Advisory Note

# PARTICIPATORY WATER MONITORING

## A GUIDE FOR PREVENTING AND MANAGING CONFLICT

June 2008

The Office of the Compliance Advisor/Ombudsman

*for the*
International Finance Corporation (IFC)
Multilateral Investment Guarantee Agency (MIGA)
Members of the World Bank Group

## About the CAO

The CAO (Office of the Compliance Advisor/Ombudsman) is an independent post that reports directly to the President of the World Bank Group. The CAO reviews complaints from communities affected by development projects undertaken by the two private sector lending arms of the World Bank Group, the International Finance Corporation (IFC) and the Multilateral Investment Guarantee Fund (MIGA). The CAO works to respond quickly and effectively to complaints through mediated settlements headed by the CAO Ombudsman or through compliance audits that ensure adherence with relevant policies. The CAO also offers advice and guidance to IFC and MIGA, and to the World Bank Group President, about improving the social and environmental outcomes of IFC and MIGA projects.

*The CAO's mission is to serve as a fair, trusted,*
*and effective independent recourse mechanism and to*
*improve the environmental and social accountability of IFC and MIGA.*

For more information about the CAO, please visit www.cao-ombudsman.org

## About the CAO Advisory Role and Advisory Notes

In its advisory capacity, the CAO provides advice to the President of the World Bank Group and to the management of IFC and MIGA relating to broader environmental and social policies, guidelines, procedures, resources, and systems. This advice is often based on the insights and experience gained from investigations and audits in the CAO's Ombudsman and Compliance roles. The objective in the advisory function, and in preparing this Advisory Note, is to identify and help address systemic issues and potential problems early.

## About the CAO Experience with Participatory Water Monitoring

This guide is based in part on the CAO's experience in participatory water monitoring in Peru, to resolve issues surrounding the Yanacocha gold mine. For more information about that experience, see the following CAO publications, especially Monograph 3 on water monitoring.

- Executive Summary. *The Power of Dialogue*
- Monograph 1. *The Formation and First Steps of the Mesa (2000–2003)*
- Monograph 2. *The Independent Water Study (2002–2004)*
- Monograph 3. *Independent Water Monitoring and the Transition of the Mesa (2004–2006)*

For more information about these monographs, please visit
http://www.cao-ombudsman.org/html-english/monographs.htm
For more information about the Mesa, please visit
http://www.cao-ombudsman.org/html-english/complaint_yanacocha.htm

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## Some Definitions for This Guide

**Participatory monitoring** is a collaborative process of collecting and analyzing data and communicating the results in an attempt to identify and solve problems together. It includes a variety of people in all stages of the monitoring process and incorporates methods and indicators meaningful to the appropriate stakeholders. Traditionally, companies and agencies initiate and undertake monitoring. Participatory monitoring requires changing the dynamic so that a wider range of stakeholders assume responsibility for these tasks and learn and benefit from the results. Participatory monitoring is not only scientific, but also social, political, and cultural. It requires openness, a willingness to listen to different points of view, a recognition of the knowledge and role of different participants, and the ability to give credit where credit is due.

**Water monitoring** involves gathering rigorous, scientific data and information about water quality and quantity. The data are analyzed to determine whether water quality supports resource uses and whether the available quantity of water is sufficient to meet the needs of these various uses. Data are also used to educate participants and to evaluate human impacts on water, as well as the effect of measures implemented to improve water quality.

**Participatory water monitoring** strives to not only generate credible data and information, but also to build trust and help resolve or avoid conflict surrounding perceived or actual impacts.

# Foreword

Participatory monitoring is one established and accepted way for the public to make informed decisions. Participatory methods have been applied to areas as diverse as monitoring revenue sharing and assessing forest impacts. Through the collection of data that is credible to multiple parties, participatory monitoring can become an essential instrument for generating trust. Thus, the Office of the Compliance Advisor/Ombudsman (CAO) sees participatory monitoring as a way to reduce or avoid conflict and improve the results of development projects.

Participatory *water* monitoring can be especially important in helping prevent water-related conflicts that may arise in the extractive industry and large-scale agriculture sectors. Participatory water monitoring presents unique challenges, however, because of the complex and highly technical nature of assessing impacts to water and the controversy surrounding the competing demands that communities and industry place on water resources.

The CAO has prepared this guide to be used as a design tool for communities, civil society organizations, corporations, and governments at both the subnational and national level that want to implement participatory water monitoring programs. The document provides a framework that can be used to develop a detailed implementation plan that meets the unique characteristics of each situation.

The CAO's interest in participatory monitoring has its origins in 2001, when the CAO received two complaints from local residents affected by the Yanacocha Gold Mine in Peru. Shortly thereafter, the CAO established the Mesa de Diálogo y Consenso CAO–Cajamarca (the Mesa) as a forum for dialogue between the mine and the community of Cajamarca and as a means to prevent and resolve conflict.

While the Mesa dealt with numerous community concerns, uncertainty regarding the mine's impact on water and the lack of trust in existing environmental data were the central sources of conflict and the focus of an independent study completed in 2003. This study actively involved community members as witnesses to field activities. Through this experience, the Mesa became interested in implementing a participatory water monitoring program.

The Mesa established the program in 2004 with assistance from the CAO. The participatory monitoring program focused on three main tasks: providing quality assurance for the water monitoring programs conducted by other institutions, communicating the results directly to communities, and arriving at practical solutions to water quality concerns in a participatory manner.

Through this experience, the CAO realized that although interest in participatory water monitoring is increasing and, in some cases, required by law or agreements, there are few resources available to help guide groups that want to implement a program. This guidance document is offered as a way to meet this need.

Meg Taylor
Vice President, Compliance Advisor/Ombudsman
June 2008

# Executive Summary

Participatory water monitoring has an especially important role to play in reducing or avoiding water-related conflict in large-scale, intensive development projects. Conflict tends to arise in situations where expectations are not being met, information is not available, stakeholder engagement is not equitable, or where there is an actual adverse impact. Participatory water monitoring can help address these causes of conflict by actively engaging stakeholders, by addressing their concerns in the design and implementation of the monitoring program, by generating credible information, and by informing solutions that can mitigate or remedy any adverse impacts. Both the process (by being participatory and inclusive) and the product (by generating trustworthy, high quality information) contribute to better development on the ground. Indeed, in important ways, the process *is* the product. The cooperation, sense of ownership, and mutual responsibility necessary to make the program succeed can strengthen community-company ties and thus strengthen sustainability—gains that can extend beyond the life of a monitoring program.

But monitoring programs need to be done right. In many instances, companies have spent large amounts of money on monitoring programs that may have a high degree of *technical* credibility, yet generate little *trust* in the community. One reason for this is that most monitoring programs are top-down, with the public receiving information that has been collected, analyzed, and reported by experts chosen by the project sponsor or company, and presented in a way that the public may not understand. In many instances, the information may not even address the real concerns of the community; rather, it may be strictly oriented toward a company's interests in compliance with regulations and legal commitments (also an important function of monitoring). Sometimes, communities become aware of monitoring results so late in the project cycle that they may have lost trust in the company before they receive the results. In such cases, there is no mechanism to generate public trust in the resulting data, and one of the principal purposes of monitoring—providing credible information to the public and authorities—is lost.

There is a better way, and this guide is offered to help provide it. Much of the discussion is structured as a series of questions that readers can tailor to their own particular circumstances, challenges, and needs.

The guide opens in chapter 1 with a discussion of the need for participatory monitoring. Chapters 2–5 describe the four components of an effective participatory monitoring program:

- Component 1. Initiating the monitoring program
- Component 2. Creating meaningful participation, effective governance, and transparent financing
- Component 3. Creating credible information
- Component 4. Evaluating the process and results

Three appendixes supplement this general discussion with specific information. Appendix A presents brief summaries of eight participatory monitoring programs surveyed to provide background for this guide. Appendix B presents sampling methods and procedures. Appendix C presents a list of additional resources, drawing on the many tools and resources available to address the social and technical details of the planning and implementation process. The glossary at the end of the document contains useful terms and definitions.

## The Benefits and Challenges of Participatory Water Monitoring

Although some general principles apply to all participatory approaches, water has some unique characteristics that make participatory monitoring especially useful.

- The health and well-being of the environment and surrounding communities depend on an adequate *quantity* of water of sufficient *quality* for designated uses.
- Water is one of the resources most at risk from development.
- The quality of water is a function of land processes that generate pollution, and thus is a good and measurable indicator of overall environmental health.
- Access to clean, sustainable water supplies lies at the heart of poverty reduction.

At the same time, participatory water monitoring presents some unique challenges:

- Assessing impacts to water resources requires a high degree of coordination with communities and officials.
- It also requires considerable technical capacity and local knowledge.

Every human activity has the potential to alter water quality. The central question that needs to be addressed by a monitoring program is the *degree* of change and whether this change impairs a *particular* use. Participatory monitoring provides a means to deepen public understanding of what is an acceptable or an unacceptable impact. In this way, it can help move public discourse beyond the simple yes or no answer of whether a project or development is contaminating local water supplies.

Before launching a participatory water monitoring program, it is important to home in on a few key questions:

- Is participatory monitoring well suited to address the root concern—and thus help prevent or manage conflicts—in comparison to other strategies?
- Can a credible convener be identified?
- Are there some minimum conditions that need to be met in order for the planning process to go forward? In many instances, there would simply be three minimum conditions:
    1. Willingness among the parties to design and implement a program
    2. Technical capacity to create a credible program
    3. Financial resources to support the program.

A thorough assessment of the social, geographical or physical, and institutional context can help answer these questions, as explained in chapter 2. The assessment also needs to gauge and manage the expectations of both the company and the community. Participatory monitoring programs convened by the project sponsor as a public relations gesture, or by advocacy groups to prove a point, are unlikely to be effective.

If the decision is made to go forward, a planning team needs to be assembled and a convener identified that is acceptable to all key parties. Then the planning team needs to clearly define the purpose of the program. The purpose helps determine how complex the monitoring program needs to be and the corresponding protocols, methods, and standards that will be incorporated. Possible purposes for participatory water monitoring programs include:

- Promoting general education and awareness
- Building capacity to delve into technical issues and understand how the scientific method can be used to answer questions
- Developing a baseline and evaluating changes over time
- Investigating a potential problem, such as
  - Identifying and monitoring sources of pollution
  - Answering specific questions about how a project or land use influences water quality and quantity
  - Determining whether the water is safe for different uses
  - Determining compliance with regulations
- Addressing public uncertainties and lack of trust by trying to answer a question that is not being addressed by any other monitoring programs, or filling in where there is a perceived lack of credibility
- Addressing public perceptions that may or may not be grounded in facts
- Establishing a technical basis for compliance and accountability
- Evaluating the effectiveness of improvements for water quality or remediation.

For water monitoring to be truly participatory and to achieve its purpose, the program must have an effective and appropriate means of engaging citizens. Exactly how public participation is incorporated into a monitoring program depends on the objectives and interests of the company and community, the resources available, and the collective vision of what participation means. Several participation approaches are explored in this guide: a community stream watch, a network of observers, monitoring committees, and independent technical experts.

The program also must have a means of governing the process that generates independence, stability, and accountability. The governance approaches examined in this document include: the project sponsor; a freestanding, legally established institution; an affiliate government organization; a civil society organization, university, or international institution; or a mixed approach that incorporates several of these elements.

The program also needs financing mechanisms that are dependable and transparent. Several possibilities are explored in this guide: the project sponsor; voluntary, in-kind support; the government; a lender or accountability mechanism, such as the CAO; a civil society organization; a religious organization; international agencies; or a mixed approach.

The next step in program design is to develop a detailed technical monitoring plan. A well-constructed technical monitoring plan helps ensure that the monitoring program:

- Conducts the right tests at the right place using correct procedures
- Generates data that meet the objectives of the monitoring program and that are more usable to others because they were collected using a consistent protocol.

Assessing water *quality* involves measuring the chemical, physical, and biological characteristics of water and comparing results to baseline conditions—data collected before a project is developed or from a similar area that is not impacted—or to applicable published criteria, such as water quality standards and guidelines.

Assessing water *quantity* is more complex; it is highly technical, and also involves legal issues, such as water rights. Unlike water quality, monitoring results cannot simply be compared to a numerical standard to determine whether there is an adverse impact or an issue with compliance, or any limitations on the use of water.

In addition to addressing the technical issues with a robust approach, the program must also address social issues. A key component of any monitoring program is to build the public's capacity and ability to understand the complex social and technical issues that are being addressed. Participants who are well trained and have a deep understanding of the purpose will take more interest in the program. In addition, the monitoring program should have an outreach and communication plan that is just as robust as the technical monitoring plan.

As the program moves from the planning stage to the point that it is collecting and analyzing data, it must ensure that all the information it generates is credible: the raw data; the analysis and interpretation of those data; and the reports, meetings, and other outreach used to disseminate findings and build public understanding.

At all stages, monitoring programs need to evaluate whether objectives are being met. Shortcomings need to be identified as early as possible so that corrective actions can be implemented. A complete evaluation includes assessment of:

- The purpose statement
- The quality of participation
- Whether governance is effective
- The transparency of financial arrangements
- The robustness of the technical approach
- How program information is used and communicated to the public.

The nine main steps of an effective participatory water monitoring program are presented below.

1. Initiate
2. Create a planning team
3. Set the context (social, geographical or physical, institutional)
4. Identify a convener
5. Develop a purpose
6. Involve the public in the planning process
7. Create meaningful participation
    a. Choose a participation approach
    b. Choose a governance approach
    c. Choose a funding approach
8. Collect credible information
9. Establish indicators and evaluate process and outcomes.

Participatory water monitoring has proven beneficial in situations ranging from oil and gas projects in Peru to copper mine sites in Zimbabwe. This guide is offered to help communities, project sponsors, and others better understand and address concerns related to water quality and quantity, and to improve the quality of public discourse and collaboration—a process that can help bring about better development on the ground.

# Part I. Introduction

*Through the collection of data that is credible to multiple parties, participatory monitoring can become an essential instrument for generating trust thereby helping to reduce or avoid conflict and improve the results of development projects*.

# Chapter 1. The Need for Participatory Water Monitoring

Development changes both landscapes and livelihoods, often for the better, but sometimes for the worse. When a new project is proposed in an area, there is often a high degree of optimism about the possibilities of jobs and economic opportunity. But optimism can turn to dissatisfaction if economic opportunities are not realized—and to outrage if the perception arises that the environment and water resources are also being despoiled. Dissatisfaction and outrage can lead to conflict if not addressed.

Conflict may occur when expectations are not being met, there is a lack of information, stakeholder engagement is not equitable, or when there is an actual adverse impact. The lack of inclusion and feeling of being dismissed give rise to suspicion and anger.

Monitoring can give people the information they need to understand positive and negative impacts. Several challenges often arise, however, in implementation. Most monitoring efforts are top-down, with the public receiving information that has been collected, analyzed, and reported by experts chosen by the project sponsor or company and presented in a way that they may not understand. In some instances, the information may not even address the real concerns of the community; rather it may be strictly oriented toward a company's interests in compliance with regulations and legal commitments. Communities sometimes become aware of monitoring results so late in the project cycle that they may have lost trust in the company before they receive the results.

In general, people want to participate in decisions that matter to them. Thus the social demand for participatory approaches is often great. In many instances, companies have spent large amounts of money on monitoring programs that may have a high degree of *technical credibility*, yet that may have no mechanism to generate *public trust* in the resulting data. In these cases, one of the principal purposes of monitoring is lost.

When implemented early in the project cycle, participatory monitoring can address these challenges by including community members in defining the questions and developing the monitoring design. Furthermore, participatory monitoring and the inherent collaboration required to design and implement a process can strengthen social capital by creating relationships, trust, and understanding (see box 1.1).

**Box 1.1. Generating Social Capital through Participatory Monitoring**

Social capital refers to the features of social life that enable participants to act together more effectively to pursue shared objectives. Networks, norms, and trust all build social capital. By giving stakeholders input, directly addressing their concerns, and fostering participation, participatory monitoring helps generate a sense of ownership and responsibility, thereby increasing social capital and diffusing possible sources of conflict. Even if a monitoring program ceases to function, the cooperation necessary to make the program succeed helps generate social capital that remains after the program has ended. The increase in social capital created is an important component of sustainability.

## The Focus on Water

### How does participatory monitoring apply to water?

Participatory monitoring has been used to give stakeholders input in areas ranging from the distribution of benefits from development projects to evaluating environmental impacts on forests and water resources. Water has some unique characteristics that make participatory monitoring especially useful.

*The health and well-being of the environment and surrounding communities depend on an adequate quantity of water of sufficient quality for designated uses, and water is one of the resources most at risk from development.* Resource development can have very tangible and profound impacts on water. One notable industry example is mining. In many countries, mining is associated with pollution and is viewed as taking a large toll on water resources. In communities that are supported by agriculture, people view water as essential to life because of the heavy dependence on the availability and quality of water. Mining and other natural resource development projects often compete with this traditional use of water. Local users often do not have sufficient access to the infrastructure necessary to make up for the change in demand. They also may not have the means to ensure that the new industry is complying with regulations and agreements.

*The quality of water is a function of land processes that generate pollution, and thus is a good and measurable indicator of overall environmental health.* Monitoring data collected over long periods of time can help communities understand how land use is changing the environment, serve as an early warning system for when pollution may impact use, and indicate whether conditions are improving or degrading.

*Access to clean, sustainable water supplies lies at the heart of poverty reduction.* The lack of access to a sufficient quantity of clean water is a key factor in spreading disease and perpetuating poverty. Promoting access to clean water is good pro-poor institutional practice.

Monitoring water also presents some unique challenges.

*Assessing impacts to water resources requires a high degree of coordination with officials and communities*. Managing water quality and quantity is typically the responsibility of the state, but the state often lacks the resources to adequately conduct monitoring. Participatory water monitoring programs, therefore, face the risk of being viewed in competition with agencies with the mandate to protect water resources if the scope of the monitoring program extends beyond the capability of the government. Monitoring also requires access to community resources and land, and this can also be a challenge.

*Water monitoring also requires considerable technical capacity and local knowledge*.
Water resource impact evaluation is a multidisciplinary field that encompasses the basic sciences (chemistry, physics, and biology), engineering, management, and law. In addition, the daily observations and experience of those local people who manage water in the field (including the hydrology of the area and how water is used) can be as important as observations from specialists when developing a thorough understanding of

local conditions. The technical nature of assessing impacts to water presents challenges, opportunities for, and in some cases, limitations to participatory approaches.

### What water resource impacts are amenable to a participatory approach?

Protection of water resources requires knowledge of the **quality** and **quantity** of the resource, as well as its sustainability. The quality of water must be sufficient to support specific uses. Understanding water quality is not as simple as saying water is contaminated or clean (see box 1.2). For example, water that is of acceptable quality to irrigate a field many not be of sufficient quality to drink. The quantity of water must be of sufficient volume to meet needs under normal conditions and during periods of high use or drought. A water resource is managed sustainably if stresses on quality and quantity are at manageable levels to ensure future needs can be met.

**Box 1.2. Getting Beyond Yes or No**

*Participatory monitoring provides a means to deepen public understanding of what is an acceptable versus an unacceptable impact.*

Often, the issue of whether water resources are affected by a project is presented to communities as a simple yes or no question: Does the project contaminate? In reality, every human activity has the potential to alter water quality. The central question that needs to be addressed is the *degree* of change and whether this change impairs a *particular* use. Participatory monitoring provides a means to deepen public understanding of what is an acceptable versus an unacceptable impact, and can help move the discussion beyond the simple yes or no answer of whether a project contaminates.

Development can alter both the quality and quantity of water available. Assessing water quality involves measuring the chemical, physical, and biological characteristics of water. As described in chapter 4, specific technical procedures are used to evaluate water quality, and these procedures vary in complexity and skill required. Because water quality is determined by observation and measurement at a point in time, it is amenable to participatory methods, with citizens working with technical professionals in an observation role or actively engaged in sampling and data interpretation if the scope of the assessment is appropriate and participants have the technical capacity required. In addition, most countries have numerical water quality criteria and standards for both industrial discharge points and uses such as human consumption or agriculture. Thus, values measured in the field with participatory methods can be compared relatively easily to these criteria and standards.

Assessing water quantity is more complex than assessing water quality; it is highly technical and also involves legal issues such as water rights. Unlike for water quality, monitoring results cannot simply be compared to a numerical standard to determine if there is an adverse impact, issue with compliance, or limitation of usability.

Potential impacts to water quantity can include increased demands from agriculture, industry, and municipalities, and land use changes affecting runoff to streams and recharge to groundwater. A complete assessment of impacts to water quantity may require complex methods, such as computer modeling, that are beyond the scope of a participatory monitoring program. An inventory of water use and basic surface water flow and ground water level measurements, however, can be incorporated into a participatory monitoring program, as described in chapter 4.

## The What and Why of Participatory Water Monitoring

To design participatory monitoring systems effectively, it is important to understand the meaning of monitoring and participation, what sort of forces are driving the creation of participatory monitoring efforts, and what might be the potential benefits.

### What is water monitoring?

Water monitoring involves gathering data and information about water quality and quantity on a regular basis by using scientifically rigorous methods. Water monitoring data are analyzed to determine whether water quality supports resource uses and whether the available quantity of water is sufficient to meet the needs of these various uses. In addition, monitoring data are used to educate participants and to evaluate human impacts, as well as the effect of measures implemented to improve water quality.

Water monitoring activities range from simple, visual observations to complex chemical, physical, and biological studies. The type of work implemented depends on the purpose of the monitoring program.

### Why is water monitoring necessary?

Government, industry, and sometimes community organizations collect and analyze water data and use these data to protect the public, promote accountability, collect baseline data before a project begins, evaluate compliance with internal or external requirements, and improve environmental performance.

### What is meant by a participatory approach?

Broadly defined, "Participation is a process through which stakeholders influence and share control over development initiatives and the decisions and resources which affect them."[1] Participatory approaches actively involve stakeholders in decision-making processes and give them some power and influence over decisions. Stakeholders are "those affected by the outcome—negatively or positively—or those who can affect the outcome of a proposed intervention."[2] More broadly, a stakeholder is anyone who has a vested interest in the outcome of a decision. Stakeholders can include companies, local communities, civil society organizations (CSOs), government agents, international financial institutions, and opposition groups.

General goals for participatory approaches can include:

- Increasing education, awareness, and understanding
- Fostering community involvement.

### What is participatory monitoring?

Participatory monitoring seeks to collaboratively identify and solve problems through the process of data collection, analysis, and communication. It does not seek to verify a predetermined view of an issue.

Participatory monitoring includes a variety of people in all stages of the monitoring process. Traditionally, companies and agencies initiate and undertake monitoring and, in turn, learn and benefit from the results. Participatory monitoring requires changing the dynamic so that a wider range of stakeholders initiates, undertakes, learns, and benefits from the results.

Participatory monitoring is not only scientific, it is also social, political, and cultural. It requires openness, a willingness to listen to different points of view, a recognition of the knowledge and role of different participants, and the ability to give credit where credit is due.

### What do different parties have to gain from participatory approaches?

Participatory water monitoring can ***benefit the public*** by helping to overcome the lack of trust in government and the private sector, as well as perceptions of weak legitimacy. Effective and meaningful public participation is essential to:

- Build public confidence and trust in monitoring results
- Build broader support for efforts to improve water management and reduce adverse impacts
- Reduce the power imbalance between industry, government, and communities
- Generate a broader public understanding of impacts to water resources
- Help companies and government agencies understand the actual concerns of citizens and find productive ways of addressing them
- Increase mutual learning through shared information, data, and experience
- Ensure that water resources management incorporates local knowledge and expertise that might otherwise be overlooked
- Reflect a wider range of public concerns and values
- Rapidly identify controversial issues before they lead to conflict
- Help bring together different points of view
- Ensure appropriate compensation for damaged or lost resources
- Ensure that those most at risk receive priority.

Participatory approaches also ***benefit project sponsors and investors*** by:

- Offering a timely, efficient mechanism to include and inform the public
- Serving as an early warning system for wider problems
- Indicating possible systemic changes that might be needed to ensure the needs of host communities are being met
- Promoting a more stable business climate for companies that reduces risk and enhances accountability to the host community
- Lowering project risk by reducing conflicts and project delays
- Enhancing a company's social license (see box 1-3).

Participatory approaches also ***benefit government agencies*** by:

- Improving credibility
- Making decisions more effective
- Increasing transparency and accountability.

**Box 1-3. Enhancing a Company's Social License through Participatory Monitoring**

Just as a company must secure permits and licenses from local, regional, and national governments, it must also secure a *social license* from local citizens to operate as a legitimate and respected member of the community. Some companies realize it is good business practice to take the level of social and environmental performance "beyond compliance" with basic legal requirements and meet or exceed societal expectations.[a] Meeting or exceeding expectations, in turn, requires companies to align operations with local needs, values, and concerns. For some companies, participatory monitoring is an integral component of the overall strategy to go beyond compliance and gain social license.

a. Gunningham, Kagan, and Thornton (2004).

In addition, participatory monitoring programs can ***benefit civil society organizations*** by giving them the opportunity to improve credibility and promote the mission of the organization.

### When should participatory monitoring *not* be used?

Private companies may be interested in developing an effective public relations campaign, and some community organizations may be interested in public advocacy. Participatory monitoring as described in this guidance document is not intended to satisfy either of these needs. Although a well-designed participatory monitoring program may be good for public relations or may prove a point, this is not its purpose. Participatory monitoring is designed to address concerns in an open and forthright manner. Sometimes this requires airing problems in a way that may not be desirable for the company's public image or that may not meet the perceptions of advocacy groups. Participatory monitoring programs convened by the sponsor as a public relations gesture or by advocacy groups to prove a point are unlikely to be effective.

### What external forces are driving the need for participatory monitoring?

Global, regional, and local initiatives promote the use of participatory monitoring. For example, the United Nations 1998 "Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters" (Aarhus Convention) established a broad framework for public participation.[3] The Convention establishes a greatly expanded role for the public in government decision-making. The three pillars are:

1. Access to information, based on the belief that knowledge is vital for informed and meaningful public participation
2. Public participation in decision making
3. Access to justice.

International financial institutions sometimes request that project sponsors implement participatory approaches to improve development outcomes, and agreements can be part of the project financing terms and conditions.

The International Finance Corporation (IFC) Stakeholder Engagement guidance document[4] defines participatory monitoring as requiring the physical presence of affected individuals at the time that monitoring takes place and incorporating methods and indicators meaningful to the stakeholders concerned. The IFC Performance Standards serve as the basis for the Equator Principles, the voluntary standards adopted by a wide range of financial institutions to manage social and environmental issues in project financing. The Performance Standards discuss the role of community participation in development projects:

> "Informed participation involves organized and iterative consultation, leading to the client's incorporating into their decision-making process the views of the affected communities on matters that affect them directly, such as proposed mitigation measures, the sharing of development benefits and opportunities, and implementation issues."[5]

In addition, government agencies, civil society organizations, and companies are either suggesting or requiring some form of participatory monitoring for high-impact projects. Government agencies have especially focused on the oil, gas, and mining sectors. For example, Peru's Ministry of Energy and Mines has suggested that participatory monitoring be implemented for oil, gas, and mining projects as early in the project cycle as the concept or exploration phase (see Box 1.4). Pressure from civil society organizations can also create a demand for participatory monitoring programs. Finally, some companies include participatory monitoring as a component of their overall stakeholder engagement approach. Companies spend large amounts of money on monitoring, and local communities often have no trust in the resulting data. When supported by a company, participatory monitoring can help refocus efforts to collect data in a way that will have credibility with the public—and thus generate more confidence in the project.

**Box 1.4. Fitting Participatory Monitoring into the Project Cycle**

*In general, it is best to start a monitoring program as early in the project cycle as possible.*

Development projects progress in six phases:[a]

- Project concept/exploration
- Feasibility studies and project planning
- Construction
- Operations/expansion
- Downsizing, decommissioning and divestment
- Post-closure legacy.

The type of monitoring necessary changes from one stage to the next, and opportunities for participation also vary with the project cycle. In general, it is best to start a monitoring program as early in the project cycle as possible, while local enthusiasm for the project is high and when it is easiest to build trust. Monitoring during the project concept phase can be fairly simple and low cost because the impacts are low or nonexistent. In this case, monitoring would be oriented toward collecting baseline information. If project sponsors wait until there is a problem or a breach in trust, the necessary program is likely to be much more expensive because it will have to address both substantive issues and perceptions.

a. IFC (2007).

# Part II. The Four Components of an Effective Participatory Monitoring Process

*The questions and steps outlined in the next few chapters can help communities, civil society organizations, corporations, and governments at both the subnational and national level better design and implement participatory water monitoring programs.*

# Chapter 2. Initiating the Monitoring Program, Setting the Context, and Planning (Component 1)

This chapter discusses how monitoring programs get started, including understanding the project context, initiating the planning process, and involving the public in planning. The discussion that follows presents a general framework for getting started. Planners for a particular monitoring program will need to adapt the guidance to their specific situation. Moreover, planning a monitoring program is an iterative process; adjustments may need to be made as the process progresses.

## Getting Started

### How do participatory monitoring programs get started?

The decision to implement a participatory monitoring program can be triggered by:

- Requirements by financial institutions, partners, or governments
- An event such as a spill
- Perceived risk of an accident
- Lack of trust in the project sponsor and authorities
- Lack of confidence in the state and mechanisms of oversight
- Prevailing perceptions of those affected by the project that there is an impact that is not being addressed
- Concerns that arise during a particular point in the project life cycle, such as expansion.

Once the need has been identified, several groups may request that a program be implemented. Community groups may request their own monitoring program, or government agencies may determine that a program is necessary. Project sponsors may include a program as part of their overall strategy to engage stakeholders, with the goals of maximizing the utility of an existing monitoring program, reducing risk, and increasing project acceptance. Technical experts may also recommend participatory monitoring as a means to follow-up a study. Finally, financial institutions and lenders may request or require a program as part of the lending agreement.

Once the need has been identified, a person or group needs to initiate the investigation and design process. Often, a representative of the company, a government official, or a representative from a civil society organization fills this role.

### How should a planning team be formed?

The person or group that initiates the program designates a ***planning team*** to begin designing the program. The planning team is composed of the person or group that identifies the need and initiates the process, together with a few, selected members from the community, government, and civil society organizations. This team makes initial decisions regarding the scope of the program.

### What agreements should be in place before planning begins?

The first activity of the planning team should be to develop a code of conduct that guides the planning team and serves as a framework for the larger planning group when planning is taken to the public (see box 2.1). The code of conduct is also the first of many agreements the planning team will need to formalize and commit.

### Box 2.1. A Sample Code of Conduct

The cornerstone of the participatory monitoring program is a strong code of conduct that establishes guidelines for how participants will work together and a framework for maintaining a broad base of support. Ten central principles form a strong basis for participatory monitoring programs.[a]

1. **Commitment.** Company management, political figures, and civil society leaders must demonstrate a strong commitment to collecting and sharing information, consultation, and active participation at the earliest stage of a project. Citizens must also be committed to the objectives of the monitoring program. Active citizens can facilitate access to community waterways and local information. They can also raise awareness, and support, encourage, and reward fellow citizens who are participating.

2. **Clarity.** The roles and responsibilities of participants, as well as the limits to information, consultation, and active participation should be well defined from the outset. The meaning of and limits to independence must be clearly defined for monitoring program participants. For citizens, roles and responsibilities, as well as the limits of citizen input, need to be clearly defined. Government and industry must have a clear understanding and mandate in areas where they will be held accountable.

3. **Inclusiveness.** Those leading the monitoring effort need to identify and include all affected parties, such as
citizens living along the streams and waterways being monitored, local community leaders and government agency staff, and people and groups in the area that use monitoring data.

4. **Objectivity.** Information produced by the monitoring program should be objective and complete. Methods for data collection, interpretation, and communication should be transparent. Participatory monitoring programs should focus on data quality as a means to increase credibility.

5. **Respect.** The participatory monitoring program respects other ways of knowing, such as observations made by community members, while maintaining objectivity. Respect and objectivity require an artful marriage of local knowledge with scientific approaches. Participants also must respect protocols for communication of details of the monitoring program and results of monitoring. The program must present a united face to the public; it is counterproductive for participants to report as individuals to the public.

6. **Resources.** Monitoring programs require adequate financial, human, and technical resources to be effective. Participants must have access to appropriate skills, training, and guidance, as well as an organizational culture that supports participation. Adequate time for consultation and participation is also necessary for participatory monitoring to be effective.

7. **Transparency.** Citizens have a right to receive information generated from the monitoring program, be consulted, provide feedback, and actively participate. The monitoring program should have an outreach and communication plan that is just as robust as the technical monitoring plan.

8. **Accountability.** Monitoring programs are obliged to account for how they use citizen views received through feedback, public consultation, and active participation. Measures to ensure that the process is open, transparent, and robust enough to stand up to external review will increase accountability. Government agencies and industry are obliged to respond to problems identified and citizen concerns.

9. **Diplomacy.** When a problem can be traced to a particular source, it is important to adopt a nonconfrontational approach and seek consensus, if possible.

10. **Coordination.** Participatory monitoring programs should be coordinated across agencies to avoid duplication, reduce the chance for creating competing monitoring results and interpretation, and reduce the risk of "monitoring fatigue."

a. Adapted from the Organisation for Economic Cooperation and Development (OECD) principles for engaging citizens in public policy making through information, consultation and public participation. Available at http://www.oecd.org/dataoecd/24/34/2384040.pdf

Next, the planning team agrees on a timeline and milestones for the planning process. It is necessary to understand from the beginning how long it may take to generate an approach and a plan, the time required for implementation, and how long it may be before the monitoring program generates public information (see box 2.2).

**Box 2-2. Managing Expectations**

*Managing expectations from the beginning is critical to developing public trust and confidence.*

As the planning process begins and before the public becomes aware of the new initiative, the planning team develops strategies for managing public expectations. Managing expectations from the beginning is critical to developing public trust and confidence. The planning team develops talking points to be presented during any interaction with the public (such as the assessment described below). Necessary points include an explanation of the monitoring program development process and decision points, the project timeline, and any limitation of the program.

### What information is necessary before the planning process begins?

The planning team next organizes a field trip to "walk the land." The field trip builds relationships and trust among participants, helps the group identify perceptions and different ways of knowing, and begins the development of a common understanding among the planners.

Based on initial meetings and the field trip, the planning team next determines how to gather the information necessary to plan the participatory monitoring program. Much of this information could be available in project documents such as the Social and Environmental Impact Assessment (SEIA) in the archives of the project sponsor, or in various government agencies. This information would be gathered into an assessment of the current situation that sets the context.

## Setting the Context

Before beginning a participatory monitoring program, the planning teams needs some way to assess the social, geographical/physical, and institutional context. This type of assessment forms an integral part of any stakeholder identification and engagement planning process,[6] but there are some specific questions related to participatory monitoring that need to be answered. The assessment is used to gauge the feasibility of implementing a program.

### Who conducts the assessment?

After initial planning meetings, the field trip, and an initial review of available information, the planning team may decide that the situation is sufficiently complex that more thorough assessments of the social, geographical or physical, and institutional context of the project area are necessary. The person or group serving the role of ***assessor*** must be viewed as credible and independent. The planning team may feel sufficiently capable of conducting the assessments or may decide that the situation is sufficiently complex and credibility is enough of a question that independent consultants are necessary.

## What information should be included in the assessment?

### The Social Context

To understand the **social context**, the assessor gauges stakeholder interest and social demand (**stakeholder analysis),** identifies potential impediments, and gathers preliminary ideas for program design through a series of interviews with a wide array of stakeholders. Questions the assessor may ask include:

- What are the priorities for different stakeholders? (What are people most concerned about or fear most?)
- Who is interested in participating, and is the interest broad enough to sustain the program?
- Which groups should be included in the monitoring program? For example, the interests of rural people may differ from those of urban residents. Sometimes a specific user group, such as farmers, may have a particular objective for monitoring.
- Should the program be targeted toward a specific user group such as irrigation canal users or should it be more oriented toward the general concerns of the community?
- What institutional constraints and special circumstances could influence whether a program is feasible and how it would be implemented?
- What kind of monitoring are stakeholders interested in, and where should the program focus (water quality and quantity, aquatic life, participatory baseline studies)?
- What resources are available?
- What potential approaches and arrangements (legal, institutional, financial) may be appropriate?
- What should the program development process look like?

The social assessment would include the information below.

1. *A gauge of public perception of water resource issues,* as defined by:
    - Knowledge. What is the public's general knowledge of water resources issues? What is the level of indigenous knowledge?[7]
    - Maturity. To what extent has the public developed opinions? Are there strong views or is the issue emergent?
    - Complexity. Are the water resource issues so complex that a large amount of technical information is required?
    - Controversy. Is there controversy over water resource impacts? If so, is the debate polarized? Will it be difficult to reach consensus?

2. *An evaluation of the relation between water monitoring and any other root problems*:
    - Are the concerns about water quality and quantity a symptom of a larger issue, such as general mistrust or concerns about economic development and the future?
    - What are the social risks and opportunities for the monitoring program? In many instances, structural factors, such as the relation between local and national government, the private sector, and communities have considerable influence over the perceptions and attitudes of people, Participatory processes can create

a forum to debate unrelated or unresolved problems or to gain the attention of the media and public.

3. *Identification of key questions and concerns*:
   - The assessment should not focus on the validity of the concerns; rather, it should attempt to draw up a preliminary list of questions that would be addressed by the monitoring program.
   - The assessment would also address how universally held the concerns are within the community. For example, are the concerns more widely held in urban or rural areas?

4. *A participant profile*:
   - Participants may come from the following groups:
     - Individual citizens
     - Industry representatives
     - Stakeholders that represent groups of citizens
       - CSOs
       - Interest and advocacy groups
       - Clubs
       - Professional organizations
       - School groups
       - Colleges and universities
       - Organized religion
   - The type of participant depends on who may be affected, who can contribute to solutions, and the type of expertise that is required.
   - The number of participants will depend on the scope of the program, as well as the geographic area of potential direct and indirect impacts, budget, and time required to implement the program. As a general rule, the more time that is required, the fewer the number of people who will be willing to participate.
     - Technical experts to provide substantive assistance
     - Policy makers (involving them from the beginning can increase the likelihood that they will support the process and results)
     - Government officials to address and enforce compliance.

**The Geographical or Physical Context**

The assessor next reviews technical information and reports to understand the **geographical or physical context** of the project and region. The geographical or physical assessment includes the following information:

1. *Project characteristics*:
   - Nature, complexity, and associated risks of the project
   - Project baseline studies, if available
   - Life cycle, the current stage, and projected duration
   - Area of influence.

2. *Regional characteristics*:
   - The state of water resources: hydrologic cycle, abundance or scarcity, and the current and future projected demands and needs
   - Information available to define the need and scope of regional baseline or complementary studies
   - Environmental vulnerability

- Magnitude of existing problems
- Regulatory framework and existing institutional channels to address problems.

**The Institutional Context**

Next, the assessor evaluates the **institutional context** to understand the regulatory environment and determine what other groups may currently be monitoring, have an interest in monitoring, or have the capacity to manage or implement a monitoring program. An evaluation of existing capabilities and programs helps identify whether complementary resources exist locally. In addition, even if the planning team decides it is necessary to create a new institution to conduct monitoring, it is possible that after the program has been operating for some time and relationships and trust improve, the monitoring program could transition to an existing, local institution.

Assessing the institutional context also provides some insight into whether the monitoring plan could be integrated into the existing legal and regulatory system, or whether it should be extralegal—with no enforcement capacity beyond compelling compliance through moral authority. In most cases, participatory monitoring programs do not have a legal or regulatory link.

## What issues should the planning team consider before determining if participatory monitoring is appropriate?

Next, the planning team uses the results of the assessment to evaluate the feasibility, opportunities, and risks of implementing the monitoring program. For example, the planning team could consider the following questions:

- Is the root concern related specifically to environmental impacts and water or to some other issue that happens to manifest itself as a concern about environmental impact?
- Is participatory monitoring well suited to address the root concern—and thus help prevent or manage conflicts—in comparison to other strategies?
- Does the project sponsor support or resist participatory monitoring, and to what degree?
- Will key stakeholders and opinion makers participate in the program?
- Is monitoring being adequately addressed by any other organizations?
- Is it likely that the purpose can be achieved?
- Are there social goals—such as increasing trust, preventing conflict, or promoting multistakeholder dialogue—that would add to the usefulness of a program?
- Are credible technical resources available locally (personnel, equipment, laboratories, and so on), or can these resources be brought in from afar?

The planning team next identifies the **minimum conditions** that need to be met for the planning process to go forward. In many instances, there would simply be three minimum conditions:

- Willingness among the parties to design and implement a program
- Technical capacity to create a credible program
- Financial resources to support the program.

## Beginning the Planning Process

If participatory monitoring meets the minimum conditions for the planning process to go forward, the planning team next uses the results of the assessment to develop a preliminary program design that follows guiding principles and can be presented to a broader public (see Box 2.3).

**Box 2.3. Seven Guiding Principles for the Development of Participatory Monitoring Programs**

Seven broad principles guide the development of participatory monitoring programs:[a]

1. **Participation**. Active participation gives those most directly affected equal voice in the design process, program implementation, and data analysis.
2. **Transparency**. Participants have access to information that is understandable and allows them to make informed decisions.
3. **Process**. A fair process leads to a credible program based on learning and mutual understanding, which becomes the basis for corrective action.
4. **Negotiation**. Parties negotiate to reach agreement at *each stage* of the process: from determining what will be monitored or evaluated to deciding how and when data will be collected, interpreting what the data actually mean, agreeing to how findings will be shared, and outlining what actions will be taken.
5. **Knowledge**. The process generates knowledge and understanding, and not simply data and information.
6. **Accountability**. Participants know that their efforts will produce results that improve project performance and that justice will be served.
7. **Flexibility**. Participants are open to results that may counter preconceived notions and are prepared to address such results with action.

a. World Bank (1996).

### Who should convene or lead the effort?

The planning team next identifies a ***convener*** or leader. The social and institutional assessment should provide the information necessary to identify an appropriate convener. Ensuring the credibility of the convener and the convening process is an essential step in developing legitimacy for the entire monitoring program and its results. Care should be taken to determine what institution is best suited for the convening role. Possible options include:

- Local, regional, or national government
- The project sponsor or a consultant
- The lender or its associated accountability mechanism
- An existing multistakeholder community group
- A development agency or a CSO.

In some instances, the individual or group that initiates the idea for a monitoring program and the members of the planning team may not be the most credible option to serve as the convener of the initiative. If the convener lacks credibility with an important party, it is unlikely that some key stakeholders will take part, and others may dismiss the process and results even if they agree to participate in the beginning. In this case, the party that initiates the process must be open to handing over the program to another party and ceding some control.

The planning team needs to clearly define the role of the convener. Generally, the role of the convener is limited (this person or group does not take part in carrying out specific activities). In general, the convener brings stakeholders together in a neutral space. The convener also provides leadership when there is disagreement or when situations are complex and has the ultimate decision authority when the group cannot reach consensus.

### What purpose might the planning team consider?

Once the need for a monitoring program has been identified, planners often jump straight to the "how" question without carefully considering the **purpose**. It is critical, however, to define the purpose before moving forward with planning. Possible purposes for participatory monitoring programs include:

- Promoting general education and awareness
- Building capacity to understand technical issues and how the scientific method can be used to answer questions
- Developing a baseline and evaluating changes over time
- Investigating a potential problem:
    - Identifying and monitoring sources of pollution
    - Answering specific questions about how a project or land use influences water quality and quantity
    - Determining if the water is safe for different uses
    - Determining compliance with regulations
- Addressing public uncertainties and lack of trust by trying to answer a question that is not being addressed by any other monitoring programs, or filling in where there is a perceived lack of credibility
- Addressing public perceptions that may or may not be grounded in facts
- Establishing a technical basis for compliance and accountability
- Evaluating the effectiveness of improvements for water quality or remediation.

The planning team evaluates and selects which purposes the program should address (there may be more than one) and then considers whether the social, geographical or physical, and institutional contexts are amenable to achieving these purposes.

### What additional technical expertise might be necessary for the program to succeed?

Based on the preliminary purpose, the planning team might choose to identify **technical experts** with capability in hydrology, biology, environmental science, and engineering. The planning team might want to engage experts early in the planning process and before engaging the public because they can take input from the design workshops and develop draft monitoring frameworks or plans for the broader group. The draft framework or plan developed by the experts can then be used as a starting point to guide the development of a final plan through workshops or other group activities.

Criteria for selecting a technical expert include capability, independence, credibility, ability to work constructively with citizen groups, and an appreciation of customary ways of knowing in addition to the scientific method.

### What monitoring program components should be evaluated before engaging the public?

Before starting the next step in the planning process and taking planning to the public, the planning team would conduct a preliminary assessment of available resources in comparison to those that may be necessary to address the project purpose:

- Time
  - How much time is required to plan and implement the program?
  - What is the frequency and duration of monitoring?
- Funding
  - How much money will the program take to implement?
  - What are some possible sources of funding?
- Materials
  - Is it likely that the program will require highly specialized materials?
- Staff
  - Does the program require a permanent staff for management?
  - Does the program require technical expertise only for planning (could be provided by consultants) or also during implementation (may require permanent staff)?

The initial assessment of resource needs would from a base for the detailed monitoring plan, as described in chapter 4.

## Taking Planning to the Public

If a participatory monitoring program appears feasible and appropriate, the planning team next develops an approach to engage stakeholders.

### What members of the broader public should participate in planning?

To determine who should participate in developing the monitoring program, the planning team:

- Uses the stakeholder analysis developed during the assessment to make a preliminary recommendation of which stakeholder organizations should participate in planning the monitoring program and further explore the willingness to participate.
- Develops a fair selection process for participants, based on clear standards and criteria
  - Incorporating diverse views and perspectives
  - Maintaining culture, age, and gender diversity
  - Respecting differences within and across organizations/stakeholder groups
  - Including those who have knowledge of water issues
  - Making sure participants can commit time and energy to the process
  - Including those who have authority to make decisions, will be affected by decisions, and have the ability to impede implementation of a decision
- Considers in what capacity the company should participate, and, who from the company should participate
- Determines how to address the legitimate, specific needs of stakeholder groups that may affect their ability to participate in planning the program (specifically, what capacity building or technical assistance might these groups need).

### How does the planning team include the views of the broader public?

The planning team then organizes a series of workshops, each with a different goal, to begin the monitoring program design process. In conjunction with the workshops, it might be useful to engage an experienced **facilitator** to help people communicate more effectively to reach consensus. A facilitator ensures that people speak one at a time, that one person does not dominate the discussion and that all have a chance to speak, and that the discussion remains on the issues. The workshops could proceed in the following sequence:

- Workshop 1. Discuss the monitoring program process and timelines.
- Workshop 2. Review and refine the purpose, goals, and key questions the program should address.
- Workshop 3. Discuss which participation approach is most likely to meet the objectives.
- Workshop 4. Develop a technical framework for the monitoring plan.
- Workshop 5. Design a governance approach, financing approach, and communication plan.

The workshops provide input to the detailed monitoring plan described in chapter 4.

# Chapter 3. Creating Meaningful Participation, Effective Governance, and Transparent Financing (Component 2)

Participatory water monitoring engages citizens in research pertaining to their own issues and interests and brings communities together with companies to monitor a project's environmental activities through a cooperative, nonadversarial partnership. The product is a body of local knowledge informed by science as well as customary ways of knowing. Participants own the information generated and use it to solve problems and influence company decisions and performance. Participatory processes are often challenging and complex endeavors, however, that must be organized, facilitated, and nurtured. This section examines the challenges of implementing good process: how to create meaningful participation, effective governance, and transparent financing.

Participatory monitoring program design requires a clear vision of what kind of participation is required for the program and its results to have the legitimacy and credibility necessary to inform stakeholders and for participants to take actions and decisions that actually count.

Participation is best understood as a continuum. Participation can range in complexity and intensity from simple to involved. At its most basic level, participation in water monitoring might simply be a public information program where citizens are informed about water monitoring results and are allowed to respond but do not take part in the program's design or implementation. With somewhat greater engagement, participation might involve allowing a group of citizens to go along with company personnel as they take samples and perform other technical monitoring tasks. A more intensive program might involve citizens in the design of the program, oversight of implementation, and interpretation and communication of results to the wider public. Some people believe that participation goes even further and extends to a responsibility to compel the company through negotiation to make changes if significant problems are identified.

For purposes of this document, participation is defined as an intensive level of engagement guided by the seven broad principles presented in chapter 2: participation, transparency, process, negotiation, knowledge, accountability, and flexibility (see box 2-4).

Thus, an effective participatory monitoring program achieves the five general goals for public participation processes:[8]

- Incorporate public values into decisions
- Improve the substantive quality of decisions
- Resolve conflict among competing interests
- Build trust in institutions
- Educate and inform the public.

When these five general goals are achieved, monitoring programs make participation meaningful rather than merely token.

For participatory water monitoring to be successful, the program must have an effective and appropriate means of engaging citizens; a means of governing the process that generates independence, stability, and accountability; and financing mechanisms that are transparent. How public participation is incorporated into a monitoring program depends on the objectives and interests of the company and community, the resources available, and the collective vision of what participation means.

## Creating Meaningful Participation

The type of participatory approach that may be implemented depends in large part on the societal, geographical or physical, and institutional context of the region, the purpose of the monitoring program, and the resources available.

A **participation approach** entails the specific methods that are used to include citizens in project oversight and monitoring. Approaches come in many sizes, shapes, and forms. Selection of a certain approach does not guarantee that a program will be effective. The effectiveness depends on how well the approach is aligned with the context as determined during the assessment, supports the goals and expectations of stakeholders, produces accurate information, generates trusted results that are broadly accepted, and compels the company to change if problems are detected.

### Types of Participation Approaches Applicable to Water Monitoring

Monitoring programs can include participants in many different ways. Four approaches are described below; they vary in the level of complexity and their requirements for technical expertise. The actual participation system implemented could be a hybrid of the approaches presented. Thus flexibility and adaptability during the design process are essential. Also, within each approach, individual participants may take on different roles. For example, some participants may merely observe, whereas others may be actively involved in all phases of the process, from data collection to interpretation to communication. In all cases, roles need to be clearly defined.

**Participation Approach 1. Community stream watch**
Community members are trained to be good observers of conditions in their waterway, to know if their community is connected to a water source potentially impacted by the project, to be educated about what is going on up river, and to report on anomalies. Citizens collect data that require limited technical resources and are based on field observation rather than laboratory analyses. This approach requires little technical expertise on the part of participants.

*Potential benefits*
Simple, inclusive, low-tech, and low-cost. Requires minimal input from external technical experts.

*Potential challenges*
Training can be difficult. Data quality is not sufficient for decision making. It can be difficult to maintain a program that relies mostly on volunteers.

*Most appropriate when…*
The purpose is *education and general awareness* of watershed conditions, and the project is not controversial.

**Participation Approach 2. Observer**
Community members accompany representatives of the project sponsor, company, or the government. This approach allows community members to see the site, learn about

the monitoring protocols, and observe the company doing its monitoring work. The approach relies on the efforts of careful community observers who will accurately communicate what they see to the public.

*Potential benefits*
Limited training required. Gives participants a chance to see the project area. Can change perceptions of citizens when they actually see the site and find out what goes on “behind the fence.”

*Potential challenges*
Controlled by the project sponsor, company, or government. Lacks independence.

*Most appropriate when…*
The purpose is education and general awareness, development of a baseline, or capacity building. Issues are highly technical, and the project is not controversial.

**Participation Approach 3. Monitoring committee**
A cooperative effort that integrates existing water monitoring programs conducted by the company, civil society, and government. It relies on joint fact-finding. Participants and technical staff collect some data at strategic locations and analyze these data with as much rigor as the participating institutions. The approach creates an integrated database; supports an integrated approach to interpretation; provides quality assurance; and ensures that results, conclusions, and recommendations are communicated to the public at large and to affected communities. Volunteer participants observe data collection in the field. A technical working group works with technical staff to analyze data, identify issues of concern, engage in problem solving with the company to address problems, and communicate to the public. The approach relies on the good will of the company to make changes.

*Potential benefits*
High credibility, transparency, and independence. May decrease the chance of competing data and interpretation among organizations that engage in monitoring. Builds public trust in data collected by company and public agencies. Provides a balance of internal and external expertise.

*Potential challenges*
Complex approach to implement. Requires dedicated technical expert(s). Potential for conflict with participating institutions over data interpretation.

*Most appropriate when…*
The purpose is to *investigate a potential problem*, *address public uncertainties,* or *evaluate the effectiveness of improvements.* Good technical capacity is in place. The issue is controversial or conflict-prone.

**Participation Approach 4. Independent technical expert**
Independent experts are contracted to conduct monitoring. The team of experts makes regular field visits. It meets with company, community, and other stakeholders as part of each field visit—at the outset, to hear complaints, and at the end of the monitoring visit to brief interested parties. Technical experts collect original data and draft a report, which is made public. The team guards public interests by making findings transparent

and using moral authority to compel the company to make needed changes rather than engaging directly with the company to negotiate compliance. The community may be involved in developing the terms of reference and selection process. The community may or may not accompany experts in the field.

*Potential benefits*
A highly profession panel or organization of technical experts can monitor geographically diverse and extensive areas, such as the terrain and communities along a pipeline route. It can provide a high degree of technical credibility. It may be perceived as more independent than other approaches. It may be able to stay above the political fray. It can consult with civil society without having to create a dialogue table of all stakeholders. It may be particularly effective when people are unable to talk together for geographical reasons or because of intractable conflict.

*Potential challenges*
Experts may not be familiar or sensitive to project specifics such as the project or process, history, constraints, local cultures and conditions, and the personalities involved. Difficulties include the cost; the effort and time involved in gaining legitimacy and credibility in the eyes of civil society and therefore the acceptance of findings and observations, the challenge of gaining compliance with recommendations, and the overarching question of to whom are they accountable.

*Most appropriate when…*
The purpose is to *investigate a potential problem*, *address public uncertainties,* or *evaluate the effectiveness of improvements*. The issues are so technically complex and difficult to understand that no amount of capacity building and experience will prepare the community to address them. There is a high degree of controversy and a low degree of trust among the participants. Parties are politically or ethnically divided, unable to build an effective working relationship, and cannot agree on an approach. Also appropriate when the spatial extent of the project is great and encompasses multiple ecological zones and communities that have little cohesiveness (such as with a pipeline).

A smaller-scale, less expensive version of this approach is appropriate when the situation is not so highly polarized, the risk is minimal, and the community is most interested in engaging a competent technical expert to periodically monitor the performance of the sponsor and report back to the public on a quarterly, semi-annual, or yearly basis.

## Guidance for Selecting the Participation Approach

### How does the planning team select an approach?

Selecting the right approach depends upon the purpose of the program and what it will take to create program legitimacy, produce accurate data, and ensure acceptance of results by the company and community.

### What role does the project cycle have on determining the type of participation?

In general, a participatory monitoring program for an exploration or pre-feasibility stage project could be fairly simple, focused on characterizing the social and natural environment before the onset of the new project. In this case, the planning team could choose an approach—such as the community stream watch or observer approach—that focuses on education and awareness or the development of an initial baseline. Conversely, a large project located in an area with a negative environmental legacy, history of violence or conflict, or weak regulatory and institutional framework would require a more complex and costly participatory approach, such as the monitoring committee model. If the project is so controversial that participants cannot work together or agree on an approach, the independent expert model may be the only solution.

### How are participants chosen?

The criteria to be used include the following:

- Participation is voluntary.
- It is preferable to have a diversity of views and perspectives and a representative spectrum of organizations and stakeholder groups.
- Participants must be available and commit to the process.

When selecting participants, it is important to consider whether representatives from organizations will participate as individuals or as representatives of their institution. Sometimes it can be difficult for organizations to designate and endorse a representative, or there may be legal impediments that may prevent a person from representing an institution. Thus, in many cases volunteers will participate as individuals.

### What is the role of participants in the monitoring program?

For each participation approach, the role of participants needs to be established, together with any limits that may be necessary. For example, observers are involved with data collection and have a responsibility to inform the public regarding what happens in the field but are generally not involved with data interpretation. Monitoring committee members may be involved with data interpretation, but they may not have the authority to communicate results to the public.

Participants needs clear, written guidance defining roles and criteria. For example, it is necessary to determine in the beginning how and when information will be given to the public. Also, participants need an established person or method for resolving disagreements and determining who has the ultimate decision-making authority.

### Should participants be volunteers or receive some compensation?

The cost of participation can vary for different participants. For example, for participants that work for the company or the government, working with the monitoring program may be part of their work responsibilities, hence compensated. For private citizens or people from an institution but working as individuals, participation is not compensated, and participants may have to stop working to participate and lose income.

Some programs choose to pay participants, but some may view this as compromising credibility. The issue of paying participants should be discussed during the planning process and should reflect the dominant view. If the general view is that paying participants is equivalent to “buying loyalty and results,” then the planning team should consider other ways of rewarding volunteers, such as training.

## Creating Effective Governance

A **governance approach** is the specific institutional arrangement for hosting and implementing a participatory monitoring program. Many different organizations could host the program, including:

- Offices of the project sponsor
- Free-standing, legally established institutions created for the express purpose of overseeing monitoring
- Affiliate organizations associated with government agencies, universities, or CSOs
- Independent, professional associations or companies.

The assessment described in chapter 2 will identify possible organizations that could host the participatory monitoring program.

Criteria that may be used to evaluate potential host organizations are:

- Credibility, community trust, and ability to operate transparently
- Capacity (technical and administrative)
- Independence
- Legal considerations, such as whether the organization is incorporated.

### How does the planning team select the right approach?

Selecting the right governance approach depends upon available resources, the purpose of the program, and what it will take to create program legitimacy, produce accurate data, and ensure acceptance of results by the company and community.

### What types of governance approaches could be applied to water monitoring?

The five approaches presented next demonstrate the range of possible governance solutions that the planning team might consider. Other approaches are possible. Each arrangement has different advantages. Selection depends on whether the project is in the concept phase or is an operating site, the concerns of the community, and whether there is conflict. Also, the organization most appropriate to host the program may change during the project cycle. In some instances, the organization that hosts the program may only provide logistical support and another organization may be responsible for implementing the program.

#### Governance Approach 1. Participatory monitoring hosted and staffed by the offices of the project sponsor

Company-initiated and supported participatory monitoring programs are convened and staffed by the project sponsor and may be created to address specific issues. Examples include company-sponsored environmental committees and advisory groups. Often, such ad hoc groups function in an advisory capacity and select their own members, establish their own informal operating agreement, and choose what issues to address.

*Potential benefits*
Company-sponsored participatory monitoring can be initiated more rapidly than more consultative approaches. Companies often feel more comfortable with this type of approach because they have increased control over the process. Because these types of programs often focus on a specific issue or concern, they can sometimes make progress more quickly than more far-reaching programs.

*Potential challenges*
Company-sponsored monitoring programs depend significantly on the good will of the company to address any problems identified. They can suffer from a failure to move beyond dialogue and relationship building to action and results. These types of programs will lack credibility with some stakeholders.

*Most appropriate when…*
This institutional arrangement may be appropriate when there is a high degree of trust and low conflict between stakeholders and the sponsor, and thus may be most appropriate for programs that use a community stream watch or observer participation approach. This situation can occur for projects in the concept phase when a company has the trust of the local community.

**Governance Approach 2. Participatory monitoring hosted by a freestanding, legally established institution**

Sometimes, freestanding institutions are created to manage and implement a monitoring program. They can have legal standing, often as a not-for-profit institution or civil society organization . These institutions have formal protocols, articles of incorporation, and by-laws. Organizations rather than individuals form the membership, and these organizations may come from the community, broader civil society, and the government. The project sponsor may also be a member. The institution may engage in monitoring on a voluntary basis or because it is part of a government mandate. A small staff often supports the work of the group.

*Potential benefits*
Legally constituted institutions engaged in designing and implementing a monitoring program can provide a durable institutional structure that can allow diverse members to work together on long-term objectives. These institutions can adapt their scope to address evolving local concerns. They can empower the community and help build trust and respect between and among the community and the project sponsor. They can be less expensive than using a team of external technical professionals. Finally, they can raise and manage their own funds independently.

*Potential challenges*
Strong community leadership is a key requirement for this governance arrangement. In addition, creating a freestanding CSO can be time-consuming and expensive. Furthermore, observers may perceive that the program lacks independence or believe the project sponsor controls the monitoring, particularly when the sponsor provides all the funding. Other difficulties can include limited technical capacity to analyze monitoring data (if resources are not sufficient to have a permanent technical staff) and perceived inability to ensure compliance and implementation of recommendations. (These institutional arrangements are often dependent on the good will of the sponsor and the stakeholders to

implement agreements.) These challenges can be addressed through capacity building.

*Most appropriate when…*
Independent, legally established participatory monitoring programs may be effective when diverse voices of the community can be identified and their legitimate representatives are willing to take part in the process; when strong community leadership is present; when the sponsor is committed to the process; where the balance of power among the parties is equitable; where capacity building will be successful and there are enough members from the community who can grasp the technical issues and work on problems; when participatory monitoring will be critical for the sponsor's long-term operations; when the government has little credibility or authority to engage in these issues, or chooses not to; and when stakeholders are committed to a system based on technical rigor and are able to avoid politicization of their work. This institutional arrangement can work best with the monitoring committee participation approach.

**Governance Approach 3. Participatory monitoring hosted by an affiliate government organization**

Sometimes a government agency (such as a national-level ministry or local or regional government) convenes, sponsors, and maintains a participatory monitoring program. It is important to consider whether the proposed governmental institution has the capacity, credibility, and authority to convene and sponsor the program, and if this arrangement will be accepted by civil society.

*Potential benefits*
Monitoring programs affiliated with a government authority do not create something new; rather, they build on an existing institution. The government, as a convener, can often induce broad participation across government and civil society. The agency has a formal mandate and authority for monitoring, compliance, and redress. In addition, technical experts and staff within the agency can offer knowledge and information about existing laws, rules, and regulations. Finally, the government can create an intermediary institution between the community and the sponsor.

*Potential challenges*
In some cases, mistrust of government resulting from corruption or perceived preferential treatment of industry controls the dynamic between communities and companies. Some communities so mistrust government agencies that it would be difficult for these agencies to host a program that would be perceived as credible and impartial. Civil society may also perceive that government could be too dominant, potentially forcing community members to accept specific solutions that may not be in their interest. Government agencies may not have the time, resources, or capacity to lead such a process. As a result, they may fail to provide adequate guidance and leadership.

*Most appropriate when…*
Neither interested civil society groups nor the project sponsor have the capacity and credibility to play a convening role. Other circumstances include when government input is necessary to oversee or implement the monitoring program,

or when government is needed for enforcement. This institutional arrangement can be appropriate for a monitoring committee participation approach or for an independent technical expert participation approach.

**Governance Approach 4. Participatory monitoring hosted by a CSO, church, university, or international institution**

CSOs, church organizations, or universities can assume the task of managing a monitoring program by sponsoring, convening and hosting the program. International institutions, such as the United Nations or development banks, can sponsor and help fund a program but will typically need local partners to convene and host the effort.

*Potential benefits*

CSOs and universities can have more credibility with communities than project sponsors or government agencies. They also can build on the existing capacity of the institutions. International organizations can be viewed as more neutral than a local or national institution.

*Potential challenges*

CSOs are sometimes not perceived as neutral, especially by the private sector. Sponsoring and convening a participatory monitoring program may be outside the mandate of a university. International institutions may not have the local experience or knowledge to effectively manage a process.

*Most appropriate when…*

CSOs, universities, or international institutions may be good alternatives when there is a lack of trust in government and the private sector and when there are impediments to creating a new institution. This institutional approach can be appropriate for a monitoring committee participation model and, in some instances, for an independent technical expert participation approach.

**Governance Approach 5. A mixed approach hosted by one organization but where other organizations provide different services and capabilities**

In some instances, planning groups may choose different organizations to fulfill the various functions necessary. For example, planners may determine that the project sponsor will host the program and provide logistical services, but not manage technical activities. Technical aspects could then be managed and implemented by a civil society organization or by a university.

*Potential benefits*

Mixed approaches can bring together the best of all the organizations that participate, while minimizing the perception that one party is controlling the program. They can be more credible to the public than a program hosted by only one organization.

*Potential challenges*

Mixed approaches need well-defined roles for each organization and stringent protocols for management of each function. They also need procedures for resolving disagreements among the different parties.

*Most appropriate when…*

There is a reasonable amount of trust in the project sponsor, and people feel the program would not be compromised with the company in the convener role. A trusted member can serve the technical role.

## Creating Transparent Financial Arrangements

Funding participatory monitoring programs poses a dilemma. On one hand, civil society wants the project sponsor to pay for both monitoring and correcting impacts because the company is viewed as responsible for changes in the environment and the company is often the only entity that has the financial resources necessary to implement a program. On the other hand, when funding sources rely on money from the project sponsor, the programs can be perceived by civil society as buying results or as more of a public relations ploy than an effective means of environmental stewardship.

Participatory monitoring programs need:

- Adequate resources to implement a robust and independent monitoring program broad enough in scope and complexity to address key questions regarding water quantity and quality
- Recognition that all participants do not have equal access to financial resources, and that other kinds of contributions beside financial support need to be utilized and recognized
- A guarantee that monitoring will be scientifically sound and impartial regardless of the source of funding.

It is accepted practice when resolving disputes that parties contribute funds to the process. It is also customary for parties to contribute in a variety of other ways, including volunteering personal time and providing in-kind support. The way stakeholders contribute money, services, and materials depends on the participants, with provision of resources varying from complete to partial to independent of stakeholders. In some instances, it is not important where money and materials come from, but rather that the appropriate mechanisms are in place to ensure transparency and credibility, and to monitor the distribution of money.

Therefore, funding mechanisms need to address questions related to the source and administration of funds:

- Where does the money come from? Is the source viewed as sufficiently independent from stakeholders and special interest groups? If stakeholders are a significant source of funding, are mechanisms in place to ensure credibility?
- How are funds administered in a way that ensures independence and builds trust?

## Funding Sources

### Mechanisms with direct involvement from stakeholders

*Funding provided by the project sponsor*

Sponsor-based funding structures include the following arrangements, ranked in order of increasing levels of supervision and independence:

- The project sponsor funds and pays for the monitoring program directly.
- The project sponsor provides funds directly to the institution responsible for monitoring. This institution creates a trust that is managed by a small group of individuals from the community in a transparent way.
- A trusted, neutral third party not associated with the project sponsor or the institution responsible for monitoring opens a bank account used exclusively to finance monitoring. The project sponsor deposits funds into that account. The account is administered independently and under the sole control of the trusted third party. An independent firm audits the financial statements and the audit results are made public.

*In-kind funding*

In-kind funding can include participants volunteering their time, and providing meeting facilities, transportation, equipment, and other resources. This approach is often combined with funding from project sponsors or elsewhere. It is best if all participants contribute something.

### Mechanisms with partial involvement from stakeholders

*Funding provided by government*

State-funded structures include the following arrangements:

- The state provides funds and pays for the monitoring program directly.
- The project sponsor contributes to a fund designated to pay for participatory monitoring. The state provides the contracting mechanism to conduct any bidding process and pay the institution in charge of the monitoring program. The state audits how the funds are used and makes the results available to the public.

*Funding provided by lenders or associated accountability mechanisms*

Most project finance comes from private banks that subscribe to the Equator Principles and, to a lesser extent, from international financial institutions such as the World Bank. The Equator Principles are based on the IFC Performance Standards and contain guidance on participatory monitoring. Depending on the financial agreements between the lender and the project sponsor or company, the lender and their associated institutions may directly provide some of the funds necessary for monitoring programs.

*Funding provided by CSOs*

In some instances, CSOs have provided funds for participatory monitoring: sometimes with the cooperation of the project sponsor or company, and sometimes without.

*Mixed funding*

Funding can be provided by a combination of the project sponsor, government, lenders, and CSOs. Mixed funding can help prevent the perception that one party has too much control over the monitoring program. Often, communities are more comfortable accepting funding from the sponsor if others are also making a contribution, even if the amounts vary.

For example, in areas where government is decentralized, regional and municipal governments may be called upon to co-finance monitoring programs to ensure continuity or to launch the programs as public initiatives. This type of funding arrangement may be especially appropriate for large projects with a high degree of public sensitivity.

**Mechanisms independent of stakeholders**

*Funding provided by religious organizations*

Sometimes, church organizations provide funding directly to organizations that conduct monitoring.

*Funding provided by international agencies*

In some instances, international agencies such as the United Nations Environment Programme or the U.S. Agency for International Development have provided funding directly to organizations that conduct monitoring.

## Funding Management

### How are the funds administered?

In some cases, the way funds are administered can overcome any concerns about the source of funding. Some monitoring programs have established an independent bank account or trust fund specifically designated to hold and manage financial contributions for the program. Once stakeholders make a contribution to the account, they no longer have any control over the funds. Money in the account would be used exclusively to fund the monitoring program. An independent party would serve as a guarantor that no party could either influence or "buy" a specific result. Details of how the money was spent—as well as nonmonetary contributions such as management, support, and materials—would be published on a regular basis and be publicly available. Information included in the disclosure would include which parties have contributed money and how the funds were administered.

### What factors should be considered when developing a budget?

As part of the planning process, the design team determines a purpose, goals, and indicators that are meaningful to participants. Often, the time and money available for the monitoring program are insufficient to completely address the purpose, goals, and indicators. Therefore, a realistic budget should be established early in the process to help ensure that expectations match resources available. The monitoring budget will depend on the land uses and size of the area being monitored, the number of participants, whether the program will complement data from existing monitoring programs or be wholly independent, the monitoring methods used, and the frequency of monitoring (see box 3.1). Some items to include in a budget are: salaries for staff and fees for consultants (if necessary), equipment and materials, training, transportation, laboratory fees (if necessary), data processing equipment such as computers, and communication materials.

**Box 3.1. A Range of Costs for Participatory Water Monitoring Programs**

Budgets for participatory monitoring program vary, depending on the type of monitoring, the geographic scope, and the industry sector that is being evaluated. For example, a volunteer-based program that relies on field data is inexpensive and can provide useful data if the purpose and degree of cooperation match the approach. A program covering a large geographic area with a high degree of conflict will require more high-level technical expertise and the services of an analytical laboratory, hence costs will be substantial. The examples that follow illustrate the range of possible costs:

- *A low-tech, low-cost monitoring program for a relatively small geographic area with low conflict*. The Agua para Siempre monitoring program in Vicos, Peru, was a volunteer-based, community stream watch program that relied only on field data to monitor water quality resulting from several small mining operations. Costs for this program were low (the per sample cost was estimated to be less than one dollar). Citizens were trained to make field measurements, participating institutions provided outside technical advice, and contract analytical laboratories were not used. For programs that rely primarily on volunteers and use field techniques only, the budget could be only a few thousand dollars per year.
- *A higher-tech, moderate-cost monitoring program for a small geographic area with moderate conflict*. The Environmental Monitoring and Oversight Committee (CMVFAH) that monitors the Antamina Mine port facilities in Huarmey, Peru, is a freestanding institution staffed by local people. The CMVFAH takes some air and water samples and has them analyzed at a contract laboratory. The Committee also works closely with Antamina environmental staff and with government agencies and has data-sharing agreements. The budget for the CMVFAH was $30,000/year (in 2006), a relatively small amount considering the very large size of the Antamina project.
- *A high-tech, higher-cost monitoring program for a large geographic area with high conflict*. The Mesa de Dialogo CAO-Cajamarca managed a participatory monitoring program to evaluate water quality impacts from the Yanacocha Mine in Peru. The program had a full-time environmental scientist and technician and part-time technical experts from Peru and the United States. Approximately ten samples were collected monthly and analyzed for metals and other water quality parameters at an analytical laboratory. The program participated with other monitoring programs and created a database of all available water quality data. The program also focused extensively on outreach and communication. The budget for this intensive program was approximately $125,000/year (in 2005).

Appendix A summarizes the features of eight participatory monitoring programs according to criteria presented in this guide.

Generally, large monitoring budgets will be required for projects that monitor sectors that have high impacts, multiple point and nonpoint discharges that span large areas and multiple watersheds, and a high potential for conflict (such as a mine). A small monitoring budget may suffice for projects with localized impacts (such as a factory with a point-source discharge).

Costs are lower if participatory monitoring programs are started early in the life cycle. When trust is low and conflict is high, monitoring costs escalate.

## Determining the Right Approach to Participation, Governance, and Financing

Before implementing specific approaches, some or all of the following questions may be worth asking:

- Has controversy about the project led to *conflict*? If so, is the approach more appropriate for high- or low-conflict situations? How mature is the conflict? If there is a high degree of organized public opposition to the project because the project is controversial and trust in the company (and, perhaps government) is low, is the proposed approach appropriate?
- Is the central focus of the program to address an actual *hazard* that presents risk to citizens, or is it to manage community *outrage* and diffuse a highly charged situation (see box 3.2)?
- How much *independence* or autonomy do the selected approaches give?
- What types of *materials and resources* does the program require, such as external laboratories, and what is the expense and difficulty in using them?
- What role do *technical experts* have in the proposed monitoring program? Can local resources provide this expertise, or is it necessary to seek outside experts?
- How much work will be expected of *volunteer participants*? Is this level of commitment sufficient to ensure the program's success?
- How likely is it that the public will accept *results* from the program?

**Box 3.2. Addressing Hazard and Outrage**

In a simple but powerful formulation, risk communication expert Peter Sandman defines actual risk as a combination of hazard and outrage: *Risk = Hazard + Outrage*.[a] According to Sandman, when people insist that something is a serious risk, they are expressing some combination of a concern (for example, this is likely to harm me) and an emotion (this really infuriates me). Actual danger to the environment and health or people's lives results in *hazard*. When communities perceive a company or a government to be dishonest, unresponsive, or lacking moral authority, they sometimes respond with *outrage.* For many development projects, community outrage can be greater than the actual hazard would indicate.

Stakeholder engagement processes such as participatory monitoring programs must assess and respond not only to hazards, but also to outrage. If outrage is driving community concern, the monitoring program must adapt by increasing the degree of independence and autonomy of the efforts to analyze, collect, and communicate data.

a. Sandman (2003).

When determining the most appropriate monitoring program structure, the planning team should create a list of relevant criteria that can be ranked for each proposed approach. Examples of relevant criteria are:

- Cost
- Volunteer commitment necessary for success
- Extent to which the proposed approach builds trust between company and community
- Technical expertise required

- Feasibility and ease of implementation
- Extent to which the proposed approach will be perceived as credible and legitimate by the community and by the company
- Degree of transparency
- Degree of independence or autonomy.

The planning team may include additional criteria identified during the assessment phase described in chapter 2. Using a matrix that compares each approach according to selected criteria can help the planning team systematically select the most appropriate approach.

# Chapter 4. Creating Credible Information (Component 3)

This section provides an overall framework for designing a monitoring plan. The section is intended to help planners design a monitoring program, but it is not a step-by-step manual. More detailed technical procedures are presented in appendix B.

Data generated by the participatory monitoring should be targeted and relevant to the problem, accessible and understandable, usable, and timely. To be effective, the delivery and communication of results to the public should suggest a course of action, allow decision makers to weigh consequences, and make those involved feel they are in control of the problem.

This section of this guide is divided into three steps, with relevant questions for each section:
Step 1. Determining what to monitor and who will participate
Step 2. Developing a monitoring plan
Step 3. Converting data to information.

## Determining What to Monitor and Who Will Participate

Six questions help frame the purpose of a monitoring program:

### Why are you monitoring?

Possible purposes for participatory monitoring programs include:

- Promoting general education and awareness
- Building capacity
- Developing a baseline
- Investigating a potential problem
- Addressing public uncertainties
- Addressing public perceptions
- Establishing a technical basis for compliance
- Evaluating the effectiveness of improvements.

Carefully considering the purpose will help:

- Focus the project to efficiently collect the most useful data
- Select appropriate protocols and parameters
- Collect data that are credible
- Evaluate whether the program has answered key questions and met objectives.

The reason for monitoring water quality and/or quantity helps determine how complex the monitoring program needs to be. Different purposes require different monitoring protocols, methods, and standards. For example, data collected solely for community education and awareness do not have to be collected in as rigorous a way as data that will be used for regulatory purposes.

### What parameters will you monitor?

Monitoring programs can measure the physical, chemical, and biological properties of water. It is usually not feasible to monitor everything, so it is important to determine what water quantity and quality parameters are the most important to monitor, based on the "why" questions presented above. It is also important to consider the skill and resources of the monitoring team.

#### Water quality parameters

*Physical measurements* include the stream channel profile and bank characteristics, flow, temperature, and streambed composition. These measurements can be used to determine if changes in land use such as agricultural tilling practices or construction are altering streams. Flow measurements give insights into water quality because quality often depends on flow (especially for sediment and associated contaminants), as well as quantity as described below. Physical measurements require the least amount of training, equipment, and time.

*Chemical measurements* include basic characteristics, such as pH, conductivity, and dissolved oxygen, as well as chemicals that can be found in the water, such as nutrients, oil and grease, and heavy metals. These measurements can be used to determine whether pollution is affecting water quality. Chemical measurements require test kits and meters at a minimum, and often require that samples be collected and analyzed at a laboratory. Therefore, they require more advanced training and equipment.

*Biological monitoring* involves collecting and identifying plants, fish, and insects that live in the water. The type, number, and variety of aquatic insects that live at the bottom of a stream (benthic macroinvertebrates) are good indicators of water quality. Some benthic macroinvertebrates are sensitive to water chemistry; thus the type and number of insects that might be found differ for different water quality. Biological monitoring can range from simple (basic surveys of plants that cover a stream bottom or identification of types of benthic macroinvertebrates) to complex (a detailed aquatic risk assessment designed to determine if a source of pollution has adverse effects on the health of a stream). Biological monitoring can incorporate local knowledge and thus can be more culturally appropriate and amenable to participatory monitoring.

#### Water quantity parameters

Potential impacts to water quantity include increased demands on the existing supply system, new withdrawals from industry or agriculture, and land use changes affecting runoff and recharge. Although evaluation of impacts to water quantity is complex, participants in a monitoring program can:

- Gather existing information on water demand by reviewing published information
- Review climate data from public weather stations to understand trends such as wet and dry years
- Measure flow in streams that can be waded at the same time as collecting water quality samples
- Measure water levels in monitoring wells.

## How do you determine what to monitor?

A step-by-step procedure can be used to determine what to monitor. First, review the assessment of the geographical or physical context (see chapter 2) to determine what activities occur in the watershed and to identify potential sources of pollution. Also, evaluate the phase of the project cycle for any existing or new industrial or agricultural activities in the watershed. For example, monitoring requirements for a greenfield mining project will be quite different from those for an existing project well into production.

Second, consider which one of the six purposes the monitoring program is designed to fulfill by answering the question, why monitor.

Third, choose physical, chemical, and biological parameters that help address the purpose. Some parameters can easily be measured in the field with a small amount of equipment and expertise. Other parameters will need to be measured in a laboratory. Table 4-1 presents a general view of the range of parameters and associated complexity that can be used to connect the purpose to the parameters. These parameters are described in more detail in appendix B.

**Table 4.1. Levels of Analysis and Parameters**

| Physical parameters | Chemical parameters | Biological parameters |
|---|---|---|
| *Level 1. General, qualitative, and simple to measure* | | |
| Streambank stability | -- | Macroinvertebrates–qualitative |
| Temperature | -- | Algae and plants |
| | | |
| *Level 2. More complex and requires specialized field equipment* | | |
| Turbidity | pH | Macroinvertebrates–quantitative |
| Streamflow | Dissolved oxygen | -- |
| Habitat | Specific conductivity | -- |
| -- | Phosphorus | -- |
| -- | Nitrogen | -- |
| *Level 3. Complex and needs external laboratory* | | |
| Suspended sediment particle size distribution | Metals in water, sediment, biota | Macroinvertebrate–taxa level |
| Streambed sediment particle size distribution | Hydrocarbons | Bacteria |

Source: Author's compilations.

The program purpose will determine the types of parameters that need to be monitored. For example:

- Promoting general education and awareness—Level 1 parameters
- Building capacity—Levels 1 and 2 parameters
- Developing a baseline—Levels 1, 2, and 3 parameters
- Investigating a potential problem—Levels 1 and 2 and selected Level 3 parameters
- Evaluating the effectiveness of improvements—Levels 1 and 2 and selected Level 3 parameters.

When choosing parameters, it is important to consider the following:

- Does the parameter help answer the questions the monitoring program is designed to address?
- Does the parameter serve as an early warning indicator of change in the watershed?
- How difficult is it to measure the parameter with the necessary accuracy?
- Does the monitoring team have the resources and expertise to measure the parameter?
- How can the meaning of the parameter be easily explained to the users of the data?
- Is this parameter being collected by any other monitoring organizations and does collecting complement the work of others?

Appendix B provides more detailed information on selecting parameters.

### Who will collect the data?

Both professionals with a high degree of expertise and community members can collect data for participatory monitoring programs. Professionals can include monitoring organization staff or environmental staff from companies that operate in the watershed or staff from the government. Community members can be stakeholder representatives, members of the general public, or students. The expertise of the people who will conduct the monitoring determines the capacity of the group—and, in turn, the complexity of the monitoring program that can be implemented.

### Who will use the data?

Identify in advance who will use the data to be collected so that the data can meet the objectives of the intended users. Possible users include:

- Monitoring program participants
- Community residents
- Local decision makers
- Landowners
- Government agencies
- Other organizations that collect monitoring data
- Civil society organizations
- Industry.

### How will the data be used?

For some groups, the act of collecting data in a participatory way is sufficient to meet the general goals outlined in chapter 1:

- Promoting education, awareness, and understanding
- Fostering community involvement and building capacity.

For other groups, the data may need to fulfill a specific purpose such as:

- Collecting baseline data
- Monitoring the effects of a discharge from an industrial activity
- Evaluating compliance with regulatory requirements that could trigger and action or mitigation measure.

The way data will be used helps determine the necessary parameters and data quality and, in turn, the level of effort required to collect, analyze, and report results.

### What data quality is necessary to achieve the purpose?

Different purposes have different data quality requirements. The data quality and rigor necessary to enhance credibility will vary depending on the use. For example, if the purpose is general education, quality assurance procedures may be minimal. If the purpose is regulatory, data quality requirements will be high. The quality of data that may be collected also depends on the resources available to the monitoring program and the expertise of the participants. It is important to make sure the data meet the needs of the monitoring group first. With time and experience, they may also meet the needs of other public and private entities.

A good quality **data set** is complete, representative, and comparable:

- “Complete” refers to whether the amount of data collected meets the desired quality standard. For example, often the only conclusion that can be drawn from the results of a single sample is that more data need to be collected.
- “Representative” refers to the extent to which the data reflect conditions in the water body being evaluated. For example, it is important to sample several hundred meters below a point discharge to ensure that any substances in the discharge have adequately mixed with the stream flow and that the resulting concentration is representative of the stream.
- “Comparable” refers to how data compare between sample locations, times of collection, or monitoring groups. For example, when analyzing water quality samples collected from a stream, it is important to compare samples collected from flowing areas to samples collected from other flowing areas, and not from still or pool areas.

A good quality **analysis** is accurate, precise, and sensitive:

- “Accuracy” refers to how close the sampling result is to the true value. Accuracy is most affected by the equipment and the procedures used.
- “Precision” refers to how well the result on the same sample can be repeated, regardless of accuracy. Human error in sampling and analytical technique is a major cause of imprecision.
- “Sensitivity” refers to the smallest change or lowest concentration equipment or methods can detect. The equipment used should be sensitive enough to give useful data.

Data quality is also enhanced by simple quality control checks such as taking duplicate (samples collected in the same way at the same time and place), blank (samples containing only ultra-pure water from a laboratory), and standard reference samples (samples with a known concentration of the chemical being measured).

## Developing a Monitoring Plan

The first section of this chapter introduces basic questions that need to be answered before developing a monitoring plan. This section describes the specific components of a monitoring plan. A **monitoring plan** describes in more detail the what, where, when, and how of monitoring.

The plan helps ensure that the monitoring program:

- Conducts the right tests at the right place using correct procedures
- Generates data that meet the objectives of the monitoring program and that are more usable to others because others will know that they were collected using a consistent protocol.

The monitoring plan includes detailed descriptions of how data will be collected and analyzed. Generally, detailed procedures for all field and laboratory sampling and analytical methods are presented in a series of guidance documents called **Standard Operating Procedures (SOPs).** SOPs contain step-by-step directions, including methods for maintenance and calibration of instrumentation.

### What methods will you use?

The methods used depend on the purpose and resources available. Possible methods include the following, ranked according to an increasing degree of necessary resources:

- Visual field observations of the physical condition of waterways
- Basic water quality parameter sampling and analysis in the field
- Measure of the flow rate in streams
- Macroinvertebrate sampling and assessment in the field
- Water quality sampling and analysis in a laboratory
- Macroinvertebrate and algae sampling and assessment in a laboratory.

When choosing a method, it is important to ask:

- Will the method produce data of sufficient quality?
- What are the accuracy, precision, and sensitivity of the proposed methods?
- Will the method give results that are within the necessary range to allow for comparison to applicable standards?
- Will the method give results that are representative of conditions?
- Can results using the proposed method be compared to results from other organizations that monitor?
- What resources (expertise, cost, and time) are required for the method?

### How will participants be trained?

Capacity building is an important part of monitoring programs, and participants who are well trained will take more interest in the program. Monitoring program staff and company and government personnel should conduct training on a regular basis, along with outside experts for specialized topics, if necessary. Possible topics include:

- The basics of the hydrologic cycle, including climate, surface and ground water hydrology
- Water chemistry
- How water quality and quantity are affected by human activities
- How the activities of the project sponsor use water and potentially alter water quality and quantity
- The relation between water quality, standards, and different uses
- Basic monitoring methods
- Data interpretation, graphing, and statistics
- The basics of negotiation and conflict resolution.

### Where will you monitor?

The program purpose and watershed inventory will help determine where to monitor. For example, if improving community awareness is the purpose of the program, monitor a site that is accessible and visible to the public, such as a park. If the purpose is to investigate a potential problem with an industrial facility, monitor above and below the facility. If the purpose is to understand baseline water quality before development occurs, monitor a representative range of streams within and downstream of the proposed development area.

Specific questions to ask when choosing monitoring sites include:

- Are other groups also monitoring the site and does the work duplicate or enhance the information from these groups?
- How accessible is the site by vehicle or by walking?
- Is the site representative of a larger area?
- Can permission be acquired to access the site?
- Is the site far enough downstream of dams, bridges, tributary inflows, or discharge pipes that these features will not affect results?

### When will you monitor?

The program purpose will also help determine when to monitor. Important considerations are:

- Seasonality of flow
  - Water quality can differ depending on whether flow is high or low.
  - Some streams flood and some streams dry up at different times of the year, making sampling difficult or impossible at these times.
- When process or storm water is released from the project.
- Proposed changes to land use and new projects within the watershed.
- The resources available for the monitoring program.
- Community perceptions regarding when water quality is worst or when a particular industry may be releasing polluted water.

Generally, it is best to monitor at least twice per year if there are two distinct seasons (such as rainy and dry) and four times per year if there are four seasons.

### How will data and samples be collected?

The monitoring plan presents specific methods for collecting physical, chemical, and biological data. For example, most monitoring programs measure some of the parameters that define water chemistry. Water chemistry parameters can be measured using field meters, test kits, or a contract analytical laboratory.

- Field meters*.* Field meters can measure basic water quality parameters such as temperature, pH, conductivity, turbidity, and dissolved oxygen, as well as the flow rate. The meters must be calibrated each time they are used.
- Field test kits*.* Field test kits use pre-packaged containers of chemicals to analyze water for a particular chemical.
- Contract analytical laboratory. Using a contract analytical laboratory is in many ways the easiest method to evaluate water chemistry, but it is also the most expensive. Laboratories have specific analytical methods and standard operating procedures as well as quality assurance/quality control programs. A sampling

and analysis plan should list bottle types, sample preservation methods, and holding times (the maximum amount of time between sample collection and when the sample needs to be analyzed).

When choosing field meters, field kits, or laboratories:

- Develop and follow standard operating procedures
- Document thoroughly how and why analytical methods were chosen
- Make sure the kits, meters, and laboratories to be used can detect the appropriate concentration range that is needed.

For each parameter that will be measured, the monitoring plan needs to describe:

- The parameter that is being measured
- The collection procedure
- The containers that will be used to store the sample
- The method used to preserve the sample and prevent the parameter from changing after collection
- The equipment and method that are used to measure the parameter.

### How will you ensure that the data are of sufficient quality to achieve the monitoring program purpose?

The first step in identifying data confidence procedures is to define the purpose of the monitoring data, as described in the section entitled “Determining What to Monitor and Who Will Participate.” Data confidence for sampling and analysis includes:

- Developing and following a written monitoring plan
- Maintaining and calibrating all equipment
- Implementing quality control checks to ensure that equipment produces accurate data
- Properly training participants
- Assessing data quality with each monitoring and adjusting procedures as necessary.

## Converting Data to Information

The goal of a monitoring program may be to make results available to others, but data alone have no value until they are interpretated and put into a form that is accessible to the public.

### How will the data be managed and interpreted?

It is important that the documentation procedure described in the monitoring plan is designed to ensure that all field and laboratory activities and monitoring results are recorded in a database.

Data interpretation involves asking a series of questions that lead to findings and then to conclusions. **Findings** present *what* the data show. **Conclusions** explain *why* the data look the way they do. Some questions that can be used to arrive at findings are:

- Do changes in one parameter coincide with changes in another?
- Do results show a trend from up to downstream or above and below potential sources of pollutants?
- Which sites do not meet water quality goals? By how much and how often?
- Do the results change by season or with changes in rainfall?

- Do industrial or municipal operations have a large effect on stream flow?

These questions can be answered by graphing data to visually display results and by statistical means, such as determining the average, median, and quartiles. Graphing and statistics are described in more detail in appendix B.

Once the data have been organized as findings, these findings can be used to address the study purpose and develop conclusions. It is important that the data support the conclusions. If the data are inconclusive, it is also important to note this. To form robust conclusions:

- Follow a logical, scientific process for data interpretation.
- Seek expert advice when necessary.
- Document assumptions and the assessment process.

To begin the process of interpretation and drawing conclusions, return to the original questions upon which the monitoring plan is based (the "why" question). If the data and findings can answer these questions and be used to draw conclusions, then the monitoring program is meeting its objective. It is more likely that some questions will be answered and others will lead to yet more questions. For example, participants may determine that findings and conclusions can be explained by natural conditions or human impacts. Participants may also determine that the results are obscured by errors in the sampling and analysis. In this case, the monitoring results can be used to modify the monitoring program.

### What actions will be taken if results exceed guidance levels or standards?

Standards are legally enforcable, numerical water quality criteria established by a government agency to assess whether the quality of water is adequate for aquatic life, recreation, drinking, agriculture, industry, and other uses. Governments use them as regulatory tools to prevent pollution. If a standard is exceeded and the cause can be attributed to a particular activity, the entity discharging pollutants and exceeding criteria may be required to stop discharging or pay a fine.

Some countries do not have stringent standards or may lack standards for certain elements. In this case, monitoring programs may use standards developed by a foreign government or international agency to evaluate water quality. Guidance values are generally not viewed as enforcable standards, but they do provide insights as to where water quality may be impaired.

Monitoring programs need to have clearly established water quality standards and guidance values that will be used to interpret data. In addition, the program needs to have clearly defined actions and an explicit mitigation plan if standards and/or guidance values are exceeded.

### How will results be presented to stakeholders?

Participatory monitoring programs are very public by nature; hence the results should also be public. It is important that all data be presented in a publicly available database and that the process of interpreting, generating findings, and making conclusions be well documented, accessible, and transparent. Participants charged with interpreting and communicating results must adhere to established protocols for presenting results.

It is also important to develop a strategy for releasing results that is most appropriate for the target audience. For example, if interested parties are primarily in an urban area, newspapers, radio, and television are good means to get the word out. If most of the interested parties are in rural area, the best communication strategy is to meet directly with people in their local area.

The public needs to know that they will receive results regularly. It takes time to collect samples, receive laboratory results, and prepare communication, so expectations for when results will be released need to be managed. Communication can be time-consuming but is an essential part of a monitoring program.

### How are differences among participants resolved?

In some instances, participants may not agree on the interpretation of the data and communication of results. In this case, it is essential to have a mechanism for resolving disputes over interpretation. Possible mechanisms include engaging a trusted, third party for arbitration or waiting until more data are collected before making a judgment and presenting results to stakeholders. A code of conduct such as that presented in chapter 2 can help participants resolve disagreements.

# Chapter 5. Establishing Indicators and Evaluating the Process and Outcome (Component 4)

Program monitors need to continually evaluate whether objectives are being met. Shortcomings need to be identified as early as possible so that corrective actions can be implemented. A complete evaluation includes assessment of:

- The purpose statement
- The quality of participation
- Whether governance is effective
- The transparency of financial arrangements
- The robustness of the technical approach
- How program information is used and communicated to the public.

## Evaluate the Purpose Statement

*The strength of the purpose statement*

- The program has a clear, written statement of purpose.
- Stakeholders have a consensus around the purpose or if not, the program acknowledges differences and limitations.
- The program sets measurable goals consistent with the purpose.
- The program has a clear plan of action to achieve identified goals.

*The relevance of the purpose statement*

- The purpose statement accurately reflects the *current* mission of the monitoring program.
- The purpose statement is updated to reflect current conditions.

## Evaluate the Quality of Participation

*Inclusion of those affected*

- The stakeholder group includes those arguably affected by the project as well as those who might affect the project.
- Those who believe they might be affected, but arguably will not be, have been considered as stakeholders and if excluded, have been "informed" why they have been excluded.

*Commitment of key participants*

- Company or project representatives are at a high enough level or have been given the mandate necessary to make decisions without having to consult off-site management.
- Community representatives include leaders and opinion makers from organized groups and government.
- Key participants have committed to investigating areas where the monitoring program identifies problems and are committed to making changes if necessary.
- Key participants commit to the range of possible actions resulting from the outcome of the monitoring program, and possible actions are clearly communicated to the public.

*Commitment of community*

- The monitoring program has a broad participant base that is reflective of local society, including schools, organizations, agencies, businesses, and individuals and the program has established cooperative partnerships.
- The monitoring program has a good working relationship with local officials and decision makers that participate in the decision-making process or act as consultants to the decision makers.
- The monitoring program is visible in its community.
    - Information is readily available in a centralized location.
    - The organizers present information to the public through civic forums.
- The community provides some financial or in-kind support.

*Commitment Volunteers*

- The monitoring program has a sufficient number of committed, regular participants.
- The program has a participant recruitment plan.
- Volunteers understand what the program can achieve as well as its limitations.
- Volunteers are supported through
    - A way to recognize participants
    - Training opportunities
    - Opportunities for participants to increase responsibility.

## Evaluate Governance Effectiveness

*Institutional arrangement*

- Participants perceive that the arrangement offers sufficient independence from stakeholders with special interests.
- The arrangement has sufficient credibility with stakeholders.
- The arrangement has the support and sign-off of participants.

*Leadership*

Ascertain whether there is:

- Strong local leadership
- Strong group support for the leader
- Paid staff or a designated volunteer program coordinator
- Clearly defined and written roles and responsibilities for staff and participants
    - Program descriptions
    - Job descriptions
    - Task outlines
- A succession plan for leadership and volunteers
- A plan to develop the skills of staff and volunteers.

## Evaluate the Transparency of Financial Arrangements

*Funding mechanisms for monitoring*

- Participants understand who is contributing money or in-kind contributions to the program.
- Financial commitments are being met without conditions that would compromise integrity.
- Funds are collected and distributed in a transparent way.
- The monitoring program has a broad base of financial support.
    - Contributions from industry, government, financial institutions, and possibly members of the group
    - Grants
    - In-kind donations of equipment, time, and other resources.
- The group has a strategic fundraising plan.

*Funding mechanisms for mitigation*

- Funds are available and committed to mitigate any impacts from the project that the monitoring program identifies as necessary.

## Evaluate the Robustness of the Technical Approach

*According to technical standards of best practice*:

- The program has a written monitoring plan that:
    - Provides information to answer questions that address program goals
    - Describes the intended use of the data
    - Describes the intended users of the data
    - Establishes data quality objectives that match the purpose of the program
    - Identifies monitoring parameters that address the study questions
    - Documents locations of monitoring sites and frequency of collection and the relation to meeting study goals
    - Describes sampling and analysis methods that meet data quality requirements for each parameter.
- The study design is consistent with the technical capacity and financial resources of the monitoring program.
- The monitoring program has a quality control plan approved by data users with internal and external checks.
- The monitoring program has a training program for staff and volunteer participants that explains field and laboratory methods.
- The monitoring program has a written data management system that includes requirements for ensuring the quality of data input and management.
- Reports are produced in a timely manner.
- Interpretation and data reports reflect issues and questions found in the study design.
- Quality control data are reported and analyzed along with monitoring data.

*According to the view of the community*

- The program incorporates knowledge from the local community in the study design.
- The program seeks to answer questions that the community has and does not focus solely on compliance.
- Data quality concerns are adequately addressed in the study design (such as timing of sampling, laboratory selected, and location of samples).

## Evaluate How Program Information Is Used and Communicated to the Public

*Data use*

- Targeted users are clearly defined.
- The data produced by the monitoring program are actually used by the target audience.
- Changes to the monitoring program and the future direction are driven by objective criteria formed from program data and analysis.
- The program presents its data to targeted users and other interested parties.
- The program has prior defined actions and a mitigation plan if trigger levels for critical water quality parameters are exceeded.

*Community outreach and public education*

- The results the group produces are used by their target audience and lead to action.
- Program outreach effectively disseminates results to a variety of interest groups.
- The program is making strides toward meeting program goals.
- The group provides presentations, workshops, and displays aimed at public education.
- The program seeks and receives media coverage.
- The program coordinates projects with other groups working on similar issues in their local area.

*Impacts and outcomes*

- The program achieves its purpose and meets its goals.
- The program has influence over the company's environmental and social performance.
- The program increases the company's reputation in the community.

A participatory water monitoring that addresses and strives to meet these evaluation criteria helps communities, project sponsors, and others better understand and address concerns related to water quality and quantity. Such a program also improves the quality of public discourse and collaboration and thereby helps bring about better development on the ground.

# Appendix A. Summaries of Eight Selected Participatory Monitoring Programs

As background for this guide, eight participatory water monitoring programs were surveyed. This appendix summarizes the characteristics of these monitoring programs, following the framework of this guide. The programs were selected because the CAO was familiar with them and some information about them was publicly available. Many of these programs are in Peru, the country where the CAO has the most first-hand experience with participatory water monitoring. The basic components of the monitoring programs are presented in tables A.1, A.2, and A.3.

**Table A.1. Basic Characteristics of Participatory Monitoring Programs Reviewed While Preparing This Guide**

| Name | Primary purpose | The community | The company | Other participants |
|---|---|---|---|---|
| Agua Para Siempre | Strengthen local capacity for management of water; evaluate community concerns regarding the potential impacts of small mines on water | Community of Vicos, Ancash Department, Peru; primarily rural; agrarian | Small, independent mining operations | Association Urpichallay<br>The Mountain Institute |
| Aruntani Participatory Environmental Monitoring Committee (CMAP) | Evaluate community concerns regarding the potential impacts of the mine on water | Communities of Ayutaya, Jancopujo, and Titire, Moquegua Department, Peru; primarily rural; agrarian | Aruntani Florence Gold Project | Asociación Civil Labor |
| Lagunas Norte, Alto Chicama mining district | Evaluate community concerns regarding the potential impacts of the mine on water | Santiago de Chuco Province, La Libertad Department, Peru; primarily rural; agrarian | Barrick Gold Alto Chicama Project | Asociación Marianista de Acción Social (AMAS),<br>Comisión Episcopal de Acción Social (CEAS),<br>Pontificia Universidad Católica del Perú (PUCP) |
| Community Environmental Monitoring Association (AMAC) | Evaluate community concerns regarding the potential impacts of the mine on water | San Miguel Ixtahuacán and Sipacapa municipalities, Huehuetenango Department, Guatemala; urban and rural; agrarian | Goldcorp Marlin Gold Project | The local Catholic and evangelic churches<br>San Carlos University, Guatemala |
| Mesa de Dialogo Tintaya Monitoring Committee | Evaluate community concerns regarding the potential impacts of the mine on water, air, and soil | Espinar, Cusco Department, Peru; urban and rural; agrarian | Xstrata Tintaya Base Metal Project | CooperAcción (Peruvian CSO), Oxfam America, CSO members of the dialogue table |
| Xstrata Las Bambas Participatory Monitoring Committee (CMP) | Develop a water quality baseline before mining starts | Provinces of Cotabambas and Grau, Apurimac Department, Peru; primarily rural; agrarian | Xstrata Las Bambas Base Metal Project | None |
| Mesa de Dialogo CAO-Cajamarca Participatory Monitoring Program | Evaluate community concerns regarding the potential impacts of the mine on water | Cajamarca, Cajamarca Department, Peru; urban and rural; agrarian | Yanacocha Gold Mine | Compliance Advisor/Ombudsman, CSO members of the dialogue table |
| Environmental Monitoring and Oversight Committee of Huarmey (CMVFAH) | Evaluate community concerns regarding the potential impacts of a mineral concentrate shipping facility on water | Province of Huarmey, Ancash Department, Peru; urban; agriculture and fisheries | Antamina Base Metal Project concentrate shipping facility | Universidad Nacional de Santa<br>Fisheries associations<br>Irrigation district users associations |

Source: Authors' compilations

Note: All monitoring programs have some involvement from the local, regional, and national government.

**Table A.2. Purpose and Approaches to Participation, Governance, and Financing**

| Program | Purpose | | | | | | | | Participation Approach | | | | Governance Approach | | | | | Financing Approach | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | PA1 | PA2 | PA3 | PA4 | GA1 | GA2 | GA3 | GA4 | GA5 | FAS1 | FAS2 | FAP1 | FAP2 | FAP3 | FAP4 | FAI1 | FAI2 |
| Agua Para Siempre | x | x | | x | | | | x | x | | | | | | | x | | | | | | | | | x |
| Aruntani CMAP | x | x | | | x | x | x | | | | x | | | | x | | | x | | | | | | | |
| Lagunas Norte | x | x | | | x | x | x | | | | x | | | | | x | | | | | | | | x | |
| Marlin AMAC | x | x | | | x | x | | | | x | x | | | x | | | | | | | | | x | | |
| Mesa de Dialogo Tintaya | x | x | | x | x | x | x | | | x | | x | | x | | | | | | | | | x | | |
| Las Bambas CMP | x | x | x | | | | | | | x | | | x | | | | | x | | | | | | | |
| Mesa de Dialogo y Consenso CAO-Cajamarca | x | x | | x | x | x | x | x | | x | x | | | | | | x | | | | x | | | | |
| Antamina CMVFAH | x | x | | x | x | x | x | x | | x | x | | | x | | | | x | | | | | | | |

Source: Authors' compilations

**Purpose**
P1. Education and awareness
P2. Building capacity
P3. Developing a baseline
P4. Investigating a problem
P5. Addressing public uncertanties and lack of trust
P6. Addressing public perceptions
P7. Establishing a technical basis for compliance and accountability
P8. Evaluating the effectiveness of improvements

**Governance approach**
GA1. Project sponsor
GA2. Freestanding, legally established institution
GA3. Affiliate government organization
GA4. CSO, church, university, or international organization
GA5. Mixed

**Participation approach**
PA1. Community stream watch
PA2. Observer
PA3. Monitoring committee
PA4. Independent technical expert

**Funding approach**
Direct stakeholder involvement
FAS1. Project sponsor
FAS2. In-kind funding
Partial stakeholder involvement
FAP1. Government
FAP2. Lenders/accountability mechanisms
FAP3. CSOs
FAP4. Mixed
Independent of stakeholders
FAI1. Religious organizations
FAI2. International organizations

**Table A.3. Data Collection and Data Interpretation and Results Communication**

| | Data collection | | | Data interpretation | | | Results communication | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Basic field parameters | Laboratory analyses | Frequency | Community | Technical experts | Multimember committee | Presentations/ assemblies | Workshops | Brochures/ reports | Radio and TV | Web site |
| Agua Para Siempre | x | | -- | x | | | x | x | x | x | |
| Aruntani CMAP | x | x | -- | | | x | x | | x | | |
| Lagunas Norte | x | x | yearly | | x | | | x | x | | |
| Marlin AMAC | x | x | quarterly | | | x | x | | | | |
| Mesa de Dialogo Tintaya | x | x | biannual | | x | | x | | x | | |
| Las Bambas CMP | x | x | -- | | | x | x | | | | |
| Mesa de Dialogo y Consenso CAO-Cajamarca | x | x | monthly | | | x | x | x | x | x | x |
| Antamina CMVFAH | x | x | yearly | | | x | x | x | | x | x |

Source: Authors' compilations.
-- not available

## Additional Information

For more information on the eight participatory monitoring programs described in this appendix, see:

Agua para Siempre (Water for Ever)

- The Mountain Institute
  http://www.mountain.org/
- The Cornell-Peru Project
  http://courses.cit.cornell.edu/vicosperu/vicos-site/water_management_page_1.htm

Aruntani Participatory Environmental Monitoring Committee (CMAP)

- Asociación Civil Labor
  http://www.labor.org.pe/titular.php?kdigo=522

Lagunas Norte, Alto Chicama Project joint monitoring

- Comisión Episcopal de Acción Social (CEAS)
  http://www.ceas.org.pe/

Community Environmental Monitoring Association (AMAC), Guatemala

- The Oil, Gas and Mining Sustainable Development Fund, IFC and World Bank
  http://ifccommdevstage.forumone.com/section/projects/participatory_environmental_mo
- Goldcorp, Inc.
  http://www.goldcorp.com/operations/marlin/sustainability/

Mesa de Diálogo Tintaya Monitoring Committee

- Cooperacción. Acción Solidaría para el Desarrollo (Solidarity Action for Development)
  http://www.cooperaccion.org.pe/
- Oxfam America
  http://www.oxfamamerica.org/whatwedo/where_we_work/south_america/news_publications/tintaya/art6242.html
- Oxfam Australia Mining Ombudsman
  http://www.oxfam.org.au/campaigns/mining/ombudsman/cases/tintaya/
- Xstrata Tintaya S.A.
  http://www.tintaya.com.pe/content/index.aspx

Xstrata Las Bambas Participatory Monitoring Committee (CMP)

- Xstrata Copper
  http://www.xstrata.com.pe/images/upload/publicacion/archivo/XSTRATA_NDP_MONITOREO_PARTICIPATIVO_Set27.pdf
  http://www.xstrata.com.pe/english/xstrata/sup_index.php?id_menu=1&pPag=77&pSeccion=6&pIDPlantilla=1

Mesa de Diálogo CAO-Cajamarca Participatory Water Monitoring Program

- Compliance Advisor/Ombudsman, World Bank Group
  http://www.cao-ombudsman.org/html-english/complaint_yanacocha.htm

Antamina Port Facility Environmental Monitoring and Oversight Committee of Huarmey (CMVFAH)

- CMVFAH
  http://www.comitemonitoreo.com/portada.php
- Antamina
  http://www.antamina.com

# Appendix B. Technical Background and Sampling Methods

This appendix provides in-depth technical information, resources, and technical methods that monitoring program participants need to develop a scientifically rigorous participatory water monitoring program. There are many excellent technical resources available for water monitoring. The aim of this survey is not to provide an exhaustive "how to" manual, but rather to highlight technical issues that are especially relevant for participatory monitoring programs and to point out useful resources for those wishing to design a program.

## Technical Background

This section describes basic properties of water and watersheds, presents a general discussion of water quality and pollutants, and introduces the scientific method.

### General Properties of Water and Watersheds

Before specific sampling methods are presented, it is necessary to understand some basic properties of water and watersheds. Properties include:

- The physical and chemical properties of water
- The hydrologic cycle
- The distribution of water on earth
- Surface water (lakes and streams) and groundwater
- Water chemistry
- The definition of watershed
- The watershed as a scale for monitoring.

The questions that follow explore these properties.

#### What properties of water make it so important?

All life on earth depends on water, and the properties of water make life possible. Water is composed of two hydrogen molecules ($H_2$) and one oxygen molecule (O); the chemical formula of water is $H_2O$. Because of its structure, water has unique properties:

- Water is the universal solvent: more substances can be dissolved in water than any other substance. This means that water can carry many substances that are also important for life (such as minerals) as well as substances that may be harmful (pollutants).
- Water is the only natural substance that can exist on earth in all three phases: gas, liquid, or solid.
- Water is the second most common molecule in the universe (after hydrogen).
- Water is the only commonly encountered substance that is less dense as a solid than a liquid. For this reason, ice floats. This property of water density has affected ocean currents, and thus the distribution of life on the planet. Water has a high capacity to store heat (what is called specific heat), and thus serves an important role in stabilizing temperatures on earth.
- Water is an essential component of all life on earth.
- Except for a few organisms called "extremophiles," life on earth has evolved to exist between the freezing and boiling points of water. These points form the

lower (0 degrees) and upper (100 degrees) range of the Celsius temperature scale.

### What is the hydrologic cycle?

The earth has always had the same amount of water. Over time, it takes different forms (vapor, liquid, or solid) and resides in different water bodies. The water in the sea one day can be the same water that falls as rain and enters a river the next. The flow of water from one place to the next and from one form to another is called the **hydrologic cycle**.

Water changes from one form to another and travels to different places in the atmosphere and on earth. For example, when the sun shines on water in the sea, the water evaporates and enters the atmosphere. Water vapor condenses into drops to form clouds, falls from the sky as rain or snow, and eventually returns to the sea by way of rivers to repeat the cycle again. Plants also contribute to moisture in the atmosphere as they release water vapor through a process called respiration.

### How is water distributed on earth?

Most of the water on earth (97 percent) is in the oceans and is too salty for use by animals and plants on land. Only 3 percent of the total amount of water on earth is low enough in salt content to be called **fresh water**.

Of the 3 percent of water on the earth's surface that is fresh water:

- 68 percent is in glaciers and ice sheets.
- 30 percent is in groundwater.
- 0.3 percent is in surface water.

Overall, of the total amount of water on earth, only 0.3 percent is usable by humans. Surface water (streams and lakes) and groundwater are the most important water supply resources for humans, and therefore are typically the focus of monitoring programs.

### How are fresh water resources used?

Globally, the majority of fresh water (70 percent) is used for irrigation to grow crops. In the future, although domestic and industrial uses are projected to increase, the proportion of total water use attributed to irrigation is expected to remain relatively constant (IPRI 2002).

### What are the characteristics of streams and lakes?

Most surface water resources are in streams, lakes, and reservoirs. Although streams account for only 2 percent of the total liquid fresh water on the earth's surface, in many places they are the most important water resource because they are more widely distributed than water in snow, ice, and lakes. Stream water is also more accessible for use than groundwater, and can be utilized using minimal technology.

**Streams** originate in the mountains or topographically higher areas. Snowmelt, lakes, springs, groundwater, and precipitation runoff provide flow. The stream gets larger as it moves downhill and gains volume from runoff from greater land area and from other streams entering.

**Lakes** and reservoirs are large, inland bodies of water, usually of fairly limited size. Lakes are located in a natural land depression, whereas reservoirs are usually formed by placing a dam on a free-flowing river and impounding the water. Lake water can be described as still or not moving, and may have an outlet stream or be terminal (water is lost from the lake by evaporation and seepage to groundwater). Because lakes are still, the hydrology, ecology, and chemistry are quite different from that of streams. The distribution of lakes on the earth's surface is not uniform, and most lakes are in the Northern Hemisphere. For example, 60 percent of all lakes are in Canada, and 20 percent of the world's fresh water is contained in Lake Baikal in Russia (Wetzel 1983).

### What is groundwater?

Groundwater is contained in the pore space between soil particles and in the cracks in rocks. The point below the earth's surface where the ground is saturated (all the pore space is filled with water) is called the **water table**. The interval between the earth's surface and the water table is called the unsaturated zone. Rain, snowmelt, rivers, wetlands, and lakes replenish the amount of water in the ground by moving through the unsaturated zone to the water table. The technical term for this process is **recharge** (Freeze and Cherry 1979).

An **aquifer** is an underground geologic formation that contains water in sufficient quantities to be used as a domestic water supply or for industrial and agricultural uses. Unconfined aquifers do not have geologic materials above them that would isolate them from the surface. Precipitation infiltrates through the ground and recharges the aquifers directly. Unconfined aquifers are very vulnerable to contamination from the land surface. Geologic materials (usually clay) cover confined aquifers and isolate them from the surface. Confined aquifers are not directly recharged by precipitation from the land surface, but rather are replenished by flow from unconfined aquifers. Confined aquifers are less susceptible to contamination from the ground surface, but if they do become contaminated, they are difficult to restore.

### How are ground and surface water connected?

Groundwater can be replenished by flow from streams, wetlands, and lakes during periods of high precipitation or snowmelt. When the flow in surface water recedes as rain or snowmelt subsides, groundwater stored in aquifers can re-enter surface water. Groundwater provides the **baseflow** for streams during periods with no rain.

### What is the difference between water chemistry and water quality?

Water in its natural state is never pure (that is, composed only of $H_2O$ molecules). The substances that are in water determine **water chemistry**. Water chemistry can be described by four basic properties: pH, buffering capacity, hardness, and salinity (Hem 1992).

- The **pH** of water determines whether it is acidic (pH below 7), neutral (pH = 7), or basic (pH above 7). Like the Richter scale that is used to describe the intensity of earthquakes, the pH scale is logarithmic. A pH of 6 is 10 times more acidic than a pH of 7. Normal rainwater is slightly acidic and has a pH between 5.5 and 6. Many streams are in contact with minerals that make the water slightly alkaline.
- **Buffering capacity** refers to the water's ability to keep the pH stable as acids or bases are added. A buffer acts like a sponge. If water is well buffered, as more acid is added, the sponge absorbs the acid and the pH changes little. In the case of fresh water, carbonates and bicarbonates provide the sponge.
- **Hardness** refers to the dissolved concentration of the elements magnesium and calcium.
    - Soft water generally has a hardness less then 140 mg/L.
    - Hard water generally has a hardness above 320 mg/L.

- **Salinity** refers to the total amount of substances dissolved in water. Water is classified as fresh, brackish, saline, or brine as follows:
    - **Fresh**: salinity < 500 mg/L
    - **Brackish**: salinity between 500 and 35,000 mg/L
    - **Saline**: salinity between 35,000 and 50,000 mg/L
    - **Brine**: salinity > 500 mg/L

  The average salinity of seawater is 35,000 mg/L.

In addition, water contains nutrients and trace elements that also contribute to the overall chemistry. These elements are important components of water quality.

**Water quality** describes the chemical, physical, and biological characteristics of water, usually with an eye toward whether the quality can support a certain use. Understanding water quality is not as simple as saying that this water is contaminated and this water is clean. Water that is of acceptable quality to wash a car many not be of sufficient quality to drink.

### What is a watershed?

A **watershed** is an area of land bounded by ridges, hills, or mountains where all streamflow, groundwater, and precipitation drain to a common point such as a lake, stream, or the ocean. Watersheds are also called **drainage basins** or **catchments**.

Watersheds vary in size and shape. Large watersheds are bordered by mountain ranges and include many subcatchments. Each subcatchment may be bordered by low hills and ridges and drained by smaller streams. Because each subcatchment flows to a larger stream, forming a stream network, what happens in the small catchments affects the water quality and ecology of the stream into which it flows.

### Why is the watershed a useful scale for monitoring?

We all live in a watershed. Many impacts are linked by water and what happens in upper parts of a watershed can affect everyone downstream. Thus land use and management issues need to be viewed on a watershed-scale.

Understanding the concept of watershed is important to monitoring because what happens in one part of the watershed can affect water quality in a different part. The size of the watershed selected for study (subcatchment, catchment, or region) can be scaled to the interests of the monitoring group.

## Water Quality and Pollutants: A General Discussion

Pollutants that occur naturally or are the result of human activity can degrade water quality, and water quality varies, depending on stream flow. In streams with larger volumes of fast-moving water, pollutants will be diluted faster than in small or slower moving streams.

### *Natural processes that influence water quality*

The chemical composition and chemical and physical weathering of bedrock and soils affect the quality of water in streams. Natural physical processes that can degrade water quality include erosion processes such as landslides, stream bank collapse, and erosion of soil induced by runoff. These processes introduce sediment into surface waters, discoloring streams and rivers, and adversely affecting aquatic life. Sediment inputs can increase water turbidity (decreasing the clarity of the water) and concentrations of iron, aluminum, and other naturally occurring metals.

In areas where rocks are highly altered and naturally mineralized, such as in the vicinity of a mine, chemical weathering can produce water with naturally high concentrations of metals and naturally low pH. The oxidation of sulfide minerals present in bedrock can form natural acid drainage. **Acid drainage** is formed by a series of geochemical and microbial reactions that are initiated when water and oxygen come in contact with pyrite (an iron-sulfide mineral), certain other metal sulfides, and certain metal salts. If the rocks that surround the acid-producing minerals do not have sufficient buffering capacity (that is, the rocks or minerals cannot neutralize acid), acidic metal-rich drainage can form, potentially adversely affecting surface waters. When mineralized soils erode, concentrations of metals carried in suspended and dissolved sediments can be elevated.

***Human activities that influence water quality***

Pollutants resulting from human activity can include fertilizers, herbicides, and insecticides from agricultural fields, heavy metals from mine sites, oil, grease, sediment from improperly managed construction sites, salt from roads, and bacteria and nutrients from livestock.

Sources of pollution can be either point or nonpoint.

- **Point sources** discharge directly to a stream:
    - A discharge pipe from a factory
    - The discharge from a wastewater treatment plant.
- **Nonpoint sources** are a result of rainfall or snowmelt moving over and through ground that contains pollutants:
    - Rainfall runoff from urban and agricultural areas
    - Mine drainage.

Nonpoint sources are more difficult to monitor and eliminate than point sources. Human land uses can accelerate natural rates of chemical and physical weathering, and can have adverse affects on water quality. Construction and disturbances that remove vegetation that stabilize soils—especially road building and agriculture—increase erosion and sediment loading to streams. Dumping of wastes, including oils, solvents, and domestic and industrial wastes, introduces potentially toxic chemical and biological pollutants to surface waters. Untreated human and livestock wastes introduce bacteria and other potentially harmful microorganisms to streams through runoff and direct discharge.

***Basic water quality parameters***

Temperature and dissolved oxygen are important parameters for the health of aquatic life such as fish. The amount of oxygen that can be dissolved in water decreases as the temperature of the water increases or as the concentration of organic compounds that consume oxygen increases. Therefore, low dissolved oxygen concentrations may result from elevated temperatures or high concentrations of organic matter and nutrients, and may limit the type of fish that can live in a stream or lake.

Total dissolved solids (TDS) is a measure of the amount of organic and inorganic solids that would pass through a 2 µm filter and thus not settle out of solution. The electrical conductivity of water is directly proportional to the amount of TDS in the water. A specific conductivity meter provides a rapid way to estimate TDS. Elevated TDS values may indicate natural leaching of salts or impacts from industries such as agriculture or mining.

**Total suspended solids** (TSS) measure the amount of sediment traveling in the water. During floods, TSS concentrations can be elevated compared to concentrations during lower flows. High TSS may also reflect erosion of areas that contain little vegetation as a result of natural or human activities.

The acidity of water is measured by its **pH**. Low pH values may be found in streams that drain naturally mineralized and/or mined areas with acid-generating minerals (such as pyrite and other metal sulfides).

Major **cations** (ionized compounded with positive charge, such as sodium, calcium, magnesium, and potassium) and **anions** (ionized compounds with negative charge, such as carbonate, chloride, sulfate, and fluoride) are the most abundant elements in water. They are measured to determine the principal chemical composition of water (for example, a water whose major salt composition is calcium and bicarbonate vs. sodium and chloride) and to check the cation-anion balance of the laboratory analysis. Trace metals and metalloids make up the remaining inorganic components of water, and include aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc.

Nitrogen and fecal coliform or *E. coli* bacteria are indictors of pollution from animal and human waste.

Rainwater may leach salts, metals, metalloids, nutrients, bacteria and other constituents from soil and rock, which can then be transported downstream to surface water and groundwater.

## The Scientific Method and Water Quality Investigations

When water quality and quantity changes, the cause is not always apparent. Watersheds are large complex systems where many different types of activities occur. Finding causes of problems or knowing there is not a problem empowers communities to be proactive and restore or protect the health of their water. In order to do so, they must conduct a scientific investigation using the scientific method.

The scientific method is a process that produces accurate, reliable, and consistent information that can be verified (see table B.1). Since personal and cultural beliefs influence both perceptions and interpretations of the natural world, scientists and citizens alike can minimize these influences by using standard procedures and criteria.

Repeating the same steps, in the same order, and using the same method is crucial to obtaining reliable, useful data.

**Table B.1. Steps in the Scientific Method**

The example that follows shows how the five steps of the scientific method can be used to investigate water quality.

| Step | | Example |
|---|---|---|
| **1** | Observe and describe. | There is excess algae in the river downstream of town. |
| **2** | Formulate a hypothesis to explain the observation. | The treatment plant is releasing untreated sewage. |
| **3** | Use the hypothesis to predict the results of observations. | Nutrient levels are the same above and below the plant when there is no discharge and elevated below the plant when there is discharge. |
| **4** | Design experimental tests to prove or disprove predictions. | Monitor nutrient levels above and below the plant on days with and without discharge. |
| **5** | Evaluate/analyze data and re-evaluate the hypothesis, if necessary. | Determine if the data are conclusive and support the hypothesis. If not, redesign the hypothesis and/or the monitoring program. |

Helping participants understand the scientific method moves debate from perceptions to conclusions founded in data.

## Methods for Studying Water Quality and Quantity

The local area and the water quality and quantity issues that may need to be addressed are unique for each monitoring program. Chapter 4 presents a series of questions that can guide the preparation of a participatory water monitoring program plan. Questions include identifying what to monitor, who will participate, what goes into a monitoring plan, and how to convert data to information. After the monitoring plan has been prepared, the next step is to prepare a detailed sampling and analysis plan. This section provides some technical details that would be included in a sampling and analysis plan, including tips for what to do in the field and what to do with the data generated once they are collected.

Excellent public resources are available to help develop the technical details of a sampling and analysis plan. For example, the United Nations Environment Programme and the Word Health Organization have prepared a guide entitled "Water Quality Monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programs" (referred to in this appendix as the UNEP/WHO guide). Additional technical resources for water monitoring are presented in appendix C.

This section does not repeat the detailed information on methods presented in other resources, but emphasizes topics that are especially important for the success of participatory monitoring and are sometimes overlooked in the planning process.

## When to Use and How to Select a Laboratory

Analytical laboratories play an important role in many water quality monitoring programs. Use a laboratory if:

- The parameters of concern can be quantified only using advanced laboratory equipment (this is the case with most trace metals and organic contaminants such as oil and grease, pesticides, and herbicides)
- The program requires data of sufficient quality to support regulatory decisions, such as whether a site is in compliance.

Monitoring groups use rigorous, specific criteria to choose an analytical laboratory. Criteria used to screen and select laboratories include:

- Ability to perform the analyses within the required time frame
- Ability to perform analyses with a high degree of precision and accuracy
- Ability to meet required detection limits (that is, the minimum value the laboratory is capable of reporting must be less than the standard or criteria against which the data are compared)
- Excellent quality control procedures
- Ease of transporting samples from the field to the laboratory
- Ability to provide high quality data reports, preferably in electronic form to allow easy transfer to the project database
- Reputation, references, and accreditation
- Customer service, including a dedicated laboratory manager.

In addition, laboratories may need to meet additional requirements for *participatory* monitoring programs, where trust is a significant concern:

- Independence from interested parties (the company that is the subject of the monitoring program, the government, or others)
- Ability to communicate easily and efficiently with participants.

When the credibility of the laboratory is a major concern, it may be useful for participants to visit laboratories and evaluate them using these criteria before selection.

### *Choosing Parameters*

Monitoring programs can be used to assess impacts from a land use or pollutant source such as forestry, mining, or agriculture (table B.2) or suitability for a use such as drinking water, agriculture, or aquatic life (table B.3). Physical, chemical, and biological measurements can be used to evaluate both of these broad categories. Some parameters can be measured using field methods; others require an analytical laboratory.

Measuring **physical characteristics** requires the least amount of training, equipment, and time. Measurements help understand basic hydrology and how the watershed changes over time. Characteristics include the flow rate or discharge, streambank stability, vegetation, and riffle/pool/bend characteristics (see glossary for definitions**).**

**Chemical measurements** require meters, test kits, and frequently a contract analytical laboratory to measure each analyte being monitored. An **analyte** is a substance or chemical constituent that is determined by using an analytical procedure. Chemical measurements require a higher degree of training and technical capacity. They provide a “snapshot” of what is happening in the stream at a moment in time and yield quantitative information that can be compared to data from other sources and sampling events.

**Biological monitoring** requires simple equipment and some training in proper methods, field identification of stream organisms, and data interpretation. The biological community in a stream reflects an integration of water quality and habitat conditions over time. Because of this, the types of insect species in a steam are an indicator of water quality.

Tables B.2 and B.3 present parameter lists for physical, chemical, and biological monitoring for different land uses or industry sectors, and for particular uses of the water. Appendix C also includes a list of guidelines and standards for different uses and industry- and sector-specific water quality criteria that can be used to develop a parameter list.

**Table B.2. Parameters for Assessing Effect of Land Use or Pollutant Sources**

| ***Land use/ Potential source*** | ***Primary concerns*** | **Chemical** | | | **Physical** | | | **Biological** | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Field* | *Field test kits or lab* | *Lab* | *Field* | | *Lab* | *Field* | *Lab* |
| | | | | | Parameters | Habitat | | | |
| Forestry | Sediment | pH, dissolved oxygen, conductivity | Phosphate, nitrate | Suspended sediment | Temperature, flow, turbidity | Streambank stability, vegetation, instream cover, riffle, pool, bend | TSS, bed grain size distribution | Macroinverts, algae | Macroinverts |
| Livestock | Bacteria, nutrients | pH, dissolved oxygen, conductivity | Phosphate, nitrate | | Temperature, turbidity | Streambank stability, vegetation | TSS, bed grain size distribution | Macroinverts, algae | ß |
| Crops | Sediment, fertilizer, herbicides and pesticides, salinity, flow | pH, dissolved oxygen, conductivity | Phosphate, nitrate | Pesticides, herbicides | Temperature, flow, turbidity | Streambank stability, vegetation | TSS, bed grain size distribution | Macroinverts, algae | Macroinverts |
| Mining | Sediment, acid drainage, cyanide, heavy metals, flow | pH, dissolved oxygen, conductivity | Alkalinity, some metals (iron, arsenic, copper), sulfate | Major cations and anions, heavy metals | Temperature, flow, turbidity | Streambank stability, vegetation, instream cover, riffle, pool, bend | TSS, bed grain size distribution | Macroinverts | Macroinverts |
| Oil and gas | Sediment, salinity, organic contaminants, heavy metals, flow | pH, dissolved oxygen, conductivity | TPH | TDS, TPH, oil and grease, BOD, COD, phenols, sulfides, chlorides | Temperature, flow, turbidity | | TSS | Macroinverts | Macroinverts |
| Construction | Sediment, chemicals | pH, dissolved oxygen, conductivity | | | Turbidity | Streambank stability, vegetation | TSS | Macroinverts | |
| Sewage treatment | Bacteria, nutrients | pH, dissolved oxygen, conductivity | Phosphate, nitrate | | Temperature, flow, turbidity | | | Macroinverts, algae | Bacteria, macroinverts, algae |
| Urbanization | Sediment, metals, organic compounds, flow | pH, dissolved oxygen, conductivity | Phosphate, nitrate | TPH, oil and grease, heavy metals | Temperature, flow, turbidity | Streambank stability, vegetation | TSS | Macroinverts, algae | Macroinverts |
| Dams | Dissolved oxygen, nitrogen, flow | pH, dissolved oxygen, conductivity | Phosphate, nitrate | | Temperature, flow, turbidity | | | Algae | |

Source: Authors' compilations.

## Table B.3. Parameters for Evaluating Suitability for a Use

| ***Use*** | ***Primary concern*** | **Chemical** | | | **Physical** | | | **Biological** | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Field* | *Field test kits or lab* | *Lab* | *Field* | | *Lab* | *Field* | *Lab* |
| | | | | | Parameters | Habitat | | | |
| Drinking water | Bacteria, chemicals, taste | pH, dissolved oxygen, conductivity | Nitrate | WHO analyte list | Turbidity | | | | Bacteria |
| Human contact | Bacteria | pH, dissolved oxygen, conductivity | | | | | | | Bacteria |
| Agriculture | Salinity, metals and organic contaminants | pH, dissolved oxygen, conductivity | | FAO analyte list | | | | | |
| Aquatic life protection | Contaminants, habitat | pH, dissolved oxygen, conductivity | Nitrate, phosphate | US EPA or Canada standards | | Streambank stability, vegetation, instream cover, riffle, pool, bend | TSS, bed grain size distribution | Macroinverts, algae | Macroinverts |

Source: Authors' compilations.

## What to Do in the Field

A **field sampling plan** contains detailed methods and procedures that are followed every time the sampling team goes to the field. The plan includes a detailed description of documentation required, where to monitor, the types of measurements to be collected, the equipment necessary, and if laboratory samples are collected, the containers and any preservatives that may be necessary to preserve sample quality. Field sampling plans also describe how samples will be transported and stored, received at the analytical laboratory, and tracked using chain-of-custody procedures. A detailed explanation of the components of a field sampling plan is contained in Chapter 5 of the UNEP/WHO guide.

### *Documenting the work*

All field activities need to be documented in bound, waterproof, and paginated notebooks that may include preformatted data sheets. The use of preformatted data sheets is a quality control measure that is designed to:

- Ensure that all necessary and relevant information is recorded for each field activity and each sample
- Serve as a checklist for the field crews to help ensure the data collection effort is complete
- Assist the field crews by making data recording more efficient
- Minimize the problem of field notebook entries that are not legible.

It is helpful to record the following general information at each sampling site:

- Description of the site location, including geographical features, flow characteristics, elevation, and coordinates using a global positioning system device (GPS)
- General weather conditions
- A number and description for each photograph taken
- Notes about any problems or unusual conditions that were encountered during sampling.

The following information should be recorded for each field measurement:

- Notes regarding field instrument preparation, calibration techniques, and concerns regarding instrument performance
- Results of all field measurements.

The following information should be recorded for each laboratory sample:

- Where the sample was collected
- How the sample was collected
- How the sample was stored, preserved, and labeled
- Information written on the sample label.

### *Determining where to sample*

Water monitoring can be conducted to determine baseline conditions or to evaluate impacts. When sampling multiple streams and locations, it is important to choose sites with similar characteristics so that results can be compared among locations where it is believed that there may be an impact and locations where there may be no impact.

**Locating sites for baseline monitoring**

Select sites that represent the range of conditions in the watershed, including:

- Different sized streams with different catchment areas, including headwaters and downstream locations within the same stream
- Undisturbed areas to serve as reference sites
- Areas with different land uses (such as urban, agriculture, forestry)
- Watercourses that receive pollution, including:
    - Point source discharges such as wastewater or industrial effluent
    - Nonpoint sources such as runoff from agricultural plots or natural sources of acid drainage.

**Locating sites for pollution impact monitoring**
First, identify all suspected sources of pollution. Next, select sites above and below the suspected pollution source:

- **Reference sites**: Located immediately upstream of the suspected pollution source
- **Impact sites**: Located immediately downstream of the suspected pollution source.

**Locating sites for whole-watershed impact monitoring**
Watersheds where the majority of the watercourse may be degraded by pollution (such as a watercourse that receives nonpoint source pollution) need to be paired with a more natural catchment. In this case, two locations would be monitored and compared:

- A site on the target watercourse that integrates the effects of the nonpoint source
- A reference or control site on a watercourse with similar features but without the suspected source of pollution of the monitored catchment.

***Collecting field data and samples***

Field sample collections involves measuring flow, and samples to be analyzed at a laboratory.

**Measuring flow**
Participatory water monitoring programs may choose to measure the stream flow rate to address water quantity concerns and to help interpret water quality data (the concentration of pollutants in water can vary with the flow rate). The **stream flow rate or discharge** is the rate at which a volume of water passes a point. It is usually measured in cubic meters per second or liters per second (metric units) or cubic feet per second or gallons per minute (English units).

The discharge is the product of two measured values: the velocity and the cross-sectional area. For streams that can be waded, discharge can be easily measured using simple equipment. A velocity meter or a simple float that travels a specified distance in a measured amount of time determines the velocity. The width and depth at multiple locations determine the cross-sectional area.

Detailed methods for measuring discharge are presented in Section 12.1 of the UNEP/WHO guide.

**Measuring water quality parameters**
Water quality monitoring may include measurements of parameters in the field and collection of water samples to be analyzed at a laboratory. Some parameters need to be measured in the field because their values would change between the time of collection and transport to a laboratory (including temperature, pH, and dissolved oxygen). In

addition, field measurements provide an immediate measurement of basic indicators of water quality, typically at less expense than a commercial laboratory.

Field instruments can be used to collect quantitative measurements of basic water quality parameters, including temperature, pH, conductivity (also called **specific conductance**), dissolved oxygen, and turbidity (see Chapter 6 of the UNEP/WHO guide). Field instruments must be calibrated before use to ensure accuracy.

In addition, some field methods are available for qualitative or semi-quantitative measurement of elements in water by titrimetric, photometric, colorimetric, or ion-specific electrode methods. Some elements that can be measured in the field include aluminum, calcium, chloride, fluoride, iron, manganese, nitrogen compounds, phosphate, potassium, selenium, and hardness, as well as some additional elements. For more information, see http://www.hach.com or appendix 1 of the UNEP/WHO guide.

Some field methods have also been developed for semi-quantitative measurement of fecal coliform bacteria concentrations (see http://www.micrologylabs.com/Home).

**Collecting water samples for laboratory analysis**

The bottles in which samples are collected and stored are specially cleaned and certified by the supplier to be free of all contamination. Bottles are usually shipped directly from the laboratory to the field. For some analyses, a preservative must be added to the bottle to ensure that the chemical properties of the sample do not change during shipment to the laboratory. The type of preservative depends on the type of sample to be stored in the bottle. The preservative may be added at the analytical laboratory before the bottles are shipped to the field, at the field office, or in the field.

Each sample bottle must be clearly labeled with the following information:

- Sample identification code
- Sample date and time
- Sample matrix
- Preservative used, if any
- Whether the sample has been filtered in the field
- Initials of samplers
- Analysis required (metals, anions, TDS/TSS, and the like).

Whether a sample should be filtered depends on the purpose of the investigation and the water use being evaluated. Water that is being evaluated for human or livestock consumption should not be filtered. Because aquatic life is sensitive to dissolved rather than particulate metals, water used to assess impacts to aquatic life should be filtered.

Reusable sampling equipment should be decontaminated before use. Disposable sampling equipment should be new and stored in a sterile container. An example procedure follows:

1. Each bottle is labeled and dated, and the sample numbers, date, time, and sampling information are noted in the field logbook.
2. If the steam can be safely waded, the samplers enter the stream downstream of the sample site and proceed upstream to the sampling site. The point at which samples are collected is as close to the stream center as safety allows.
3. If the samplers cannot wade to the stream center, the sample should be collected near the bank in an area of flowing water.

4. The samplers' hands or gloves are rinsed in the stream being sampled for 10 seconds.
5. Samples are collected from middepth or in deep water as close to middepth as possible (given safety constraints).
6. If the bottles do not have a preservative in them, they are rinsed three times and then immersed in the water until the bottle is filled. If the analysis requires a preservative, it is added after sample collection and before the bottle is sealed.
7. If the bottles contain a preservative, water should be pumped into the bottle so that all the preservative remains in the bottle.
8. Samples that require field filtration (such as dissolved metals) require additional equipment and steps. One method is to use a hand peristaltic pump with tubing connected to a cartridge filter with a pore size of 0.45 μm (the standard cutoff value between "total" and "dissolved" concentrations). Water can be pumped directly from the stream to sample bottles containing a preservative for filtered sample analysis.

**Quality control samples**

Quality control samples are an important part of any sampling program, and are especially important if data collected for participatory programs will be used to evaluate compliance. Blank samples are used to ensure that the sampling equipment and bottles are clean. Equipment blanks are samples of ultrapure water from the analytical laboratory that are subjected to the same collection procedures as the surface water samples. Bottle blanks contain ultrapure water and any preservative that may be required for the analysis. Field duplicates are a check on the reliability of the field collection procedures. **Field duplicate samples** are two samples collected consecutively and submitted for the same analysis. **Standard Reference Water (SRW) samples** contain a known concentration of the chemical being measured. Field duplicates and standard reference water samples can be used to verify that the analytical laboratory is producing consistent, reliable data.

All quality control samples are submitted to the laboratory "blind" so that the laboratory does not know that they are analyzing a sample that is supposed to be clean (a blank), with a known concentration (an SRW), or that is supposed to have the same value as another sample (a field duplicate).

**Delivering samples to the laboratory**

"**Chain of custody**" refers to documentation that describes how a sample is handled and stored from the time it is collected in the field until it is placed in the sample container, shipped to the laboratory, analyzed, and finally discarded.

When the samples are being collected in the field, the field team is responsible for sample chain of custody. While in the field, the field team must make sure that no one tampers with the sample bottles and that they are properly stored. After returning from the field, sample information is logged into a database, and samples are securely stored until they are shipped to the laboratory.

Samples are shipped to the laboratory with the original chain of custody form that includes the following information:

- Project name
- Sample identification (unique for each sample)
- Date and time of sample collection

- Sample matrix (such as surface water)
- Analysis required for each sample
- Name and signature of individual relinquishing custody
- Inclusive dates and times of possession for each person
- Sample shipping date and mode.

A copy of all the chain of custody forms remains with each person who has custody of the samples. Custody seals are placed on the shipping container to detect unauthorized tampering with samples between the time of collection and analysis in the laboratory. The seals are signed, dated, and attached so that they must be broken to open the shipping container. Intact chain of custody seals at the laboratory demonstrate that the samples arrived without tampering.

Samples are placed in coolers and shipped as soon as possible after collection. If possible, the samples should be kept cold during shipment. Many analyses have a "**hold time**" that specifies how soon after collection samples must be analyzed to ensure that the sample's properties do not change between the time the sample is collected and the time it is analyzed.

**Measuring biological indicators**

**Biological monitoring** focuses on observing changes in the number (density) and diversity (richness) of organisms in a stream. Changes in density and richness between monitoring events often indicate a change in water quality. Many organisms live in water, but benthic macroinvertebrates are the best biological indicator of stream health. **Benthic macroinvertebrates** are animals that live on the bottom of streams (benthic), are large enough to see (macro), and have no backbone (invertebrates). They include aquatic insects (such as mayflies, stoneflies, caddisflies, midges, beetles), snails, worms, freshwater clams, mussels, and crayfish. Benthic macroinvertebrates sampling forms the basis for the U.S. Environmental Protection Agency's Rapid Biological Assessment Protocols (Barbour and others 1999).

Benthic macroinvertebrates are useful organisms for monitoring because each species reacts to pollution in different ways. For example, species such as mayflies, stoneflies, and caddisflies require very clean water to survive and are not very tolerant to pollutants. Species such as midges and worms are more tolerant of pollution and less susceptible to changes in water quality. When a stream becomes polluted, sensitive species such as mayflies, stoneflies, and caddisflies decrease in number, and tolerant species such as midges and worms increase in number.

Several other factors make benthic macroinvertebrates an excellent choice for monitoring water quality:

1. They are relatively immobile. Whereas fish can swim away when a pollutant is spilled into a waterway, macroinvertebrates are constrained to a small area of the stream bottom.
2. Water chemistry measurements demonstrate water quality at a particular moment, but the density and diversity of benthic macroinvertebrates reflect the stream conditions over time. Therefore, they reflect the impact of pollution events, intermittent releases of pollution, or chronic, long-term change.
3. Benthic macroinvertebrates are a critical part of the food web. They consume algae and plant material and form the food base for many fish.
4. They are abundant and easily sampled and identified.

**Locating macroinvertebrates in the stream**
Moving watercourses have four distinct types of habitat: riffles, runs, pools, and edgewater. Macroinvertebrates tend to survive best in areas that provide protection, a place to hide, and a food source. Each of the different types of habitat will have a different macroinvertebrate composition.

- Riffles are shallow, rocky sections of stream with fast water flow that support a great diversity of insects. They provide the best habitat because the rocks provide a stable environment that is not easily washed away when the flow is high and a great amount of habitat. In addition, water in riffles has a higher oxygen concentration and a more continuous supply of food than water in slower moving sections.
- Runs are deeper sections with slower water flow. They tend to collect sand and gravel that can be washed away in high flow. Because the streambed in runs has less surface area and tends to erode when there is flooding, the habitat is less stable than riffles.
- Pools are characterized by very slow or stagnant water and sandy or muddy bottoms. As with runs, they provide less habitat then riffles.
- Edgewater areas are next to the bank. Plants rooted to the bank, overhangs, and tree roots form habitat in edgewater areas.

Riffles in streams have the most diverse habitat for macroinvertebrates and generally have the greatest abundance and diversity. Organisms in riffles range from very tolerant to very sensitive to pollution. When there are no riffles in the area you want to sample, it is best to sample macroinvertebrates living in and around vegetation at the edges of a stream, or edgewater habitat. Some streams are too fast or too deep to wade, making it difficult or impossible to sample riffles. In this case, edgewater habitat can be sampled from the bank.

**Methods for collecting macroinvertebrates**
Benthic macroinvertebrates are collected with nets. The best nets to use have a long handle and a triangular or D-shaped frame and a mesh size of about 0.3 mm.

Use kick sampling if the sample site is a riffle. Collect samples by wading into the stream at the location of the riffle. Place the net downstream with the opening facing upstream. Disturb the rocks by shuffling and kicking as you move upstream a distance of 10 m. (kick sampling). Insects and other detritus will be carried into the net by the current. Riffle habitats for kick sampling should:

- Have a reasonably fast current velocity (0.1 to 0.5 m/s)
- Have a cobble and gravel bottom with little fine sediment
- Be 10 to 50 centimeters in depth.

Use sweep sampling if the sample site is an edgewater habitat. Collect samples by sweeping the net upstream against vegetation along the perimeter of the bank (sweep sampling). Dislodged insects will be carried into the net by the current.

Edgewater habitats for sweep sampling should:

- Have a stable bank
- Be well vegetated
- Be representative of the watercourse.

**Methods for identification**

Once the samples are collected, they are identified and sorted by insect type. The following links provide useful keys for macroinvertebrate identification in streams and lakes or ponds:

http://clean-water.uwex.edu/pubs/pdf/wav.riverkey.pdf

http://clean-water.uwex.edu/pubs/pdf/wav.pondkey.pdf

The number of individual of each insect type is an important indicator of water quality, as described in the following data evaluation section.

## What to Do with the Data When Back in the Office

### *Develop a water monitoring database*

Data collected in the field should be transferred to an electronic database upon return. In addition, laboratory data should be entered into the database. It is best if the data come from the laboratory in electronic form so that they can be transferred to the project database with minimal chance of transcription errors.

### *Evaluate laboratory data quality*

**Quality Assurance/Quality Control (QA/QC)** refers to the overall program used to ensure that data collected are of known and acceptable quality. The QA/QC program includes specific procedures in the field and in the laboratory.

**Field QA/QC samples**

Blank, duplicate, and standard reference water (SRW) samples are collected during field sampling to determine whether samples collected in the field have been contaminated by external materials and to verify that the analytical laboratory is producing data that meet the quality goals of the investigation. To prevent the analytical laboratory from treating these samples differently from field samples, field QA/QC samples are labeled and packaged so that they appear the same as the other samples.

The typical sample collection frequency is one QA sample for every 20 samples, or once per sampling event if fewer than 20 samples are collected. Blank samples are used to assess whether contamination was introduced into samples during the sample collection, handling, preservation, and shipping procedures. Field duplicate samples are used to check on the reliability of the field collection procedures. Standard reference water samples, which are samples with known concentrations of a chemical, are used to assess whether the analytical laboratory produced consistent, reliable data.

- **Equipment blank** samples are ultrapure water from the analytical laboratory that are collected in the same way as water samples collected from a stream. If the equipment blanks do not contain detectable concentrations of the analytes measured, it can be concluded that no contaminants entered the samples during collection.

- **Field duplicate** samples are samples from a single location, collected consecutively and submitted for the same analysis. They are used to assess the consistency and repeatability of the field collection and analytical procedures. Because the samples are from the same location and are collected close in time, the water chemistry should be similar. If the sample concentrations differ greatly, either the laboratory analysis was inaccurate or the samples were not representative of the medium sampled. The measured analyte concentrations in each duplicate pair is compared against each other, with the difference between the two results expressed as the **relative percent difference (RPD).** RPD is calculated as the difference between the two values divided by their mean. Generally, the RPD should be less than 35 percent for the analysis to be acceptable.
- **Standard reference** samples have a known and certified concentration of chemicals in the sample. The analytical laboratory should generate data that differ by less than 10 percent from the standard reference sample published concentration for the analysis to be acceptable.

**Laboratory QA/QC**

Laboratory quality control procedures are performed to verify that the instruments are functioning properly and to ensure the samples and instrument standards are properly stored, prepared, and analyzed. QC procedures in the laboratory include the following:

- Instrument calibration
- Instrument performance checks
- Documentation on the traceability of instrument standards, samples, and data
- Documentation of sample preservation and transport.

Instrument calibration involves running samples of known concentrations, called “standards,” through the instrument that serve as “reference” concentrations. When an instrument is calibrated properly, the standards will bracket the range of concentrations in the samples and will ensure the accurate reporting of sample concentrations.

Instrument performance is checked by using a variety of substances, including chemical standards, external reference materials, and blanks. In general, the purpose of analyzing these materials is to ensure that the instrument is accurately reporting the sample concentration.

Method blanks and continuing calibration blanks are used to assess whether samples became contaminated during sample preparation and analysis. Laboratory duplicate samples are used to test for analysis precision. Matrix spike samples (a known amount of chemical added to an actual field sample) are used to ensure there were no matrix interferences. Laboratory control samples and continuing calibration verification are used to ensure **sample accuracy** (how close the measured value is to the “true” value). For each of these laboratory QA/QC samples, the laboratory statement of work specifies acceptability limits for results and corrective actions that had to be undertaken if the sample results did not meet acceptability limits.

Documentation is an important part of laboratory quality control and is used to verify that the samples and standards were properly handled, analyzed, and stored. The laboratory must maintain a record of quality control procedures. For example, the laboratory must document that standards were prepared at the appropriate frequency and that instruments were calibrated appropriately. Additionally, the laboratory must document when the field samples were analyzed to ensure that sample holding times were not exceeded.

**Data validation**

The monitoring program data manager reviews the laboratory data to determine if they are acceptable. If there appears to be problems with the data, the project manager will communicate any concerns to the analytical laboratory and work on resolving any conflicts. Resolution could involve reanalysis of samples, recalculation of concentrations, or correction of transcription errors.

One important check of laboratory data quality is to determine the charge balance for a complete water analysis. If the sum of the cations and the sum of the anions are not equal (taking into account the charge on the cation or anion and analytical variability), then the laboratory analysis is suspect, or an important constituent may not have been measured in the sample. Therefore, the cation-anion balance serves as a check on the validity of the laboratory analysis.

***Evaluating water quality data***

Water quality is evaluated by measuring the concentrations of elements in the water and comparing them to baseline water characteristics, to historical concentrations, and to the water quality laws and standards that protect human health and the environment.

*Statistical analysis*

Statistics can help with interpretation of the large amount of data generated by monitoring programs by reducing the data to a few numbers. Common statistical values include the average, geometric mean, median, and quartiles. The statistical summary is more meaningful if more data are available.

**Average (arithmetic mean)**. The average is calculated by adding all the values and dividing by the number of values. A few very high or low values (outliers) can have a large influence on the average.

**Geometric mean.** The geometric mean is the *n*th root of the product of *n* values. The geometric mean reduces the influence of outliers.

**Median**. The median divides the data distribution in half: 50 percent of the values are above the median and 50 percent of the values are below. The median is not affected by outliers and can be more meaningful than the average.

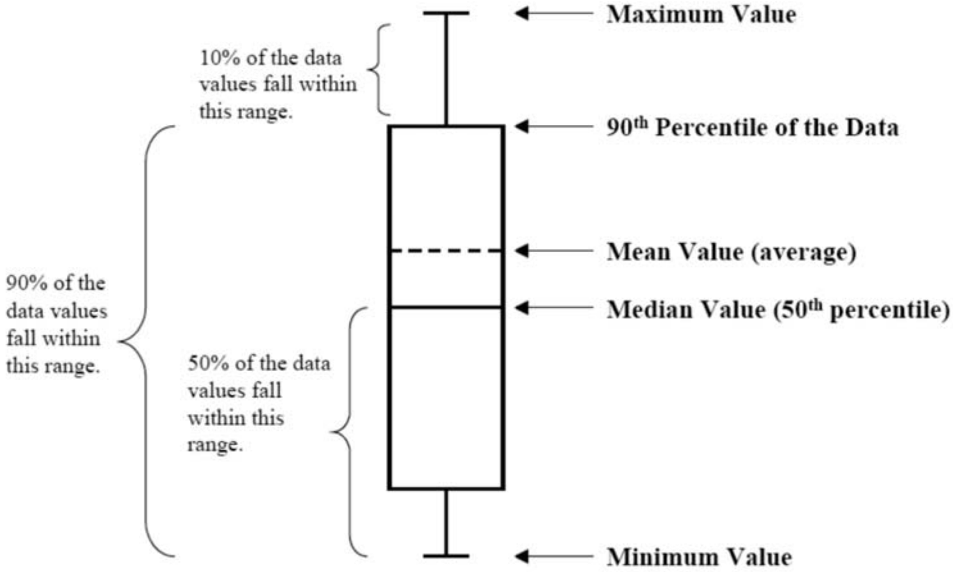
**Confidence interval.** The confidence interval is a range that tends to include the value a predetermined portion of the time. For example, if the 95 percent confidence interval for a data set is 5 to 20, this means that 95 percent of the time, the actual value will be between 5 and 20.

**Standard deviation.** The standard deviation (SD) quantifies how the data are distributed around the average. When data are normally distributed (shaped like a bell curve), plus or minus one standard deviation represents the 66 percent confidence interval. The standard deviation is higher when there is more variability in the data.

**Quartiles.** A quartiles is the value below which 25 percent, 50 percent, or 75 percent of the numbers in a data set lie.

**Percentile value.** The percentile value is similar to a quartile, expect that the value is different from 20, 50 or 75 percent. For example, the 90th percentile value is the number where 90 percent of the values are lower, and approximately 10 percent are higher.

**Figure B.1. Percentile Values**




**Presenting results**
Generally, graphs and charts are easier for people to use and understand than tables full of numbers. Graphs are also very useful to show trends between sample locations at a particular time and at different times for a single location.

The most common type of graph used to present water quality data is a line graph. A line graph usually presents concentration on the y-axis and time on the x-axis, with data points joined by a line. This type of graph emphasizes trends and the relationship between data points.

Some tips for graphing include the following:

- Graphs should always have a specific purpose, such as demonstrating a trend over time; be easy to interpret; and play a specific role in a presentation or report.
- Graphs should be to scale, unless otherwise noted.
- Graphs should be simple, to avoid misinterpretation.
- The number of datasets in a line graph should be limited to fewer than three.
- Simple titles that are also accurate should be used.
- A legend and captions should be used where necessary.

***Evaluating Macroinvertebrate Data***

There are numerous indicators for determining stream health using macroinvertebrate data. Some are specific to a certain ecological zone (for instance, the tropics vs. alpine environments), or a particular continent, country, or region.

The **EPT index** is an especially useful indicator of water quality that applies to a large range of stream types and ecological zones. It is based on the abundance of three pollution-sensitive orders of macroinvertebrates relative to the abundance of a hardy species of macroinvertebrate. The EPT index is calculated as the sum of the number of individual insects belonging to the *Ephemeroptera* (mayfly), *Plecoptera* (stonefly), and *Trichoptera* (caddisfly) orders divided by the number of *Chironimidae* (midges). Midges are a species of fly that are present in large numbers in streams that are both clean and polluted.

When analyzing macroinvertebrate data, compare samples from the same habitats (for example, compare riffle to riffle and edgewater to edgewater).

# Appendix C. Useful Resources

Note: All Web-based resources were accessed on April 9, 2008.

## Stakeholder Analysis, Engagement, and Mapping

*Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets* (IFC, May 2007)
http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/p_StakeholderEngagement_Full/$FILE/IFC_StakeholderEngagement.pdf

"Good Practice Note: Addressing the Social Dimension of Private Sector Projects" (IFC, December 2003)
http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/p_SocialGPN/$FILE/SocialGPN.pdf

*Social Analysis Sourcebook: Incorporating Social Dimensions into Bank-Supported Projects* (The World Bank Group, December 2003)
http://www.worldbank.org/socialanalysissourcebook/SocialAnalysisSourcebookFINAL2003Dec.pdf

*Engaging Citizens in Policy-making: Information, Consultation and Public* Participation (Organisation for Economic Co-operation and Development, July 2001) http://www.oecd.org/dataoecd/24/34/2384040.pdf

.
*Stakeholder Engagement and Facilitation* (AccountAbility)
http://www.accountability21.net/default.aspx?id=256

"Stakeholder Engagement Issue Brief" (Business for Social Responsibility, April 2003)
http://www.bsr.org/research/issue-brief-details.cfm?DocumentID=48813

*Tools for Development: A Handbook for Those Engaged in Development* (Department for International Development [DFID], September 2003)
http://www.dfid.gov.uk/pubs/files/toolsfordevelopment.pdf

*Community Development Toolkit* (ESMAP, the World Bank, and ICMM, November 2005)
http://www.icmm.com/library_pub_detail.php?rcd=183

*Stakeholder Influence Mapping* (International Institute for Environment and Development [IIED], 2005)
http://www.policy-powertools.org/Tools/Understanding/SIM.html

*Stakeholder Power Analysis* (International Institute for Environment and Development [IIED], 2005)
http://www.policy-powertools.org/Tools/Understanding/SPA.html

"The Four Rs: Rights, Responsibilities, Relationships and Revenues" (International Institute for Environment and Development [IIED], 2005) http://www.policy-powertools.org/Tools/Understanding/TFR.html

*Community Engagement and Development Handbook* (Australian Government Department of Industry, Tourism and Resources, October 2006)
http://commdev.org/content/document/detail/909/

*Socio-Economic Assessment Toolkit* (SEAT, Anglo American)
http://www.angloamerican.co.uk/cr/socialresponsibilty/seat/

## Public Participation

*Public Participation Toolbox* (International Association for Public Participation [IAP2], 2006)
http://www.iap2.org/associations/4748/files/06Dec_Toolbox.pdf

"Spectrum of Public Participation" (International Association for Public Participation [IAP2], 2007)
http://iap2.org/associations/4748/files/IAP2%20Spectrum_vertical.pdf

*The Citizen Participation Toolkit: Tools to Promote Citizen Participation, a Forum for Discussion, and Articles for Further Reference*. A Web-based clearing house for citizen participation resources.
http://www.toolkitparticipation.nl/index.php

*World Bank Participation Sourcebook* (The World Bank Group, February 1996)
http://www.worldbank.org/wbi/sourcebook/sbhome.htm

"Public Participation: International Best Practice Principles" (International Association for Impact Assessment, August 2006).
http://www.iaia.org/modx/assets/files/SP4%20web.pdf

"Principles for Engagement with Communities and Stakeholders" (Australian Government Department of Industry, Tourism and Resources, 2005)
http://commdev.org/content/document/detail/1171/

*Participatory Methods Toolkit: A Practitioner's Manual* (King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment in Collaboration with the United Nations University, December 2003)
http://www.viwta.be/files/handboek.pdf

Participation, Power and Social Change Team of the United Kingdom Institute for Development Studies (IDS)
http://www.ids.ac.uk/ids/part/

*Resource Book on Participation* (Inter-American Development Bank)
http://www.iadb.org/aboutus/vi/resource_book/table_of_contents.cfm

*Handbook on Stakeholder Consultation and Participation in ADB Operations* (African Development Bank, 2001)
http://www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/ENVIRONMENTALANDSOCIALASSESSMENTS/PARTICIPATORY%20HAND%20BOOK_0.PDF

## Forming an Organization

*Mechanisms for Organization That Best Serve the Poor* (International Institute for Environment and Development [IIED], 2005)
http://www.policy-powertools.org/Tools/Organising/MO.html

## Participatory/Independent Monitoring

"Independent Forest Monitoring: A Tool for Social Justice?" (Global Witness and International Institute for Environment and Development [IIED], 2005)
http://www.policy-powertools.org/Tools/Ensuring/IFM.html

"Participatory 3-dimensional mapping for watershed analysis" (Integrated Approaches to Participatory Development)
http://www.iapad.org/applications/application_03.htm

"Monitoring for Impact: Lessons on natural resources monitoring from 13 NGOs" (World Resources Institute, September 2000)
http://www.wri.org/publication/monitoring-impact-lessons-natural-resources-monitoring-13-ngos

## Conflict Analysis

Conflict, Crime and Violence: Conflict Analysis (Social Development Department, The World Bank, 2008)
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTCPR/0,,contentMDK:20486708~menuPK:1260893~pagePK:148956~piPK:216618~theSitePK:407740,00.html

"Conflict-Sensitive Business Practice: Guidance for Extractive Industries" (International Alert, 2005)
http://conflictsensitivity.org/node/102

"Conducting Conflict Assessment: Guidance Notes" (United Kingdom Department for International Development [DfID], January 2002)
http://www.dfid.gov.uk/Pubs/files/conflictassessmentguidance.pdf

"Cultivating Peace: From Conflict to Collaboration in Natural Resource Management" (International Development Research Centre of Canada, 1999)
http://www.idrc.ca/en/ev-25654-201-1-DO_TOPIC.html

"The Role of Development Aid in Conflict Transformation: Facilitating Empowerment Processes and Community Building" (Berghof Research Center for Constructive Conflict Management, 2004)
http://portals.wi.wur.nl/files/docs/ppme/bigdon_korf_handbook.pdf

"The Berghof Handbook for Conflict Transformation" (Berghof Research Center for Constructive Conflict Management, 2008)
http://www.berghof-handbook.net/std_page.php?LANG=e&id=1

"Tools and Conflict Sensitive Approaches to Development" (Swiss Peace, 2008)
http://www.swisspeace.ch/typo3/en/peacebuilding-activities/koff/topics/tools-and-conflict-sensitive-approaches-to-development/index.html

“Managing Conflicts in Protected Areas” (The World Conservation Union [IUCN] and the Keystone Center, 1996)
http://www.personal.ceu.hu/students/03/Iordan_Hristov/managing%20conflicts%20in%20prot%20areas.pdf

“When the sparks *fly*: Building Consensus when Science is Contested” (RESOLVE, May 2003)
http://www.resolv.org/publications/reports/When_the_Sparks_Fly.pdf

“Building Trust: When Knowledge from ‘Here’ Meets Knowledge from ‘Away’” (The National Policy Consensus Center, Resolve, and the Keystone Center, October 2002)
http://www.resolv.org/publications/reports/buildingtrust/building_trust.pdf

## General References for the Extractive Industries

*Mining, Environment and Development: Documents on Mining and Sustainable Development from the United Nations and Other Organizations* (UNCTAD, UNEP, UNIDO, ILO, The World Bank Group, UN DESA, Environment Australia, MMSD, and others, 2008)
http://www.natural-resources.org/minerals/CD/guidelin.htm

*Good Practice: Sustainable Development in the Mining and Metals Sector. A Library of Good Practice Guidelines, Standards, Case Studies, Legislation and Other Relevant Materials on Mining and Sustainable Development* (International Council on Mining and Metals [ICMM], United Nations Conference on Trade and Development [UNCTAD], United Nations Environment Programme [UNEP], UK Department for International Development [DfID], 2008)
http://www.goodpracticemining.org/index.php

*Oil, Gas and Mining Community Development Fund: A Resource Center with Toolkits, Handbooks, Guidelines and Other Documents* (World Bank and IFC, 2008)
http://commdev.org/section/documents

## General Water Resource References

United Nations Water (UN-Water)
http://www.unwater.org/flashindex.html

United Nations Educational, Scientific and Cultural Organization (UNESCO) Water
http://www.unesco.org/water/

World Bank Water Resources Management
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTWRM/0,,menuPK:337246~pagePK:149018~piPK:149093~theSitePK:337240,00.html

World Water Council
http://www.worldwatercouncil.org/

Water Environment Federation
http://www.wef.org/Home

Worldwide Water Monitoring Day (Water Environment Federation)
http://www.worldwatermonitoringday.us/

U.S. Geological Survey
http://water.usgs.gov/

Stockholm International Water Institute
http://www.siwi.org/

American Geophysical Union Hydrology Section
http://hydrology.agu.org

American Water Resources Association
http://www.awra.org

American Institute of Hydrology
http://www.aihydro.org

International Association of Hydrological Sciences
http://www.cig.ensmp.fr/~iahs

Canadian Water Resources Association
http://www.cwra.org

International Association of Environmental Hydrology
http://www.hydroweb.com

The Watershed Management Council
http://www.watershed.org

## Water Quality Standards and Criteria

### *General Standards and Criteria*

U.S. Environmental Protection Agency (US EPA) Water Quality Standards Home Page
http://www.epa.gov/waterscience/standards/

U.S. Environmental Protection Agency (US EPA) Water Quality Criteria Home Page
http://www.epa.gov/waterscience/criteria/
http://www.epa.gov/waterscience/criteria/wqcriteria.html

Canadian biocriteria for bioassessment of water quality
http://www.ccme.ca/assets/pdf/biocriteria_report_e_web_1.0.pdf

### *Drinking Water Criteria*

World Health Organization
http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

Canada
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index_e.html

European Union
http://ec.europa.eu/environment/water/water-drink/index_en.html

U.S. Environmental Protection Agency
http://www.epa.gov/waterscience/criteria/humanhealth/

### Contact Criteria (bathing and recreation)

U.S. Environmental Protection Agency
http://www.epa.gov/waterscience/criteria/recreation/

World Health Organization
http://www.who.int/water_sanitation_health/bathing/srwe1/en/

### Agriculture

Canada
http://www.ccme.ca/assets/pdf/wqg_ag_protocol.pdf

Agricultural impacts on water resources (United Nations Food and Agriculture Organization, FAO)
http://www.fao.org/docrep/W2598E/W2598E00.htm

Water quality for agriculture (United Nations Food and Agriculture Organization, FAO)
http://www.fao.org/DOCREP/003/T0234E/T0234E00.HTM

### Aquatic Life

Canada
http://www.ccme.ca/assets/pdf/wqg_aql_protocol.pdf

U.S. Environmental Protection Agency
http://www.epa.gov/waterscience/criteria/aqlife.html

### Industry Sector-Specific Effluent Monitoring Criteria

Canada Environmental Effects Monitoring (EEM) for metal mining and pulp and paper effluent guidance
http://www.ec.gc.ca/eem/

"Environmental Health and Safety (EHS) Guidelines: Wastewater and Ambient Water Quality" (IFC, April 2007)
http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_GeneralEHS_1-3/$FILE/1-3+Wastewater+and+Ambient+Water+Quality.pdf

"Environmental Health and Safety (EHS) Guidelines: Industry Sector-Specific Guidelines for Forestry, Agribusiness/Food Production, General Manufacturing, Oil and Gas, Infrastructure, Chemicals, Mining and Power" (IFC, April 2007)
http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

## Monitoring Methods

### *Community Monitoring*

Waterwatch Australia: Monitoring Water Quality
http://www.waterwatch.org.au/monitoring.html

Missouri Stream Team Volunteer Water Monitoring
http://www.mostreamteam.org/pubs.asp

Volunteer Stream Monitoring: A Methods Manual (US EPA, November 1997)
http://www.epa.gov/volunteer/stream/

Monitoring and Assessing Water Quality: Volunteer Monitoring (US EPA)
http://www.epa.gov/owow/monitoring/volunteer/

Wisconsin's Citizen-Based Water Monitoring Network (University of Wisconsin Extension)
http://watermonitoring.uwex.edu/

A Guide to Water Monitoring Programs in the US
http://www.uwex.edu/ces/csreesvolmon/VolunteerMonPrograms/

California Watershed Assessment Manual
http://cwam.ucdavis.edu/

Volunteer Water Monitoring Resource List (University of Wisconsin Extension)
http://www.uwex.edu/ces/csreesvolmon/links.html#manuals

Hoosier RiverWatch Volunteer Stream Monitoring Training Manual
http://www.in.gov/dnr/riverwatch/trainingmanual/

Vermont Surface Water Volunteer Monitoring Guide
http://www.vtwaterquality.org/lakes/htm/lp_monitoringguide.htm

### *Specific References for Participatory Water Monitoring*

"Connected Water: Managing the Linkages Between Surface Water and Ground Water" (Natural Resource Management Ministerial Council of Australia)
http://www.connectedwater.gov.au/framework/water_users.html

Integrated Water Resources Management Toolbox (Global Water Partnership)
http://www.gwptoolbox.org/

Integrated Water Resource Management Glossary of Terms (Network on Government, Science, and Technology for Sustainable Water Resource Management in the Mediterranean)
http://www.feem-web.it/nostrum/glossary.html

### *Technical Resources*

United Nations Environment Programme and World Health Organization Guidelines for Water Quality Monitoring
http://www.who.int/water_sanitation_health/resourcesquality/wqmonitor/en/index.html

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF) *Standards Methods for Examination of Water and Wastewater*
http://www.standardmethods.org/

U.S. Environmental Protection Agency *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers*
http://www.epa.gov/owow/monitoring/rbp/download.html

U.S. Environmental Protection Agency guidelines for water quality monitoring
http://www.epa.gov/watertrain/monitoring/index.htm

U.S. Geological Survey chemical sampling protocols
http://water.usgs.gov/nawqa/protocols/methodprotocols.html

U.S. Geological Survey biological sampling protocols
http://water.usgs.gov/nawqa/protocols/bioprotocols.html

University of Wisconsin-Extension and Wisconsin Department of Natural Resources Water Action Volunteers *Volunteer Monitoring Methods Factsheet Series (Introduction to Monitoring, Biotic Index, Dissolved Oxygen, Habitat, Stream Flow, Temperature, Transparency)*
http://watermonitoring.uwex.edu/wav/monitoring/methods.html

University of Wisconsin-Extension and Wisconsin Department of Natural Resources Keys to macroinvertebrate life
http://clean-water.uwex.edu/pubs/wav.htm#key1

## Notes

[1] World Bank (1994).
[2] World Bank (1996).
[3] http://www.unece.org/env/pp/welcome.html
[4] http://www.ifc.org/ifcext/enviro.nsf/Content/Publications_GoodPractice_StakeholderEngagement
[5] See *Performance Standard 1: Social and Environmental Assessment and Management Systems*. Available at: http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/pol_PerformanceStandards2006_full/$FILE/IFC+Performance+Standards.pdf
[6] For more information on stakeholder mapping processes, see http://www.policy-powertools.org/Tools/Understanding/docs/stakeholder_influence_mapping_tool_english.pdf
[7] Knowledge is considered broadly and includes customary and traditional knowledge, as well as technical expertise.
[8] Beierle and Crawford (2002).

## General Terms

**Accountability mechanism.** An office within an institution with a mandate and standardized procedures, designated roles, and responsibilities to ensure that the institution complies with external and/or internal laws, policies, procedures, or guidelines related to the institution's performance.

**Assessor.** A person or group that reviews information and interviews stakeholders to develop the background necessary to develop a monitoring program.

**Civil society organization (CSO).** A legally constituted organization that carries out a social mandate or delivers a social service and that is created by private individuals with no participation or representation of government (although they may receive some funding from government). Some CSOs focus on delivering social services and development as a complement to government action, especially in regions where government presence is weak. Same as nongovernmental organization (NGO).

**Compliance.** Commitment to follow and implement—in both spirit and letter—relevant laws, rules, regulations, or negotiated agreements.

**Compliance Advisor/Ombudsman (CAO).** The independent recourse mechanism of the International Finance Corporation (IFC) and the Multilateral Investment Guarantee Agency (MIGA), the private sector lending and insurance members respectively of the World Bank Group.

**Compliance audit.** An impartial assessment by an independent third party focused on whether an institution has complied with relevant policies, standards, guidelines, and procedures.

**Conflict.** A serious and potentially costly dispute over perceived or actual incompatible values or more tangible interests. When acted upon, conflicts are often damaging to all concerned in terms of relationship, time, personnel, and resource and opportunity costs required to resolve them. Often used synonymously with dispute.

**Convener.** A person or institution of stature, widely respected and viewed as fair-minded, that leads the participatory monitoring process. In this context, the primary role of the convener is to invite stakeholders with different views and interests to come to the table to design and implement a participatory monitoring program. A respected convener brings legitimacy and credibility to the program.

**Enforcement.** Means and procedures to assure commitment to and implementation of relevant laws, rules, regulations, or negotiated agreements, regardless of the cooperation or will of involved parties.

**Facilitator.** A facilitator helps people communicate more effectively to reach consensus. A facilitator ensures that people speak one at a time, that one person does not dominate the discussion, that all have a chance to speak, and that the discussion remains on the issues.

**Governance structure.** Roles, procedures, and institutional host for the management of a participatory monitoring program.

**Greenfield project.** A project that is built on undisturbed land.

**Intermediary/Intermediaries.** Individuals or groups that are not a party to a complaint, grievance, or dispute—such as facilitators, mediators, process coaches, fact finders, compliance advisors, arbitrators, or community elders—who provide assistance to involved parties that enables them to reach voluntary agreements, secure nonbinding advice, or obtain a binding judgment to settle differences. Synonymous with third parties.

**International Finance Corporation (IFC).** A member of the World Bank Group that focuses on private sector projects in developing countries. It provides financing to private sector projects, helps private companies in developing countries mobilize financing in international financial markets, and provides advice and technical assistance to businesses and governments.

**Moral authority.** The power to exercise authoritative control or influence over standards of behavior based on a sense of right and wrong. A person with moral authority sets the standard for acceptable and unchangeable behavior.

**Multilateral Investment Guarantee Agency (MIGA)**. A member of the World Bank Group whose mission is to promote foreign direct investment in developing countries. MIGA offers political risk insurance, technical assistance, and dispute mediation services to private sector clients.

**Negotiation.** Communication among individuals for the purpose of arriving at a mutually agreeable solution that improves the situation of all parties. Negotiation is not facilitated by a third party; the parties negotiate directly.

**Ombudsman**. An official charged with representing the interests of the public by investigating and addressing complaints reported by individual citizens. The government or parliament or other official body usually appoints the ombudsman. The office of the ombudsman is said to offer an “ombuds” service.

**Participation approach.** Participation approaches actively involve the public in monitoring in ways that match the context and allow the program to achieve its purpose and goals for a wider range of stakeholders.

**Performance Standards** (IFC and MIGA)**.** A series of standards published by IFC that are applied to manage social and environmental risks and impacts and to enhance development opportunities of projects in which IFC and MIGA invest or serve as partners.

**Planning team.** A multistakeholder group that plans a participatory monitoring program.

**Pro-poor practice.** Practices that lead to economic growth where wealth is distributed in a way that measurably decreases the poverty index.

**Project sponsor.** The company that builds and operates a project. Includes the individuals as well as the organization responsible for the project. Sometimes called project proponent.

**Scientific method.** A formal, systematic technique for investigating a phenomenon or learning something new, that can yield verifiable and replicable results. Elements include observation, experimentation, and the formulation and testing of hypotheses.

**Social capital.** The features of social life that enable participants to act together more effectively to pursue shared objectives. Networks, norms, and trust all build social capital.

**Social license.** An implicit contract between a company and society that constrains the company to meet societal expectations and avoid activities that societies deem unacceptable, whether or not those expectations are embodied in law.

**Stakeholders.** Persons or groups that are directly or indirectly affected by a project as well as those that may have interests in a project or the ability to influence its outcome, either positively or negatively. Stakeholders may include locally affected communities or individuals and their formal and informal representatives, national or local governmental authorities, politicians, religious leaders, civil society organizations and other groups with special interests, the academic community, or other businesses.

**Stakeholder analysis.** A method to evaluate how stakeholders may influence and interact with a project. Analysis steps involve identifying and prioritizing, according to power and interest; understanding the views of key stakeholders; and determining how best to gain support for the project.

**Stakeholder engagement.** An umbrella term encompassing a range of activities and interactions between a company and community over the life of a project that are designed to promote transparent, accountable, positive, and mutually beneficial working relationships. Stakeholder engagement includes stakeholder identification and analysis, information disclosure, problem/conflict anticipation and prevention, ongoing consultation, formation of partnerships, construction of grievance resolution mechanisms, negotiated problem solving, community involvement in project monitoring, regular reporting forums and procedures, and other management functions.

**Third party/parties.** See intermediary/intermediaries.

## Technical Terms

**Acid rock drainage.** Water of low pH (less than 6) that flows through rock containing sulfide minerals such as pyrite. When low pH water is associated with a mine, it is called acid mine drainage.

**Algae**. Small plants that lack roots, stems, flowers, and leaves; live mainly in water, and use the sun as an energy source.

**Alkalinity**. A measurement of water's ability to neutralize acid.

**Analyte.** A substance or chemical constituent that is determined using an analytical procedure, such as at a laboratory.

**Anion.** An ion that has a negative electric charge.

**Aquatic habitat**. All of the areas in a stream, lake, or wetland that are occupied by an organism, population, or community of organisms that live in the water.

**Aquatic insect.** An insect species that spends at least part of its life in water. Often the juvenile stage of flying insects.

**Aquifer**. Any geological formation containing water, especially one that supplies water for wells or springs.

**Arithmetic mean.** The average of a group of numbers or measurements. Calculated by adding all the values together and dividing by the number of values.

**Banks**. The portion of the stream channel that restricts the movement of the water out of the channel during times of normal water depth. The exposed terrestrial areas on either side of the stream.

**Base flow.** The lowest flow rate in a stream. Often, base flow is provided by groundwater flowing into the stream.

**Bedrock**. Unbroken solid rock, overlain in most places by soil or rock fragments.

**Benthic**. An adjective describing anything associated with the bottom of a stream or its sediments.

**Benthic macroinvertebrates.** Animals that live on the bottom of streams (benthic), are large enough to see (macro), and have no backbone (invertebrates).

**Bedrock**. Unbroken solid rock, overlain in most places by soil or rock fragments.

**Biochemical oxygen demand (BOD)**. An empirical test in which standardized laboratory procedures measure the oxygen required for the biochemical degradation of organic material, and the oxygen used to oxidize inorganic materials, such as sulfides and ferrous iron.

**Biological monitoring.** The use of the presence and response of biological entities as detectors of environmental conditions.

**Blank.** A "clean" sample (distilled water) that is sent to the lab for analysis with samples collected in the field. Results are used to evaluate quality control.

**Catchment.** The land area draining into a body of water. The same as watershed or drainage basin.

**Cation.** An ion that has a positive electric charge.

**Complete metamorphosis**. The type of insect development that includes four stages; egg, larva, pupa, adult.

**Conductivity.** A measure of the water's ability to conduct an electric current. Directly related to the mass of dissolved ions (salts) in the water.

**Confidence interval.** A group of continuous values that tends to include the true value a predetermined portion of the time.

**Current.** The velocity of flowing water.

**Discharge.** The rate at which a volume of water passes by a certain point per unit time.

**Dissolved oxygen (DO).** The amount of oxygen dissolved in water. Generally, higher amounts of oxygen can be dissolved in colder waters than in warmer waters.

**Drainage basin**. The total land area draining to any point in a stream. A drainage basin is composed of many smaller watersheds.

**Duplicate.** A repeated measure of the same sample to determine if the sample is reproducible.

**Ecology**. The relationship between living things and their environments or the study of such relationships.

**Ecosystem.** The interacting system of a biological community (plants and animals) and the land, air, water, rock, and other nonliving entities that surround it.

**Effluent.** A discharge of partially or completely treated pollutants into the environment; generally used to describe discharge into the water.

**EPT index.** A measure of the presence and diversity of three pollution-sensitive orders of macroinvertebrates relative to the abundance of a hardy species of macroinvertebrate. The EPT index is calculated as the sum of the number of individual insects belonging to the *Ephemeroptera* (mayfly), *Plecoptera* (stonefly), and *Trichoptera* (caddisfly) orders divided by the number of *Chironimidae* (midges).

**Erosion.** The wearing away of the land surface by wind or water.

**Escherichia coli (*E. coli*)**. A bacterium of the intestines of warm-blooded organisms, including humans, that is used as an indicator of water pollution for disease-producing organisms.

**Eutrophic**. A highly productive water body that may become “choked” with abundant plant life and depleted of dissolved oxygen through algal blooms. The input of large amounts of nutrients from human sources can cause or accelerate the productivity of the water body.

**Eutrophication**. Natural eutrophication is the natural process of lake aging. Cultural eutrophication occurs when nutrients are added as byproducts of human activity, such as agricultural runoff or sewage.

**Fecal coliform bacteria** . The portion of the coliform bacteria group that is present in the gut or feces of warm-blooded animals. The presence of fecal coliform bacteria in water is an indication of pollution and potential human health problems.

**Floodplain**. An area on both sides of a stream where flood waters spread out during high rains. The surface may appear dry for most of the year, but it is generally occupied by plants that are adapted to wet soils.

**Gaining stream.** Term used to describe when a stream receives water into its channel from inflowing groundwater.

**Geometric mean.** The *n*th root of the product of a series of numbers. The geometric mean reduces the influence of very high and very low numbers in a dataset.

**Gradient.** The slope or steepness of a stream.

**Habitat**. The area in which an organism lives and depends on for food and shelter.

**Hardness.** A measure of calcium and magnesium ions in water.

**Headwaters.** The start of a stream or river.

**Hydrologic cycle.** The transfer of water from precipitation to surface and ground water and eventually back to the atmosphere via evaporation.

**Indicator organism**. Organisms that respond predictably to various environmental changes, and whose presence, or absence, and abundance are used as indicators of environmental conditions.

**Inorganic**. Any compound not containing carbon.

**Intermittent stream.** A watercourse that flows only at certain times of the year, receiving water from springs or surface sources; also, a watercourse that does not flow continuously, when water losses from evaporation or seepage exceed available stream flow.

**Invertebrate**. An organism without a backbone.

**JTUs (**Jackson Turbidity Unit). A unit of measurement commonly used in electronic turbidity meters that indicate how far light can penetrate into a water sample before the cloudiness of the sample cuts the light. Similar to NTUs,

**Lake**. A body of fresh or salt water of considerable size, whose open-water and deep-bottom zones (no light penetration to the bottom) are large compared to the shallow-water (shoreline) zone, which has light penetration to its bottom.

**Losing stream.** A stream that loses water to the ground.

**Macroinvertebrates**. Animals that lack backbones and are large enough to be visible without the aid of a microscope.

**Median.** The middle value between the highest and lowest value data points.

**Metamorphose**. To change into a different form, such as from an insect pupa to an adult.

**Mollusk.** Soft-bodied (usually hard-shelled) animals, such as clams or mussels.

**Monitor.** To measure a characteristic over a period of time.

**Nitrogen**. A limiting nutrient for the aquatic environment. Nitrogen is considered to be limiting because the plants and animals in the stream need it in moderate amounts. Large amounts of nitrogen, which may result from fertilizer runoff from local farm fields enters a stream, causes algal blooms and a depletion of dissolved oxygen (eutrophication).

**Nitrogen cycle.** The transfer of nitrogen from bacteria to plants to animals and back in an ongoing cycle.

**Nonpoint source pollution.** A type of pollution whose source is not readily identifiable as any one particular point, such as pollution caused by runoff from streets and agricultural land.

**NTU (**Nephelometer Turbidity Unit). A unit of measurement commonly used in electronic turbidity meters that indicate how far light can penetrate into a water sample before the cloudiness of the sample cuts into the light. Similar to JTU.

**Nutrient**. Any substance that is necessary for the growth of living things.

**Nymph**. A juvenile, wingless stage of an insect.

**Outlier.** A data point that is far away from the rest of the values.

**Organic material**. Any compound containing carbon.

**Parameter.** A characteristic being measured or described.

**Pathogenic.** Capable of causing disease.

**Perennial stream.** A watercourse that flows year round and whose upper surface generally stands lower than the water table in the area adjacent to the watercourse.

**pH**. The measurement of acidity or alkalinity on a scale of 0-14. A pH of 7 is neutral, less than 7 is acidic, and more than 7 is alkaline (basic).

**Phosphorus.** An essential plant nutrient that, in excessive quantities, can contribute to the eutrophication of water bodies.

**Photosynthesis.** Process by which green plants use sunlight to produce food.

**Phytoplankton.** Small, free floating aquatic plants.

**Point source pollution.** Pollutants originating from a "point" source, such as a pipe, vent, or culvert.

**Pollution sensitive organisms.** Those organisms that cannot withstand the stresses applied on the aquatic environment by pollution.

**Pollution tolerant organisms.** Those organisms that can withstand many of the stresses applied to an aquatic environment by pollution.

**Pools.** An area of a stream often following a rapids (riffle), which is relatively deep with slowly moving water.

**Precision.** A data quality indicator that measures the level of agreement or variability among a set of repeated measurements obtained under similar conditions.

**Pupa.** The stage of an insect during which it is enclosed in a protective case while changing from larva to an adult.

**Quality Assurance (QA).** An assessment of data quality, including accuracy, precision, completeness, representativeness, and comparability.

**Quality Assurance/Quality Control (QA/QC)**. Refers to the overall program used to ensure that data collected are of known and acceptable quality. The QA/QC program includes specific procedures in the field and in the laboratory.

**Quartile.** A division of a data set into four parts. The values below which lie 25 percent (first quartile), 50 percent (second quartile), and 75 percent (third quartile) of the values in a data set.

**Reach.** A stream section with fairly homogeneous characteristics.

**Riffle.** In a watercourse, an area often upstream of a pool, which is relatively shallow and where water runs swiftly compared to the pool.

**Riparian zone**. An area, adjacent to and along a watercourse, which is often covered with vegetation and constitutes a buffer zone between the nearby lands and the watercourse.

**Run.** A stretch of fast, smooth current deeper than a riffle.

**Runoff**. Water from rain, snowmelt, or irrigation that flows over the ground surface and runs into a water body.

**Secchi disk.** A black and white disk used to measure water transparency.

**Sediment.** Soil, sand, and minerals washed from land into waterways.

**Sedimentation.** The process by which soil particles (sediment) enter, accumulate, and settle to the bottom of a waterbody.

**Sewage**. The organic waste and wastewater produced by residential and commercial establishments.

**Silt**. Fine particles of soil or rock that can be picked up by air or water and deposited as sediment.

**Siltation.** The process in which silt settles out of the water and is deposited as sediment.

**Standard.** A sample of known concentration.

**Stream bed.** The bottom of a stream where the substrate and sediments lay.

**Stream depth.** A measurement of the depth of a stream from the water's surface to the stream bed.

**Stream flow.** The amount of water moving in a stream in a given amount of time.

**Substrate.** The surface upon which an organism lives or is attached.

**Suspended sediments.** Fine material that remains suspended in flowing water until deposited in areas of weaker current. Also called total suspended solids or TSS.

**Taxon.** Short for taxonomic unit. A name designating an organism or group of organisms. Plural is taxa.

**Tolerant species.** An organism that can exist in the presence of a certain degree of pollution.

**Topographic map.** A map representing the surface features of a particular area.

**Total coliform bacteria.** A group of bacteria that are used as an indicator of drinking water quality. The presence of total coliform bacteria indicates the possible presence of disease-causing bacteria.

**Total dissolved solids (TDS).** Substances, such as salts, that are dissolved in water. Tannic acids that leach from tree roots or from decomposing leaves can color the water brown to black due to dissolved chemicals. This color does not disappear by filtering the water.

**Total suspended solids (TSS).** Whole particles carried or suspended in the water, such as silt, sand, small algae, or animals, that cause a green or brown color in the water. These substances can be filtered out of the water and weighed.

**Toxicity.** A measurement of how poisonous or harmful a substance is to plants and animals.

**Trend data.** Data or measurements of a stream system that will show how particular characteristics changed over time.

**Turbidity.** Sediment in water, making it murky, or opaque.

**Urban runoff.** Water that has drained from the surface of land that is used for urban uses, such as paved roads, subdivisions, and parking lots.

**Wastewater**. Water carrying unwanted material from homes, farms, businesses, and industries.

**Water quality.** The condition of water, including whether it is polluted and can support certain uses.

**Water quality guidance value.** Standards developed by a foreign government or international agency to evaluate water quality. Guidance values are generally not veiwed as enforcable standards, but they do provide insights as to where water quality may be impaired.

**Water quality standard.** Legally enforcable, numerical water quality criteria established by a government agency to assess whether the quality of water is adequate for aquatic life, recreation, drinking, agriculture, industry, and other uses.

**Watershed.** The entire surface drainage area that contributes water to a stream or river.

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