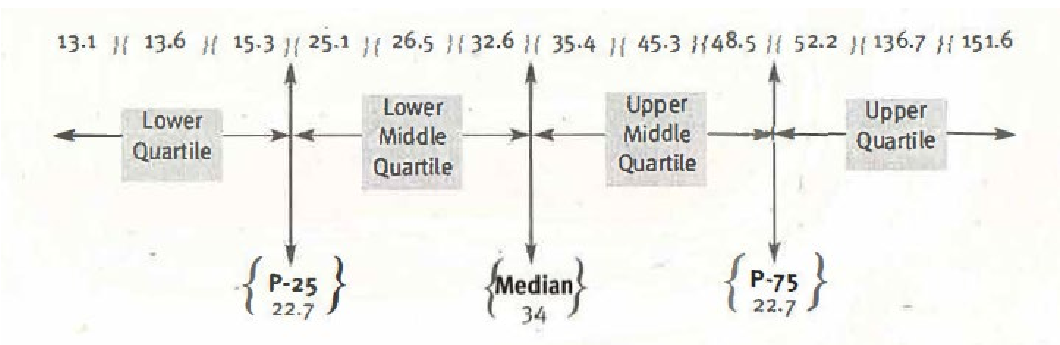
The three values that are the divisions between the quartiles are called percentiles:

- The median (or 50th percentile) divides the data in half.
- The 25th percentile (aka P-25) defines the upper boundary of the lowest 1/4 of the number of values in the data set.
- The 75th percentile (aka P-75) defines the lower boundary of the highest 1/4 of the number of values in the data set.

The interquartile range is the P-75 minus the P-25, essentially, the range of the middle 50% of your data set. If these values are close together (a narrow range. it means that your data set is relatively consistent and clustered around the median. If they are far apart (a wide range), it means that there is a lot of variation in your data. This measure of variation is useful information when you're trying to determine if there is a trend over time or space. Many computer applications calculate quartiles for you, but it's important to understand what the numbers mean.

Example of Quartiles

Here is a set of results for total suspended solids (in mg/L). First, the data are arrayed lowest to highest. Quartiles and percentiles are identified based on their values and where they lie in this array.



In this data set, the P-25 is calculated from the two values it lies between: (15.3) and (25.1). Excel calculated the P-25 for this data set as 22.7. The median is the average between the two central values (32.6) and (35.4). In this data set, the P-75 is calculated from the two values it lies between: (48.5) and (52.2). Excel calculated the P-25 for this data set as 49.4.

-Commonly Used Data Summaries-
Aquatic Life Data

The numbers of plants or critters in various taxonomic groups are frequently summarized using metrics that represent different aspects of the part of the community. Some of the statistical summaries used for core indicators can also be used on the metrics values, especially when you have more than five years of data. Individual metrics that respond in a predictable way to watershed stressors are frequently combined into a multi-metric index.

METRIC CATEGORY	DEFINITION	EXAMPLES
Benthic Macroinvertebrates		
Richness Measures	The number of distinct taxa in the sample	Total # of taxa, # of EPT taxa, # of mayfly taxa
Composition Measures	The percent of the sample in selected taxa	% Major groups, % EPT, % mayflies, % dominance
Tolerance/Intolerance Measures	Represent the relative sensitivity to perturbations	Biotic index, # of intolerant taxa, % tolerant organisms
Feeding Measures	Balance of feeding strategies in the sample (e.g., predators, grazers, shredders, collectors)	% In each feeding group
Habitat Measures	Describe the behavior adaptions	# Of clinger taxa, % clingers
Life Cycle Measures	Describe the length of life cycles	% Multivoltine (short), % univoltine (long)
FISH		
Richness Measures	The number of distinct taxa or groups in the sample	Total # of taxa, # of natives, # of salmonid age classes
Number and Identity of Species	Diversity and identity of indicator species	Darters, sunfish, suckers, green sunfish
Number of Intolerant Species	Number of species that are intolerant of chemical and physical perturbations	# of sensitive species, % cold water species
Feeding Measures	Balance of feeding strategies in the sample (e.g., insectivores, omnivores, carnivores)	% in each feeding group
Abundance Measures	The number of individuals in the sample	Density, % abundance of dominant species, biomass
Reproductive Measures	Measure of the suitability of the habitat for reproduction	% hybrids, % introduced species, % native species
Disease Measures	The percent of the sample that shows evidence of disease	% of individuals with deformities, eroded fins, lesions, tumors
Periphyton		
Abundance Measures	Represents the amount of production	Mass, ash-free dry mass, chlorophyll *a*
Richness Measures	The number of distinct algae species in the sample	# of diatom species, # of soft algae species, total # of genera, total # of divisions
Composition Measures	The percent of the sample in selected taxa or groups	Shannon Diversity, % specific taxa, % live diatoms
Pollution Intolerance Measures	Represent the relative sensitivity to perturbations	Pollution Tolerance Index, % sensitive diatoms

-Commonly Used Data Summaries-
Physical Habitat Data

Geomorphology: This includes various measurements of the stream bottom, the depth to which the stream has carved its channel, channel width/depth ratio, sinuosity (meandering pattern), number of channels, slope. These data can be summarized in several ways:

- **Stream Classification**: There are various systems that use the basic data to divide streams into different types.
- **Channel Evolution Models:** Describe the sequence of changes a stream undergoes after certain kinds of disturbances.
- **Proper Functioning Condition:** This is a methodology for assessing the physical functioning of a streamside wetland area. The result is an assessment that places an area into one of three categories: proper functioning, functional-at-risk, or nonfunctional.
- **Stream Stability**: This summarizes data to assess whether a given reach is stable and, if not, whether it's just a local condition or stream system-wide.

Flow: Flow (aka "discharge") data describe the volume of water passing by a particular location over some time interval. At the simplest level, flow data are typically summarized as cubic feet per second. Other types of flow summaries include:

- **Flow Duration**: This is the amount of time certain flow levels exist in the stream. This is usually expressed as the percentage of time a given stream flow of interest (e.g., drought or flood flows) is equaled or exceeded over a given period. These are summarized using "flow duration curves".
- **Flow Frequency**: This is the probability (or a percent chance) that a given flow will be exceeded in a given year. These frequencies are determined by applying statistical methods to a long-term set of flow data. The flows of interest are usually one or all of the following:
    - **Flood frequency:** The probability that given flood flows will occur in a given year.
    - **Low flow frequency:** The probability that given low flows will occur in a given year.
    - **Channel-forming flow:** This is actually a variety of theoretical flows that maintain the geometry of the channel. Common measures are the bankfull discharge, effective discharge, mean annual flow, etc.

Substrate Quality: The substrate is the bottom of a water body. Quality refers to its usefulness for various biological functions, such as attachment, shelter from the current, shelter from predators, spawning, rearing, etc. It is usually based on an inventory (aka "pebble count") of the number of particles in various size classes, such as bedrock, boulders, cobble, gravel, silt and organic material. The most common summary technique is a size distribution. This plots the different; particle sizes according to the frequency with which they occur at a given location. These distributions are then related to the requirements of different organisms.

Riparian Vegetation: The data gathered are typically focused on changes and functions of vegetation close to the water.

Develop Findings, Conclusions and Recommendations

After making the appropriate comparisons with your data you now have the information you need to develop the story. The limits of the story lay in your quality assurance/quality control results. You determined the measures you were going to undertake to determine the reliability of your data. In order to avoid developing findings that are not supported by your data you might answer some preliminary questions, including:

- Did you collect the required number of samples from the minimum number of sites (completeness)?
- Did you collect samples frequently enough, at the right time of year, at the right time of day to be representative of the conditions you are assessing?
- How did your quality assurance results (from split, duplicate, spiked, replicate, known, unknown, and blank samples) compare with expected results? Did they meet your data quality objectives?

If these objectives weren't met, then your data may not be able provide reliable answers to your questions and it will be necessary to limit your findings.

Some of the information it might be important to have available for review when developing findings includes:

- A map of your watershed with the sites marked on it and the classification of the segments you sampled.
- A map or list of open or closed shellfish beds, areas closed to fishing or swimming, etc.
- A map of areas where community members most often use water and are exposed to pollution or toxics during traditional or contemporary practices.
- Correct units of measurement clearly reported on your data tables and graphs.
- General observations, such as habitat, wildlife, tide, storm and wind-related surface water conditions, and weather information for each sampling date and site.
- Your cultural ecosystem story or source of traditional ecological knowledge.
- The appropriate water quality standards (tribal and state or federal) or reference conditions for each indicator.
- Historical or current information gathered from other water quality data sources, such as the state or other monitors, in a format similar to your data.
- Anecdotal information on beaver pond construction (or "deconstruction"), highway projects, dam or tidal gate repair, intensity of various recreational uses, vacation home rentals, etc.

Develop Findings: Are there differences and are they meaningful?

Findings are observations about your data. They are the statements that summarize the important points, but do not explain them. We tend to look at data and then begin to try to explain it before thoroughly observing and summarizing the trends, patterns or lack of patterns. Findings should support your conclusions.

For example, let's look back at the sample "box and whisker" plot. Let's assume that Site 1 is the reference site, and we are using a criterion, which says that sites with interquartile ranges that don't overlap with the reference site are significantly different.

Your findings could be:

- The site most like the reference site is Site 7,
- The sites least like the reference site are Sites 5 and 10 (though they are quite similar to each other), and
- That Sites 5 and 10 are not healthy.

In order to help you develop findings, look for patterns within your data set, as well as comparing your results to reference conditions. You might answer any of the questions listed below.

General questions to ask of your data set:

- Which sites had the highest or lowest readings?
- Which dates had the highest or lowest readings?
- Which tidal stage had the highest or lowest readings?
- Are there numbers that seem to be much higher or much lower than typical results ("outliers")? Are you confident that these numbers are reliable? Verify that the numbers were transcribed or entered correctly.
- Do your results show a consistent pattern of change upstream to downstream or close to and further from the impact source? Do levels increase or decrease in a consistent manner?
- If you are monitoring the impact of a pollution source, for example, are your results different above and below the impact or at different tidal stages?
- Do changes in one indicator coincide with changes in another? As illustrated earlier, there is usually an inverse relationship between water temperature and dissolved oxygen, since warm water can hold less oxygen than cold water. There's a similar relationship between an increase in water column algae and a decrease in water clarity.
- How do your results compare among tributaries?

Questions to ask of your data when comparing them to reference conditions:

- **Comparisons with maximum and minimum**: Did the results exceed the maximum and minimum acceptable levels set by the tribe? Where? When?
- **Comparisons with ranges:** Were the results inside or outside of your acceptable range? Where? When?
- **Comparison with allowable number of times**: How many times did your results not meet your reference conditions? Your reference conditions or your assessment procedure might specify a maximum number of times, or percent of the time, when results do not meet standards. How many times (or what percent of the time) were reference conditions not met? Where? When?
- **Sampling dates**: Are there sampling dates when most or all results did not meet your benchmarks?
- **Special weather or hydrologic conditions:** Were there any conditions (dry or wet periods; large or long precipitation events; tidal stage; wind conditions; day of the week; time, etc.) when most or all results did not meet your benchmarks?
- **Percent Similarity:** This is the similarity of the assessment site to the reference condition. Developing a finding about what the resulting percentage means usually involves some sort of

guidance. For example, here's a list that could be used to evaluate the percent similarity for benthic macroinvertebrates:

- *>79% Non-impaired:* Comparable to the best situation expected within an ecoregion. Good representation of pollution intolerant organisms. Optimum community structure compared with reference.
- *29-72% Moderately Impaired:* Partly comparable to the best situation expected within an ecoregion. Community structure shows decrease in richness and pollution intolerant organisms.
- *<21% Severely Impaired:* Not comparable to the best situation expected within an ecoregion. Low richness, dominated by few families.

Develop Conclusions: What do you think is causing this change?

If you've determined that there are meaningful differences in your data, and that these differences indicate a problem, the next step is to develop your explanation of what might be causing the problem. This might require another look at your data in light of the following questions:

- Does weather and/or tidal stage appear to influence your results?
- If you are monitoring the impact of a pollution source, does the presence of this source explain your results?
- Might natural changes explain your results?
- Did the time of day you sampled affect your results?
- For episodic discharges, did your sampling coincide with the discharge?
- Do changes in one of your indicators appear to explain changes in another?
- Could your visual observations help explain any of your results?
- Might management activities affect your results?

This step is the link between your results and the next steps you might want to take to solve problems.

Some important things to keep in mind when analyzing your data:

- **The degree of trust** you have in the quality of the work done to obtain the data. For the first sampling time, you might learn more about how to use the equipment and the procedures than you will about the actual water quality. Although this is excellent information about the process of science, any data that is the result of learning by trial and error should not be reported, unless you are confident that the procedures were not compromised. Alternatively, you can report it, if you note the sampling and/or analysis problems which may have occurred.
- **The sensitivity of the methods and equipment** you used. This will constrain what you can and can't say. For example, if you used a color wheel to determine orthophosphate concentration, you can't detect concentrations below 0.1 mg/L. So you shouldn't report these as "0." You should say that the results were "< 0.10 mg/L."
- **The degree of change** that is important for each indicator. You may be able to detect some fairly small changes in the levels of indicators. Yet, these changes may not be very important in terms of their impact on the river, estuary or lake.

Whether this change is important depends on several factors:

- **How the change compares** with the natural, background or baseline levels of that indicator in your waterbody. If natural levels are high (compared with typical water bodies). it may take a relatively large change in conditions to impair ecological processes.
- **How the change compares** with the natural variability of the indicator in your water body. The level of most indicators varies naturally over time and space. If the change you measure is within the range of this natural variability, it will probably not affect the waterbody.
- **Whether the change crosses a threshold.** *There are two types of thresholds that might be important:*
  - The absolute level of an indicator. If your results fall above or below this value, an impact results (such as a level that is critical for the survival of aquatic life), and
  - The magnitude of the change. For example, a certain fish may be acclimated to the current water temperature, but sensitive to changes beyond a certain range.

Develop Recommendations

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

Examples of recommendations for action:

- Consider fencing the farm animals (including the horses) out of the stream and re-establishing a buffer of natural vegetation to grow between the fence line and the brook.
- Carry out educational activities for homeowners about the effects of pesticides and fertilizers from lawn treatment and provide examples of alternatives.
- Organize an educational workshop for waterfront landowners about the benefits of best management practices to control erosion.
- The tribe should install a sediment trap basin at the storm drain outlet on West Street.

Examples of recommendations for further information:

- Sample the storm water drains at Main and Elm streets to determine if they contribute to elevated bacteria levels.
- Carry out a sanitary shoreline survey.
- Conduct storm event monitoring in the upper estuary to determine whether or not the treatment plant improvements have worked.
- Begin intertidal habitat monitoring to determine the impact on the estuary of an industrial discharge.
- Monitor dissolved oxygen over a 24-hour period at sites 1, 2, and 6 to determine the daily range of dissolved oxygen levels.
- Conduct wet weather water sampling and analysis for *E. coli*, total phosphorus, and turbidity at all sites.
- Monitor for total and orthophosphate at sites 8 and 9 to determine if increased algae growth is caused by fertilizers.
- Continue monitoring the benthic macroinvertebrate community at all sites on an annual basis to document whether the improvement is long-term.

- Measure instream embeddedness or do a benthic macroinvertebrate survey to see if sedimentation is causing habitat impairment.
- Carry out a pollution source inventory to locate and test discharge pipes.

Telling the Story

Audience and Format

Once you've converted your raw numbers into an interesting story, there are many ways to tell it. Your community will have its own decisions to make about the people with whom you are going to share your knowledge. And your community knows best how your members communicate, how information is shared and the words and formats that should be used to tell your story to outside entities. You may have requirements from funding agencies or other data users that you want to fulfill first. Those requirements will dictate the format and content of the presentation you generate for them. Otherwise, the choices you make about your presentation depend on the type of audience with whom you are trying to communicate. In addition to the data users you listed in your study design, you might choose other types of audiences, including:

- **Native Community**
  - Tribal Council and other leaders
  - Community members
  - Other Native communities and program staff
  - Organizations
  - Businesses
- **Non-Native Community** *(at the local, state or national level)*
  - Grassroots watershed protection groups
  - Municipalities
  - Organizations
  - Businesses
  - General public
- **State or Federal Agencies** *(Tribal or otherwise)*
  - Environmental and wildlife protection
  - Public health
  - Resource management

Appropriately targeting any of these audiences involves considering their many different perspectives. People and groups within each of these audiences will have various cultural backgrounds or experiences, levels of technical expertise, objectives and goals. The length, clarity and amount of technical detail you include greatly affect how much your audience understands and remembers. A great, easy-to-read summary of general presentation considerations can be found in the Massachusetts Water Watch Partnership's "Ready, Set, Present!" manual. (http://www.umass.edu/tei/mwwp/datapresmanual.html)

Varying the technical level of your story can be one of the most difficult aspects of presenting monitoring information and telling your story – you can never reach everyone. An additional challenge can be the translation of technical information from a western perspective into a culturally relevant format for Native communities. For example, state and federal agencies might require a technical scientific report for their information. Even if your audience is familiar with all of the technical details of your work, not everyone wants or has the time to deal with a lot of information. So you might want to summarize that information into a less detailed format for tribal council or community members.

Basic Tools To Tell the Story

- Maps
- Graphs
- Illustrations and Paintings
- Music
- Story-telling

Formats to Present the Story

- Newsletters
- Written Reports
- Video
- Poster Exhibits
- Oral Presentations
- Slides

Places To Tell the Story

- Radio Broadcasts
- Newspaper Articles
- Web Sites
- Public Meetings
- Formal and Informal Cultural Gatherings

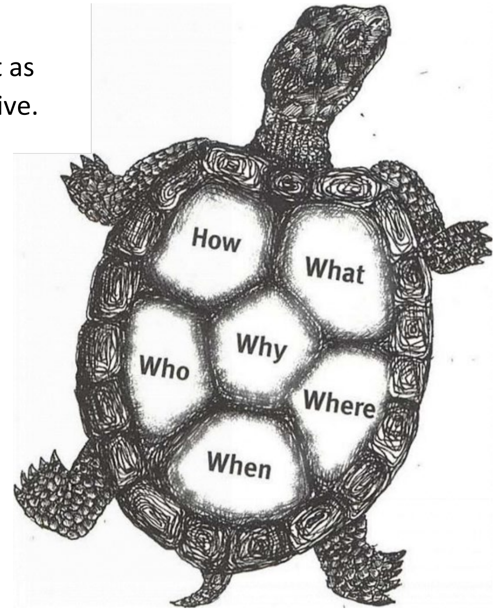
Producing a Written Report

No generic format can incorporate all of the unique Native perspectives. Your community has a unique set of traditions and ways of expressing their connection to water and the changes they have seen as a result of degradation. Furthermore, every community is facing different watershed impacts and water quality problems. Thus, just like the process of coming up with monitoring purposes, the community should first consider how best to present their perspective and monitoring results. Even the very notion of a written report might be seen as unnecessary in a culture which has relied on an oral tradition of story-telling.

If the community decides to create a generic report, there is a format that can help summarize your monitoring work and could be useful for many types of presentations. This could also be used in other presentations in which you include cultural information tailored to your audience. A generic report typically includes the following: a summary of your monitoring activities and results, a statement of your findings and conclusions, and your recommendations for actions to address problems or, if needed, changes to your sampling program. Some programs produce an annual "state of the watershed" report that summarizes and analyzes the results of the preceding year, and all previous years, highlighting trends, clean-up progress, new trouble spots, etc.

Using the Story to Evaluate Assessment

While answering your original questions, you may generate just as many new ones. You may also find that your data are inconclusive. Perhaps you're not measuring the right indicators at the right time or at the right place. Maybe you need to gather data for a number of years before you can answer your questions. Use these findings to evaluate your present assessment work and to design your future work. Your assessment work will likely evolve as you learn more about the watershed and as the science of assessment changes.



Resources

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Endnotes

Preface

[1] Haudenosaunee Environmental Task Force, "Words That Come Before All Else."

[2] Haudenosaunee Environmental Task Force, "Words That Come Before All Else."

[3] LaDuke, Winonna, 1999. "All Our Relations: Native Struggles for Land and Life." South End Press, Cambridge, MA.

[4] DePree, Max, 1990. "Leadership is an Art." Dell Publishing Company.

Chapter I: Why

[5] Haudenosaunee Environmental Task Force, ''Words That Come Before All Else."

[6] See LaDuke, Winona, 1999. "All Our Relations: Native Struggles for Land and Life." South End Press, Cambridge, MA for a review.

[7] "Our Common future" (The Brundtland Report): Agenda 21, Chapter 26. (http://www.un.org/esa/sustdev/agenda21chapter26.htm) and Article 8j of the Biodiversity Convention (http://www.biodiv.org/socio-eco/traditional/background.asp)

[8] Ankrah et al., 1997. "Cultural Ecosystem Stories Workgroup, Cultural Ecosystem Stories: a guide to preparing natural resource case studies." Unpublished Report. Cultural Ecosystem Stories Workshop, U.S. EPA, OPPE.

[9] Gold, Julia, 2001. "Cultural Ecosystem Stories: Tulalip Pilot Project 1999-2000." Unpublished Report. Tulalip Tribes Department of Natural Resources.

[10] During your information gathering, you might also start building a small tribal water law library.

[11] Unger et al, 1999. "7 Generations: Addressing Village Environmental Issues for the Future Generations of Rural Alaska." Alaska Department of Environmental Conservation. (http://www.state.ak.us/dec/dsps/compasst/nenerations/nen.htm)

[12] The General Assistance Program and certain other grant programs (e.g., grants under CWA § 104) do not require tribes to go through this process.

[13] Subchapter V-1377, section518. Read this section for requirements-it can be found online at http://www.4.law.cornell.edu/uscode/33/1377.html.

[14] Contact the Northwest Indian Fisheries Commission for the perspectives they have looked at over the years.

[15] Haudenosaunee Environmental Task Force.

Chapter II: What

[16] Cajete, Gregory, 2000. "Native Science: Natural Laws of Interdependence." Transcontinental, Canada.

Chapter III: Where

[17] Reference sites might be considered "high quality waters" under the anti-degradation provisions of applicable water quality standards.

[18] Often referred to as "305b" (section of the Clean Water Act) report.

Chapter VI: How

[19] U.S. EPA, 1994. "Guidance for the Data Quality Objectives Process." EPA QNG-4, Office of Research and Development, Washington DC. (You can download the guidance document at: http://www.epa.gov/quality/qs-docs/g5-final.pdf

[20] For example, see Sanders (1983), Design of Networks for Monitoring Water Quality.

[21] The percentage that the results for two replicate sample results should be within.

[22] Note that some types of methods don't involve actually "collecting" a sample-for example visual 96 observations.

[23] These criteria are being established by the National Methods Board of the National Water Quality Monitoring Council. Visit http:/wi.water.usgs.gov/pmethods/ for more information.

[24] See the sidebars which list methods sources. The numbers in this column refer to the numbers in the lists.

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