9.0 Environmental Monitoring Program

Environmental monitoring provides feedback about the actual environmental impacts of a project. Monitoring results help judge the success of mitigation measures in protecting the environment. They are also used to ensure compliance with environmental standards, and to facilitate any needed project design or operational changes.

The importance of monitoring can be illustrated by using a hypothetical example of a wastewater treatment plant. The plant may have been built according to the Environmental Management Plan specified in the Environmental Impact Assessment (EIA). However, due to lack of funds, bad management, or insufficient skills, the plant is functioning poorly. Without monitoring, the impacts caused by the poor functioning could continue indefinitely. With monitoring (and response by the appropriate regulatory agency), the problems can be recognized and resolved. For example, assume that the wastewater treatment plant described above is operating as originally planned. The receiving body of water, for instance a river, was assumed to have sufficient capacity to assimilate wastewater that had received only primary treatment. If, however, a large amount of water is abstracted upstream of the wastewater treatment plant, the assimilative capacity of the river will be reduced. The monitoring program would show the water quality had deteriorated and that secondary treatment was required. (This situation could be avoided by proper regional environmental planning.)

A monitoring program, backed up by powers to ensure corrective action when the monitoring results show it necessary, is a proven way to ensure effective implementation of mitigation measures. By tracking a project's actual impacts, monitoring reduces the environmental risks associated with that project, and allows for project modifications to be made where required. An excellent example of an effective monitoring program is the irrigation component of the Tarim Basin Project in the PRC. Previous irrigation facilities in the area did not include appropriate drainage, and severe soil salinization occurred, resulting in large reductions in crop yields. The Tarim Basin Project, which was initiated in 1992, provides adequate drainage to prevent additional salinization, and to reverse some of the damage already done. The need to obtain firm data on the extent of the problem during project operation was recognized. A detailed, continuing monitoring program to evaluate the actual project impacts, and to initiate research and development work to optimize the irrigation techniques, was specified in the EIA.

9.1 Implementing an Environmental Monitoring Program

9.1.1 Environmental Monitoring Defined

In general, environmental monitoring programs will collect data for one or more of the following purposes (Everitt, 1992):

1. to establish a baseline; that is, gathering information on the basic site characteristics prior to development or to establish current conditions;
2. to establish long term trends in natural unperturbed systems to establish natural baselines;
3. to estimate inherent variation within the environment, which can be compared with the variation observed in another specific area;
4. to make comparisons between different situations (for example, pre-development and post development; upstream and downstream; at different distances from a source) to detect changes; and
5. to make comparisons against a standard or target level.

Compliance Monitoring

Compliance monitoring is a commonly practiced form of environmental monitoring. The purpose of compliance monitoring is to ensure that the quality or quantity of an environmental component is not altered by a human activity beyond a specified standard of regulation level. An example of compliance monitoring is a sampling program conducted by either industry or government to ensure that concentrations of a contaminant do not exceed a specified level either in the effluent or in the receiving waters. Implicit in compliance monitoring is the assumption that if the characteristic being monitored is within acceptable limits, then the effects will be within acceptable limits. *Compliance monitoring is not concerned with determining actual effects.*

Environmental Effects Monitoring

When the objectives of the monitoring program require that actual effects be determined, environmental effects monitoring is required.

Environmental effects monitoring has been defined as the repetitive measurement of environmental parameters to test specific hypotheses of the effects of human activity on the environment (LGL Ltd. et al 1984). Conover (1985) added to this definition the notion that environmental monitoring measures changes for the purpose of establishing cause-effect relationships. This manual adopts the following definition of environmental monitoring:

> *Environmental effects monitoring is the repetitive and systematic measurement of the characteristics of environmental components to test specific hypotheses of the effects of human activity on the environment. Environmental monitoring is undertaken primarily to determine the environmental effects of human activities, and secondarily to increase understanding of cause-effect relationships between human activity and environmental change.*

The implications of this definition are that:

1. environmental monitoring programs should involve repetitive sampling over a number of years;
2. environmental monitoring programs should be scientifically rigorous and be based on testable hypotheses;
3. sampling programs designed to test the hypotheses should be such that the results may be used to detect temporal trends and/or spatial differences; and
4. environmental monitoring programs should attempt to establish empirical links between human activities and their effects on the environment.

Environmental Effects Monitoring in Environmental Impact Assessment

Environmental effects monitoring programs provide the necessary information to:

1. verify the accuracy of EIA predictions; and
2. determine the effectiveness of measures to mitigate adverse effects of projects on the environment.

Feedback from environmental monitoring programs may be used to:

1. determine whether more or less stringent mitigation measures are needed; and
2. improve the predictive capability of EIAs.

Improving the Predictive Capability of Environmental Impact Assessments

In recent years, the effectiveness of EIA studies has come under serious challenge, and repeated calls have been made for a new, more scientifically sound approach to forecasting environmental effects. Unfortunately, despite the large number of impact predictions that have been formulated, few attempts have been made to test previous predictions (Marmorek et al., 1986; Munro et al., 1986; Bernard et al., 1989). As a result, many inaccurate predictions are probably being propagated in ongoing EIA processes.

Environmental monitoring programs capable of detecting environmental effects are essential if we are to learn from experience. In addition to enhancing the predictive capability for assessing potential effects, information generated from environmental monitoring programs can benefit future EIA activities by providing for better monitoring plans.

Assessing the Effectiveness of Mitigation Measures

Without monitoring there is no mechanism for evaluating the success of the mitigation measures undertaken. Environmental monitoring provides important information that allows for more effective planning and an adaptive response based on an assessment of the effectiveness of mitigation measures. Normally a number of environmental operating conditions are laid down upon granting of project approval. These, along with any conditions set out in permits and licences, become part of the overall environmental management regime for the project.

Environmental monitoring is required to assess whether the various mitigation measures are effective in attaining the goals of environmental protection. Without an environmental monitoring program, it is not possible to determine whether the environment is being protected or not. The absence of such a program also leaves the EIA process without a mechanism for evaluating its performance against its goals. Environmental monitoring can help to:

1. describe the extent of environmental effects and resource losses;
2. provide scientific information about the response of an ecosystem to a given set of human activities and mitigation measures; and
3. provide data for use as a part of environmental auditing of environmental management practices.

9.1.2 Monitoring Program in the EIA Methodology

Environmental monitoring must be an integral part of all phases of the project cycle. By providing information about the current status of our environment, environmental monitoring programs provide information feedback on the actual effects of human activities on the environment, and of the effectiveness of prescribed mitigation measures to protect the environment. This feedback is essential to ensure that those who plan development and those who manage environmental resources are supplied with information upon which to base their decisions and follow up activities (Everitt, 1992). This is critical if we are to learn from one project to the next. Information generated from environmental monitoring will increase the scientific understanding of environmental impacts, thereby permitting increasingly better EIA of future projects.

The role of environmental monitoring programs in EIA can be seen by examining the three major information feedback loops they provide (Figure 9-1):

1. *Within project corrections (loop 1-2-3-1).* Mitigation measures are implemented as specified by project planning and the EIA. These measures, together with the project activities, lead to actual effects (Figure 9-1: link 1). Environmental monitoring provides information on the actual effects (link 2), which can be used by management to modify how they execute the project (link 3). Information through this loop continues because adjustments to project management can lead to new environmental effects.

2. *EIA process helps monitoring design which in turn provides information to the EIA process (loop 4-5-6-7)*. Scoping and analysis of issues in the early stages of the EIA process helps define the monitoring program plan (Figure 9-1: link 4), and then, the monitoring program (for example, baseline monitoring) (link 5). Initial monitoring data guides the impact assessment (link 6), which in turn can be used to revise the monitoring program (link 7).

3. *Environmental monitoring programs provide information for follow up activities (loop 8-9)*. Environmental monitoring data provides the information upon which environmental follow-up programs can evaluate the success of mitigation measures and determine the accuracy of impact predictions (Figure 9-1: link 8). Once the evaluation is complete this information will lead to better design of mitigation measures, more effective EIA procedures, increased predictive capability, and improved monitoring programs for future projects (link 9).

9.1.3 Objectives of Project Based Environmental Monitoring Programs

Two phases of monitoring are undertaken. The first is baseline monitoring (or surveys), which takes place during the EIA phase (or earlier). Baseline monitoring records the status of the environment prior to project implementation. Requirements for baseline data are normally outlined in the terms of reference for the EIA. The second stage, which is the focus of this chapter, is monitoring undertaken in the project design, construction, and operation stages.

Both compliance and environmental effects monitoring are required. The objectives of project-based monitoring programs are to: 1) ensure compliance with the mitigation measures (including off-setting and enhancement measures) identified in the EIA; and 2) determine the project's actual environmental impacts so that modifications can be made to the project or the project's mitigation measures, if necessary (Asian Development Bank, 1994). Most monitoring is directed towards these objectives.

The goal of the environmental management plan is to ensure that all necessary corrective actions, both mitigative and off-setting, are carried out to counter any adverse environmental impacts, and that enhancement measures are used where feasible and practical. One of the goals of the monitoring program is to actually observe and analyze the project's impacts, thereby providing information to help in re-designing mitigation measures to reduce the risks associated with a project.

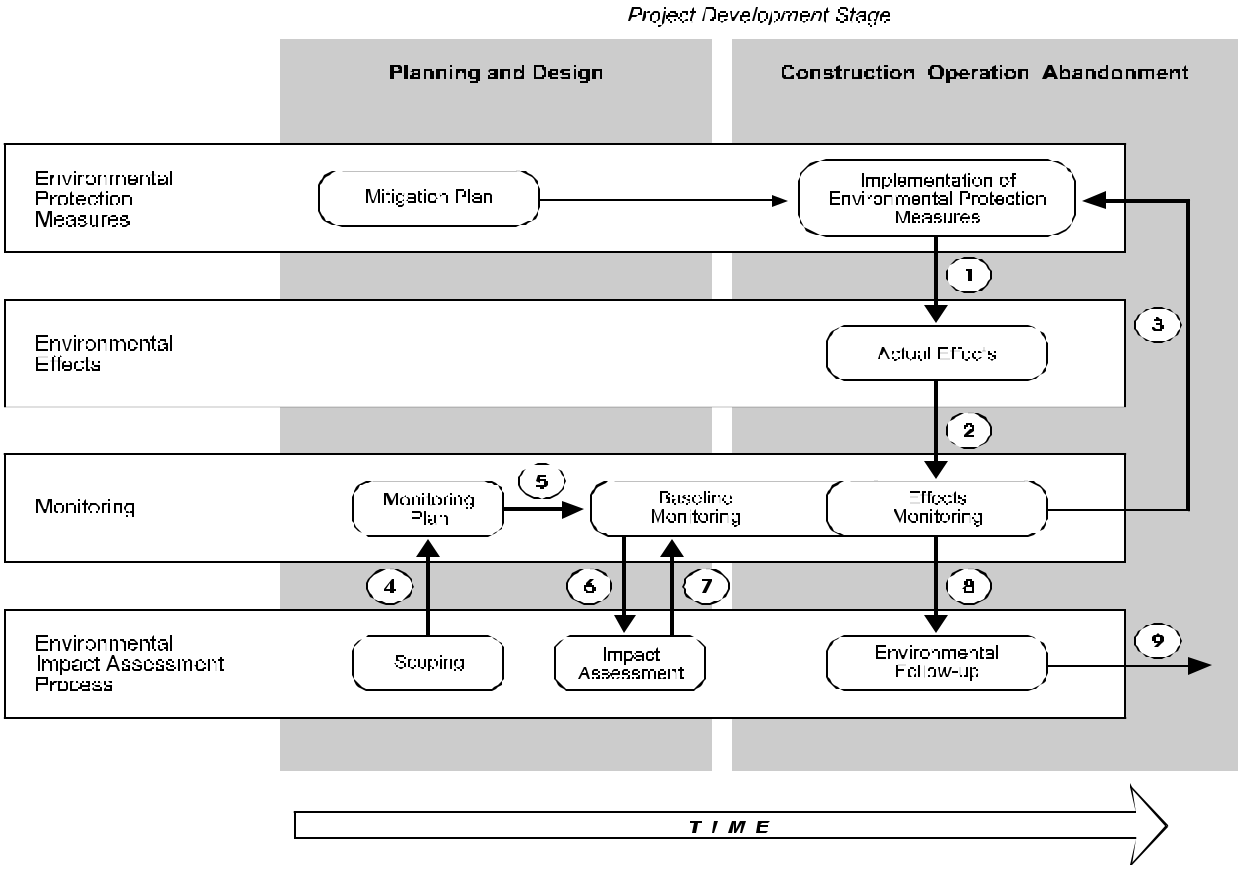

Figure 9-1: Monitoring provides important information feedback for more effective planning for environmental protection (*source:* Everitt, 1992).

Compliance and effects monitoring occurs during the project construction, operation, and abandonment stages. The resources and institutional set-up should be available for the monitoring at these stages. All large-scale construction projects will require some construction stage monitoring. To control the environmental hazards of construction as specified in the EIA, a monitoring program should be established to ensure that each mitigation measure is effectively implemented. There are numerous potential areas for monitoring during operations.

Two questions must be asked regarding each mitigation measure: 1) is it necessary to include monitoring provisions to ensure that the mitigation measure will be successfully implemented (constructed and operated) as outlined in the EIA; and 2) is there a chance that the actual impacts will be different from the predicted impacts, and are the associated risks great enough to warrant a monitoring program to track the actual impacts and make modifications to the project if required? If the answer to either of these questions is yes, then a monitoring program for the mitigation measures needs to be developed.

Institutional Requirements

In addition to devising a monitoring program, it is also necessary to work out a plan for its implementation. This includes assigning institutional responsibility, reporting requirements, enforcement capability, and ensuring that adequate resources, in terms of staffing and skills, equipment, training, and budget, are provided. A monitoring program that does not have a management component will have little chance of success. Often an environmental management office (see Chapter 10) must be included in the overall project management structure. The organization responsible for monitoring must have sufficient staffing and skills, training, equipment, and funds to carry out the required monitoring tasks.

9.1.4 Cost Justification for Monitoring

The EIA report should show clearly how the recommended monitoring will enhance, rather than detract from, the project's economic and environmental objectives. The proposed monitoring program should include its own benefit/cost analysis to ensure the monitoring program will bear critical scrutiny whenever cost-sensitive project review officials evaluate the program.

A monitoring program should be the least cost alternative to achieve the stated monitoring objectives, and should be included in the core project funding. It is crucial to include the monitoring program budget in the project core budget. Experience has shown that it is extremely difficult to go back and obtain more funds for monitoring after the core budget has been approved. Most developing country EIAs in the past did not arrange for such funding, and in most cases, the recommended and approved monitoring was not implemented.

9.1.5 Reporting and Enforcement Capability

Should the data analyses indicate that corrective actions are needed, information collected through the monitoring program must be transmitted to an organization that has the power to take appropriate action. The institutional arrangements for monitoring, including who should receive the results and analysis, and who is responsible for taking corrective actions, should be specified in the EIA. Enforcement capability implies that some government organization has the power to compel the implementing organization to abide by the terms of the original project agreement. This usually implies either legal or financial power. Since it is often difficult to obtain legal power to enforce the conditions in the EIA, it may be more effective to apply financial pressure. For example, if the resettlement program for a reservoir project was not proceeding as outlined in the EIA, further funding for the construction of the dam could be withheld until compliance was achieved.

9.1.6 Monitoring Requirements For Effective Pollution Control

Environmental monitoring is absolutely essential to the success of any program aimed at controlling environmental degradation, including environmental pollution control. Four elements are needed to achieve effective control: 1) appropriate environmental standards; 2) enforceable legislation and regulations; 3) enforcement capability; and 4) adequate monitoring to obtain the data required by the regulatory agency to enforce the regulations in the courts. Without monitoring there can be no awareness of noncompliance.

Most developing countries have enacted pollution control regulations, but lack the monitoring capabilities necessary to enforce them consistently. Some developing countries have carried out pilot monitoring projects, mostly in the fields of water and air pollution control. The programs have been sponsored by various international assistance agencies and implemented by the national environmental protection agencies. Designed to demonstrate proper use of monitoring, and to train staff in appropriate environmental monitoring technologies, the intent of these pilot monitoring projects was that they would be followed up by continued monitoring financed locally. Most of the projects have been unsuccessful because the sponsors and developing countries alike did not realize the complexities of planning and conducting a meaningful environmental monitoring program. To be sustainable, a

national environmental monitoring program requires a sound foundation of technical, institutional, economic, and financial structures.

9.2 Designing Environmental Monitoring Programs

There are many institutional, scientific, and fiscal issues that must be addressed in the implementation of an environmental monitoring program. Careful consideration of these issues in the design and planning stages will help avoid many of the pitfalls associated with environmental monitoring programs. Completion of the following tasks will lead to an effective environmental monitoring program.

9.2.1 Analysis of Significant Environmental Issues

At the outset of planning for an environmental monitoring program, the manager of the program may not know exactly what should be monitored, when monitoring should begin, where it should occur, which techniques should be employed, and who should take responsibility for its conduct. Because there are usually a number of subjective decisions to be made, it is important to start with an analysis of environmental issues. The scoping phase of EIA is designed to identify and focus the major issues. Scoping should provide a valuable source of information on the concerns that need to be addressed by the monitoring program (see Chapter 11). Practical experience with environmental monitoring programs in developed countries shows there is a wide range of public and professional concerns that are industry specific. Broad participation by a range of interests will likely be required. Stakeholders that should be considered include government environmental and regulatory agencies, environmental interest groups, local communities, industry, and the professional community (Everitt, 1992).

9.2.2 Formulation of Specific Objectives

It is often necessary to formulate broad objectives for an environmental monitoring program. For example, suppose the objective is to protect the environmental quality of an estuary but most of the concerns relate to a fishery, fish populations and fish habitat that may be affected by effluent from an industrial outfall. In the design of the monitoring program more specific objectives must be developed. For example, the:

General Objective: *to protect the environmental quality in the estuary*

could lead to the:

Specific Objectives: *to determine amount of degradation of fish habitat associated with the industrial effluent;*
to determine population trends in fish populations; and
to determine losses to the fishery.

9.2.3 Formulation of Specific Questions — Defining Assessment Endpoints

Effects monitoring programs work best when the scientific method guides data collection, analysis, and interpretation. Formal hypotheses of the effects of a project help link the subjective issues and objectives to the more objective field sampling and data analyses. Prior to defining a hypothesis, a question to be answered must be formulated. The answers to these questions are the assessment endpoints. Assessment endpoints are information a decision or policy maker might wish to know about the status of valued environmental components (VECs).

Environmental monitoring programs collect data on *environmental indicators*, to provide information for the evaluation of *assessment endpoints*, which reflect *environmental values* (Figure 9-2).

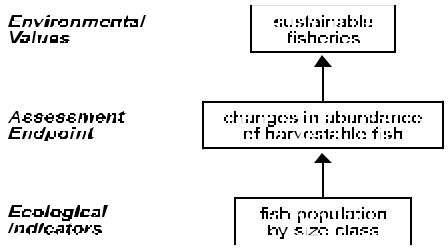

Figure 9-2: The relationship between environmental values, assessment endpoints and environmental indicators in environmental monitoring (*source:* Everitt, 1992).

Environmental values are the qualities or quantities we desire in our environment. The environmental values are what we ultimately are trying to protect, or are striving for, with respect to the environment. Examples of environmental values are contaminant-free fish, or sustainable fisheries.

Environmental monitoring programs must have clearly defined assessment endpoints. Assessment endpoints are expressions of the environmental values that are to be protected (Suter, 1990). An assessment endpoint is generally the answer to a question regarding the environment effects that was posed at the beginning of the environmental monitoring programs. If the question was embodied in a formal hypothesis, the assessment endpoint is the rejection or acceptance of the hypothesis. Without assessment endpoints, environmental monitoring programs may be terminated prematurely or be continued longer than necessary.

Assessments often fail because the endpoints lack unambiguous operational definition. A complete operational definition of an assessment endpoint requires a subject (for example, a rare and endangered species) and a characteristic of the subject (local extinction or percentage reduction in range) (Suter, 1990).

The choice of VECs is related to the perceived significance of the environmental components (Everitt, 1987). In general, the significance or importance of environmental components may be based on: 1) legal status (for example, rare and endangered species); 2) political or public concerns (for example, resource use conflicts); 3) scientific judgement (for example, ecological importance); or 4) commercial or economic importance. In addition to their economic, social, political or ecological significance, chosen components should: 1) have unambiguous operational definition; 2) be accessible to prediction and measurement; and 3) be susceptible to hazard.

In many cases, VECs can be directly measured (for example, extent of habitat for an endangered species), however in other cases, direct measurement is impossible or impractical. The chosen measurement endpoints or environmental indicators must correspond to, or be predictive of assessment endpoints (see box 9-1 and 9-2).

Environmental indicators must be: 1) measurable; 2) appropriate to the scale of disturbance/ contamination; 3) appropriate to the impact mechanism; 4) appropriate to temporal dynamics; 5) diagnostic; and 6) standardized; as well as have: 1) a low natural variability; 2) a broad applicability; and 3) an existing data series.

Box 9-1: Environmental indicators correspond to assessment endpoints.

People wish to be assured that fish is wholesome and free from contamination. This environmental value might be reflected in environmental monitoring programs that determined assessment endpoints that show that the body burdens of chemical *x* in fish increased after an industrial plant became operational, or that fish harvests (consumption) did not decrease despite the discoloration of fish flesh from accumulation of chemical *x*.

Environmental indicators corresponding with these assessment endpoints are the concentration of chemical *x* in a sample of fish, and the size class structure of the population of fish that have accumulated chemical *x*.

For example, key questions associated with the objectives defined above might be:

1. *will or has fish habitat in the estuary been degraded as a result of the human activity?;*
2. *are fish populations declining, increasing, or stable?*
3. *are current levels of fish harvests sustaining the local fishery?*

The VECs in the key questions are fish habitat, fish populations, and fish harvests.

Box 9-2: Criteria for Choosing VECs for Assessment Endpoints.

The following criteria are useful when choosing assessment endpoints:

- predictable and measurable
- legal, political, economic, ecological relevance
- unambiguous operational definition
- sensitive to human activity

Box 9-3: Monitoring programs require specific objectives, specific questions, valued environmental components and environmental indicators.

Suppose the objective is to protect the environmental quality of an estuary but most of the concerns relate to a fishery, fish populations and fish habitat that may be affected by effluent from an industrial outfall.

General Objective:

- *to protect the environmental quality in the estuary*

Specific Objectives:

- *to determine the amount of degradation of fish habitat associated with the effluent*
- *to determine population trends in fish populations*
- *to determine losses to the fishery*

Valued Environmental Components

- *fish habitat*
- *fish populations*
- *fish harvests*

Specific Questions – Assessment Endpoints

1. *will, or, has fish habitat in the estuary been degraded as a result of the human activity?*
2. *are fish populations declining, increasing, or stable?*
3. *are current levels of fish harvests sustaining the local fishery?*

Environmental Indicators

1. *fish population by size class;* and
2. *area of contaminated fish habitat*.

9.2.4 Construct Simple Conceptual Models of Impact

It is desirable to have simple conceptual models of the mechanisms by which impact might occur. In addition to being useful in determining which variables to monitor, these models are extremely valuable in communicating the rationale for monitoring. One of the best ways to represent a conceptual model is with an impact hypothesis (see Chapter 4). An impact hypothesis is simply a statement of our understanding of the mechanism of the potential effect of the particular activity. Mechanisms of effect can be physically, ecologically, physiologically, and behaviorally based. For example, the three questions above can be embodied within an impact hypothesis that incorporates the environmental components: the fishery, fish, and fish habitat (Figure 9-3).

The hypothesis exemplified in Figure 9-3 describes the cumulative effects through time of industrial effluent on fish harvesting. An elaboration of the hypothesis in Figure 9-3 that would exemplify a spatially cumulative effects hypothesis would be inclusion of the effects of other human activities (for example, fishing pressure, erosion from forestry activities, and acidic precipitation) on fish harvesting. In practice such multi-

activity hypotheses are not testable as a whole, but need to be disaggregated into component activities. An example of a hypothesis of an immediate and direct effect drawn from Figure 9-3 could be the effects of industrial effluent on bottom substrate.

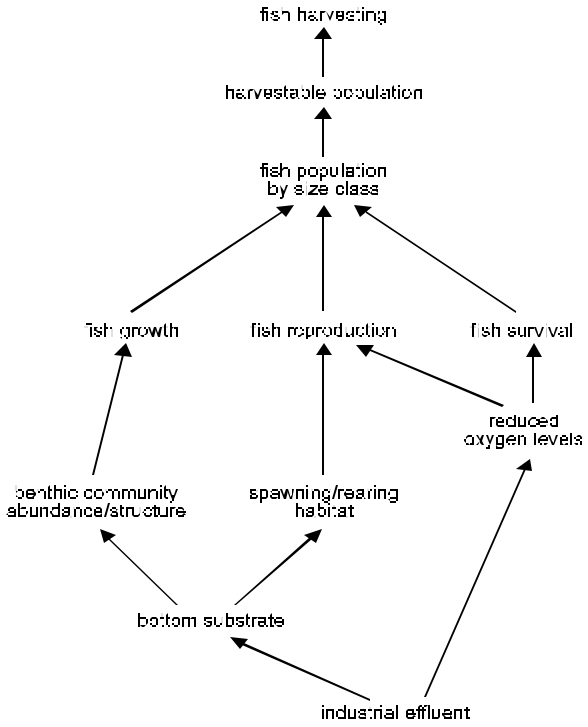

Figure 9-3: Example impact hypothesis of the cumulative effects through time of industrial effluent on fish harvesting (*source:* Everitt, 1992).

9.2.5 Selecting Environmental Indicators

After the impact hypothesis is defined, monitoring effort can be concentrated on the specific environmental indicators of impact. It is necessary that the indicators chosen be relevant to the impact mechanisms, be indicative of the VECs of interest, be measurable, and be appropriate to the spatial and temporal scale of disturbance/contamination (see Box 9-4). Where possible, standardized indicators with existing data series should be chosen. Other desirable characteristics of environmental indicators include: 1) low natural variability; 2) broad applicability; 3) being diagnostic with respect to the potential cause.

Two environmental indicators relevant to our example are:

1. *fish population by size class;* and
2. *area of contaminated fish habitat.*

The complexity of most ecosystems makes it impractical to measure environmental indicators corresponding to all the desired VECs. A smaller, more manageable set of environmental indicators must be chosen. In selecting indicators it is desirable to identify those which reflect the response of other indicators. This form of correlation amongst the responses of indicators can expedite effects evaluation in environmental monitoring because the response of one indicator can be taken as being representative of the response of other indicators. For example, if a particular color of fish flesh is specific to chemical X, then fish color observation alone, instead of time and resource consuming tissue residue analyses, could be used as the indicator of chemical

accumulation in fish. However, in most cases the development of multiple lines of evidence of effects is still necessary in environmental monitoring (Cairns, 1990).

Box 9-4: Criteria for Selecting Environmental Indicators.

The following criteria are useful in selecting environmental indicators:

- measurable
- indicative of VEC
- sensitive to VEC
- standardized
- appropriate to the scale of disturbance/pollution
- low natural variability
- appropriate to the impact mechanism
- broad applicability
- appropriate to temporal dynamics
- existing data series
- diagnostic with respect to the potential cause

9.2.6 Establish an Information Management System

An information system for receiving, storing, retrieving, manipulating and disseminating data must be in place in the monitoring program. Because monitoring requires that repetitive measurements be made, the information management system needs to be capable of processing time series data for reports based on the analytical framework required for interpreting monitoring results. In the absence of existing data collection programs, baseline data will have to be collected as part of the initial stages of the environmental monitoring program.

Define Data Analyses Prior to Data Collection

The data analyses to be conducted are dictated by the objectives of the environmental monitoring program. The statistical methods used to analyze the data should be described in detail prior to data collection. These methods should be chosen so that uncertainty or error estimates in the data can be quantified. Example statistical methods useful in an environmental monitoring program include: 1) frequency distribution analysis; 2) analysis of variance; 3) analysis of covariance; 4) cluster analysis; 5) multiple regression analysis; 6) principal components analysis; 7) time series analysis; and 8) the application of dynamic systems models (Green, 1979).

Reporting

A critical component of environmental monitoring is the reporting phase. A report that documents the environmental monitoring from rationale to results and interpretations must be prepared. It should include recommendations, where appropriate, for more or less stringent mitigation measures, or improvements in the effectiveness of EIA procedures. In addition to documenting present environmental monitoring, information in the environmental monitoring report is also used to assist in the development of future environmental monitoring programs.

9.2.7 Development of a Rigorous Sampling Design

There is a need for more consistent, systematic, and statistically valid approaches to sampling. Green (1987) provides a set of guidelines for statistical design in research and monitoring:

1. Clearly formulate the question. Rephrase as a null hypothesis (see also Box 5-4) and an alternative hypothesis.
2. There should be a control. If it is an observational study over space and time, try to have both a spatial and temporal control (reference site).
3. Have replicate samples within treatments, areas, etc.
4. There should be a balanced (equal) and random (or at least unbiased) allocation of samples with respect to the variables of interest (see #8).
5. Do some preliminary sampling (a pilot study) so that steps 6-9 can be done.
6. Evaluate the sampling method for consistency (lack of bias) over the entire universe that will be sampled.
7. Estimate necessary sample number (or adequacy of feasible sample number), and optimum sample unit size.
8. If there is a large scale spatial pattern, consider a stratified sampling design. To estimate spatial distribution allocate samples evenly over the area; to estimate abundance allocate samples proportional to estimated abundance.
9. Decide how to handle problems in data: transform it? use nonparametric statistics? use simulation, randomization or jackknife? use sequential sampling? apply corrections for bias?
10. Stick with the results (that is, let the hypotheses be falsifiable).

Formulate Statistical Hypotheses

Statistical hypotheses (see Box 9-5) will have to be formulated as a part of the statistical design of the data analyses.

Box 9-5: Example statistical hypotheses.

Hypothesis 1:

Ho: Fish habitat in the effluent-exposed area is as productive as non-exposed area.
Ha: Fish habitat in the effluent-exposed area is not as productive as non-exposed area.

Hypothesis 2:

Ho: There is no change in the fish community in the effluent-exposed area.
Ha: The fish community in the effluent-exposed area has changed since effluent discharge began.

Hypothesis 1 implies that sampling will have to be stratified spatially; Hypothesis 2 implies that time series information will be required.

9.2.8 Establish Rigorous Quality Assurance Quality and Quality Control

The accuracy and precision of data generated by a monitoring program can only be assessed if a good quality assurance and quality control program is in place. The objectives of the quality assurance and control programs are to:

1. generate quality analytical data using standardized and accepted sampling techniques;
2. capture natural spatial and temporal variability in environmental indicators;
3. be sensitive to sampling and analytic error;
4. be sensitive to sample contamination, and to extreme values due to natural or special source conditions;
5. ensure complete documentation and defensibility of all data; and
6. expedite data evaluation and acceptance.

A successful environmental monitoring program requires field and laboratory staff trained in sample collection and sample processing procedures. If appropriately trained staff are not available, the available staff should be sent to a commercial or government laboratory for detailed instruction in the methods required. Specific protocols for: 1) sample collection and storage; 2) sample shipments; and 3) testing laboratories should be provided in the overall design.

9.2.9 Prepare a Cost Estimate for the Entire Monitoring Program

There are at least six major cost elements associated with monitoring programs (in addition to overall administration and coordination costs):

1. program design costs;
2. field sampling programs;
3. laboratory analyses;
4. operation and maintenance costs associated with information management;
5. quantitative analysis and reporting; and
6. communication and liaison.

A cost estimate for each of these program elements should be provided in detail at the outset of the monitoring program.

9.2.10 Periodic Program Review

The environmental monitoring program must continue through time as prescribed by the objectives and endpoints of the program. Explicit in an environmental monitoring program is periodic program review to ensure that the data being collected and the information being provided to decision makers is still relevant, and of maximum utility. Systematic review of the program will allow for new scientific understanding to be incorporated into the program, conceivably leading to additions, deletions, and modifications to impact hypotheses and to the sampling programs.

9.3 Examples of Monitoring from Developing Country EIAs

Samut Prakarn Wastewater Management Project, Thailand

This Asian Development Bank funded project has a long history — dating back to the early 1980s — of planning and environmental analysis. Initially the concept was to build an industrial pollution control facility for a relatively small area of high density industrial development in Samut Prakarn, south of Bangkok (see Chapter 16 in the case studies volume for a more detailed review of this project). Environmental analysis took place over the period from the early 1980s until the project was approved in 1985. Decisions on the need to invest in the project and on the scope of the project were based on two main sources of information: 1) monitoring by the Thai government which indicated continuing environmental degradation, and 2) a periodic review of the alternative approaches to dealing with the water pollution problem. A technical assistance study determined that both a cost comparison and an environmental comparison of the alternative approaches to wastewater management were needed.

The EIA consisted of a two-staged approach. An initial environmental examination (IEE) was used to evaluate thirteen options (including a no-action option) for wastewater management. The IEE results were combined with the results of the cost comparison to identify the optimum approach to wastewater management. The preferred alternative is two large centralized collection and treatment schemes, servicing industry as well as community or domestic wastewater. The IEE also outlined the detailed analysis required for the highest priority alternative. A subsequent EIA of this alternative was undertaken as a part of the feasibility study.

As a follow-up to this EIA, an environmental monitoring program with the following two objectives was designed:

- to monitor changes in key environmental elements so any long-term adverse impacts caused by project interventions can be predicted in a cost-efficient and timely manner; and
- to provide a tool for decision-making on whether any project modifications or mitigation of adverse impacts are necessary.

Monitoring programs included:

1. unit operations and processes, of the collection, transfer, treatment and disposal facilities of the project, and their relevant health and safety features.
2. beneficiaries, including industries, commercial establishments and households. Apart from gathering data that are necessary for assessment of impacts on communities and beneficiaries, this type of monitoring can also help increase awareness of users and enhance the public-relations strength of the project. Whether the project achieves overall environmental improvement benefits will depend largely on the attitudes and awareness of beneficiaries.
3. Chao Phraya and khlong water quality. The current Pollution Control Division monitoring program is sound in its methodology and approach. Its areal coverage is to be expanded to provide a more meaningful picture of the entire project area.
4. human use values, with a focus on agriculture and both freshwater and brackish/coastal aquaculture. As mentioned above, concerned relevant sector agencies could participate in the monitoring program, perhaps with minor modifications to their current effort.
5. special ecosystems, with a focus on the mangrove forest areas, the marine environment and the Bang Krachao area.

Tarim River Basin Comprehensive Water Resources Development Project

The Tarim project, including a detailed EIA, was completed in 1991 under the direction of the Xinjiang Provincial Water Conservancy Bureau (Gunaratnam, 1992). The monitoring program specified in the EIA for comprehensive water resource development in the Tarim River Basin of Xinjiang Province, northwestern PRC, includes all parameters relating to irrigation, drainage, land reclamation, and regreening for anti-desertification (Table 9-1). Full scale monitoring was initiated in 1992. Financing for monitoring was included in the project loan.

A primary goal of the project was to increase the area under irrigation. The danger of salinization due to improper application of water and insufficient drainage was addressed in the EIA, however the factors affecting the actual extent of salinization are extremely complicated and could not be assessed until irrigation actually began. The project hence included a monitoring program to determine the extent of salinization and to take corrective actions where necessary as part of the environmental management plan (EMP).

Table 9-1: Monitoring parameters for the Tarim River Basin Project (*source:* Asian Development Bank, 1994).

Resource	Parameter or Unit of Measurement
Socio-economic	
Crop yields	bushels, bales, kilos or output
Animal productivity	kilos produced per year
Family income	income per household per year
Public health	doctor visits per capita specific cases by disease per capita
Status of relocated families	homelessness per capita persons per household
Water Resources	
Water resource balance	groundwater depth surface water levels flow rate
Water distribution to three areas	flow rates through each of the supply canals
Water quality: salinity	total dissolved solids
Ecology	
Effectiveness of regreening program (lower Tarim Basin)	ratio of ground area covered by plants to total surface area
Effects on wetlands	abundance of 4 indicator plant species

Xiaolangdi Dam and Reservoir Comprehensive Water Resources Development Project

The Xiaolangdi Project is a US$1.3 billion project to stop the continuing serious flooding hazards in the Lower Yellow River Basin which is inhabited by 70 million people. In addition, the project has large-scale irrigation and hydro-power components, plus numerous additional components of lesser scale as needed for comprehensive water resources development. These include measures to minimize or offset environmental hazards, and environmental enhancement measures. The project EIA team was converted into the Project's Environmental Management Office, and was given the responsibility to implement and coordinate a comprehensive environmental monitoring plan. Funding is included in the project loan.

The EIA covered all environmental aspects. The assessment singled out four issues of significance: 1) dam stability and safety; 2) resettlement; 3) cultural heritage; and 4) public health. These issues became the focus of the environmental management plan and subsequent monitoring activities. The institutional arrangements for the environmental management plan and environmental management office for the project are described in Chapter 10.

During the pre-construction phase, environmental monitoring involved environmental surveillance and inspection during the preparation of the construction site and monitoring activities related to resettlement. During the construction and operation phase, the monitoring system is designed to: 1) ensure that contractors and operators properly carry out mitigation measures; and 2) evaluate the adequacy of the environmental management plan. Monitoring programs are designed to observe actual effects; and in the event there are unacceptable adverse effects, recommend corrective action.

9.4 Post Audit and Evaluation

Post project evaluation procedures are becoming a more common practice, particularly with International Financial Institutions. For example, after the completion of project construction, the Asian Development Bank sends a review mission to undertake discussions with concerned executing agencies to determine the implementation of environmental mitigation measures earlier agreed upon by both the borrower and the Bank. It is the task of the review mission to verify that environmental safeguards built into the project design are satisfactorily implemented by the borrower/executing agency during the construction and operation of the project. The Asian Development Bank's post-evaluation reports and project performance audit reports include a final assessment of the degree to which the projects satisfied the proposed environmental requirements, the effectiveness of mitigatory measures and institutional development and whether any unanticipated effects occurred as a result of project activities. These reports are often prepared within a year or two of the completion of construction. As such, they cannot identify long term adverse effects or failures in mitigation measures that may occur later in the project's life.

Post audit and evaluation of environmental management plans and monitoring programs provides us with a way to learn from experience. Monitoring results are an important source of information to verify the accuracy of EIA predictions. Systematic evaluation of monitoring results allows EIA practitioners to understand strengths and weaknesses in existing approaches. This understanding will naturally lead to better techniques and approaches to impact assessment. Monitoring information is essential in helping us determine the effectiveness of mitigation measures. Without essential feedback provided by monitoring programs on "what works" and "what does not work," each new project will be designed like the last one. There will be little opportunity to learn from our mistakes and to apply new and better mitigation techniques.

Post evaluation reports like those prepared by the Asian Development Bank are a useful source of information, however, one further step is required. We must ensure that we learn from experience. From time to time, there needs to be a formal and systematic post hoc evaluation of the effectiveness of our environmental protection efforts on development projects. The results need to be gathered together and disseminated, widely and rapidly.

9.5 References and Further Reading

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